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The Quicksilver Quest:  
Two Psychological Studies Investigating  
the Effects of Mercury in Dentistry

A thesis presented in partial fulfilment  
of the requirements for the degree of

Doctor of Philosophy  
in Psychology

at Massey University,  
Wellington Campus, New Zealand.

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2005

## ABSTRACT

The longstanding debate over the safety of mercury in dentistry has latterly moved from scientific argument to public health dilemma. Mercury is a neurotoxin. Adverse psychological outcomes can result from exposure, so *The Quicksilver Quest* aimed to investigate mercury in dentistry from a qualitative, critical health psychology perspective, and a quantitative, neuropsychology assessment. The qualitative study used focus group methodology to explore micro-mercurialism linked to dental amalgam fillings. A random sample of people, who had been medically diagnosed with mercury poisoning, formed seven focus groups. The discussion of experiences, beliefs, and health was analysed for themes and issues. The main findings were that the participants were not a homogeneous group, as had been anticipated, but fell into categories differentiated by their symptoms, fiscal resources, and motivation. A placebo effect was rejected as an exclusive explanation for the positive health outcomes reported by those who had had amalgam removal and detoxification. The quantitative study investigated the long-term effects of occupational mercury exposure on a cohort of women in dentistry. The aim was to test the null hypothesis: that women who endured high occupational mercury exposure in the 1970s (43 participants), and matched controls (32 participants), would show no between-group differences on a general and reproductive health survey, and a nine-test neurobehavioural assessment. Results generally supported accepting the null hypothesis. Significant exceptions were current symptom experience, reproductive health, and two mood subscales. There was a suggestion of peripheral nerve damage in the exposed group. Overall, the general discussion systematically reviews tension points in the debate, in light of a proposed model of tolerance to mercury. This begins to explain how it might appear that mercury in dentistry is safe for dental personnel, as pro-amalgam debaters claim, yet unsafe for some dental patients, as anti-amalgam debaters claim. Further study is suggested for occupationally exposed women, on tremor, and to test the proposed tolerance to mercury model. Finally, as the debate has a political aspect, a recommendation is made for a shift in public health policy to dental amalgam being restricted to use only in an adult population.

## ACKNOWLEDGEMENTS

I wish to thank a host of people for their contribution to my thesis endeavours, from those who have guided my academic work to those who have waited through my absences and are cheering now.

To Drs Julie Bunnell and Jennifer Stillman, thank you. I could not have had better supervisors: both warm and generous women; and sceptical scientists. It was my very great privilege to be your student. You have surely lifted my game.

I appreciate the advice I have received from academics Dr John Miller, Victoria University, Wellington, for reading and commenting on my understanding of the chemical and biological aspects of mercury; and Dr Alistair Noble, Massey University, for advice on statistics.

Thanks to Dr Terry Cutress and Dr Mike Godfrey for asking me to investigate their mercury dilemma, that became the study *Biting the Silver Bullet*; and to Dr Colin Feek and Peter Hunter, from the Ministry of Health, for support-in-principle of the thesis, and the *Mercury and Venus* study in particular.

The greatest thanks goes to Colin, and I'll be home soon. Thanks for holding the fort and so much more besides. I know and appreciate that through everything I've strived for, you have been there with unfailing love and support. I couldn't have done this without you.

To our children Kathryn, who completed a BSc/BCA and BSc (Hons) while I wrote this thesis; Jennifer, who completed a double major BA, is in the final semester of an LLB, and is Victoria University Students' Association Vice President (Education); and Andrew, who finished secondary school and is a second year BIT student, I trust that my being a student for so long, has been positive role modelling for the joys of academia. It is looking that way. Thanks for your patience, encouragement and willing help at home.

Other family and friends were important too. For unflagging interest and pride in my work, thanks go to parents Bill and Audrey Mail, brother Markham Mail and friend and sister-in-law, Catharina Mail. Dad died while I was on a data-collecting trip in Jan. 2003, so he has missed the finale. Long-time friend Ruth Page was a great help, especially in the *Mercury and Venus* pilot phase.

Special thanks for being a positive and motivating force in my life for nearly 30 years; and for hospitality throughout the *Biting the Silver Bullet* study, goes to my pro-amalgam mentor from the dental profession, Dr Gus Guise. He has the distinction of being the first person to ask me what my thesis would be, way back when I was an undergraduate student. There was a lot I didn't know then, including this being it.

Thanks for endless support and ideas shared at early morning Friday ☘ L'affaire meetings goes to colleagues from Wellington Polytechnic who, following the merger with Massey University, enrolled for higher degrees: Jenny Jakobs (M.Phil any day now), Dr Lesley Patterson (first to finish), and Sue Scott (PhD candidate, c'mon Sue). It has been also been helpful and supportive to have School of Psychology colleague Ruth Tarrant share the PhD journey. I hope we graduate together.

Participants in the Quicksilver Quest.

To the pilot-volunteers, and the patient-volunteers of the Bay of Plenty Environmental Health Centre, and School Dental Service volunteers, your friends and your sisters - for your willing participation, thank you. You have made a valuable contribution to my understanding of the neurotoxic effects of mercury from dentistry, and one I hope will be shared by the scientific community.

The Quicksilver Quest is dedicated to Colin.

Linda Jones, 2005

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## LIST OF ABBREVIATIONS

Adult Environmental Neurobehavioral Test Battery	AENTB
Agency for Toxic Substance and Disease Register	ASTDR
American Dental Association	ADA
Appendices to the Journals of the House of Representatives	AJHR
Blood Brain Barrier	BBB
California Verbal Learning Test	CVLT
Central Nervous System	CNS
Chronic Fatigue Syndrome	CFS
Copper Amalgam	CuAm
Detoxification	detox.
Environmental Risk Management Agency	ERMA
General Practitioner (medical)	GP
Identity	ID
International Academy of Oral Medicine and Toxicology	IAOMT
Lowest Observable Adverse Effect Level	LOAEL
Ministry of Health	MoH
Neurobehavioural Test Battery	NBTB
New Zealand	NZ
New Zealand Dental Association	NZDA
New Zealand Dental Journal	NZDJ
No Observable Adverse Effect Level	NOAEL
Occupational Overuse Syndrome	OOS
Preliminary Questionnaire	PQ
Profile of Mood States	POMS
Silver Amalgam	AgAm
Simple Reaction Time	SRT
Symbol Digit Modalities Test	SDMT
Threshold Limit Value	TLV
Time Weighted Average	TWA
Tolerable Daily Intake	TDI
Tolerance to Mercury Continuum	TMC
World Health Organisation	WHO
X-Ray Fluorescence	XRF

## INTRODUCTION

Academic researchers and professional personnel from various health fields have contributed to the understanding of whether the mercury component of dental fillings is causally linked to ill health. As a toxic substance, mercury ranks third in the Agency for Toxic Substance and Disease Register<sup>1</sup> (ASTDR), after arsenic and lead, so the common sense view would be to expect adverse health outcomes from exposure.

Stakeholders such as dentists, professional dental associations, amalgam manufacturers, environmentalists and politicians, and to a lesser extent, medical doctors, have taken sides in an acrimonious debate on the safety of mercury in dentistry<sup>2</sup>. They present their arguments as pro-amalgam (see Wahl, 2001a, or the American Dental Association website for the protagonists' position, [www.ada.org](http://www.ada.org)) or anti-amalgam (see Hanson, 2003; Hanson & Pleva, 1991, or the International Academy of Oral Medicine and Toxicology website for the antagonists' position, [www.iaomt.org](http://www.iaomt.org)).

The psychological interest in, and contribution to, the debate is a more politically and affectively neutral scientific position. Mercury is a neurotoxin, and exposure can produce observable and measurable psychological outcomes (Hartman, 1995).

*The Quicksilver Quest* explores some aspects of the safety of mercury in dentistry from a psychological perspective. Unresolved safety issues exist within the broader debate, for the general well-being and the neuropsychological health of both the dental practitioner who is using mercury fillings in conservative dental practice, and for the dental patient who is receiving mercury fillings as a treatment for dental disease.

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<sup>1</sup> [www.atsdr.cdc.gov](http://www.atsdr.cdc.gov) The information is current. ASTDR is an agency of the United States of America.

<sup>2</sup> Hereafter referred to as "the debate"

The present research makes a contribution to the debate by presenting studies from critical health psychology and experimental neuropsychology. This required separate qualitative and quantitative research designs, and an interpretation and application of the complementary findings.

The critical health psychology perspective ensured that the investigation was placed in the world of the dental patient. Their position was explored using qualitative methodology in the first study, *Biting the Silver Bullet*. This study subjects the participants' collective health biographies to discourse analysis and the findings are considered in triangulation with the existing pro-amalgam and anti-amalgam debate arguments.

The value in the critical health psychology approach is in the fact that dental patients are the people with the least scientific knowledge on which to base informed consent to the placement of silver-mercury fillings, and who experience uncertainty about the health benefits versus the toxic effects of their fillings. Until this study there has not been a scientific documentation of patient beliefs, attitudes and behaviour in relation to dental amalgam fillings.

The experimental neuropsychological perspective ensured a focus on the relationship between occupational mercury exposure and psychological health outcomes of dental personnel. The position of some women in dentistry was explored using quantitative methodology in the second study, *Mercury and Venus*. In this study the long-term effects of occupational mercury exposure on general health, reproductive health and as a neurotoxin, were assessed.

Prior to 1975, young women who trained for a career in the New Zealand (NZ) School Dental Service were occupationally exposed to high levels of mercury through skin contact and inhalation of mercury vapour. In the more than 30 years since their exposure, these women, now in their sixth decade, have had a growing concern about the impact of their youthful occupational choice on their subsequent health and illness experiences.

The value of the experimental neuropsychological study was that the methodology was designed to show causal relationships between occupational mercury exposure and various health indicators; and that the present

investigation extended the understanding of the effects of occupational mercury exposure on a specific population over a long timeframe.

In addition, women have been all but invisible in the occupational mercury exposure literature, so the present study adds a gender-dimension. Also, while the effects of mercury exposure are well established in some occupations, there are only a few studies that have followed mercury poisoned individuals or groups for more than a year.

Together the two diverse studies were designed to contribute a psychological perspective to the incomplete multi-disciplinary jigsaw of mercury in dentistry. With this perspective the debate may be challenged or to some extent resolved.

### **Overview of the Structure of the Thesis**

#### *Chapter One: Open Wide - Mercury for Psychologists*

Chapter 1 presents an overview of mercury and mercury poisoning for a psychology readership that may be aware that there are neurotoxic effects from mercury exposure, but not of the complexities that the chemical forms of mercury, or the variables of level and duration of exposure, have on the effect mercury may produce in animals or humans at different ages.

Mercury in different chemical forms is described, and how each form may enter a biological system. Mercury poisoning is explored from a medical perspective, from published case histories; then from an occupational safety perspective, from published accounts of industrial accidents or safety monitoring and surveillance. The reviewed literature covers mercury exposure from a range of industrial and occupational settings where the findings have added to the understanding of the neurotoxic effects of mercury exposure, or where a specific unanswered question has been raised by the work; and a comprehensive range of papers that are relevant to understanding mercury exposure for dental patients and dental personnel. This section aims to establish the functional impact of mercury, and the issues from previous assessment of the neurotoxic effects of occupational mercury poisoning, that

may be applied to the studies in the present thesis, and ultimately to the debate.

### *Chapter Two: Mirror and Probe – An Overview of the Debate*

Chapter 2 sets out the issues in the debate on the safety of mercury in dentistry. This chapter explores what protagonists and antagonists in the debate claim and counter claim, and the evidence promulgated to support their perspectives. From the Literature reviewed in Chapter 1, and discussion of the debate, come the aims and objectives of the thesis as a whole.

### *Chapter Three: Biting the Silver Bullet – Experiences of*

#### *Mercury Poisoning*

Chapter 3 reports the critical health psychology study, *Biting the Silver Bullet*. It describes the qualitative assessment of a random sample of people who had been medically diagnosed with mercury poisoning, and who were advised to have their amalgam fillings removed to improve their health. The aim of this study was to explore and document the experiences of people who have lived through the diagnosis of mercury poisoning attributed to their dental amalgams.

The rationale for the choice of focus group method is discussed. The sample was a random selection of patients from one medical practice, all of whom had biological evidence supporting their mercury poisoning diagnosis<sup>3</sup>. Seven focus groups discussed set trigger questions and the discussion was analysed for common themes. The study reports health beliefs, such as how participants came to link their dental amalgam fillings and their health, and it documents the outcomes of health seeking behaviour such as amalgam removal.

From the analysis of the results, four main findings are discussed, that are an advance on the previous scientific understanding of the dental patient's

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<sup>3</sup> The evidence was a urine mercury test result above 50µg/l.

experience of mercury exposure from their fillings (see L. Jones 1999; and L. Jones, 2004a, in Appendix A and B respectively). The study suggests that the low but unrelenting dose of mercury vapour from dental amalgams may produce the symptoms of mercury poisoning, so that with the source of the exposure identified and removed, and with detoxifying drugs, health may be restored. This conclusion is supported or corroborated by the medical evidence reviewed in Chapter 1, that a very low but chronic exposure to mercury vapour can cause neurotoxic effects that respond to detoxifying drug treatments.

The discussion considers a placebo effect and reduced galvanism in the reported recovery stories, but finding the same logical progression of mercury poisoning from dental amalgams as mercury poisoning from, for example, a broken thermometer, suggests an explanation in a toothless-body metaphor.

#### *Chapter Four: Mercury and Venus – A Study of Women*

##### *Occupationally Exposed to Mercury*

Chapter 4 reports the *post ipso facto* experimental study, *Mercury and Venus*. This was the long-term, follow-up study of a cohort of mid-life women who were occupationally exposed to high levels of mercury as young women. The introduction reviews methods used in some previous studies of occupational mercury exposure: in studies with dental personnel as participants; in studies with women as participants; and longitudinal studies of mercury exposure from various occupational settings. A rationale is presented for the use of a general and reproductive health survey and a specific set of neurobehavioural tests. The aim of this study was to compare the test and survey results from a sample of women controls and women who had worked for the NZ School Dental Service at a time when copper amalgam filling material was supplied for filling carious deciduous teeth.

The results were subjected to statistical analysis and showed that the exposed and control groups were equivalent not only on those variables that one would want to be matched, like age, alcohol consumption, or general health, but also on most of the neurobehavioural test battery scores. Some statistically

significant between-group differences were revealed in current health symptom experience, reproductive health, mood, and tremor.

A discussion of the findings and conclusions in relation to the aim of the study took into account the existing literature, some sample and equipment issues, possible alternative explanations for the findings, and where it was possible, the comparison of test findings with clinical norms.

#### *Chapter Five: Crown and Bridgework – A New Critical Discourse*

Chapter 5 is a general discussion of the combined contribution that the two studies make to the debate on the safety of mercury in dentistry. It begins with a summary of the findings of *Biting the Silver Bullet* and *Mercury and Venus*, then considers some issues of methodology or interpretation that either an antagonist or protagonist in the mercury debate might raise about them. Where either or both the studies contribute to the understanding of particular premises from the debate, the contribution is discussed. Where either or both studies point to flaws in the conceptualisation of the debate, these are debunked.

In the Crown and Bridgework chapter an original model is proposed, that may account for the some differences between premises in the debate. It offers dentistry a unified explanation for mercury exposure to be both safe, as the protagonists would have it, and unsafe, as the antagonists claim.

This chapter includes the limitations of the thesis and is where the general conclusions in relation to the aims of the thesis are drawn. Recommendations are made for future directions to test the conclusions and to further the understanding of the neurobehavioural effects of mercury. Recommendations are also made for public health policy, based on the position that science should engage in informed social action. In the case of the debate on the safety of mercury in dentistry, the combination of a precautionary approach to public health policy (Pearce, 2004; Rose, 1992), and the proposed model of the public risk from mercury in dentistry, is used to suggest changes in evidence-based best dental practice.

## **CHAPTER ONE: OPEN WIDE - MERCURY FOR PSYCHOLOGISTS**

### **Chemical and Biological Aspects of Mercury**

Mercury is a metal that occurs in various chemical states, none of which have any known biological function. Health risks arise when mercury breaches the body's primary defence system and enters the blood stream. While mercury can potentially be transported to and stored in any tissue, current thinking is that potential toxic effects depend on the form of mercury and duration of the exposure (Wright & Welbourn, 2002).

There are many forms of mercury from elemental mercury, which has the chemical symbol Hg, to mercurous salts and mercuric compounds. Of these, two forms will be described and discussed for the debate. These are the elemental, inorganic form and organic mercury.

#### *Metallic Mercury*

The term used throughout the thesis for the elemental form of mercury is metallic mercury. This is the metal commonly known as "quicksilver". It has natural geological origins associated with volcanic activity and is commercially mined from cinnabar ore for a variety of industrial or medical uses; and cultural or religious practices. From these uses and practices, life forms are exposed to inorganic toxins and the environment to mercury pollution.

Metallic mercury can be liquid or gas at room temperature, and there is a multiplicity of ways that it can be introduced into the biological systems of animals including humans. In its liquid metallic form, mercury can be absorbed through contact with skin or mucous membrane. Metallic mercury can be intentionally or accidentally swallowed. It has also been both accidentally injected (S. Smith, Jaffe, & Skinner, 1997), and intentionally injected (Torres-Alanis, Garza-Ocanas & Pineyro-Lopez, 1997) into human tissue.

Where there is liquid metallic mercury there is mercury vapour. This is a colourless and odourless gas, so it is inhaled without conscious awareness of

its presence in ambient air. In occupations where metallic mercury is used, for example in a thermometer factory or a dental surgery, there will be some level of mercury vapour always present in the environment (D. Jones, Sutow, & Milne, 1983; Malecki, 1998; Mantyla & Wright, 1976). Mercury vapour can be ingested if air is swallowed.

Mercury vapour is also measurably present in many non-occupational, everyday environments, as it is emitted from mercury-containing electrical devices such as fluorescent lights, switches or batteries. Further, anyone with dental amalgam fillings has a minimal but unrelenting intra-oral source of mercury vapour that may be inhaled. (Abraham, Svare, & Frank, 1984; J. Patterson, Weissberg, & Dennison, 1985; Snapp, Boyer, Peterson & Svare, 1989; Vimy & Lorschieder, 1985a; 1985b; 1990).

There are documented non-western medical practices where people ingest metallic mercury believing it brings health benefits (Kew, Morris, Aihie, Fysh, Jones, & Brookes, 1993), and around the Caribbean there are religious sects where the intentional inhalation of mercury vapour is part of the ritual associated with *espiritismo*, a spiritual belief in mercury preventing evil (Baum, 1999).

In contemporary western society the most likely situation where a person may contact or swallow metallic mercury or inhale or swallow mercury vapour is during either the removal of an old amalgam filling, or the insertion of a new one (Berglund, 1990), although in Latin American countries, the toxic addition of metallic mercury to cosmetics such as a skin whitening creams may rival exposure from dental sources (McRill, Boyer, Flood, & Ortega, 2000).

### *Organic Mercury*

Bacteria can cause a chemical transformation in metallic mercury. In this process, metallic mercury is bonded to carbon as it is converted to one of several organic forms (Wright & Welbourn, 2002). The most ubiquitous form of organic mercury encountered by humans is methylmercury. Methylmercury accumulates in cells so that as increasingly larger organisms ingest it, there is a cumulative effect in their biological systems. The higher up

the food chain an animal is, the greater will be the burden of methylmercury in its own cells. This is commonly understood in the aquatic food chain, so that communities dependent on fish as their main protein source, may suffer some of the effects of mercury poisoning (Grandjean, 1997; Grandjean, Cardoso, & Guimaraes, 1993).

In humans, ingested methylmercury enters the bloodstream to be circulated and stored in any or all tissues of the body, although the brain, kidneys, and testicles are considered to be the main targets (Murry & Butler, 1988).

In New Zealand at the present time, the Food Safety Authority names eight fish species, plus any fish from waterways supplied from geothermal sources, as fish not to be eaten because of the mercury content (NZ Food Safety Authority, 2005). A further warning is made to pregnant women, who may regularly consume fresh fish, to limit their intake to less than 600 grams per week, or the mercury that crosses the placenta may adversely affect their children.

There is some evidence that metallic and inorganic mercury can also bio-transform in the mouth to methylmercury, in the presence of infection, salty foods or acidic foods (Sellars & Sellars, 1996). If this is supported by further research it will suggest that mercury from dental sources makes a greater contribution to the body burden than is currently believed.

Finally, as a preservative ingredient in vaccines, and as a fungicide used in grain silos, another organic form of mercury, ethylmercury, can also affect the central nervous system and kidneys. Ethylmercury may be injected directly into body tissues with vaccines, although this may not be apparent to a patient reading the contents list, as mercury in vaccines is labelled Thimerosal. Mercury in vaccines is becoming the focus of its own safety debate, with anti-mercury campaigners claiming that Thimerosal causes serious developmental delays and autism in a small percentage of toddlers who receive immunisations (Magos, 2001).

Ethylmercury, when used as a fungicide, preserves grain before planting, but was the cause of a mass poisoning and death in Iraq, when fumigated wheat,

donated during a famine, was eaten instead of planted (Bakir, Al-Shahristani, Al-Rawi, Khadouri, & Al-Mufti, 1976; Damluji & Tikriti, 1972).

For people living in the 20-21<sup>st</sup> centuries in industrialised countries, there may never be a point in their lives when they do not have some measurable level of stored mercury. This is the result of mercury crossing the blood-testes barrier and being carried by sperm. It continuously crosses the placenta from the mother to the developing embryo and foetus. For the growing infant, mercury passes into breast milk, and later, mercury is a trace element in almost every kind of foodstuff (NZ Food Safety Authority, 2005).

## **Mercury Poisoning**

### *Evidence of Mercury in the Brain*

Metallic mercury particles tend not to be absorbed into the human body. Metallic mercury vapour and organic mercury can be absorbed and are neurotoxins. On entering the human body mercury is readily taken up in the bloodstream and converted to the organic form. However, amounts in the order of 10 percent are estimated to cross the blood brain barrier (BBB) before it has oxidised, and this is ionised in the brain and effectively trapped on the 'wrong side' of the BBB (Eto, Takizawa, Akagi, Asano, Takahata, & Tokunaga, 1999; Langan, Fan & Hoos, 1987; Richardson, 1995).

Sites of storage in the brain have been deduced from in vivo studies, autopsy, as a result of observable effects, and from neurobehavioural testing of known mercury poisoned people. Effects from neurobehavioural testing will be discussed shortly.

In a pilot study, Nylander, Friberg and Lind (1987) examined brain tissue from autopsy samples, to investigate the relationship between amalgam fillings and total mercury in the occipital lobe. Using Spearman's  $r$  statistic, they found a significant, positive correlation. This led to their undertaking of a further study, with more precise operationalisations of amalgam load and mercury concentration. The Swedish Board of Health and Welfare (Dental Division) were consultants for the amalgam quantification, which included not only an

oral examination but also recourse to dental records for extracted teeth. Thirty-four autopsy samples were analysed. Of these, three were known to be from electricians, (an occupation with low mercury-exposure) and nine were known to be from alcoholics (where alcohol is thought to be a protective factor in mercury poisoning)<sup>4</sup>.

Nylander et al. (1987) found that whether using an index of the number of fillings or the number of tooth surfaces with amalgam, there was a strong correlation between amalgam and total mercury in the occipital lobe ( $r=0.5$  and  $r=0.54$  respectively,  $N=34$ ,  $p < 0.001$ ). The findings are similar to those of Eggleston and Nylander (1987) who report a larger American study of the same design, although the authors indicate that the diet of the American and Swedish populations would have been different, particularly in fish intake, and possibly smoking and alcohol intake. However, this led to a conclusion that it is mercury vapour from amalgam fillings that makes the greatest contribution to total mercury in the occipital lobe.

Nylander and Weiner (1991) explored the relationship between mercury and selenium in dental personnel, and compared them to a control group from the general population. Animal studies suggested that selenium has a protective effect from mercury in the way it binds with protein. In experimental mice studies (Kristensen & Hansom, 1979, cited in Nylander & Weiner, 1991), in naturally occurring dolphin and seal population studies (Koeman, van der Ven, de Goeij, Tijoe, Haaften et al. 1975, cited in Nylander & Weiner, 1991) and in one study of ex-mercury miners (Kosts, Byrne & Zelenko, 1975 cited in Nylander & Weiner, 1991), high correlations or near 1:1 ratios of mercury and selenium had been reported.

Nylander and Weiner (1991) analysed pituitary glands, occipital cortices, thyroid glands and tissue from two other sites, taken at autopsy from seven dentists and one dental assistant, and found a similar ratio. Medical records did not indicate mercury poisoning had ever been considered for the deceased, although one dentist was being investigated for a peripheral nerve disorder. Mercury concentrations in the pituitary and thyroid samples were “considerably higher” (p. 731) than found in the general population as too were

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<sup>4</sup> Occupations for alcoholics were not given in the paper.

the selenium concentrations. A main effect was revealed for mercury concentration in the pituitary gland and occipital cortex when selenium was the dependent variable.

Mottet and Body (1974) analysed mercury concentrations from 14 different tissue-types taken from 113 persons during autopsy, to establish what a normal body burden of mercury was. They suggest that as humans have evolved with mercury and with other trace elements in their environment, their biological systems have developed ways to eliminate these toxins. They found rural – urban residency affected mercury levels with urban body burdens higher, leading to a conclusion that where levels of exposure are higher, such as in polluted industrial environments, the evolving biological mechanisms may not be effective in managing toxic effects. Selenium was mentioned as another trace element that interacts with mercury, although when the paper was published, Mottet and Body did not speculate on the interaction. Rather, they commented that, “The full importance of the body burden of one metal can only be known when the burden of all interacting metals is known” (p. 24).

Few of the papers reviewed for the present thesis dealt with metal or chemical interactions with mercury, other than selenium and alcohol intake. This included other autopsy reports that aimed to clarify questions of mercury concentrations in the brain. This raises a question as to the extent to which the Mottet and Body (1974) paper should inform a psychological thesis. In terms of methodology, alcohol intake as a confounding variable can be tested, but selenium cannot easily be accounted for, except where it is taken as a mineral supplement.

### *Mercury Poisoning in Medical Practice*

In western medicine, mercury poisoning may be termed frank mercurialism; micro-mercurialism, when the level of exposure to mercury is low; or acrodynia, the condition in children which has additional curious symptoms. Documented cases, published in medical journals, show that the main symptoms related to mercury exposure are from mercury being both a nephrotoxin and a neurotoxin. The present thesis will focus on mercury as a neurotoxin.

There is a set of signs and symptoms for mercury poisoning, but confusingly, any may be present or absent as there is wide individual variation in presentation. The symptoms include erythism<sup>5</sup> (an illness medically defined in its own right, with emotional lability: depression, anxiety, shyness in social situations, outbursts of anger or crying, blushing and sweating), psychomotor difficulties (e.g. balance difficulties, a change in gait and fine tremors), sensory loss including numbing of the extremities, visual disturbances and colour vision loss, cognitive difficulties (e.g. attention and concentration problems, memory loss); and symptoms of psychosomatic illness such as fatigue and insomnia.

Acrodynia sufferers are children. They have the added signs that their hand and feet may discolour to shades of bright pink, with numbing or tingling and loss of function, itchy eczema and developmental regression (Black, 1999; Danthan & Harvey, 1965).

Medical literature on mercury poisoning reports more child case histories than adult case histories, and papers tend to be published with the message that the causal role of mercury was overlooked, which had made it difficult to reach the correct diagnosis. Case studies of acrodynia in medical journals show that relatively small amounts of metallic mercury can cause mercury poisoning. Even for adults working in dentistry, the possible causal role of mercury in ill health may be overlooked, again creating difficulty in reaching the correct diagnosis.

Von Muhlendahl (1990), writing in the *Lancet*, warned general practitioners that because the onset of mercury poisoning from low-level but chronic exposure is slow, the signs may be imprecise, and patients presenting with it are few, resulting in the cause being easily overlooked. Von Muhlendahl described three children from one family who had an accident with a domestic thermometer, spilling mercury in an area with floor heating. Only one child had the pink, scaly palms that permitted the differential diagnosis of acrodynia, but this did not become evident until eight months after the accident. All the children had itchy eczema with skin infections and mood

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<sup>5</sup> Erythismus mercurialis (Dorlan's Illustrated Medical Dictionary, 1967).

changes. The worst affected had general malaise and was “bad tempered” (p. 1578). Two of the three were described as anorexic.

Bonhomme, Gladyszczak-Kholer, Cadou, Ilef, and Kadi (1996) reported the case histories of siblings with acrodynia. Mercury was spilled on their bedroom carpet and was gradually vaporised with vacuum cleaning. The two-year old child was admitted to hospital with a kidney condition, and then two months later her three-year old brother was admitted with a general mood change (described as sadness), walking difficulty and weight-loss. The older child’s pink-skin colouration was the key to identifying metallic mercury vapour inhalation as the cause of these children’s conditions. The diagnosis of acrodynia was confirmed after the family home was tested and the mercury source located. This case study supports Von Muhlendahl’s (1990) suggestion that medical practitioners may easily overlook mercury poisoning as a diagnosis.

Rennie, McGregor-Schuerman, Dale, Robinson, and McWilliam (1999) reported the case of a nine-year-old boy presenting with increasingly impaired sensation that had reached the point where he could not pick up objects. The boy had mood changes and psychosomatic illness that was linked to a mercury spill from a sphygmomanometer on home-loan from a hospital. This paper emphasises individual variation in presentation.

The case histories of twin infant girls were reported by Weinstein and Bernstein (2003). The girls had weight-loss, rashes, raised blood pressure, and “increasingly swollen red and painful hands and feet of one month duration” (p. 201). Weinstein and Bernstein used their paper to remind medical practitioners to consider mercury when “family members present with the same unusual constellation of symptoms” (p. 201).

Further examples include the report on three adolescents who played with mercury they had taken from barometers. These boys developed hypertension, skin rashes and behavioural changes. One died (Koyun, Akman & Guven, 2004). Beck, Krafchik, Traubici and Jacobson (2004) reported on two hospitalised infant boys, where the presenting symptoms made the eventual diagnosis of mercury poisoning difficult. Like von Muhlendahl, (1990) they published to remind medical practitioners (as their

title in *Pediatric Dermatology* states) “Mercury intoxication. It still exists” (Beck et al., 2004, p. 254).

For adults, Cook and Yeates (1969) report the tragic case of a dental chairside assistant who presented to her General (medical) Practitioner (GP) with kidney problems and died 10 days later despite specialist hospitalisation and various treatments. None of her tests had included urine mercury levels, so it was only at autopsy that her mercury-laden kidneys were found to be the cause of her death. The pathologist reported that he had no data on possible co-morbid signs that there may have been mercury poisoning, beside the obvious 20-year occupational history of working with mercury. The implication was that for people working with toxins, there should be a routine test to eliminate any possible toxic involvement. With mercury, this does not seem to occur.

The Cook and Yeates (1969) report is not dissimilar to the report by Iyer, Goodgold, Eberstien and Berg (1976) on a 53-year-old dentist who had experienced emotional lability and depression for several years. His GP referred the dentist to a psychiatrist, but the treatment had no effect. Later the dentist reported a tingling sensation and numbness in his feet, and was examined for vascular disease, but this was not confirmed. A neurological examination also proved normal. More than four months later he began to have difficulty holding and dropping instruments, and only then was a urine mercury test performed. Mercury was not initially considered in his diagnosis but with a mercury-urine level of 33 µg/litre, detoxification treatment was begun. The dentist’s urine mercury level was monitored frequently for a year, during which timeframe there was a downward trend, but not a steady decrease. There were fluctuations and intermittent rises. From a behavioural perspective, the man’s motor skills and sensation did gradually return to normal.

Symington, Cross, Dale and Lenihan (1980) reported two further cases of mercurialism in dentists. The men, aged 44 and 50, both had marked finger tremor, and in addition, the younger dentist experienced headaches and insomnia as well as being “irritable and argumentative” (p. 37). They suggest that although the risks from mercury exposure for dental personnel are well documented, few case studies get published. They refer to four case studies

reported by Merfield, Taylor, Gemmell and Parrish (1976), and the one by Cook and Yeates (1969), as the exceptions.

In the Merfield et al. (1976) paper, two dentists and their assistants developed headaches, insomnia, gastro-intestinal disorders, and mood changes, as the result of a large metallic mercury spill that had occurred after-hours. One of the dentists had developed fine motor tremor, such that he could no longer perform his normal work. The temporary assistant, who caused the accident, did not report it, and her clean-up attempt was inadequate. Mercury had pooled under the sterilising unit, behind cupboards and into the flooring. The GPs involved with the mercury-poisoned staff did not initially suspect mercury poisoning, and testing took place only after the temporary assistant had been contacted to check on her health; a call that resulted in her admission, and the eventual (temporary) closure of the contaminated building.

The conclusion of the Symington et al. (1980) paper was a call for greater awareness of the potential for mercury to be the root cause of vague symptoms of ill health; and to the hazards of mercury. They demonstrated that even when patients were occupationally exposed to mercury, some GPs may approach diagnosis and treatment as though mercury could not have had a causal role in illness, despite typical symptoms being present.

In medical patients, some symptoms may dominate in a presentation, particularly the mood disorders, so that mercury poisoning may be treated as depression, or for women, the emotional lability may be medically interpreted as a normal state for western females (Glass, 1981), with the underlying cause becoming only apparent when the woman fails to respond to treatment.

### *Mercury Poisoning Outside Medical Practice*

Outside of medical practice, mercury poisoning has been documented for over two centuries. Doherty (2004) reports perhaps the first occupational mercury poisoning in a paper on the neurological health of British seamen involved in the salvage of metallic mercury from a Spanish ship in 1810. The seamen developed tremors, paralysis, skin problems and pulmonary problems from skin contact and breathing mercury vapour.

Reviews of mercury poisoning, however, tend to refer to two critical events to show the adverse effects of mercury exposure. For metallic mercury exposure it is the report on occupational mercury poisoning in the hat manufacturing industry (Neal & Jones, 1938). For organic mercury exposure it is a number of studies of subsistence fishermen and their families who were the inhabitants of Minamata Bay, Japan, where, in the 1950s, there was widespread environmental mercury pollution from the waste products pouring into Minamata Bay from a chloralkali factory.

Neal and Jones (1938) reported the medical assessment of all the workers from five fur-cutting factories, representing approximately a quarter of employees in that occupation in the United States of America, in 1935. They suggested that chronic mercurialism was a known occupational hazard, but it had not been quantified before their study. Of the 529 people studied, whose work involved preparing fur-pelts for felt hats using a solution of mercury, 43 were diagnosed as having chronic mercurialism. In describing the differences between fur-cutters and other industrial workers, Neal and Jones suggested, "the most conspicuous difference between the two groups concerns the functioning of the nervous system" (p. 338). Symptoms reported included a fine intentional tremor that in advanced stages was disabling, some muscle weakness and psychiatric illness. Thyroid enlargement was explored and rejected as an explanation for tremors.

Tremor was seen as a key to a differential diagnosis of mercury poisoning, as there was a strong correlation between those with tremor and those with adverse mood changes; and there was a strong correlation between the degree of tremor and the deviation from expected normal behaviour of the times. Neal and Jones (1938) also suggested that "psychic disturbances" (p. 340) are the first sign of mercury poisoning and these may occur with low dose exposure. Of note were mood disorders including irritability and social withdrawal. Their conclusions were supported by medical reviews published concurrently.

The first signs of mercury in the food chain came from the observation that cats who consumed Minamata Bay fish developed severe balance and gait problems. The bio-magnification of methylmercury in the food chain led to mass intergenerational mercury poisoning for the local inhabitants. Members of the local population, where fish was the staple diet, are now extensively

studied. They developed the crippling, degenerative psychomotor and cognitive disorder termed Minamata disease. For over 1600 Minamatis, methylmercury poisoning was fatal (Eto, 1997; Eto, Takizawa, Akagi, Asano, Takahata, & Tokunaga, 1999; P. Powell, 1991; Tsuchiya, 1992).

Korogi, Takahashi, Okajima and Eto (1998) reviewed findings from a study of Minamata disease, which showed that the main brain changes were “atrophy of the occipital lobe and cerebellum” (p. 308). They described the clinical presentation as having: sensory disturbance in the distal parts of the extremities, ataxia, disequilibrium, concentric constriction of the visual fields, impairment of gait and speech, muscle weakness, tremor, abnormal eye movement, and hearing impairment reflecting cerebral and cerebellar lesions (p. 308).

Japanese accounts of Minamata disease do not describe mood changes, and focus on psychomotor, gait and visual field disturbances. This is surprising given the frequency with which affective changes are linked to mercury poisoning in other literature, and that experimental animal studies show the pituitary as an early site for mercury storage (Hahn, Kloiber, Leininger, Vimy, & Lorscheider, 1990).

Other mass poisonings have been documented in animal populations, as industrialisation takes its toll on wild species. This is relevant to the present thesis in that animal studies show the impact of mercury on reproduction. For example, Weech, Wilson, Langelier and Elliot (2003) report that birds such as Canadian bald eagles are threatened by environmental mercury pollution, as measured by mercury in live birds’ feathers or deceased birds’ livers. Mercury decreases successful reproduction, and egg-shells thin to such a degree that eggs may be broken by the nesting parent. Weech et al. claim that 6 percent of bald eagles were recorded as dying from metal toxicosis in a recent 7-year period.

The other species whose reproduction is much-studied is the American Common Loon. While the impact of mercury on Loons’ reproductive health is of concern because they feed on lake fish, this species also has documented visual impairment linked to mercury: an additional problem for birds described as visual predators (Atchison, 1995; Nocera, 1999).

### *Different Effects from Different Exposures*

Tremor, adverse mood changes and skin problems are the most likely symptoms to be observed in people with mercury poisoning, but there is no clearly predictable pattern to the presentation of intoxication. Acute and chronic exposures appear to have the same presentation, as do high and low dose exposures. The vagaries of the dose-response relationship are demonstrated by the experience of small amount of mercury from a broken domestic thermometer being sufficient to cause acrodynia, while occupational mercury exposure, over a long period of employment, may not necessarily result in any reported effects. These observations lead to a discussion of what is a sufficient and necessary cause.

#### *Acute Exposure*

Acute and high-dose exposure is rare and also usually accidental, as in the fatal case of a scientist working with di-methylmercury in a laboratory, where protective clothing and latex gloves did not provide sufficient protection from a few drops of this extremely toxic form (Zacks, 1997). The scientist developed gait and speech problems slowly, so at first the problem was not connected to the apparently tiny spill and mercury poisoning was not explored, or detoxifying drugs begun, until six months after the accident. However the symptoms of poisoning were aggressive, including tingling in her hands, visual disturbances and visual field constriction, and hearing loss. By seven months post-accident she was “unresponsive to all visual, verbal, and light-touch stimuli” and was described as appearing to be in a “persistent vegetative state with spontaneous episodes of agitation and crying”, before her death 298 days from the accident (Nierenberg, Nordgren, Chang, Siegler, Blayney, Hochberg, et al., 1998, p. 1673; also see Nierenberg, Blayney & Clarkson, 1998).

Nierenberg, Nordgren, et al. (1998) reported that the only three other cases of di-methylmercury exposure they found were all fatal, and that the progression of the signs and symptoms was the same as severe methylmercury poisoning, as seen in Minamata disease.

Lowry, Rountree, Levin, Collins, and Anger (1999) investigated an incident where teenagers played with several kilos of liquid mercury they had “found” and taken into their homes. The teenagers experienced flu-like symptoms, fine tremors and irritability, and although there were 61 people exposed by the teenagers’ actions, most were not accounted for in the paper, as few had agreed to be studied.

The flu-like symptoms are described more fully in Lim, Shim, Lee, Lee, Kang, Jo, et al. (1998), who have proposed a three-stage model to explain the progression of mercurialism from a case study of a 72-year old man who used a mercury-lead amalgam to treat haemorrhoids. Flu-like symptoms were described as the first stage. The second stage appeared 2-3 weeks after acute exposure and involved the central nervous system (CNS), respiratory tract, renal and gastrointestinal symptoms. In the third stage, the CNS symptoms persisted, while symptoms involving other organs responded to treatment.

Reports of acute and low-dose exposure are uncommon. The case of a boy who fell on a domestic thermometer and implanted both metallic mercury and glass into a contused wound on his arm (S. Smith, Jaffe & Skinner, (1997), and the case of a man who attempted suicide by injection of metallic mercury are examples (Hohage, Otte, Westermann, Witta, Welling, Zidek, et al. 1997). The boy who fell on the thermometer had a local allergic reaction and inflammation of the site, which healed quickly following surgery to remove the foreign matter. The man who attempted suicide also had the local inflammation; and the additional symptoms of headaches and intermittent tingling in his legs. His elevated urine-mercury levels did not appear to be related to the symptoms of mercurialism, other than mild depression. He began detoxification treatment three years after the suicide attempt, showing no side effects from the chelating drugs, which did initially elevate his urine mercury level further, but this lowered to within a normal range within six months.

There is one well-documented example of acute, high-dose exposure from an occupational setting, where the mercury involved was the same form as that used in dentistry. Bluhm and Branch (1996) report on the welfare of chloralkali factory maintenance men following an accidental metallic mercury exposure of 16 hours duration. The work involved pipe replacement requiring welding with oxyacetylene torches. The workers did not know the pipes

contained mercury residue, so that the welding resulted in the workers inhaling mercury vapour. In addition, men were required to clean up the metallic mercury from the pipes. The men had no protective clothing or breathing apparatus.

Nineteen days following the exposure incident, an assessment of 26 of the workers began. This involved assessing general health symptoms, blood and urine mercury levels, and the administration of neuropsychological tests. For 10 of the men, detoxification and neuropsychological monitoring continued for more than eighteen months. Seven non-mercury exposed men were monitored as controls (Bluhm & Branch, 1996).

Somatic symptoms that were initially reported included fatigue, sleep disturbances, weakness, and weight loss. Symptoms linked to CNS effects included headaches and dizziness. Mood changes were experienced by most of the group, including irritability, anxiety, loss of confidence and depression. Half the group reported tremor and just under half reported dermatitis and conjunctivitis. (For the complete list see Bluhm & Branch, 1996.)

Approximately two months following the accident, Bluhm and Branch (1996) used the Symptom Checklist-90 Revised to assess “the magnitude of erythism” (p. 422) in the exposed workers, and neuropsychological tests for psychomotor function and cognition, to monitor changes against clinical norms. They found a trail-making test and a Stroop test showed significant variation from the norm, but not a tapping test or the Grooved Pegboard task. Bluhm and Branch found that there was wide individual variation in results across the biological assays, the Symptom Checklist-90 Revised, and the neuropsychological tests.

Although Bluhm and Branch (1996) do not explicitly state that it took 19 days to link the pipe-cleaning and welding incident with the workers’ deteriorating health, it is implied when they proposed a four-way model to assist in the diagnosis of mercury poisoning. Their model is based on what is known of the mercury exposure, what symptoms were reported, and biological measures.

Bluhm and Branch (1996) outline the usual criteria for medical doctors to consider a patient may have mercury poisoning. This is where the exposure is

known, there are symptoms, and a biological mercury test has been conducted (Pattern A). They suggest that mercury poisoning should also be considered where exposure is known and symptoms are present, but a urine test has not been possible (Pattern B); exposure is not known but symptoms are, and biological indicators are present (Pattern C); and when there is no identifiable exposure and no reported symptoms but a urine test shows a mercury exposure has occurred (Pattern D) (see Table 1). The model is consistent with the medical papers already reviewed.

Table 1

*A Model for Diagnosis of Mercury Toxicity (Adapted from Bluhm and Branch, 1996, p. 424)*

Variable	Pattern A	Pattern B	Pattern C	Pattern D
Exposure	yes	yes	no	no
Symptoms	yes	yes	yes	no
Mercury levels	yes	no	yes	yes

The work presented by Bluhm and Branch (1996) summarises the current position for general medical practitioners when patients present with mercury poisoning. The diagnosis of mercury toxicity is challenging and confounded by difficulty in identifying sources of mercury exposure, the length of time that the symptoms continue in exposed individuals and the presence of measurable blood and urine mercury in the normal population. However, when mercury is present in the occupational environment, as it is for most dental personnel, Bluhm and Branch say that a diagnosis of mercurialism “must always be considered”, even in the presence of non-specific symptoms (p. 242).

### *Chronic Exposure*

Chronic high-dose is rare. A residential example is described by Fiedler, Udasin, Gochfeld, Buckler, Kelly-McNeil, and Kipen (1999). Pools of metallic mercury were found between the floors of a building that was being renovated. It had been a mercury-vapour lamp factory 60 years earlier. Residents, an artists’ collective, tended to work at home, and although no family had lived in

the building for more than two years, 26 of 29 occupants tested had elevated mercury urine levels; and ambient air mercury readings ranged from  $5\mu\text{g}/\text{m}^3$  to  $888\mu\text{g}/\text{m}^3$ . In a report on residential mercury exposure, linked to the artists' building, the Centers for Disease Control (1996) state that for the protection of public health, indoor mercury in air should be  $<0.3\mu\text{g}/\text{m}^3$

The residents' exposure level greatly exceeded public health standards, and comparison can be made with air tested in occupational settings, for example, a miners' dining room, above a gold recycling and recovery area of a mining operation. Malecki (1998) reported a prosecution resulting from a breach of the Nevada Mine Safety and Health Administration's limit of  $50\mu\text{g}/\text{m}^3$  for ambient air mercury, when readings over two days showed levels ranging from  $14\mu\text{g}/\text{m}^3$  to  $58\mu\text{g}/\text{m}^3$ . During the trial, the company's monitoring records revealed levels had on occasions reached  $200\mu\text{g}/\text{m}^3$ , and liquid mercury had contaminated the eating area. There were instances when there was a greater level of ambient air mercury in the dining area than the processing plant below.

Fiedler et al. (1999) reported that the residents experienced fine motor tremor and hand-eye coordination problems. They were all evacuated, and the building condemned; but because of the confounding effect of the emotional trauma created by the need to relocate, reported anxiety and symptoms of stress were not attributed solely to the mercury.

The miners' dining room case (Malecki, 1998) and the artists' condominium (Fiedler et al., 1999), further illustrate the apparent lack of a dose-response relationship, when people are living and working in toxic environments, but with little immediate adverse effect. The ambient air levels are notable in chronic high-level exposure, and will be considered in the *Mercury and Venus* study.

Chronic, low-dose exposure is the most common cause of mercury poisoning, whether from metallic or methylmercury. Studies from occupations where workers are exposed to metallic mercury, as dental personnel are, show that while it is necessary to be exposed to experience effects (obviously) it is not enough just to be exposed. In various reports that will be discussed below, it is

clear that workers may have similar occupational exposures, but they can have very different outcomes.

Vroom and Greer's (1972) paper on workers in a thermometer factory is frequently cited. Vroom and Greer describe nine case studies of workers affected by mercury vapour from a cracked oven used to bake decals on mercury thermometers. All nine workers initially had tremor and difficulty in concentration. Other initial symptoms may have included emotional lability and memory loss, for five workers; and muscular rigidity and mask face for four. Five of the workers experienced aural or visual sensory impairment, and five reported psychosomatic symptoms such as headaches and diarrhoea. The workers all had urine tests over a period of between eight to 15 months, during which time they had no further mercury exposure. Seven took a detoxification drug regimen.

Just as there were mixed symptoms, there were mixed results for recovery. More importantly, there was no strong correlation between recovery and treatment. Recovery was operationalised as a summary of motor skills and Wechsler Memory test results (no references given), and these showed that three workers recovered excellent motor skills, four recovered to a good level, and one worker, who did not have treatment, remained with poor motor skills. Five workers demonstrated recovery of good memory, while four were reported as still having a poor memory. Two of the workers whose memory did not improve, were the two who did not have treatment, and it was suggested their impairment was consistent with temporal lobe damage (Vroom & Greer, 1972).

Vroom and Greer (1972) summarised their scientific understanding of mercury poisoning from metallic mercury vapour as having the same clinical signs and symptoms as organic mercury poisoning, with a range of degrees of severity of symptoms. They suggested that some of the emotional lability might originate in the loss of memory causing anxiety, irritability, insecurity, and the like. Tremor was severe in all workers, but it showed the most rapid recovery with treatment.

Kishi, Doi, Fukuchi, Satoh, Ono, Morikawa, et al. and a mercury workers' study group (1993) were among one of the first to publish a study of residual mercury effects in occupationally exposed workers. Their population of

interest was men who had worked in a Japanese mercury mine that had been closed for 18 years. Archived employer and union address lists identified 149 miners, from which fifteen had died and 117 volunteered for the health survey. From these, 76 men, who had a history of mercury poisoning, were selected for neurobehavioural testing, along with a matched control group from the miners' community.

The health and symptom survey was by mailed questionnaire. Sections of the questionnaire covered both symptoms recalled during employment as a mercury miner and current symptoms, which Kishi et al. (1993) referred to as acute and chronic symptoms. Participants responded on a three-point scale to a list that included the symptoms of erythism, sensory symptoms, sleep and cognitive problems, skin and digestive disorders, sexual desire and senility, as well as issues for miners such as respiratory symptoms and musculo-skeletal pain. The assessment with a neurobehavioural test battery (NBTB) included coordination, cognition and psychomotor function, with tests selected especially for the elderly sample.

Findings from the 72-symptom survey were compared with a published list of miners' symptom experience from the time the mine was open, and there was little difference in the two lists. Of the symptoms of erythism, the most commonly reported were fatigue, insomnia, irritability and depression. It was noted that tremor, gingivitis and erythism were reported less in the chronic list; while joint pain and respiratory problems, and presbyopia and sexual decline, were reported more.

Apart from symptoms related to mining (e.g. pneumoconiosis), and those related to senility, there were significant between-group differences on the tremor measure, headache frequency and slurred speech. On the matched pair analysis of the NBTB scores, grip strength, short-term memory, pegboard and finger dexterity tasks, a hand-eye coordination task, and digit-span forward were all significantly different (at  $p < 0.05$ , and more often,  $p < 0.001$ ).

Of the 15 miners who had died, reports of two autopsies are published (Takahata, 1970 in Kishi et al., 1993). These were notable because the miners had been suffering from tremors and ataxia 10 years after the mine closed. Mercury concentrations in the brain were considered to be very high,

particularly in the occipital cortex, the parietal cortex and the substantia nigra.

Kishi et al. (1993) expressed the opinion that, from an epidemiological perspective, locating a suitable control group was a problem mainly because of the variety of work histories the men had. Nevertheless they believed that their significant findings did represent effects from the earlier mercury exposure that had endured over time.

Not all papers explore a range of CNS effects from mercury exposure. Cavalleri and Gobba (1998) looked specifically at colour vision loss in a study with thermometer factory workers. Visual disturbances have been discussed already, given that the occipital cortex appears to be a preferred site for mercury storage. Colour vision loss has been rarely examined, although Murry and Butler (1988) suggest that with dentists, it should be.

Cavalleri and Gobba (1998) used a desaturated hue panel to test 33 mercury-exposed workers and an unspecified number of controls, and found dose-related colour vision loss. Subsequent to this, the factory altered the work environment to minimise mercury exposure, and one year later Cavalleri and Gobba repeated the colour vision test with 21 of the workers and a control group. There were three main findings from the study. These were that colour vision loss was measurable in the mercury-exposed workers; that the loss was reversible when mercury exposure had been greatly reduced for a year; and that the workers had no subjective awareness that their colour vision was impaired during the period that it was.

A relatively new area for occupational mercury study was introduced by Maloney, Phillips and Mills (1998), with their study of crematorium workers. At the time the ratio of cremations to burials for United Kingdom deaths was 7:3, and crematoria were incinerating an estimated five and a half kilograms of metallic mercury from fillings per year. Hair samples from workers and controls were analysed and showed significant differences between the crematoria workers and controls ( $p < .0001$ ). While the paper signalled a need for mercury filters to limit mercury exposure for the workers and environmental pollution of soils in the surrounding area, it also highlights the

impact of dental mercury as a source of health risk beyond the dental practitioner and patient.

Hanninen, Piikivi and colleagues have published numerous papers on neurotoxins, including lead and mercury, from a behavioural toxicology perspective (for example, Hanninen, 1985; 1988; 1990; Piikivi & Hanninen, 1984; Piikivi, Hanninen, Martelin, & Mantere, 1984). Much of their work has focused on trying to establish a dose-response relationship, and on the relative permanence of symptoms that they had found through regular surveillance of exposed workers.

After a ten-year monitoring programme of chloralkali factory workers, Hanninen (1985) suggested that her results, particularly on cognitive impairment as assessed with the Wechsler Memory Scale, supported an upper limit of 25 µg/m<sup>3</sup> mercury vapour in ambient air, for minimising the effects of occupational mercury exposure. However, she expressed concern that even when exposure was below this level, some workers exhibited symptoms or adverse effects that were not reflected in raised urine mercury levels.

Triebig and Schaller (1982) found no dose-response relationship in their study of two women and 19 men from a chemical plant where workers used mercury, and another study of nine women and nine men from a thermometer factory. They reported tremor and short-term memory loss in the exposed workers, but did not say what assessment instruments were used.

Also finding that memory can be affected in occupationally exposed workers was the Soleo, Urbano, Petrera, and Ambrosi (1990) investigation of eight chronically exposed workers from a fluorescent lamp factory, a further 20 workers who were only occasionally exposed, and 22 non-exposed controls. Only two tests showed a significant difference between the chronically exposed workers and the other groups (at  $p < 0.05$ ). These were short-term memory, as assessed by the digit-span subscale of the Wechsler Adult Intelligence Scale (WAIS); and depression, from a clinical depression questionnaire.

Ellingsen, Morland, Andersen, and Kjuus (1993) reported on workers from a chloralkali plant that operated between 1947 and 1987. The focus of their study of occupational mercury use was neuro-psychological outcomes from

exposure. The main finding was that the younger a worker was on first exposure to mercury, the more likely they were to develop tremor or impaired coordination.

Mathiesen, Ellingsen, and Kjuss (1999) reported a follow-up study of 75 workers and 52 age-matched controls from the Ellingsen et al. (1993) study. They reported the findings of neurobehavioural testing and note some persistent effects on the central nervous system and visual system. In particular they found that simple reaction time and grooved pegboard tests had significant differences between exposed and control groups, on average 12 years after exposure to mercury had ceased.

T. Powell (2000) assessed 16 Zulu ex-workers from a mercury processing plant, as part of litigation proceedings by the workers against the factory management. The men had worked at the factory and been exposed to mercury for varying lengths of time, from under one year in the least case, to nine years for the longest serving worker. It was five years since their exposure ceased. Fifteen Zulu men matched for age and educational attainment formed the control group. T. Powell's test battery was based on a World Health Organisation (WHO) neurobehavioural test battery, with a test of malingering included to identify any lack of effort by those who might gain financially from the findings.

T. Powell (2000) reported that the men were affected in various ways, including having poor memory, as assessed by the Rey Complex Design test, and poor motor speed and manual dexterity, as assessed by the grooved pegboard. Significant differences were found for tremor, mood (depression and anxiety) and personality. Although only five years had passed, T. Powell suggested that these symptoms of mercury poisoning were not necessarily reversible.

Albers, Kallenbach, Fine, Langolf, Wolfe, Donofrio, et al. (1988), Letz, Gerr, Cragle, Green, Watkins and Fidler (2000), and Frumkin, Letz, Williams, Gerr, Pierce, Sanders, et al. (2001), all undertook follow up studies of chemical factory workers who had ceased contact with mercury. Albers et al. suggested that little was known about long-term effects, and their paper was the first to find a significant age-mercury interaction, raising the possibility that the natural aging process may gradually reveal sub-clinical damage from mercury

in previously exposed people. Letz et al. reassessed men from the same cohort a decade on, with the aim of replicating the Albers et al. study, and further exploring the effects of age on neurobehavioural measures. Their study did not find evidence to support a higher rate of cognitive dysfunction or dementia, but it did support the Albers et al. finding of persistent psychomotor deficits. Finally in the same cohort, Frumkin et al. added the dimensions of reproductive health, general health symptoms, and the effectiveness of detoxifying agents.

The occupational studies that have been reviewed are a sample selected from a large body of literature published in predominantly environmental or occupational health journals rather than in the medical journals, which is where the medical cases have been published. There is a consistent pattern to the reports. In summary, there is a range of presentations of adverse effects from toxic exposures, with no dose-response relationship; but symptoms generally did respond to chelation treatment with good recovery of general health.

### *Dental Studies*

Very low-dose chronic mercury exposure was studied by Siblingud, Molt and Kienholz (1994) in a study that aimed to explore a hypothesised link between mercury from dental fillings and mood. They recruited 25 women with silver amalgam fillings and 23 women who had never had amalgam fillings. Women with amalgams scored significantly higher on the Beck Depression Inventory, particularly with fatigue and insomnia; recorded more health problems on the Symptom Checklist 90, and had significantly higher mean scores for angry temperament and angry reaction on the State-Trait Anger scales. Women without amalgam fillings scored significantly better for anger control. Siblingud et al. concluded that mercury did affect neurotransmitters in the brain, and could be considered to have a role in the aetiology of mood disorders.

The conclusion reached by Siblingud et al. (1994) is consistent with post-mortem findings of Eggleston and Nylander (1987) who showed that there is strong correlation between the number of amalgam filling surfaces and mercury in brain tissue; and animal studies, (e.g. Hahn, Kloiber, Vimy,

Takahashi, & Lorscheider, 1989; Hahn, Kloiber, Leininger, Vimy, & Lorscheider, 1990), where the pituitary was identified as a prime site for raised mercury-tissue concentrations.

Despite this, it would be interesting to know more than is presented about the sample in the Sibling et al. (1994) study, as the strong support for a causal relationship between silver amalgam fillings and negative affect has not been replicated elsewhere. Questions of how the sample was recruited, and how the women were matched, may be pertinent for evaluating the findings, but so too are dental issues. It could be important to know if the women all attended the same dental practice, what the quality of dental work was like for the women with amalgam fillings, or possibly, for a dental materials scientist, the type of silver particle used in the amalgam. Further, these women would have been interesting to follow longitudinally, and particularly in light of any changes that the women with amalgam fillings made, after learning of the results of the study, but this opportunity seems to have been lost.

Shapiro, Cornblath, Sumner, Uzzell, Spitz, Ship, et al. (1982) in keeping with a medical approach to mercury poisoning, studied chronic health problems in dentists from one geographic region of North America. They used X-ray fluorescence (Bloch & Shapiro, 1981) as their indicator of the dentists' body burden of mercury. The X-ray fluorescence technique was favoured by Shapiro and Bloch, as it gives an indication of stored rather than excreted mercury, as a urine test would.

Shapiro et al. (1982) tested close to 300 dentists at a conference. Twenty-six dentists, showing mercury levels at more than 20µg/g tissue, volunteered for the high-mercury sample, and their health was compared with 17 dentist-volunteers who showed no detectable mercury. The mean age for both groups was 51 years. Some neuropsychological tests were administered as part of the study. These were the Wechsler Adult Intelligence Scale, the Bender Gestalt visual perception test, a finger tapping task, and the Grooved Pegboard. Symptoms were recorded on the Symptom Checklist-90. The high-mercury dentists differed significantly on the Bender Gestalt task from their low-mercury peers; five had carpal tunnel syndrome, and on the overall measure of general distress, 14 of the high-mercury group and three of the low-mercury group had T-scores above the normal range.

Uzzell and Oler (1986) partially replicated the Shapiro et al. (1982) study with a sample of 13 dental assistants and 13 matched controls with no occupational mercury exposure. They found, as had Shapiro et al., greater general distress, particularly contributed to by anxiety, obsessive-compulsive and psychotic scores; and a significant between-groups difference on a recurrent figures task.

Authors of both of the studies suggest that their findings raise questions about legal safety levels for occupational mercury exposure. This was because general cognitive functioning was not impaired in the participants of either study, but specific deficits were detectable at a sub-clinical level.

Murry and Butler (1988) undertook an investigation into all possible harmful chemicals in the dental office, and the effects of these products on dental personnel. Mercury was one of five harmful chemicals they identified. Fifty-one dentists or dental assistants, who were attending a dental conference, were recruited for the study. No control group was recruited; rather the neuro-physiological scores were compared with college norms.

The Murry and Butler (1988) study had four main findings where the dentists performed poorly on standardised tests. These included memory problems, concentration and attention problems, fine motor tremor, and a group of symptoms referred to as personality problems, but described as “difficulty in maintaining emotional stability and coping, as well as mild to moderate depression” (p. 45).

Personality was assessed by Murry and Butler (1988), using the Clinical Analysis Questionnaire (Krug & Cattrell, 1980). They found that 40 percent of the sample scored more than one standard deviation from the norm. Of those, 18 percent had very high scores, that Murry and Butler interpreted as showing that the participants were “warm hearted and personable” but with an “unhealthy and overriding need for approval from others”; while 27 percent had very low scores that were interpreted as “indicating a history of unsatisfying interpersonal relationships.” (Murry & Butler, 1988, p. 57).

The clinical factor analysis showed that 27-30 percent of the sample had mild to moderate depression, had signs of suicidal depression placing them at risk

of suicide, increased anxiety, and loss of confidence in their ability to practice. Murry and Butler (1988) concluded that there was much to be concerned about from the chemical/heavy metal work environment, stating:

Very often symptoms of poisoning will be vague and subjective particularly with low dosage in the early stages of the reaction to toxins, e.g., forgetfulness, tired, irritable, feeling down, weak etc., and the standard medical clinical test will not be adequate to point to the toxicity and its cause (p. 65).

Occupational stress is a confounding issue. As a professional group, it is claimed that dentists experience symptoms of negative affect, and are said to be at greater risk of suicide than their medical peers (Annan, 2001). Murry and Butler's (1988) findings suggest that there may be a causal link with the chemicals in daily practice, rather than either occupational stress *per se*, or predisposing personality traits.

McNerney and McNerney (1979) were also concerned about the dental office as a source of mercury exposure. In a review paper for a dental journal, they describe micro-mercurialism, with a focus on erythism and tremor; identify the most likely sources of mercury contamination; and, referring to an American Dental Association recommendation that dentists have annual urine-mercury test (American Dental Association, 1976, cited in McNerney & McNerney, 1979), suggest the alternative of using a mercury 'sniffer' instrument to monitor ambient air mercury. McNerney and McNerney reinforce the anecdotal evidence that dentists do not take the potential hazard of mercury seriously.

An alternative to 'spot' urine testing, as recommended for dentists to monitor their mercury exposure, besides air monitoring, is described by Gonzalez-Ramirez, Maiorino, Zuniga-Charles, Xu, Hurlbut, Junco-Munoz et al. (1995). It is the 'challenged' urine test. This technique requires a fasting period, the administration of a chelating drug, and the collection of a urine sample. Gonzalez-Ramirez et al. tested 15 dental personnel and 13 non-exposed controls, in an experiment to compare different methods of testing for mercury levels, and to correlate urine test results with the results of a neurobehavioural test battery. The findings showed that the 'challenged' mercury urine test was a better indicator of mercury exposure than urine

sampled before the chelator drug was administered. A regression analysis showed that chelated urinary mercury levels were “statistically and adversely” associated with the attention task, a digit-symbol substitution task, mood, and reported symptoms. Gonzalez-Ramirez recommended the ‘challenged’ urine test for monitoring occupational mercury exposure.

Canadian dentists were also reminded to treat mercury in their offices as an environmental hazard. D. Jones, Sutow, and Milne (1983) surveyed 139 dental surgeries, taking air tests at specific locations, and recording details of floor coverings, frequency of recycling of scrap amalgam, and the like. While D. Jones et al. did not collect health data, they did conclude that there was a worrying level of apathy in dental practitioners about safe mercury practices. In their 1983 study only 3 percent of surgeries exceeded the ‘threshold limit value’ (TLV) for ambient mercury, whereas 10 percent had exceeded the TLV five years earlier; but there was still a “low level of usage of protective measures and insufficient planning for accidental spillage...” (p. 393).

Ngim, Foo, Boey, and Jeyaratnam (1992) reported on a study of 98 dentists and 54 non-mercury exposed controls, where the aim was to identify early changes in the skills that dentists need to perform their work, such as sustained concentration, manual dexterity and visual scanning. Dentists performed more poorly than controls on all tests except the Wechsler Adult Intelligence Scale, and significantly poorer on finger tapping, symbol-digit exchange, digit span, trail making, logical memory, visual tasks and the Bender Gestalt task. On the Profile of Mood States (POMS) assessment, dentists scored higher on aggression than controls. A dose-response effect was found for neurobehavioural test performance and mercury exposure for the dentists. Ngim et al. (1992) concluded that, as none of the dentists perceived themselves to have problems in performing their job, the results had shown a pre-clinical level of dysfunction. They expressed concern that if exposure to mercury continued, pre-senile dementia and finger tremor were both possible outcomes for the dentists.

Ritchie, Macdonald, Hammersley, O’Neil, McGowan et al. (1995) incidentally used dentists as participants in a pilot study of a computerised cognitive assessment programme. They presented a somewhat biased review of psychological assessment, for example stating that there has been a range of

different measures used to assess the psychological effects of low-level mercury exposure, which is accurate, but going on to suggest that nowhere has there been a systematic development of a neurobehavioural test battery (NBTB), which is misleading. (See Chapter 4 for a review of NBTBs.)

Ritchie et al. (1995) present the findings from groups of 20 older dentists (mean age of 40 years), 19 younger dentists (mean age of 23 years), 20 older controls (mean age of 44 years) and 20 younger controls (mean age 28 years). They acknowledge that the controls were not well matched, and they had “a poor response rate” (p. 814) especially for controls. That said, a significant difference was found ( $p < 0.05$ ) with simple reaction times, where the older dentists performed faster than both the younger and older control groups, but not the younger dentists. There was one memory test where the older dentists were reported to do less well, but Ritchie et al. did not say in comparison with which group. They did suggest that a larger study (with their NBTB) is needed, because they found with simple reaction time, that it was “implausible that this was due to mercury”; while at the same time they have accepted that their memory test result “was modest and might have been due to mercury exposure” (p. 816).

This paper is a useful reminder that not all papers that focus on mercury and dentistry do so without a hidden (or not so hidden) agenda. The Ritchie et al. (1995) paper is not contributing to the neurobehavioural perspective in the mercury debate, so much as being a pilot for a commercially available product. However, this does not mean the data collected were not useful; rather, having Ritchie et al. accept only the results that fit their position while rejecting results that are more difficult to explain, leads to the conclusion that their work is of questionable value.

### *Swedish Studies*

The agenda underpinning the steady output of research from Langworth and colleagues is more subtle. Langworth's early writing on occupational mercury exposure involved chloralkali factory workers and aimed to differentiate the contributions of occupational mercury exposure, methylmercury (presumably from fish in the diet) and an individual's dental amalgam fillings to human

mercury body-burden (Langworth, Elinder, Gothe & Vesterberg, 1991). The current understanding of the oxidisation and ionisation of mercury from any or all sources suggests that these are inappropriate or futile distinctions to pursue, because both inorganic and organic mercury cross the blood-brain barrier and both circulate in the blood and are stored in any tissue. At the time, however, there was a belief that mercury from a metallic source was likely to be stored in the brain, while the primary storage site for mercury from an organic source was in the kidneys. In the 1991 study Langworth et al. suggested that mercury from occupational sources, i.e. metallic mercury, overshadowed mercury that may have come from fish or amalgam fillings.

Langworth, Almkvist, Soderman and Wikstrom (1992) reported the CNS effects of occupational mercury exposure, from the same group that participated in the Langworth, Elinder, Gothe and Vesterberg (1991) study. This involved 89 chloralkali factory workers and 75 controls. The neurobehavioural test battery included a tremor measure, a hand-eye coordination task, a tapping task, a simple reaction time task, a digit span measure, and a short-term memory test. None of the tests showed any significant differences between the groups. Mood, assessed with the POMS, showed the mercury exposed workers to be more confused and more tired than the controls; while personality assessment with the Eysenck Personality Inventory showed the exposed workers to be more neurotic. Langworth, Almkvist, et al. had expressed concern over the potential for over-reporting of symptoms and had selected the POMS and the Eysenck Personality Inventory because these two tests were thought to be more resistant to over-reporting.

From the study, Langworth, Almkvist, et al. (1992) concluded that there was only weak evidence of CNS effects, even from those workers who had been working at the factory for a long time. At the end of their paper they make reference to the debate on the safety of amalgam fillings, saying that because there is a debate they “tested the relation between the number of amalgam surfaces and some of the effect parameters. These calculations showed no significant correlations...” (p. 554).

It is not surprising to find, that in a sample where there was little evidence of CNS effects linked to occupational mercury exposure, that participants’ dental work made no difference. What is surprising is that with a much larger

sample than other studies of chloralkali factory workers, where CNS effects are consistently found, the Langworth, Almkvist, et al. (1992) study reported significant between-group differences only for mood change and neuroticism; and these with the implication that a neurotic worker may over-report symptoms. Langworth, Almkvist, et al. appear to suggest that personality is the key determinant of reported CNS effects from occupational mercury exposure. They made no comment on the relative safety records of Swedish chloralkali factories *vis a vis* Japanese or American chloralkali factories, or any particular commitment by the factory under investigation, to mercury hygiene. These are confounding variables that could explain why this study has uncommon findings.

Langworth later reported working in an 'Amalgam Unit', set up in 1992, in a Swedish hospital. The unit was established in response to the Swedish public's questioning of general medical practitioners about adverse health effects from their fillings and that "This was a question their regular physicians could not always handle" (Langworth, 1997, p. 65).

The unit is reported to have seen 1300 people who were referred there because they believed their amalgam fillings compromised their health. Langworth (1997) reports on the psychosomatic symptoms of 379 people, of whom 263 were women aged between 40 and 50 years. The paper does not explain why this sample was selected, or why others were excluded, or what the time frame was for the 1300 referrals. Of the 379, 30 percent were in work, 30 percent on sick leave from work, and 30 percent retired sick. General symptoms frequently reported included general weakness, fatigue, dizziness, lack of concentration, headaches, metallic taste, anxiety and depression. Tremor was not often reported.

The Amalgam Unit protocol was described as follows: patients first saw a dentist who examined the oral mucosa, and quantified their amalgam load. The following month the patient had a physician's appointment where a medical history was recorded and a battery of biological tests was arranged. The tests included a skin patch test where there was facial eczema or oral lichen. Finally the patient saw a psychologist for a one-hour interview on "life history, mental trauma, social network, and personality" (Langworth, 1997, p. 66). The end of this process was that the dentist, physician and psychologist

met to make a diagnosis before the patient was called back to be given treatment recommendations.

Of the 379, 10 percent were found to have undiagnosed medical conditions including thyroid and kidney disease, and 10 percent had an allergic reaction to the metals patch test. For the remainder the treatment focus was to “strengthen the patient’s social network” and give “correct information about the adverse effects of mercury” (Langworth, 1997, p. 66), where patients had been misinformed by mass media sources. Langworth concluded that the patients had no clinical signs of mercury poisoning, but that there were signs of somatization, and he did not support the opinion that mercury poisoning underpinned what the public may have considered to be “amalgam disease” (p. 67).

Langworth and Stromberg (1996) report one case history of a woman who believed her amalgam fillings were causing fatigue, dizziness, headaches, a metallic taste, gastrointestinal problems and other symptoms, and had increasingly done so over a 10-year period. They recorded an unchallenged urine-mercury level for her, before the intervention began, and this was 223 $\mu\text{g}/\text{l}$ : a level well above the internationally constructed ‘lowest observable adverse effect level’ of 50 $\mu\text{g}/\text{l}$ . Subsequent regular urine samples were taken and frozen for later testing, so that knowledge of her results could not inform the woman’s reported symptom experience that was documented along with the process of deamalgamation.

Stromberg removed the amalgam for this patient over an eight-month period. Ten months following the first appointment, the woman reporting feeling healthy, a state that had endured for two years at the time of publication (Langworth & Stromberg, 1996). The urine samples showed a steady decline in excreted mercury over the 10-month period, along with the symptoms. Despite a strong negative correlation between both the number of amalgam fillings and urine mercury level as variables in a relationship with self-reported health, Langworth and Stromberg suggest the woman must have had a tooth grinding habit, that there still could have been a placebo effect, and that health improvement could have been spontaneous and only coincidentally related to the amalgam removal and mercury-urine decline. They state, “therefore it is

impossible to draw any conclusions regarding mercury intoxication in this case" (p. 321).

There appears to be a pattern in papers authored or co-authored by Langworth, that if the findings of a study supported his position that mercury poisoning symptoms are mediated by personality, he accepts them without considering limitations or confounding variables; but when the findings do not give support, he does not modify his position. In the case reported by Langworth and Stromberg (1996), the authors could have reported the patient's propensity to grind her teeth, as this should have been a consideration in her treatment planning, as some filling materials are not suited for tooth-grinders. The placebo suggestions are not well supported after a 10-year illness was followed by two years of sustained health. It is only in the final sentence that Langworth and Stromberg consider that mercury poisoning may vary greatly in individual presentation, leaving it to the reader to come to the more likely explanation, that the woman had a classic case of mercury poisoning resolved by deamalgamation and detoxification.

Finally, Langworth, Sallsten, Barregard, Cynkier, Lind, Soderman (1997) document mercury exposure from mercury in 22 dentists and 22 dental assistants from six dental clinics, and 44 hospital employees without occupational mercury exposure. To assess CNS effects of mercury exposure, three self-report measures were used: the POMS for affect, the Eysenck Personality Inventory for personality, and a questionnaire for symptoms. Only the POMS showed a significant between-groups difference, and then only on the 'anger' subscale. Discussion skirted around the occurrence of occasional high peaks in ambient air mercury in Swedish dental clinics, claiming that they were essentially workplaces with good mercury hygiene; and staff who showed no adverse health effects.

In the papers by Langworth and colleagues discussed above, there was a tendency for the studies to omit assessment of some symptoms that other investigators have found to show differences between exposed and control groups. The assessment of tremor is an example. There was a further tendency to discount the symptoms that previous studies say may indicate intoxication, even in the absence of a raised biological indicator of mercury intoxication. The list of symptoms that Langworth refers to, as evidence of

somatisation, is very similar to lists of symptoms from medical cases of mercury poisoning that did respond to detoxification treatment. This raises the possibility that where most physicians acknowledge erythism as a symptom of mercury poisoning, Langworth and colleagues see erythism as evidence that the patient simply has a psychiatric disorder. There remains the possibility that this could be a problem that arises from the translation of Swedish research, but the trend over many years is for Langworth and colleagues to take the position that people who believe in amalgam illness are poorly informed, psychiatric patients.

### *American Studies*

The last and contrasting set of papers centre on the work of Echeverria and colleagues, from the Battelle Centre for Public Health Research, in the United States of America, who have been looking specifically at low-level mercury exposure in dentists (Bittner, Echeverria, Woods, Aposhian, Naleway, Martin, et al., 1998; Echeverria, Aposhian, Woods, Heyer, Aposhian, Bittner, et al. 1998; Echeverria, Heyer, Martin, Naleway, Woods, & Bittner, 1995).

Dentists attending an American Dental Association Conference were 'spot' tested for mercury in urine. Of the 1706 tested, 29 had mercury levels above an arbitrarily selected level of 19µg/l, and of these, 19 volunteered for a study that would contribute to the understanding of the 'lowest observable adverse effect level' for mercury. For 150 dentists mercury levels were non-detectable, and 20 of this group were randomly sampled for a control group. Mood was assessed with the POMS, and a NBTB measured memory, attention, simple reaction time, symbol-digit substitution, and vocabulary. As all the participants were expected to have equivalent vocabulary levels, the vocabulary test was included to assess concentration level. Motor skill was assessed with a pins placement task (Echeverria, Aposhian, et al., 1998; Echeverria, Heyer, et al., 1995).

Even with a small sample, Echeverria, Heyer, et al. (1995) and Echeverria, Aposhian, et al. (1998) found various adverse pre-clinical effects. Using a sum of ranked scores statistic, overall lower performance was significantly associated with higher mercury urine levels. Mood showed the clearest

association, with the total POMS score significant to  $p < 0.001$ . On the strength of the association across all categories, the authors recommended that mood assessment always be included in mercury exposure research.

Further papers, and work-in-progress, from Echeverria and colleagues at the Battelle Centers for Public Health, extend the study of toxic effects on dentists to their use of nitrous oxide, and to establishing more precise and reliable biomarkers for pre-clinical mercury effects through urinary porphyrin analysis (Bittner et al., 1998). They espouse the view that an assessment of the adverse effects of mercury exposure does require the use of measures that are sensitive to sub-clinical effects, and that cover the domains established for mercurialism in medicine.

### **Chapter Summary**

Mercury is a neurotoxin in all of its forms, and this is well established in medical cases, at autopsy, in naturalistic observation of animal species, and through biological monitoring and neurobehavioural testing.

There is an accepted set of clinical signs and symptoms of mercury intoxication, but not all, or any specific sign or symptom, need be present for a diagnosis of mercury poisoning, varyingly labelled mercurialism, micro-mercurialism, acrodynia or Minamata disease. There are some symptoms of general distress commonly seen on presentation for medical examination and these include headaches, skin problems, insomnia, fatigue and dizziness. Other insidious symptoms such as depression, emotional lability, and anxiety, may be linked to erythism, a psychiatric mood disorder linked to mercury exposure. There may be psychomotor problems including fine tremors, sensory changes such as visual or auditory disturbances, and some cognitive decline.

Invariably the authors of medical case histories reported that, in medicine, mercury is not readily investigated. This may be because patients do not realise, or do not acknowledge, that they had contact with mercury. Further, there is a wide variation in presenting symptoms, and finally, the onset of those symptoms is often so slow that an accidental exposure may be forgotten

or overlooked. In occupational settings very small amounts of metallic mercury or mercury vapour have been sufficient to cause mercury poisoning for some people, while others, who may have greater exposure, may show no ill effects at all.

From this, journal contributors, who are medical practitioners, suggest that mercury should be investigated whenever occupational exposure to mercury has occurred, where more than one family member is unwell, or where there is some combination of tremor, rash, mood change, memory loss or visual disturbance.

The most common mercury exposure is chronic, low-level occupational exposure. In occupational mercury studies there is a well-established pattern for such adverse effects as tremor, psychomotor changes, erythema, somatic symptoms and visual disturbances to develop, and to endure after exposure to mercury has ceased. There are unanswered questions about continued effects with aging and about the effectiveness of treatment. Scientists, other than those interested in behavioural toxicology, are not in full agreement about safe levels of exposure – either as determined by a biomarker such as urine-mercury, or in the work environment such as air-mercury. They do agree, however, that workers in dental surgeries should manage their exposure and monitor their body burden.

There appears to be no controversy over the adverse effects of mercury exposure except where the source of exposure is said to be dental amalgam fillings. This is the topic of the following chapter.

## **CHAPTER TWO: MIRROR AND PROBE – AN OVERVIEW OF THE DEBATE**

### **The Debate and Mercury Safety Defined**

In the debate on the safety of mercury in dentistry, the simplest expression of the moot is whether or not the inclusion of metallic mercury as approximately 50 percent of dental amalgam filling material presents a risk to the health of dental patients, or to dental personnel who use the toxic material in their dental practice.

The reality is not quite so simple. There are confounding variables from exposure to mercury from environmental and dietary sources, and from individual variation in susceptibility to store rather than excrete mercury. These are rarely accounted for in the scientific discourse.

The World Health Organisation states that there is no safe level of mercury exposure (Friberg, 1991). The various studies that have attempted to quantify a safe level have suggested using indicators such as the 'lowest observable adverse effect level' (LOAEL) (Echeverria, Heyer, et al., 1995), the 'no observable adverse effect level' (NOAEL), and the 'tolerable daily intake' (TDI) (Eley, 1998), or the 'threshold limit value' (TLV) (Berglund, 1990). The threshold limit value has been adapted to cover a time period, such as a working day, to give a time weighted average (TLV-TWA) (Soleo et al., 1990). There is minimal scientific agreement on medical or legal biomarkers for the point at which exposure places a person at risk, because there is no dose-response relationship, and there is little agreement about the manifestation of unsafe exposure.

Presently, various occupational health and safety guidelines for best practice, or legally sanctioned limits, have set the maximum level for individual exposure between 40-50 $\mu$ g of mercury per litre of urine; and in workplace ambient air at 25-50 $\mu$ g of mercury per cubic meter over a 40 hour working week (Eley, 1998). There is no agreement on the number of amalgam fillings, or because fillings vary in size and shape, the number of tooth surfaces with

amalgam, that, irrespective of other sources of mercury, would take a dental patient over the individual limit.

### **A History of the Debate: 1830 - 1995**

The ideology of the safety of mercury in dental fillings has been debated intermittently since 1833 (Talbot, 1882), and has dominated the politics of western dental practice. The differences of opinion about the potential for mercury in dentistry to cause mercury poisoning in patients have been referred to as the amalgam debate for over 170 years; and in some literature the differences have been referred to as “the amalgam wars” (Mackert, 1991, p. 54).

Talbot (1882) reported that the use of mercury in tooth filling material was believed to endanger patients. It was “declared to be malpractice” (p. 3), in 1843, by members of the first American dental association, the American Society of Dental Surgeons. They wished to “rid the profession of charlatans and their obnoxious materials” (p. 3). By 1850, when neither dental patient health problems, nor dental practitioner health problems appeared to be linked to mercury-based fillings, members split into pro-amalgam and anti-amalgam lobbies. Dividing the nascent dental profession was the ethical problem that mercury had simply not been found to be unsafe, rather than members having empirical evidence of its safe use. The first political casualty of the debate was the Dental Society, with pro-amalgam members forming the a National Dental Association in 1897, renamed the American Dental Association in 1922 (also see [www.ada.org](http://www.ada.org) ).

The next major anti-amalgam challenge to dentistry came from Europe in the 1920s. Stock, a Professor of Chemistry, focussed on the toxic effects of mercury vapour, and in particular argued against the use of copper-mercury amalgam in dentistry (Stock, 1971). While a medical investigation supported his concern about the toxicity of copper amalgam, silver and tin mercury mixes were considered as safe tooth filling materials. This was because copper amalgam required a heating process that greatly increased the release of mercury vapour from the amalgam, while silver and tin were mixed with mercury at room temperature.

An amalgam myth was debunked in the 1950s. The understanding of the physical properties of dental amalgam was that once the mercury and metal(s) were mixed, the mercury component became inert – being bound up inexorably once the amalgam had hardened or set (Frykholm, 1957). This is not the case. Mercury is continually leached from amalgam, primarily as vapour, but also as mercuric ions, and in quantities that can be detected in a dental patient's mouth, by instruments that can detect mercury-in-air (for example, the Jerome mercury-sniffer, McNerney & McNerney, 1979). Over a 10-year period this leaching may result in amalgam losing 40-50 percent of the original mercury content (J. Patterson, Weissberg, & Dennison, 1985; Vimy & Lorscheider, 1985a; Vimy and Lorscheider, 1985b). A metaphor for a layperson would be to say that a 10 year old filling, when viewed microscopically, resembles Swiss-cheese, with the silver being the cheese and the holes being the places from where mercury has been entirely lost.

Eley (1998) reviewed a number of studies of intra-oral mercury concentrations, and a variety of ways of calculating speed of release. The wide range of variables highlights the impracticality of placing too much emphasis on exposure alone, rather than individual body burden or symptoms (see Table 2).

Until the 1980s the debate was primarily argued in scientific circles. Then an anti-amalgam dentist, Hal Huggins, caught the public and the media attention alike, with claims that mercury fillings were causally linked to a wide range of general health problems, and specifically Alzheimer's disease (Huggins, 1993). His personal anti-amalgam crusade was enhanced in the eyes of supporters, and doomed in the eyes of detractors, when Huggins was struck-off his State Dental Register following a dental misadventure lawsuit, linked to amalgam removal. Later, on an international lecture tour, Huggins claimed his Coors (Beer) Corporation funded study<sup>6</sup>, showing positive health outcomes for dental

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<sup>6</sup> The wife of the Coors Corp. President was a patient of Huggins' dental practice, and it was claimed by Huggins that she had a personal health-recovery story following deamalgamation. The claim supported his explanation for a beer manufacturer being a funder of dental research.

patients who underwent deamalgamation, was blocked from publication by the power of the pro-amalgam lobby<sup>7</sup>.

Table 2

*Variables in Intra-Oral Exposure from Mercury Released from Amalgam Fillings. (Adapted, modified and extended, from Eley, 1998, p. 25)*

Variables	Examples of operational definitions
Amalgam load	Number of amalgam fillings, number of amalgam surfaces, galvanic activity.
Eating habits	Frequency of meals, frequency of snacks, duration of chewing, texture of foodstuff, temperature of foodstuff.
Drinking habits	Frequency of taking drinks, duration of drinking, temperature of drinks, alcohol intake.
Tooth-brushing habits	Frequency of brushing, toothpaste type and quantity, type of brush, duration of brushing, manual or electric technique.
Breathing habits	Mouth to nose breathing ratio, inhalation-exhalation rates.
Saliva flow	Frequency of swallowing, viscosity of saliva.
Other oral habits	Gum chewing, smoking, tooth grinding.

<sup>7</sup> The present author attended a public lecture by Huggins, in Auckland, Feb 1999, where he made these claims. The New Zealand Academy of Oral Medicine and Toxicology hold videotapes of his lectures, including the Auckland lecture.

The public interest in the safety of dental amalgam also coincided with two other societal changes: the rise in the level of patient dissatisfaction with their relatively 'ignorant' positioning in practitioner-patient communications (see Jeffreys, 1998); and the rise of mass communication of health 'facts and fiction', beginning with computer discussion lists, and later *via* the internet. Since the mid-1990s the debate has been endemic in health fora.

### **A Decade of Reviews: 1995 – present**

Some countries have adopted public health policy to voluntarily reduce the level of amalgam use through the promotion of preventive dentistry, rather than conservative dentistry; and by providing incentives for dentists to consider alternatives to amalgam fillings in treatment planning. One of the first countries to do this was Sweden. Sweden legislated against the use of any dental amalgam filling material in pregnant women in 1988, in children in 1993, in youth under 19 years in 1995, and withdrew amalgam completely in 1997.

The legal right for Sweden's total amalgam withdrawal was unsuccessfully challenged in the European Economic Community report on *Dental Amalgam* (Cooper, 1998). The challenge was not on safety grounds, but concerned economic agreements, where a European Economic Community member country (for example, Germany) that produces dental amalgam, must be allowed to market it in another member country (for example, Sweden).

Health Canada commissioned Richardson (1995) to prepare the most extensive report on amalgam to be written in the last decade. From Richardson's report, Health Canada made specific recommendations for dentistry, including: Non-mercury fillings should be considered for the primary teeth of children..[and] whenever possible, amalgam fillings should not be placed or removed from the teeth of pregnant women. (Health Canada, 1996, p. 15).

Following the public release of the Richardson (1995) report, Health Canada held a controversial stakeholders' meeting to decide how to implement the findings. Participants included the Canadian Dental Association and amalgam manufacturers, as well as academics, environmentalists and patient advocacy

groups. The outcome was a set of guidelines for amalgam use in Canadian dentistry (Health Canada, 1996), but the anti-amalgam lobby claimed stakeholders had exerted undue influence on the proceedings.

Health Canada's (1996) guidelines for amalgam use were focused on giving dentists and their patients more treatment options, and amalgam removal or use was contraindicated in patients with kidney disease, or during pregnancy. In the final document there were some minor additions to these two criteria agreed by the stakeholders' meeting. They were the recommendations not to place amalgam in children's teeth; in contact with metal orthodontic braces; to avoid amalgams in hypersensitive patients; and to use techniques that minimise mercury exposure for staff and patients alike, during dental treatment. It was suggested that dentists try to empower patients to make non-amalgam choices. Of importance to the debate was the conclusion that "...evidence does not warrant the removal of amalgam fillings from individuals who have no indications of adverse effects" (p. 14).

In New Zealand, the Ministry of Health (NZ MoH) commissioned its own review (Cutress, Godfrey, Millar & Whyman, 1996, embargoed until 1997). The review generally supported the American pro-amalgam position based on mercury threshold limit values (Berglund, 1990), while acknowledging that there were gaps in scientific knowledge, specifically on the effects of long-term occupational exposure, and the quantification of individual variation in susceptibility.

One author, Godfrey, continued to stress the point that his medical and clinical judgement had been overruled in the report, and in a letter to the Editor of the New Zealand Medical Journal (Godfrey, 1998), claimed he was vindicated when two amalgam manufacturers (Ivoclar and Dentsply/Caulk) changed their Material Safety Data Sheets to include warnings about the unsafe use of their products in an even wider range of situations than Health Canada had proscribed (see Appendix C for manufacturer's contraindications to amalgam use). Godfrey requested that the Ministry of Health reassess the New Zealand policy position.

The NZ Ministry of Health issued an open letter to dentists in 1999, with an attachment from the British Department of Health's Committee on Toxicity of

Chemicals in Food, Consumer Products and the Environment. In it, the New Zealand Ministry of Health state that while it had not changed its position on amalgam, attention was drawn to the British policy shift, that recommend limiting placement or removal of amalgam in pregnant women, and for dentists to advise patients carefully. There has been no further change in this policy, in New Zealand or elsewhere, in the last five years.

### **The Pro-Amalgam Perspective**

The contemporary argument offered for the pro-amalgam (protagonist) position can be summarised as follows:

#### *Allergic Responses*

Pro-amalgam debaters acknowledge that *rare* allergic responses to mercury have been documented, as have some mercury tattoo effects, where amalgam causes a metallic pigmentation in the gingival (gum) tissue adjacent to a filled tooth. Beyond this, they make the oxymoronic claim, that there is no scientific evidence to suggest that, although toxic, mercury from fillings does any harm (Dodes, 2001; Eley, 1998; Wahl, 2001a).

Mackert (1991) critiques the findings of a study of mercury allergy where the researchers reported a 16 percent positive response to a patch test (Djerassi & Berova, 1969), saying that there was a gross overestimation of the level of population hypersensitivity based on the type of mercury solution placed on the patch<sup>8</sup>, and that the study did not use a double blind procedure. Mackert estimated the correct figure to be closer to 3 percent, from a large, double-blind study where the patch contained “1% ammoniated mercury in petrolatum” (p. 56).

#### *Published Research*

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<sup>8</sup> 1% mercuric chloride

The acceptance of research into mercury poisoning from dental amalgam is problematic for the protagonists, if it is not from a randomised clinical trial, which is the level of scientific 'proof' required. The Federacion Dentaire Internacionale<sup>9</sup> (FDI) issued the 1997 statement: "No controlled studies have been published...demonstrating systemic adverse effects from dental amalgam." (no longer available on the FDI website, but accessed January 29, 2005, on [www.ada.org/public/media/others](http://www.ada.org/public/media/others), p. 3).

The resistance to, or denial of, mercury being implicated in disease is a strong theme in pro-amalgam literature. Wahl (2001a) claims that it is a myth that mercury has any causal role in kidney damage, diseases of the central nervous system, mental diseases, immune system damage, antibiotic resistance, or reproductive health, and critiques various studies that purport to show a causal link.

#### *False Cure Claims*

Reported cures of people who have been chronically ill, had their mercury removed by removal of teeth or replacement of fillings, and a chelation process, (for example, Godfrey & Campbell, 1994) are said to be not scientific, or that the journals publishing the studies are low-ranked and/or unscientific. Case studies that apparently demonstrate a link between amalgam fillings and ill health (for example, Chu, Huang, Ryu & Wu, 1998) are rejected for a variety of reasons such as: case studies have little scientific validity, they only demonstrate a placebo effect, the results are a coincidence, the treatment was quackery, or the findings are an inaccurate representation of the truth (Wahl, 2001a).

Overnight cures are a bugbear for protagonists in the debate. These are said to occur when a person has their fillings replaced with a non-amalgam material, and in the process reports immediate relief from some illness.

Wahl (2001a) goes to some length to point to a flaw that shows how any person who reports such a 'miracle-cure' story is irrational or perhaps

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<sup>9</sup> The Federation of World Dental Associations

deluded. The flaw is that the removal of mercury fillings by drilling out the fillings creates friction and heat at the filling-drill interface, and this releases more mercury and mercury vapour than having the filling age in place. When amalgam removal is undertaken, a patient's blood and urine mercury levels will increase. If a person's health was already compromised by mercury or hypersensitivity to mercury, the amalgam removal would or should make them feel worse, if the causal effect was real. A discussion of this point, informed by focus group discourse, appears in Chapter 3; with a magazine cutting of this genre of journalism. However, the story does not claim an overnight-cure.

The New Zealand Dental Association's (NZDA) official website illustrates the pro-amalgam position, and the possibly fallacious (straw man) pro-amalgam response. In a FAQ<sup>10</sup> page on silver amalgam, a question posed is, "I've heard that people are cured from illness when amalgam fillings are removed – is this true?" However, the answer does not address the question but shifts the definition of the phrase "cured from illness" to "overnight cures from serious diseases", in the misleading answer ([www.nzda.org.nz/public/amalgam.htm](http://www.nzda.org.nz/public/amalgam.htm), see Appendix D, accessed October 22, 2004). It is easier to debunk claims of overnight cures, where the disappearance of symptoms would be inconsistent with no real change in stored mercury; but a gradual cure from progressive detoxification is more plausible.

#### *Exposure by Dental Personnel*

The point has already been made that for pro-amalgam dentists, patient safety is to some extent guaranteed by their belief that if anyone were to show adverse effects from the use of mercury in dentistry, it would be dentists.

D. Jones et al., (1983) have assessed ambient mercury vapour in a range of dental surgeries in North America, and report on various aspects of office environment risk factors. They suggest that there are many variables within an office or surgery that can influence the level of staff exposure to mercury, and that these variables should be manipulated by the dental staff to minimise exposure. Variables include the type of floor covering and cleaning, ventilation

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<sup>10</sup> Frequently asked questions

(especially on the workbench), whether or not amalgamators have covers, and the disposal of waste amalgam.

D. Jones (1999) has also attempted to answer to the question of who is actually more exposed, dentist or patient? For patients, this required an estimation of mercury release from fillings, with the difficulties of this already discussed, plus the development of a model of absorption and storage of mercury over the estimated life of a filling. There was no comparable model for dental personnel exposure. D. Jones estimated a patient would need nearly 500 amalgam tooth surfaces to reach Health Canada's tolerable limit value and concluded dentists were more at risk. Richardson (1995) had suggested the limit would be reached with 10 fillings per adult and fewer for children. The 50-fold difference between the two models has not been resolved, but in a side-step around the issue, D. Jones suggests that both dentists and their patients are more at risk from mercury poisoning from eating fish than occupational or amalgam filling exposure.

The final range of issues in the pro-amalgam arsenal relates not to the toxicity of mercury and its possible adverse effects, but rather to three unrelated matters. The first of these is that amalgam is easy to use, and that relative to the alternatives, amalgam is less costly for patients. Time and again, amalgam is touted as the most cost effective filling material available where function and not cosmetics is of primary importance. The second issue is that when risks from amalgam are raised, it will be suggested that there are biocompatibility issues with amalgam alternatives. The third issue is that there is a trend, based on amalgam review recommendations, for a gradual decline in amalgam use. As the present thesis is an investigation into neurotoxic effects from mercury in amalgam, none of these aspects will be considered. It is acknowledged however, that from a patient's perspective of the debate, these are important considerations for informed consent to amalgam or its alternatives.

### *The New Zealand Dental Association Position*

New Zealand Dental Association members may still tell patients that silver amalgam is inert in the mouth, or that it releases only tiny amounts of mercury when patients chew vigorously or grind their teeth. They may still tell patients, as the website does, that there is there is "no valid scientific evidence that associates this tiny amount of mercury vapour with any health problems" ([www.nzda.org.nz](http://www.nzda.org.nz), accessed January 29, 2005). Support for the website's statements and claims come not from research, but by reference to the authority of the opinions of world dental associations with whom they are aligned; plus the neutral fact that amalgam has a long history, and by changing and limiting the scientific evidence to the inexact term 'controlled studies'. The pro-amalgam perspective is summarised in the following FAQ question and answer:

[Question] Is the mercury in my amalgam fillings safe?

[Answer] The mercury used in fillings is safe for most people. Authorities such as the British Dental Association, US Public Health Service, FDI World Dental Federation and World Health Organisation state that amalgam has been used for more than 150 years in millions of patients and no controlled studies have shown adverse health effects, except for rare cases of mercury allergy<sup>11</sup> ([www.nzda.org.nz](http://www.nzda.org.nz), accessed January 29, 2005).

Critiques from the pro-amalgam perspective do not generally present evidence of safety, but rather they reject or ignore research that might show that leakage of mercury from fillings could cause concern, or evidence of neurotoxicity and the like. Articles with the pro-amalgam perspective can be found in dental journals and for the public, in publications on the Internet. They can be summed up by Wahl's (2001b) proclamation that the "biocompatible material for the new millennium: (is) dental amalgam" (p. 16).

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<sup>11</sup> The WHO position is misrepresented. Their position is that there is no established safe level of exposure (Friberg 1991).

## *The Nun Studies*

In the last decade, in response to increasing criticism that the pro-amalgam position does not offer proof of safety so much as a rejection of the evidence that there may be a safety issue, a longitudinal study known informally as the Nun Studies began to explore the link between dental amalgam and Alzheimer's disease (AD) (Saxe, Snowdon, Wekstein, Henry, Grant, Donegan, et al., 1995; Saxe, Wekstein, Kryscio, Henry, Cornett, Snowdon, et al., 1999). In their first report, the researchers found that 129 elderly women<sup>12</sup> who had been living in a "total institution" type of environment (see Goffman, 1965), for all their adult lives, showed no correlation between the number of their amalgam fillings and scores on eight cognitive tests.

In their follow-up study, Saxe et al., (1999) reported mercury levels from various brain areas at autopsy, from 68 AD patients, and 33 controls without AD. Ten of the AD group and 12 controls were women from the Saxe et al. (1995) study. In each case the deceased had a dental status score that depended on the number of amalgam surfaces, the age of the fillings and the like. Saxe et al. (1999) found no association between AD and dental status scores. Their conclusion was that dental mercury was not apparently neurotoxic in predisposing AD; and that except for the olfactory region, dental status did not explain any of the variance in mercury stored in the brain. The findings were used to support the continued safe use of amalgam.

### **The Anti-Amalgam Perspective**

The key argument, and the support offered for the anti-amalgam (antagonist) position can be summarised as follows:

#### *Toxicity*

Mercury has acknowledged toxic properties. When mercury from dental fillings sits in the oral cavity, its route into the body is inevitable, and some level of

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<sup>12</sup> Nuns, aged 75 and over.

poisoning is a logical consequence (Friberg, 1991). The onset of any symptoms of mercury poisoning is usually insidious and the effects only slowly reveal themselves. However, as there is a multiplicity of presentations of effects, for those people who seek medical advice for possible consequences of mercury toxicity, presenting health problems are unlikely to be seen in a causal relationship with a gradual build up of mercury from any source.

### *Biomarkers*

Critical to making an appropriate medical diagnosis of mercury poisoning is the issue of biomarkers. Urine is most commonly 'spot' tested against the 50µg/l threshold limit value. In cases involving possible individual poisoning, antagonists argue that a conventional 24 hour urine test gives a misleading result, as it shows only the level at which mercury is being excreted. Antagonists argue for a "challenged" mercury urine test where a chelating drug is given<sup>13</sup>. These tests invariably result in a much higher mercury-in-urine level than would be considered safe by any of the various operationalisations of mercury safety.

Aposhian, Bruce, Alter, Dart, Hurlbut, and Aposhian (1992) experimented with dimercapto chelating compounds in people with and without amalgam fillings, and compared urine test results. They concluded that the challenged urine test is a more reliable indicator of body burden than an unchallenged test, as over 60 percent of excreted mercury appears to be of dental origin. They state that, "Linear regression analysis indicated a highly significant positive correlation between the mercury excreted in urine 2 hours after (the chelating drug) administration and the dental amalgam scores" (p. 2472).

Hair, while not as commonly tested, can show the body burden of mercury in combination with other trace elements. This is challenged as a biomarker for dental mercury, as mercury from all sources will show in the hair test.

In Saxe and colleagues' Nun Studies (1995; 1999), that showed no correlation between mercury exposure and AD, the index of mercury exposure was based

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<sup>13</sup> This has been described by Gonzalez-Ramirez et al. (1995).

on the number of fillings the women had on examination. Antagonists may say that this did not account for fillings in teeth that had been extracted before the study, or, in the first study, the age of the observed fillings. The alternative is to look at the mercury in hair test findings of Cornett, Markesbery and Ehmann (1998), Hock, Drasch, Golombowski, Muller-Spahn, Willershausen-Zonnchen, Schwarz, et al. (1998), Pendergrass and Haley (1994), and Pendergrass, Haley, Vimy, Winfield, and Lorscheider (1997), to argue that trace element imbalance with elevated mercury and interactions with other elements (Br, Ca, Co, K, Se, and Zn) is associated with Alzheimer's disease (Haley, [www.altcorp.com](http://www.altcorp.com), accessed April 14, 1999).

Self-declared antagonists, such as Haley, also point out that the Saxe et al. (1999) paper, where no association was found between mercury and AD, involves dental researchers, while the studies that do find an association are mainly from university Chemistry Departments. This serves to fuel the acrimony in the debate as it appears on the internet. It would be more accurate to say that the papers where associations are demonstrated between mercury and AD have been published in peer-reviewed, ranked journals (for example, FASEB); while the Nun Studies have been published in peer-reviewed *dental* journals. Haley implies that dental journals would be the only place such papers would be accepted. (Haley, [www.altcorp.com](http://www.altcorp.com), accessed January 29, 2005).

### *Animal Studies*

The anti-amalgam position is supported with two *in vivo* experimental animal studies (Hahn, Kloiber, Leininger, Vimy, & Lorscheider, 1990; Hahn, Kloiber, Vimy, Takahashi, & Lorscheider, 1989). Hahn et al. (1989; 1990) used a sheep in their first study; and a monkey in a follow-up study, to implant silver amalgam fillings with a radioactive isotope of mercury in the molars of the animals. Soon after, the animals were euthanised, and mercury storage was traced through X-ray and tissue sample.

These studies are used to support the argument that mercury vapour is rapidly released from amalgams and stored initially in kidneys, liver, the gastrointestinal tract, pituitary, adrenal and thyroid glands and in the brain (frontal cortex, occipital cortex, and thalamus). The counter-argument is that

the animals may have stored mercury, a necessary variable for mercury poisoning, but that this in itself not a sufficient finding to support an anti-amalgam position because the animals were euthanised before any behavioural effects could be noted. The suggestion is that Hahn et al. (1989; 1990) cannot demonstrate that the stored mercury would have eventually had any adverse health effects.

Finally, because the debate has always been political, the antagonists claim that it is difficult to get anti-amalgam papers published in journals that are controlled by the powerful medical and dental associations. Papers on mercury poisoning are more likely to appear in environmental journals (see Bluhm & Branch, 1996; McCullough, Dick, & Rutchik, (2001); toxicology journals (see Beuter & de Geoffroy, 1996; Biernat, Ellias, Wermuth, Cleary, de Oliveira Santos, Jorgensen, et al., 1999; Bittner, Echeverria, Woods, Aposhian, Naleway, Martin, 1998); or engineering journals (see Edwards & Beuter, 1999). These are journals that, it is suggested, are not routinely accessed by dentists and general medical practitioners.

Within non-medical publications, anti-amalgam dentists, environmentalists, chemists, and the like, claim that mercury toxicity has been extensively reviewed scientifically, and it is without a clear safety record. They suggest that there are biocompatible alternatives to amalgam, and that amalgam fillings are not cost effective if the cost of environmental pollution or the social cost of consequent ill health is included. They do not specifically comment on dentists' health but do assert that amalgam predisposes some patients to amalgam related illnesses, and that some patients have suffered from undiagnosed mercury poisoning from their amalgam fillings (Hanson, 2003; Null & Feldman, 2002).

#### *Gaps in the debate*

Throughout the debate there is surprisingly little reference to neurotoxic effects, or the use of neuropsychological (non-invasive) instruments as indicators of the threshold limit value or the lowest observable adverse effect level. The trend is for dentists to focus on biological indicators and disease, as shown in the response that Whyman, then NZD Chief Executive Officer, made to a suggestion by Green Health spokesperson, S. Kedgley, that dentists do not

discuss health risks from amalgam with their patients. On the NZDA web page (accessed January 24, 2003), Whyman reported the comments made by Kedgley in 2001, and responded:

The New Zealand Dental Association's own monitoring confirms that there is no current scientific literature to show that patients may develop diseases as a result of the placement of amalgam fillings ([www.nzda.org](http://www.nzda.org).)

Whyman's (2003) response evades the question of what a dentist might convey to patients who want to make real informed consent for amalgam fillings. It ignores the wider picture. Environmentalists have concerns about mercury from dental sources polluting the food chain. Health economists, and public health policy analysts, have concerns about the fiscal implications of amalgam, from manufacture through to scrap amalgam pollution; and there are implications for a range of other interest groups, from engineers and chemists to health professionals and politicians. Perhaps patients would like this information too.

All forms of mercury are toxic to animals, including humans, through being readily absorbed, inhaled, or ingested. Observations of animals showing the neurobehavioural and reproductive health effects of mercury poisoning have been the first indicators of environmental pollution problems. The question of human safety when exposed to mercury is one of uncertain safe exposure levels. Although there are various ways of determining a probable safe level of mercury exposure, many studies have demonstrated sub-clinical effects at lower exposures, supporting the WHO contention that there is no safe exposure level (Friberg, 1991).

When methylmercury is present in large doses in the food chain, mercury poisoning becomes insidiously endemic, and on occasion, has reached epidemic proportions. It is from epidemics that strong evidence for central nervous system and reproductive health effects have been seen.

The neurotoxicity of mercury has been documented in Chapter 1 as having dysfunctional effects in five domains: cognitive skills, mood disorders, psychomotor skills, sensory abilities and psychosomatic illness experience. In

a recent review, Clarkson, Magos and Meyers (2003) expressed the current state of scientific evidence like this:

All forms of mercury have adverse effects on health at high doses. However, the evidence that exposure at very low doses of mercury from fish consumption, the receipt of dental amalgams, or thimerosal in vaccines has adverse effects, is wide open to interpretation (p. 1737).

### **General Aims and Objectives**

From the review of publications in Chapter 1, the positions in the debate, and the gaps in the debate, comes the overarching aim of the thesis: to contribute a psychological perspective to some aspects of the debate. In particular, the pro-amalgam premise will be studied: that dentists do not show adverse health effects from occupational mercury use, and from this, the deduction that patients must also be safe.

The first approach to achieving this aim is to further explore the debate from the perspective of the dental patient. Much of the focus has been on establishing that dentists are not affected by the mercury they use, but that is only one side of the issue. There is a pattern of findings represented by the Swedish studies, where people who believed that they had some kind of amalgam related illness were found to be more in need of psychiatric care than deamalgamation. This is in contrast to the strong message from medical case studies that suggest that amalgam related illness is under-diagnosed. There would appear to be the potential for psychiatric illness to be erythism, and that this has been overlooked. The first objective therefore is to explore the situation for the NZ dental patient who may believe their health is compromised by their amalgam fillings.

The second approach is to build on the limited range of neurobehavioural assessment of dental personnel in the occupational exposure literature. While there are some studies with dentists, these have mainly involved men as participants. Indicators that metallic mercury may affect reproductive health have led to the objective to target women as participants. In addition, there is a dearth of long-term occupational studies, and fewer still that follow dental personnel over time. A second objective, therefore, is to test the null

hypothesis for general health, reproductive health, and domains covered by a neurobehavioural test battery, with mid-life women who were occupationally exposed to mercury as young women. New Zealand is a unique country for such a study. In the 1970s, a cohort of young women was chronically exposed to various forms of metallic mercury, while working for the Department of Health, in a School Dental Service scheme.

Finally, the thesis aims to synthesize the psychological findings of these two studies, with the current contestable knowledge on the safety of mercury in dentistry. The objective is to see how far findings generated in a discipline outside dentistry, such as psychology, can go towards clarifying some aspects of the debate, where there is confusion caused by conflicting 'scientific' arguments.

### **Chapter Summary**

The safety of mercury in dentistry is beset by disagreements about what constitutes scientific evidence of harm to humans; about difficulty separating dental amalgam mercury from other common sources of mercury; about what tests or biomarkers should be used in the diagnosis of mercury poisoning, or in research; and where and why papers get published. From the pro-amalgam perspective, evidence that dentists do not appear to have impaired health, gives support to safety claims. From the anti-amalgam perspective there is medical evidence that dentists are not always unaffected. In the past there has been debate over the likelihood that amalgam either leaches from fillings or is inert. Leaching is accepted now, but what is not accepted is that leached mercury is necessarily stored in the body, or that it predisposes illness.

While both sides of the debate use medical evidence in support of their positions, there is little research from a psychological perspective in dentistry. Studies with NBTBs tend to be from occupational mercury exposures in other occupational settings. Most research has had male participants.

This led to the present thesis aiming to explore the New Zealand dental patient's perspective, when mercury poisoning is medically diagnosed; and to undertake a study of women in dentistry, with neurobehavioural, general health, and reproductive health measures.

## **CHAPTER THREE: BITING THE SILVER BULLET – EXPERIENCES OF MERCURY POISONING**

### **Introduction**

Chapter 3 reports the qualitative investigation of people who have considered removing their dental amalgam fillings following a medical diagnosis of mercury poisoning. Chapter 1 established that people who have amalgam fillings are exposed to various forms of mercury. With filling placement, the initial risk is from ingestion of amalgam particulate. Further, from oral mucosa contact with metallic mercury and from breathing the mercury vapour, dental patients experience elevated blood and urine mercury levels for several days after filling placement. Thereafter they are continuously exposed to very small but varying levels of mercury vapour being released from the amalgam, and possibly the conversion of metallic mercury to methylmercury by bacteria in the mouth. The reviewed literature demonstrated that while mercury from dental sources enters the body to be stored or excreted, there is a lack of scientific information on individual variation in storage and excretion. In the debate, this uncertainty underpins the positions taken on any claimed causal relationship with ill health.

One of the protagonist premises is that, in the general population, mercury does not cause diseases in people who have mercury urine levels below an arbitrary safe limit such as 50µg/l urine. However, there is another variable embedded in the premise. It is not known how people who excrete mercury well, and hence may show high urine mercury level on testing, are likely to fare *vis a vis* people who have a similar potential for exposure but appear to store mercury, as demonstrated by a lower urine mercury level on testing (Lorscheider, Vimy, & Summers, 1995). That is to say, a urine test showing excreted 'safe' mercury level of 35µg/l for example, does not indicate whether the donor is a 'storer' of mercury or an 'excreter', and hence how representative the test is of the body burden.

Mercury from dental amalgam does contribute to the total bodily uptake, but the limits for observable effects following uptake are contestable. Richardson (1995) suggested that for Canadians, fewer than 10 amalgam surfaces is the mercury exposure level at which four persons in a thousand may show adverse health effects, when combined with mercury from all sources. A question remains about the appropriateness of this figure being generalised to New Zealanders.

The NZDA advises patients that the daily dose of mercury from fillings is well tolerated, without reference to the number of teeth, or surfaces on teeth that are amalgam-filled, or aspects of the patient's lifestyle beyond dentistry. It is NZDA policy to assert that amalgam use is safe and cost effective. However, this century has seen new (NZ) local government by-laws requiring dentists to install mercury filters to minimise environment pollution. Until the mid 1990s, consumer demand for non-mercury filling materials had been a minor issue (M.Thompson, Stewart Carter, & Spencer, 1997), but at the time the present study began, people were starting to question whether mercury was safe for them, if environmental protection was necessary.

The genesis of the present investigation was the lack of consensus among the authors of the commissioned NZ Ministry of Health report on *Mercury and Human Health* (Cutress, Godfrey, Miller, & Whyman, 1996)<sup>14</sup>. Cutress, the principal author, was head of the New Zealand Medical Council's Dental Research Unit. He held, and still does, (see Yip & Cutress, 2003) a pro-amalgam position, but was open to the potential for new evidence from reputable sources. Godfrey, one of three co-authors, was, and still is, a registered medical practitioner in general practice. He had documented and published journal articles on cases of mercury poisoning from his practice. (Godfrey, 1990; 1996). He espoused an anti-amalgam position.

Cutress et al. (1996) reviewed selected literature from 1993 onwards, claiming that a United States of America, Public Health Service pro-amalgam review (USPHS, 1993) should be taken as an incontestable baseline for the New Zealand review. When *Mercury and Human Health* was publicly released, a year after it was completed, the report stated that the authors could not agree

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<sup>14</sup> This is the Dr J. Miller who proof-read Chapter 1, on mercury for psychologists.

on whether people who have had their dental amalgam fillings removed, following a medical diagnosis of mercury poisoning, actually achieved the enduring health gains that both doctors and patients may have anticipated.

Cutress and Godfrey (personal communication, August 21, 1996) agreed that the toxicity of amalgam fillings was due to the mercury content, but they did not agree that chronic ill health was a consequence of exposure to it. They accepted that some people do believe this and proceed to have their amalgams removed. They also accepted that there was a general lack of understanding of the relationship “between the contribution of amalgams to total mercury uptake and the claimed consequent ill-health caused by chronic mercury toxicity.” (Cutress et al., 1996, p. 2).

The unresolved issues for them then became:

- the likelihood that amalgam removal would or would not make any difference to health or illness;
- that reported health improvements may or may not be attributed to a placebo effect; and therefore
- that any initial report of health improvement following amalgam removal would or would not become a long term health gain.

The experience of people who have removed their dental amalgams has little profile in academic literature, but can contribute to a valid understanding of tolerable limits in relation to illness experience. Godfrey’s own work had suggested that there was evidence of a causal link, but for Cutress this was countered by claims of underlying psychopathology such as those made by Langworth and colleagues (reviewed in Chapter 1). Cutress was persuaded that psychiatric conditions underpinned patient beliefs and experience that ill health could be caused by dental mercury (personal communication, August 1996).

The tendency to dismiss alternative health beliefs or anecdotes of health recovery following amalgam removal are more explicitly expressed by Lindberg, Lindberg and Larsson (1994) who used psychodynamic methods to assess the anti-amalgam health beliefs of 11 Swedish medical patients, six of whom were dental personnel with occupational exposure to mercury. They declare:

All patients had experienced important psychic traumata in close connection with the first appearance of symptoms. It can be concluded from the psychodynamic dialogues, that they had not been able to mourn for a loss in an adequate manner and that the body had been forced to symbolise the great pain in their souls (Lindberg et al. 1994, p. 219).

Langworth, who consistently reported that people with 'amalgam illness' were most likely suffering from psychiatric conditions, also authored a single case study where amalgam removal was associated with the patient's enduring return to health (see *Dental Studies*, Chapter 1). Stromberg, the patient's dentist, was the co-author. Their paper documented Stromberg's patient's amalgam replacement treatment programme and a concurrent series of urine tests. The placebo effect is one explanation offered for the relationship between the removal of amalgams, the decrease in urine mercury and the return of good health. (Langworth & Stromberg, 1996).

However, in order that the present thesis does not appear, without careful critique, to dismiss anything written by Langworth and colleagues, it is acknowledged that the Swedish work was generated within a paradigm from the 1980s where there was scepticism about patterns of brain mercury concentrations from autopsy findings (Cavanagh, 1988). The problem was that there was no way of testing whether autopsy findings of particular mercury levels in different brain locations was actually related to overt behaviour during the deceased person's life. Cavanagh suggested that where mercury poisoning was being considered, a patient's psychological state should have been assessed first. This was not to document erythism for example, but rather to give some assurance that the underlying cause of subjectively claimed mercury poisoning was not somatization of mental ill health.

The aim of the present study was to undertake an exploratory study that privileged the voice of real people who had demonstrated their belief that exposure to mercury from dental amalgam had caused illness, by their acceptance of a medical 'mercury poisoning' diagnosis for their presenting illness(es), and their proceeding to having their amalgam fillings removed as their treatment.

The specific objectives were to document themes from patients' collective, subjective experience; and to analyse the phenomenological data for a reported link or lack of it, between their specific illness experience and dental amalgam. The findings were expected to be useful in triangulation with the existing pro- and anti-amalgam literature. New perspectives could be generated on health beliefs, health outcomes, and psychosocial issues, for people who have been advised to consider amalgam removal by a registered medical practitioner.

## **Method**

### *Rationale for Method*

As this research was designed to explore and document a new field - the experiences of people who have linked their health problems and their dental amalgam fillings - exploratory methodology was reviewed.

Survey and interview methods were not selected on the basis that there was insufficient pre-existing knowledge from which to prepare either a questionnaire or interview schedule without imposing questions that arose from one or other either side of the debate, and hence had the potential to bias the findings.

In exploratory work the validity of survey methods can be problematic when the construction of questions relies on the knowledge of the topic by the designer, and the designer cannot be well informed by current literature. Further, questionnaires can be inappropriate for some potential respondents, simply because the respondents' position is not understood. In the present study survey methods were inappropriate because knowledge of the participants' experience had not been systematically studied.

In an exploratory study, using a survey to direct and quantify responses requires researchers to privilege their objective position above respondents' subjective experience, and this can act to prematurely close avenues of enquiry that might yield meaningful data. In addition, even unintentionally biased questions could be de-motivating to people who saw an opportunity to have a scientific community hear their perspective, if the questions appeared

not to encompass their experiences nor the meanings constructed around those experiences.

For qualitative researchers, the focus group method has become a standard research tool. It is a technique where a relatively few informed participants, working in small groups, can explore or elaborate on a phenomenon of interest, and produce data that can be analysed in a variety of ways. (Kreuger, 1994; Stewart & Shamdasani, 1990; Wilkinson, 1998). The 1990s saw a shift in social exploratory research to a greater use of focus groups, where the aim was “not to generalise ...to a broad population or universe, but to maximise discovery of the heterogeneous patterns and problems that occur in the particular context under study” (Erlandson, Harris, Skipper & Allen, 1993, p. 82).

Focus groups were seen as the method that located common themes from the stories of participants, in the context of their talking with others who had lived through and sought meaning in, and explanations for, similar experiences. In the present study, focus group discussion was seen to allow the reporting of participants' illness experience, health beliefs and practices, without prematurely challenging the scientific validity of their claims.

Focus group interaction tends not to be a forum for scripted responses but one where the participants actively create a discussion 'product'. They construct a version of the experience that should accommodate a variety of conceptualisations of the key issues and outcomes (Pottter & Wetherall, 1994). Where the discourse arises from a group with a specific focus, such as exploring the phenomena of mercury poisoning, there can be more confidence that the components of the experience will be described in depth (Kreuger, 1994). Focus group discussion generates the participants' context for their experiences and so ensures that the issues and outcomes are those that the participants have validated.

While there is no way of predetermining what or how many key issues and outcomes there will be, focus groups may be expected to achieve a theoretical saturation point; that is, where the researcher has a high level of confidence that key issues have all surfaced. After two groups have discussed a topic there should be a number of apparent common themes. After four groups have

discussed a topic, there will be few new ideas being generated. With a minimum of five groups, most of the common ideas will have been generated and discussed and the theoretical saturation point reached (Kreuger, 1994).

Within the focus group process a researcher can have a level of control without strongly influencing the direction of group discussion and the generation of novel data. A discussion schedule can ensure discussion-trigger questions will be common to all groups. The preparation of a broad discussion schedule may ensure the participants do discuss topics of importance to the researcher, while the range or depth of discussion following a discussion-trigger are meaningful to the participants' subjective experience.

In the present study for example, where the researcher was interested in understanding the participants' health beliefs on any link between fillings and ill health, then that would be incorporated into a trigger question. How the participants then choose to develop the discussion would be over to the group. Because it is the participants and not the researcher who have experienced the phenomena under study, the researcher would be interested in whatever discussion or directions were offered. If the researcher already knew what the important issues were, then the research exercise would be redundant.

Trigger questions also serve structural functions. Kreuger (1994) suggests that types of trigger question may include:

- the opener – a factual question with no right, wrong, or socially desirable answer;
- an introductory question that explores experience;
- transition questions that broaden the topics under discussion;
- probe questions for detail; and
- end questions that check back with the group on key issues.

Finally, having people talk about their experiences in a normal social context changes the power relationship between a researcher and participants in the research. Participants are less likely to feel constrained when they wish to express uncommon or unpopular views, when they are discussing them with other participants than when they are in a one to one interview or communicating directly with a researcher by questionnaire (Denzin & Lincoln, 1994). This is important in critical health psychology because it is the

participants' version of phenomena that is the basis of scientifically informed action.

### *Sample*

A random, purposive, criteria-sampling method was used on the computerised patient records of the Bay of Plenty Environmental Health Centre, where Godfrey runs his medical practice.

With Godfrey's agreement, Cutress had approached the author of the present thesis to undertake a study, but with seeding funding being conditional on the author accepting that Cutress would set two criteria for participant selection. The selection criteria were aimed to exclude those patients who may have experienced a placebo effect from their treatment; and to ensure that there was some objective, biological support for the patients' medical diagnosis of mercury poisoning.

The imposed operationalisation of the criteria were, for the former, that the participants could not have attended Godfrey's medical practice for two years<sup>15</sup> prior to the start of the present study; and for the latter, that the participants had to have been urine-tested for mercury toxicity with a result above 50µg/l.

A list of over 700 surnames of patients meeting these criteria was generated from the medical practice's records by the office manager. From the list, 200 names were randomly selected using a random numbers table.

The specific number was determined by taking the minimum number of groups considered to be needed to achieve theoretical saturation, five, and a preferred minimum average group size of four, giving a target of 20, then multiplying by 10 to the predicted 10 percent response rate to an unsolicited and mailed invitation to participate in research.

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<sup>15</sup> Dr Cutress explained his choice of two years as being a passage of time he believed any placebo effect would have worn off. No scientific basis for the period was offered, but it was suggested by Langworth and Stomberg (1996).

While random selection is not necessary for a purposive sample, there was a sufficiently large population for random sampling to be undertaken and add to the power of the study. Such a variation from the basic focus group method is supported by Reason (1994).

A participant contact process was designed to protect doctor-patient confidentiality in relation to patient records. The author was not to know patient details other than the surname in the sample frame, and the doctor was not to know which of his patients had been sampled or who had responded to the researcher.

The author prepared information packs for potential participants. These contained a covering letter from Dr Godfrey, a cover page, an 'Information for Volunteers' sheet, a contact address list for Research Staff and the Bay of Plenty Ethics Committee, a volunteer's reply form (see Appendix E) and a stamped envelope addressed to the author. Two hundred packs ready for posting were supplied to the office manager of the medical practice who added addresses and completed the mail-out.

There were 46 positive responses from 180 invitations to participate in a focus group discussion (26 percent)<sup>16</sup>. At this point it became apparent to the author that the patients of the medical practice came from a wide geographical area, so while it had been envisaged that all focus groups would be conducted in one city, this was no longer feasible. Not all volunteers could attend one of seven meeting times and locations, and five potential participants were therefore excluded, leaving 41 who were sent a focus group appointment and a consent form (see Appendix F).

The final sample was 35. They attended one of seven group meetings that were conducted over the course of one week. The mean group size was five participants, and range was two to seven. There was one women-only group and six groups with both men and women. All but one group had fewer participants on the day than had initially agreed to attend, accounting for the difference between the sample of 35 and the 41 volunteers.

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<sup>16</sup> Twenty information packs were returned "gone, no forwarding address".

In one group the non-sampled wives of two of the men who were participating had completed the deamalgamation and detox process, so the experiences recounted by each man tended to include the experiences the couple. In another group, the husband represented another couple, but in this case only the non-sampled wife had completed a deamalgamation - detoxification process.

There were also two negative responses. One person who replied to the invitation, declined to participate, and stated his belief that there was no link between amalgam and health. A second person replied and stated the same belief, but volunteered to participate conditional on being part of a like-minded group. This could not be arranged, as other volunteers did not state their position in their form-letter reply.

#### *Materials - Discussion Schedule*

Trigger questions were used to begin and end the focus group sessions. Groups then directed their own content, while covering health beliefs, health experiences, and the outcomes of any steps taken to improve health since the mercury-poisoning diagnosis.

The opening trigger question combined a factual-type request for information that all participants would be able to answer, with a leading introductory-type question that would ensure the initial discussion explored mercury-poisoning phenomena. The common opening trigger question was, "When did you first hear about mercury poisoning or begin to consider that your fillings were linked to your health?"

The end question was, "If you could give one piece of advice to people who are doing amalgam research or who regulate the use of amalgam, what would it be?"

Probe and transition questions varied between groups. They were usually generated by group members, but by the author on some occasions. Questions that more than one group grappled with included:

What does good health mean to you?

How did you come to (the particular) medical practitioner?

Has the way you think about mercury / dentistry / medicine changed now?

Of the things you have done to improve your health, what has been effective?

### *Procedure*

#### *Pilot testing of the discussion schedule*

A pilot discussion was conducted with two local people who had replaced their amalgams for health reasons. A man was located through an amalgam internet discussion group<sup>17</sup> and the woman from a newspaper article on mercury poisoning (Decker, 1998). They did not know each other. Their telephone numbers were in the local telephone directory.

The pilot discussants met the author and agreed to two tasks: to respond to the proposed trigger questions as the future participants may respond; and to provide feedback on the relevance of the trigger questions. The latter included comments on how the proposed questions might be interpreted by a participant in ways that were not intended by the author.

The pilot discussants were able to use the trigger questions to begin a dialogue on their experiences. Notably, they did prompt each other in areas outside the author's mercury poisoning experience, and gave the author a conviction that the focus group method was an appropriate choice.

### *Facilitation*

The author facilitated all focus groups. They were held in a variety of locations in the North Island of NZ. In Tauranga, two groups were held in a central

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<sup>17</sup> Amalgam@listserv.gmd.de

motel conference room. Rotorua and Hamilton groups also met in motel conference rooms. In Auckland three groups were held, but at different locations: the Auckland College of Education, a private home, and a seminar room at the Albany Campus of Massey University.

Each group commenced with a welcome and refreshments. The author briefly explained the background to the study and the choice of focus group methodology. Participant consent and confirmation forms had been sent with the information material and these were signed and collected. The group work began with the opening trigger question and followed the schedule described above.

Discussion lasted between 90 and 120 minutes, depending largely on the number of participants. In most cases people stayed longer, and shared resources that they had brought, or followed up issues they wanted to further pursue, in smaller groups or dyads. Morgan and Spanish (1984) referred to this in their description of a focus group discussing health risks, saying that some participants had subsequently regrouped to produce the consensus they had not reached in the formal session.

L. Patterson (1996) reported on a series of women's focus groups on retirement, and had also observed the informal continuation of discussion. Her interpretation was that this was not aimed to produce a late consensus, but an "echo" (p. 9), or elaboration and consolidation of the key issues. In the present study the facilitator became a systematic observer of the echo.

At the conclusion of the formal discussion, participants were given a \$5 petrol voucher to offset their travel costs.

### *Recording*

All seven sessions were audiotape recorded, and at five of the seven sessions, one of two shorthand note-takers was also present. The note-takers prepared transcripts from their notes. The facilitator took some notes during the sessions and wrote further observations immediately following each session. Notes included the formal focus group discussion and the echo period.

Facilitator notes were verified later with the audiotapes, and for the two sessions without a note-taker that were not transcribed. In addition, some participants wrote to the author to follow up with further thoughts, usually related to the echo dialogues. The audiotapes were used for the verbatim recording of quotes used in the results and discussion section.

### *Ethics Approval*

The study was approved by the Bay of Plenty, Crown Health Enterprise Ethics Committee, protocol number 17/96, and the Ethics Committee, School of Nursing, Health and Environmental Science, Wellington Polytechnic<sup>18</sup>.

## **Results and Discussion**

### *Overview*

This section begins with a quantitative summary of the health status of the participants and responses to the opening trigger question. Following this are the illustrated themes, the responses to the closing trigger question and a summary of the key findings. Verbatim quotations have been cleaned of non-verbal utterances. This related to the potential for quotations with ‘ums and ahs’ to reinforce hierarchies of the researcher over the participants, and academic (objective) over personal (subjective) representation (Standing, 1998) of qualitative data.

From the notes and transcripts it was possible to establish themes and the origins of the health beliefs that led to the participants having the mercury-urine test. Unexpectedly it was also possible to quantify patterns of presenting health problems, and long-term health changes. This was because every participant spoke of both their presenting symptoms and their health outcomes, in response to the opening trigger question.

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<sup>18</sup>Protocol numbers were not given for approved applications by this committee.

While quantification was not an objective, nor is it typical of focus group analysis, it was seen as a useful way to demonstrate that the participants were a cross-section of ordinary New Zealanders who had consulted a registered medical doctor about their health or illness. It had been suggested to the author, by both Drs Cutress and Godfrey (personal communication, August 1996), that there was a perception held by mainstream medical and dental professionals, that those people who believed that having amalgam fillings removed would benefit their health, comprised a group stereotyped as anti-amalgam, alternative-health 'freaks' and psychiatric patients, and this was one reason they had initiated a psychological study.

### *Quantified Health Outcomes*

The dominant discourse across all groups was that over the course of many years of chronic ill health, some had come to believe that mercury in their dental amalgams may have had a causal role in their health problems. This belief had been confirmed by a medical doctor, following a diagnostic urine-mercury test where, in all cases, the result was above the 50µg/l level. The recommended treatment was amalgam (or tooth) removal and taking a mercury chelating drug regime. This is termed deamalgamation and detoxification (detox.).

Thirty-two of the 35 participants had begun amalgam removal. Thirty had demonstrated their belief in the link between their mercury-urine test result and their ill health by completing both a deamalgamation and a detox. process.

Of these 30, 21 had experienced a full return to health and the activities of daily life. A further eight reported recovering from the symptoms they attributed to mercury, but now had a new problem related either to the detox. process or to a pre-existing, unrelated condition.

One person reported following the deamalgamation and detox. protocols and had experienced no lasting improvement. However, she demonstrated her belief that mercury in amalgam is causally linked to ill health by expressing relief for having eliminated mercury as a future threat to her immune system.

Of the remainder, one had completed amalgam removal, but had not realised there was a detox. process. This person reported some initial relief from the affective disorder that was part of his presenting symptoms, but was again taking anti-depressants. The other had begun amalgam removal and taking detox. drugs concurrently, experiencing painful side effects. This person stopped both processes and was still ill.

The three who had not begun amalgam removal were still ill, and reported deteriorating health over the (minimum) two-year period since consulting the medical practice.

Three wives of participants were reported to have had chronic ill health, the urine test, deamalgamation and detox., and had regained good health and active lives.

While there is no way of knowing how representative the participants were of the population of people who had at least considered a causal link between mercury and health, it appeared from the range of responses to the opening trigger question, that not only was the stereotype proposed by Cutress (of the alternative health freak) not supported, but more positively for the present study, the participants were not a homogenous group, nor unanimously converts to the anti-amalgam cause.

### *Themes*

#### *Diverse Patterns of Experience.*

Participants did not conform to an anticipated stereotype of a chronically ill person who had shopped around<sup>19</sup> for doctors, specialists and alternative health providers (Parsons, 1975) and 'passed through' the medical practice that was the target of the present study, without regaining health. Rather, participants' experiences fell into four distinct categories closely related to their presenting symptoms; and this in turn was indicative of how they came

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<sup>19</sup> Shopping around: a stage in Parson's Sick-Role Model of illness behaviour.

to believe there was a link between dental amalgam mercury and health. Each category is discussed separately.

### *Category A: Chronic Illness Experience*

A typical person from this category reported having had chronic and severely debilitating ill health and had spent years searching for a medical explanation and effective treatment. Many had been told their problems were psychosomatic. One had been admitted to hospital for an unnecessary psychiatric assessment. There was an apparent negative correlation between length of illness and both social activity and cognitive ability, and specifically memory, attention and the ability to concentrate, that was referred to, by some participants, as 'brain fog'. This had the effect of restricting and compromising self-efficacy.

A first reference to mercury might therefore come from a light reading source such as a magazine (for example, *The New Zealand Woman's Weekly*, *Metro* and the *New Zealand Listener* were mentioned) or a newspaper article. Several people brought the actual old article with them to their focus group (see Figure 1) demonstrating that this was seen as a personally significant turning point in their search for health.

The common conditions prior to making a link with mercury included: chronic fatigue syndrome (CFS), candida, allergies (especially to wheat), migraines, fibromyalgia, and chronic or recurring influenza symptoms. Frequently Category A participants reported being treated for depression as their illnesses became protracted. They had initially adopted the sick role (Parsons, 1975), complied with medical advice, and took prescribed medication. As one participant explained, she had "every test in the book from blood counts to CAT scans". As was reported by others from Category A, the tests never showed anything abnormal and this led to several being told by previous doctors that they were "making it up". As illness persisted without a medical label or as a psychosomatic condition, these people experienced the negative social stigma of being labelled hypochondriacs.

Participants described clinging to their belief that there was a physical cause to their illness. Many kept diaries, letters and notes of their symptoms while they searched for a cure. Some stories told of the social and economic aspects of a psychosomatic misdiagnosis, including how the money for amalgam removal came from a divorce settlement or selling a business: events that were seen as indicative of the impact of chronic illness.



Figure 1. Magazine article that led one participant link her illness to mercury poisoning. (Participant could not recall the magazine title or date. Cropped.)

Participants in Category A had to be their own researchers for anything that would provide them with a clue to understanding their health problems, but still at an accessible level. For example:

A woman wrote a letter to The Herald and I rang her and she told me about the book and that she had hers done [amalgam removal] and then she had gone to a naturopath at [location] and then she had gone on to [Godfrey's medical practice]. So I followed it up and at that stage I was very concerned about the state I was in ..." (man, G5).

I was getting magazines from England, which were called What the Doctors Don't Tell You. They were fascinating articles... one was on amalgam (woman, G6).

The consequence of not knowing what was wrong was a major part of the narrative: not having respect from friends and family. One woman said:

My husband took me to [hospital] for the scan. We both hoped it would show something - anything. At least then there would be a reason for all my symptoms. I would be able to say - see, *this* is why I've been so sick. I would regain my credibility and people would start looking at me the way they used to when I was superwoman. There would be an illness with a name and there would be a known cure and I would take the pills and be better and back at work and life would be back to normal. The scan was clear. The specialist and his nurse told me the good news with a smile and sent me on my way. My husband helped me back in the car where I collapsed from exhaustion, too tired to even cry. The disappointment was overwhelming. I would have been more relieved if they had found cancer (woman, G1, referring to personal notes).

There were two health outcomes for participants in this category, following deamalgamation and detox. Most had recovered completely. However, some reported new problems that they attributed to the detox. drugs. Those who began to detox. prior to the 1990s reported more side effects than those with more recent experience. It was suggested that the lack of widespread use in the New Zealand population of drugs like DMPS<sup>20</sup> and DMSA<sup>21</sup> meant there was an element of trial and error and some had experienced the latter. There was general agreement that a greater interest in mercury chelating drugs by the medical profession, or affordable post-tests, would have given them more protection as patients.

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<sup>20</sup> 2,3-dimercaptopropane-1-sulphonic acid

<sup>21</sup> Meso-2, 3-dimercapto-succinic acid

### *Category B: Experience of Minor Worries*

A typical person in this category was someone who was alerted to a possible health risk from dental amalgam from personal contact with someone who had experienced benefits from deamalgamation and detox. They were health-conscious and making lifestyle choices in line with currently accepted health practices. They reported doing things in moderation: exercise, eating “properly” and not smoking. They avoided known hazards such as chemical garden sprays.

They had not considered they were ill when they consulted the medical practice, reporting only minor health worries including having a metallic taste in the mouth, tinnitus, and a reduced cognitive efficiency that they too referred to as brain-fog, although others referred to having a bad memory. They also reported having frequent tonsillitis, colds and flu; and noticing a minimal sense of taste and smell. Their decision to have the urine test and to remove amalgam was for future illness prevention, linked for some with mercury suppressing the immune system.

These participants reported reading more scientifically informed magazines (for example, *New Scientist*), and discussed concerns with health professionals. They tended to be middle-aged, employed and financially secure.

A strong message from this category, that was endorsed by other participants, was that to question the link between health and mercury triggered a reaction from health professionals (dentists and specialists more than doctors in general practice) requiring the person to justify having asked the question rather than being provided with information.

As responses followed a line they were unconvinced by such as, “Who told you there is anything wrong with amalgam?” or “I’ve got amalgams and there’s nothing wrong with me”. They assessed their own exposure to risk, adding their observations and self-appraisal. “My mouth was black,” said a woman in G1 (and man G6). “Mine too,” interjected another woman in G1, showing that

concern about the safety of dental amalgam was positively reinforced by the visual cue of the fillings themselves.

Several participants from category B had asked their family dentist and been told that mercury in fillings is safe.

My experience has been that if I mention it to some doctors... (or) if I mention it to some dentists, they just pooh pooh the idea as much to say well, you're from another planet or something like that, it's crazy (man, G7).

I got into this because when I was about 50 I got into alternative medicine. I have come to the conclusion that the medical schools and the dental schools are living in the past, and have no respect for other opinions. I looked in the alternative magazines. One day I was having lunch with [a friend] who mentioned this person involved with mercury testing. At the end of the day I don't know just how good it was getting it [amalgam] removed. It wasn't that bad that suddenly I felt good again. Basically I've got superb health. I believe people should look after themselves in advance rather than be collected at the bottom of the cliff (man, G6).

These participants formed an unexpected subgroup; interesting in view of the findings of an Australian study where nearly 40 percent of a postal survey expressed concern over the mercury content of fillings but the concern was not translated into demand for alternative dental treatment following discussion with the dentist (M. Thompson et al., 1997). Dentists were still advising their clients that amalgam is safe, but participants in the focus groups were reporting disregard for that advice, and contrary to M. Thompson et al.'s findings, taking action.

After deamalgamation and detoxification, these people were surprised both at the return of lost sensation and the speed of recovery. They had not anticipated any immediate benefits but reported the lifting of the 'brain fog', improved smell and taste, years of no influenza symptoms, and the end of the metallic taste. The author of the present thesis categorised this as a major health gain.

### *Category C: Still Sick and Still With Amalgam*

The three people in this category had been unwell for many years, and were the only participants who had not begun amalgam removal or detox. They attended the focus group to hear what the others had to say. They all knew at least one person, none of whom were participants in the present study, who had told them a personal story of recovery from illness following deamalgamation, but as there would be some financial hardship for them in choosing amalgam removal for health gains, they wanted to be reassured.

A typical story from a person in Category 3 would be of someone not feeling very well who has made an effort to get to the focus group, or someone who is still well to the extent that they are able to go to work and meet their role expectations but are struggling to cope with deteriorating levels of wellness:

My link was through a friend really because he had a lot of problems, he wasn't thinking properly for work, and he read in one of the health books about the amalgam and it was quite good, and he went down there [Godfrey's practice] so I got all the information from him. I read up about it and I went down there myself, and I had the hair test, and the urine test and it came back high. I had been getting chronic bronchitis and every year it was getting worse and worse, and then I got diagnosed as emphysema and had my upper right lung out, and now I've got chronic fatigue syndrome and I haven't had my amalgam out, so its just sort of dragging on and on... and I've been off work for 18 months (woman, G6).

From people in this group there was some reservation expressed about the likelihood of amalgam removal being a cure for them. They all accepted that the urine test results showed they had high mercury levels, but this alone had not justified the financial hardship that they suggested would be a consequence of opting for deamalgamation. One participant said his wife, who had not been sampled for the study, had had amalgam removal first, as she had been very ill, but now she was well and supporting him until they could afford his treatment:

I've still got the amalgam in my teeth and am looking to get it removed. For many years, just lived with it. Episodes in my life where my health wasn't what I thought it should be - psoriasis, throat problems, lack of

energy and the metallic taste - and my wife had been having problems with her health too. She'd been to a lot of health professionals and hadn't got the answer. Tried various things without realising it someone must have mentioned it along the way that it could have been her teeth and she went to [Godfrey's practice] and he convinced her that she should get her amalgams out, which she did and she's had, well she's had them out now probably two or three years and its changed her life. She feels much better and as a result of that I've been thinking about my problem and how in my 20s I was fit and enjoyed life... (man, G2).

Some people from the 'chronic illness' category reported being in similar positions until they found the money for treatment, and reinforced the discourse, so although there were few people in this category, there was still a pattern of discourse across groups that one needs both a conviction about the efficacy of deamalgamation, and the money.

#### *Category D: Single, Major Illness Experience*

Several participants reported having had an original medical diagnosis of something other than mercury poisoning, which they accepted (hyperthyroidism, cancer) but in the course of complying with orthodox treatment for this, they had explored amalgam removal as a way of minimizing a perceived threat to their immune system. Amalgam removal was seen initially as supporting other treatment.

A typical person in this category would be someone who had been referred by his or her general (medical) practitioner (GP) to a specialist, and had been following an orthodox treatment plan. However, during the course of their illness they heard from a friend or relative that it could be worthwhile getting a second opinion about mercury. This was explained to be the same kind of belief as 'making sure you have enough fibre in your diet or getting enough vitamin C.'

These people did not take lightly their decision to remove amalgam. They were not convinced at the time of their first and often subsequent consultations that there was any link between amalgam and health, and they left many

months between the urine test and taking action. When they did decide to try amalgam removal the results were dramatic: one participant had not had scheduled surgery, and another had not required a planned programme of chemotherapy. All report that their return to health has been enduring, albeit with disease-in-remission diagnoses. One narrative explains:

I've always been very lucky to enjoy really good health, so when I started to feel really bad a few years ago I ignored it because I don't often go to doctors. (Then her mother persuaded her to go.) I went to see our GP who did thyroxin tests, and I can't remember the figure but it was very, very high thyroxin level, so he sent me off to a local surgeon who said that in his opinion, my thyroid gland was very swollen, you could see it by then, that it would have to come out, but that the modern way of doing it is not by surgery anymore, its by drinking radioisotopes or some radioactive stuff. Anyway, he sent me to a specialist in Hamilton who also said he didn't see any other option, that I should drink this stuff and it evidently goes straight to your thyroid gland and it disintegrates it. So you don't have a thyroid gland anymore, which means that you then have to take medication for the rest of your life to replace what the gland is not producing in your body. I said to husband, I'm just not sure I want to do this. It seems to me like such a drastic step, by those sort of means. It went against the grain I suppose. I didn't actually know anything about [Dr Godfrey], but a friend suggested I go and see him, so that was actually my first exposure or meeting with Mike, and he said he believed, he did that test, that hair test and other tests, and he believed that, and I had lots of amalgam fillings, if I had them removed he believed that, but he couldn't guarantee it, that it would solve my thyroid problem. So I decided I that I would go ahead and do that, and it was quite a big decision. I hate dentists. I suppose like everybody else here. (General hum of agreement) I also thought for my long-term health it probably was a good idea if, if, if I was suffering from mercury poisoning and it was affecting my thyroid gland, what was the future? I mean I could go and have the thing removed and go onto medication but 10 years down the track I might have something else wrong with me (woman, G2).

## *Deamalgamation and Detoxification*

Within every focus group some participant mentioned a “bath” metaphor as a heuristic that explained deamalgamation and detox. Their body was likened to a bath, and dental amalgams likened to a dripping tap. For a person with dental amalgams the tap was turned on, but with amalgam removal the tap was turned off. In the metaphor this left “water in the bath” and it needed to be drained. To detox. was to “pull the plug”.

In the group with a man who had amalgam removal but no detox., this story was used to suggest to him that he should consider going back to the doctor because he should not expect to get better while his body still held the toxin.

While there was general agreement that the medically recommended treatment for mercury poisoning was deamalgamation, there was a lack consensus by participants on the detoxifying procedures. Between them they had taken a variety of pills, or no pills but modified their diet to include antioxidants. Detoxification was described as another expense that some people decided not to incur, and these people had stopped once their first prescription had been taken.

Some of the eight participants who gave qualified reports on their health outcomes said that people who had been on detox. programmes many years ago seemed to have had more trouble than those with more recent experience. The explanation for this difference was that the procedure was new eight to 10 years ago<sup>22</sup> and now much more is known about side effects. Because chelating drugs like DMPS and DMSA had not been widely used in the New Zealand population, the participants saw their detox. programmes as having an element of trial and error. Three of the participants reported on-going health problems from the latter. There was a general agreement amongst participants that knowledge is expanding in this area all the time. Typical comments included:

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<sup>22</sup> Eight to 10 years ago from 1998

(Dr Godfrey's) treatment certainly helped me enormously. It took the mercury out of my system but it also left me depleted of nutrients (woman, G6).

Another speaking in support said:

I had my detox. I took DMSA tablets and I think I had too strong a dose (women, G6).

People who got better quickly explained it in terms of the detox and that it was really only the mercury in dental amalgam that they were reacting to, whereas others who took longer explained this as their having multiple sensitivities like mercury and pesticides, and they had had to "peel off" or "drain" layers of poisons. This metaphor is consistent with the bath story and a different way of explaining health from the medical model. For example:

(With a doctor other than Dr Godfrey) ...I had to be drained of the anti depressant as well as the giardia, an amoeba, a strep, a garden spray and others. As each one was drained I regained my strength slowly but surely. [Then] I faced the expense of having my amalgams removed and drainage of mercury from my body. I did not have immediate relief from the dental treatment, but the medication X-IT and Transmix which I took for several months had a very definite beneficial effect. When I finished the bottles I found my tiredness returning so I took a second lot which appeared to be all I needed (woman, G1 - with an 'open letter' summarising her story)

Neither was deamalgamation without side effects. Dental pain following amalgam removal was widely reported. Mostly it was worse than people had expected. Participants explained it as related to "something the body doesn't want to let go of" or "the system having become addicted to a substance (mercury) and it goes into shock when it's withdrawn". Parallels were drawn with the immune system having been suppressed or non-existent and now having a chance to "bounce back". Some talked of the preservative properties of mercury and "releasing the immune system" when removed.

## *Psychological Problems with Mercury Poisoning*

Psychological problems related to the mercury poisoning experience arose from two sources. First were the problems directly attributed to mercury toxicity - memory loss, mood swings, and loss of sensation. Secondly were the problems related to the consequences of having symptoms that were not readily diagnosed by GPs. Issues here were self-efficacy; the social stigma of being labelled a hypochondriac; the concomitant loss of social support; of being referred for psychological assessment or hospitalised for psychiatric assessment; and being prescribed anti-depressant medication. People described the process of being ill and slowly getting worse, saying they talked about their illnesses less and less as they were progressively stigmatised by doctors, friends and family, as hypochondriacs.

Participants from several groups had considered suicide. In one group a person said they had read that the two most common causes of death with chronic fatigue syndrome were suicide and drowning-in-the-bath. The group discussed and amended this, saying that perhaps the chronic fatigue syndrome sufferers drowned when they were too tired to stay awake in the bath, or more likely that this too was suicide. Ending their misery by (variations of) falling asleep in a hot bath and hoping to drown, was the method that four people in one of the focus groups stated that they had considered. Suicidal thoughts were also referred to during discussion in other groups, including praying to die, and dreaming of (welcome) death. All of the participants who had considered suicide had deamalgamation and detox. and were well or thriving, and no longer had suicidal thoughts.

Within the groups who raised the topic of death as relief from chronic illness was a consensus that people could not rely on medical treatment. They agreed that people had to be in tune with their own body and monitor their own symptoms. For some this meant realising that prescribed medication made them feel worse, and trusting their own assessment to discontinue using it. Most frequently mentioned as medication that made people feel worse were anti-depressants; these were reported to be prescribed when general medical practitioners apparently suspected, or openly stated, that the person's symptoms were psychosomatic.

Particularly for people diagnosed with chronic fatigue syndrome and taking prescribed anti-depressants, suicide was reported as an option. When the topic of suicide surfaced in any of the focus groups, the facilitator asked directly how many participants had been this desperate. Always there were more who talked about suicidal thoughts than not.

The scenario followed the line that if your doctor tells you your problems are psychosomatic, and your usual support network thinks you are a hypochondriac, then you have no one to turn to. The pills are making you worse and there are periods where you cannot get out of the darkened room where you sleep for days on end. Of course you wonder why you bother to go on. As one person put it:

And my health went down hill and I tried every track and I realised I could spend every cent I had for the rest of my life and not have health. I shied away from doctors because they pooh-poohed me. I prayed to die and lived in a blackened room. I couldn't remember my children's names and I thought there was no reason to live (woman, G5).

For this woman the word mercury came into her head as an answer to her prayer to die. Then she heard about someone who "had a mercury change". She took the step of having a total clearance of her natural dentition, rather than amalgam replacement with another filling material, as the quickest way to, using the bath metaphor, turn off the tap. Within six months:

I felt I was a new person. I could never make an appointment or anything because I never knew whether I would be well enough to keep an appointment. That was one of my first thrills. I kept a diary (woman G5).

This story links the concept of 'listening to your body', and how people initially made the link between health and mercury. Several of the participants first heard about mercury in their heads, as in the answer to a prayer, or in dreams.

Stress was definitely seen as having a role in the progress of illness. It was discussed as evidence that there is a trigger to really bad health. For example, it was said that people's health may show signs of stress like frequent influenza and virus episodes, and lethargy, but something will happen that

heralds the start of the debilitating symptoms now attributed to mercury poisoning. Pregnancy, child birth, death of a friend or family member, immigration, moving to another town and other illness like glandular fever, were all seen as stressors capable of triggering the body into an inability to cope with stored mercury.

The reference to a trigger point when health problems escalate, is consistent with the Lindenberg et al. (1994) psychodynamic assessment of people who, like the focus group participants, had a belief in the link between amalgams and illness. Unlike the Lindberg et al. conclusion that unresolved trauma symbolically somatized, and was the *real* cause of amalgam illness, the focus group participants have demonstrated or reported that the appropriate treatment for them was not increasing their social support networks (also Langworth's main treatment for patients referred to the "Amalgam Unit" at Huddinge Hospital in Stockholm) but deamalgamation and detox.

Sensation, particularly taste and smell, were not widely discussed, except for the ubiquitous metallic taste, and by participants from Category B. One man, after talking about his balance improving on amalgam removal, said on metallic taste:

Yes, the other symptom that was removed once I had the amalgam out was the taste of tannin. That has gone completely. It was like licking a battery (man, G7).

Another participant who still has amalgams said,

I suffer from tiredness a lot, and lack of energy and latterly I've got a bit of a throat problem so I wondered, you wake up in the morning and you've got a throat that, you know, you're always swallowing, and I feel that when I wake up in the morning the first thing I've got to do is rinse my mouth out, cause I feel as if the taste's there, you know, the metallic taste (man, G2).

In my case I was constantly getting heavy flu. Every year I would get sick. And I had this bad metallic taste in my mouth (oh yes say one or two others) yep, metallic taste, and I was losing my sense of taste, I couldn't taste my food properly, and I could stick my nose over a pot of

food cooking and I couldn't even smell it. And at night I'd be clogged up. Now (using a more cheerful tone) I can taste things, I can smell things ... (man, G7).

He went on to describe the progressive return of senses after deamalgamation for prevention. This was a benefit he was not expecting, and may seem unconnected except for Saxe et al. (1999) suggestion that in autopsied brains, only the olfactory region had a positive association with dental status.

There were some specific comments on cognitive function. 'Brain fog' or the inability to concentrate, were part of the perceived mercury-poisoning syndrome, but after treatment participants said things like:

I had a brain again. My brain was so fuzzy I used to think I know under here I've got a brain that does work. I could concentrate again. I hadn't even finished the treatment, I'd only had half my fillings done and I had a brain again. My nervous system just calmed down continuously (woman, G7).

My memory has improved tremendously, but I still have a problem. Before I had my teeth out I couldn't say a sentence. I had no idea I was saying things back to front. I had to concentrate on everything I said. This year I can live." [This was followed by another saying] "Yes and you make lists to cover for memory loss" (two women, G5).

### *Health Professions' Role in the Illness Experience*

It was reported that in the early stages of the illnesses that are now attributed to mercury poisoning by the participants that the link between amalgam and health was generally not made through a consultation with a GP.

The level of personal searching for a link between amalgam and health tended to relate to the presenting category for each person, with only chronic illness (Category A) people 'shopping around' to find a doctor who would take them seriously (Parsons, 1975). The participants were generally involved in conventional medical testing, with doctors, patients, and families of Category A

at a loss to explain their illnesses. However naturopaths and health shops featured strongly for diagnosing problems and maintaining recovered health.

People attending general medical practitioners reported always complying with tests, but not always with treatment (medication). Although people had been introduced to the concept of amalgam and illness, there was scepticism until the urine test results showed the raised level. However the prevention-motivated people (Category B) found that reading literature, and discussion with others, was enough motivation to go ahead, without knowing the test results. One participant commented:

We only paid one visit to Dr Godfrey and we said we were on our way to (a dentist). He said aren't you going to wait for the (urine test) results? and we said no [general laughter]. We were just going to go and get them [fillings] out (man, G7 speaking about himself and his wife).

The connecting theme was that taking all the conventional medication and accepting the medical diagnosis was attending only to the symptoms of medical problems rather than dealing with the cause. A participant in another group said:

(Before going to Dr Godfrey's practice) I was seeing a new doctor and she was very thorough. She diagnosed each ailment separately and put me on medication for each. She kept a close eye on me and threatened to put me in hospital. She said I was suffering from executive stress (woman, G1 who had transferred to another city for a new job).

Participants said that doctors did not look for the underlying cause of their health problems. If they followed conventional medical practices there was no cure on the horizon, only years of medication ahead. Hearing from a doctor that mercury could be explored as the cause of their various ailments, came as a surprise to most participants.

One issue that was of concern to the authors of the MoH report on *Mercury and Human Health* (Cutress et al., 1996), and to the focus group participants, was how people (doctors, dentists or ill people themselves) could have recognised the gradual onset of micro-mercurialism.

Allergies were reported so frequently as to be almost the symptom that all the previously-ill participants had in common, but while this may be a somatic symptom that is necessary before mercury poisoning is considered, it is certainly not sufficient a symptom alone. Similarly sleep problems were frequently reported, and not only by those with chronic fatigue syndrome. People would “wake up tired, never refreshed” and found themselves “sitting around not doing anything after an active life” (woman, G1). In bed they were restless, and felt muscular aches and pains.

Many of the minor symptoms that ceased after amalgam removal, were centred on the head: throat and neck problems, tongue feeling too big, the metallic taste, migraines and headaches, dripping noses, tonsillitis, bad breath, and sinus infections.

Before amalgam removal, and possibly because of the claimed impact of mercury on the immune system, participants reported being constantly ill with recurring influenza and colds. The symptoms ceased, and new infections were rarely experienced following deamalgamation. A typical comment was, “I was crook for 6 years before (amalgam removal), always having colds. They would be bad colds. Very rarely get colds now” (woman, G1).

Participants talked about the body being an object to doctors who treated separate parts but ultimately did not see the whole picture. This is consistent with the western medical practice paradigm. One participant said, “They do bits, like an infected throat, but not considering what’s in the mouth” (woman, G4). This would seem to be a profound comment given the separation of the professions of medicine and dentistry. It may be that because the teeth are not the doctor’s professional territory, that unless there is gross infection, teeth are, in effect, invisible in a medical examination. The toxic vapour that is emanating from fillings in the teeth, is not considered in the general diagnostic process, nor is it a medical issue.

One woman seeking help had spoken to an Auckland Hospital toxicologist by phone. He asked if she had been exposed to mercury because he acknowledged that her symptoms fitted his criteria for mercury poisoning. She said she had worked with a dental technician and she had amalgam fillings.

Referring to the fillings, the specialist said they did not count as exposure to mercury, in terms of Auckland Hospital regulations.

Several groups made reference to a topical event. There had been a metallic mercury spill on a Manukau beach at the time the focus groups were being conducted (see Figure 2). People commented on the fuss being made: the media exposure about the dangers of mercury being in contact with bare human skin, people inhaling the vapour, and damage to marine life. The discussion followed the line that they had been in contact with mercury (from their amalgams) without their doctors even noticing.

Herald 5-6/Sept 98

## Race with tide to contain mercury spill

Chemicals found on Manukau Harbour's foreshore endanger people and marine life

By ANDREW YOUNG

A part of the Manukau Harbour is at risk of being dangerously contaminated after mercury was discovered dumped on the Onehunga foreshore.

The chemical compound can cause health problems if handled or if vapours are inhaled. Medical officials also fear people could eat poisoned shellfish from the area and become ill.

The Auckland Regional Council was last night racing against the clock to clean up the liquid metal before high tide.

The council's pollution control officer, Barry Strong, said even a tiny amount of mercury left on the foreshore could poison 10,000 cubic metres of the beach.

It is believed the mercury may have been on the beach since Wednesday, posing a great threat to the foreshore and those using it.

Mr Strong said the chemical was highly toxic to marine life, and council staff would continue to check for any more traces during the weekend.

An Auckland medical officer of health, Dr Donald Campbell, said people should be aware of mercury poisoning symptoms, which include gastro-intestinal, nervous system and co-ordination problems.

About two cups of mercury is believed to have been dumped on the foreshore, and much of it had been recovered by late yesterday afternoon.

Mercury is a shiny silver chemical, which forms into tiny globules when spilled. It is often found in thermometers, barometers and in laboratories.

The council yesterday brought in a digger to remove contaminated sand from the beach. Staff were using syringes to pick up the tiny globules around rocks.

Dr Campbell said it was suspected that the mercury might have been stolen and then dumped when the thief found no use for it.

Health officials yesterday afternoon put warning signs around the affected area, near Onehunga Wharf.



HEALTH DANGER: Pollution control officer Barry Strong and his team from the Auckland Regional Council used a digger and even syringes to gather highly toxic mercury from an Onehunga beach yesterday.

HERALD PICTURE / YANKEE MARTIN

Figure 2 Newspaper coverage of a mercury spill. (NZ Herald September 5, 1998, p. 1. Printed with permission).

When participants were talking about doctors evaluating medical records to ascertain health improvement, a novel reflection was offered. It was, that the participants said their doctors did not record a lot of the things that were

troubling them at a consultation. This was described as an issue of 'big problems versus detail'. Many participants did not feel that their doctors wanted to know the things that were really worrying them. Appointments were rushed, and people said that they may have rehearsed saying what they wanted to say before going to their doctor, or writing a list of the little things, but when they were in the surgery they found themselves answering questions about the big problems and giving formal responses.

This was contrasted with consultations with the Bay of Plenty Environmental Health medical practice. A typical response was that they took time to listen and Godfrey would "look at your fingernail if you wanted him to without seeming silly" (woman G2).

Participants said that doctors (naturopaths, herbalists, and health workers generally) all have their favourite therapy and patients themselves have to decide what will best suit their needs. It was important to some, but not to others, that Dr Godfrey was a registered medical doctor. As a probe question, participants in the first focus group were asked whether they still consulted conventional doctors. This question was aimed especially at those participants who had reported being really debilitated and treated conventionally, but unsuccessfully, for years. "Yes," they answered, "but we're no longer sick." [Then they all laughed and one continued]:

They will still give you five minutes and you only tell them the big problems, whereas Mike looks at minutiae and for as long as you needed. You feel thoroughly examined. GPs dish out antibiotics and you know they're the wrong ones, or send you for tests, but Mike had answers" (woman, and G1).

When discussing dentists, the participants said that dentists tell you "It's nonsense that filling mercury could affect your health". When removing fillings dentists were said not to be concerned about vaporising mercury: "they just bore away" (woman, G1).

Participants claimed that New Zealand dentists are known for not using rubber dam, and if they had asked dentists about white fillings or if they had said "white fillings only," some dentists replied, "Why? What's wrong with

amalgam?” Participants said dentists made them sound like the stupid ones. One commented:

Ask to look at their teeth - if they have amalgam get out of the chair quick. My friends all ask to keep their children amalgam free but the dental therapists say the white ones will fall out, last a year. There is propaganda about the white fillings and no good information. Still don't have amalgam (woman, G4).

While it was usual for participants to go to a mercury-free dentist who practised a safe removal protocol, some had asked their own dentist to do the amalgam removal, and usually were put off by their dentist's attitude. A typical comment was, “If you want it, I'll do it.” These participants felt their dentist was condescending and one reaction was, “(I would) go somewhere where they would believe in what they were doing” (woman, G1).

Dentists were reported to have said the white fillings were more expensive and harder to place. The reaction to this was, “Well I'm paying so do it.” However one person found her local dentist was helpful:

I couldn't afford to be rushing around the dentists on (a list) because they are very expensive. I just happened to be talking to our local dentist in (town named) and he was very good. I think I have got the best I could have got. I think he got it all out and I feel infinitely better (woman, G5).

Only three groups explored the durability of white fillings, and between the participants they had had various named and unknown brands of fillings for over 6 years with no problems. When asked why they did not appear to know much about the white fillings one said “Well I didn't with amalgam either, and my amalgams broke, but the white stuff is standing up. I take care flossing” (woman, G3). Another replied that she “might have worried about chewing hard things, but I'm a vegetarian and it hasn't been a problem” (women, G3).

### *Responses to the Final Trigger Question*

Participants from all four categories identified three overarching concerns in response to the final question concerning the continuing use of dental

amalgam. These were the cost, stopping amalgam use and educating doctors and dentists to be more open-minded about the relationship between illness and mercury from dental amalgams.

### *The cost*

Participants felt they were unfairly treated by the health system, and that there should be funds available for tests, and for amalgam removal if the medical diagnosis is mercury poisoning. Parallels were drawn with other diagnoses requiring operative treatment, and although amalgam is a dental device, its removal was seen as equivalent to removing a tumour or an operation to treat appendicitis.

Some participants also wanted compensation for having been poisoned by amalgams, without informed consent. Others believed the compensation should cover suffering as well as the direct costs.

The cost of amalgam replacement and the detox process was referred to throughout the discussion and the final trigger question served as an opportunity to summarise this aspect of mercury poisoning treatment. In 1998 the upper range of costs for people who had amalgams replaced was NZ\$7,000 to NZ\$10,000. This included bridgework for one and a complete second replacement for another with biocompatibility problems with the amalgam replacement material. It did not include other visits to doctors, dietary supplement, tests and travelling to Godfrey's practice from other locations. More commonly it was said to be around NZ\$3,000 - NZ\$5,000. Most participants had to plan for the expense, and spent money from selling businesses or divorce settlements on the treatment. One participant observed, "Perhaps they wouldn't have divorced if the amalgam poisoning had been diagnosed sooner" (woman, G2).

There were compensations for the expense as shown in this exchange between three people in G5:

- (1) I think they said 3 to 4,000 for mine and that was a few years ago.
- (2) By the time it's all finished you don't want to see dentists again.
- (3) But that is offset by not having to see doctors!

Not many participants had post-deamalgamation hair or urine tests. It was not because they did not want a post-test, as many would have preferred to have one, if the additional cost had not been an issue. Some participants also felt that the detox. process could be more precise if post-tests were affordable<sup>23</sup>.

Some participants minimised the problem of expense by waiting for fillings to become painful or break, and then having them replaced with a non-amalgam material. There were several complaints that medical insurance companies would not cover amalgam removal even though in their cases it was a recommended treatment by a registered doctor. As the participant from Category D explained:

It's crazy though, because the medical aid is happy to pay, (for her thyroid radio-active chemo-treatment) I mean, if I'd gone and drunken the stuff they would happily pay 2,000, 3,000 dollars for me to have it done, and then for medication for the rest of my life, and yet what I did I had to finance myself, and I'm a good bet for them again because haven't had to go back and make any claims. Yeah. It's just crazy (woman, G2).

This dialogue highlighted the well-documented problem of who gets well and who stays sick. While all people living in New Zealand, of a certain age, have probably had many amalgam fillings, there is now an obvious tendency for the financially secure to replace their amalgams and for their children never to have had them. This was discussed with the discourse that it is people who are better-off financially who are opting for removal for prevention and are able to afford elective treatment when ill. For people who are out of work or are sickness beneficiaries there is a perceived 'Catch-22' situation, as they may never get into a financial position to seek their treatment of choice.

Finally, with regard to cost and the related expenses of illness, the New Zealand Accident Compensation Commission was strongly criticised. Groups 3 and 5 each had a participant who had unsuccessfully claimed personal injury by accident following their mercury poisoning diagnosis. Claimants had

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<sup>23</sup> Dr Godfrey's medical practice now offers a routine [naturopathic] post-test NZ\$60). (C. Cooper, Practice Manager, personal communication, 26 January, 2005)

lawyers' bills in addition to doctors' bills. Neither had thought the process of declining their claims was fair or transparent.

### *Stopping amalgam use*

There was strong and unanimous support for the discontinuation of mercury in fillings. Participants would initially accept a regulation such as Canada has, restricting the use amalgam. In particular they supported the banning of amalgam use in children. This was an issue where participants felt politicians never heard their voice.

### *Educating doctors and dentists*

Participants wanted to send the medical and dental professions an unequivocal message that there was a link between health and mercury from fillings. The most targeted comments were for doctors who, it was suggested, should always consider amalgam poisoning with chronic fatigue syndrome, and with people to whom they were tempted to give a psychosomatic label.

In a paradoxical discussion on how positive health outcomes for people could be demonstrated to doubters who may be doctors, dentists or medical researchers, participants suggested that a retrospective evaluation of medical records would not show that mercury should have been identified earlier. This went back to the issue of big problems versus detail. Participants suggested their GPs would not have recorded the things that were worrying them and that are now resolved.

Concepts from medical sociology might explain the incongruence between patient experience and medical notes. Scripted communication and the competency gap between patient and doctor are well documented in phenomenological studies of medical practice (Freund & McGuire, 1995; Radley, 1997).

### *Implications for the Debate*

In analysing the impact on the wider amalgam debate of the focus group discussion, participants had talked about their real experiences in their search for health in a way that supported the diagnosis of mercury poisoning from dental amalgams. Participants had described their subjective experiences from making a possible link between mercury and health, to mercury testing, through to the processes of removing mercury, detox., and regaining health. In considering the contribution of the Category C participants, they formed a quasi-control group for those who had undergone deamalgamation. Participants from categories except Category C had the expected, if somewhat delayed, pattern for experiences where health is impaired: illness, tests, diagnosis, treatment and return to health. There are however, confounding issues, when exploring health outcomes following deamalgamation. Galvanism is one; and a possible placebo effect is another, and there may be an interaction between the two.

#### *Galvanism*

The mouth provides ideal conditions to produce electrical currents in adjacent or occluding teeth when amalgam fillings that contain dissimilar metals are placed in close proximity (Eley, 1998). Galvanic activity between fillings is said to cause headaches, tinnitus, and the ubiquitous metallic taste (Ayres, 1986). Removal of multiple amalgam fillings reduces or eliminates galvanic activity and the outcome may be what is experienced as 'instant relief', in the uncommon event that there is immediate relief. Amalgam manufacturers contraindicate the placement of fillings with dissimilar metal composition, in contact with each other (see Appendix C) but the common New Zealand experience is that this is totally ignored, if it is accepted that no two filling mixes are identical. Claims made by some people that they feel better immediately after amalgam removal have been used by dentists to support a counter-claim that this must be a 'placebo effect' (Wahl, 2001a).

## *Placebo Effects*

The logic of the placebo argument in deamalgamation is, that amalgam removal releases mercury vapour and, in the short-term, this should make a mercury-sensitive patient feel worse. Their mercury levels would rise, so symptom experience should rise with it (Wahl, 2001a).

A rejection of the placebo effect and a rejection of Wahl's reasoning were warranted, according to the focus group discussion, because not all people who had mass amalgam clearances had their fillings drilled out. Some reported choosing to become edentulous in one session, to get the exposure over with, and to not have to worry about sensitivity to another type of filling material. Also, almost all the participants had attended a dentist who used protective procedures like covering the patient's mouth with a 'rubber dam' and having the patient breathing through an oxygen mask when the dentist was drilling out the old amalgam. Only two participants reported anything like an 'instant recovery', and both had chosen tooth extraction.

It is possible, as the present author did not find any documented 'instant cure' reports, that this aspect of the debate is a straw-man argument from the pro-amalgam debaters. In the present study, Category A participants reported a general decline into very poor health. This is consistent with the bath metaphor, with symptoms increasing as the body stores mercury. Similarly, although the mercury release from fillings does cease with deamalgamation, the body only gradually excretes stored mercury, a process that is consistent with the gradual recovery narratives.

The gradual return to health was to good health that had persisted. In the longest example, recovery had endured 10 years. Two Category D participants, plus the wife of another, who had (or have) cancer, had also been well for four to five years since symptom remission followed their amalgam removal. They saw mercury in a causal role, if not with the cancer, then at least with suppressing their immune system's ability to fight cancer.

Finally, unlike scientific enquiry seeking a cause and effect relationship, or needing to attribute reported return to health to a placebo effect, some of the

participants were happy with a holistic explanation of their return to health. One said:

Five years ago I was diagnosed with a blood disorder and towards the end of that year my blood count was going down. The specialist I was going to started talking about chemotherapy. I can't quite remember how I got to go to Dr Godfrey, but anyway I went to him and he felt that I did have mercury poisoning and so I said to the specialist I didn't want to have the chemotherapy, there's a few things I want to get done, and she said, "I've got a mouthful of fillings and there's nothing wrong with me." you know, "I'm fine," (this set several people all talking at once validating her experience), but then you see her immune system might have been as strong as mine. So I had my fillings taken out and all my double teeth had fillings so I had a quarter at a time and I had the vitamin C drip and the DMSA and over the next three months my blood count came back to normal. At the same time that I had my fillings out I was having a lot of vitamin C, having a lot of carrot juice, and I had a lot of people praying for me, so who's to say which of those three, four things it was, or whether it's a combination?" (woman, G2).

Another said, on having her amalgams removed:

So, generally speaking the experience was unpleasant while it lasted (everyone joins in agreement). I had it done in quarters, I can't remember, a month apart I think two weeks apart? (Several offer time frame suggestions.) The one quarter gave me some problems and it was painful. My thyroid gland has, first of all, the symptoms disappeared gradually, not just all in one go, but gradually, and my thyroid gland which was like a melon (showing with her hands how large the gland was at the base of her throat) is now almost normal (everyone looks and her neck is of unremarkable appearance). I've still got it, I don't have to take medication, and I'm enjoying very good health again and hope to do so for a long time. So, my experience is a good one. Of course you could say well maybe if you hadn't had the mercury removed it might still have gone away, of course that fact always remains, but neither of the specialists I saw even hinted at the fact that it could naturally right itself. They were both for 'it has to go, it's too bad, its too big, the symptoms are too strong.' So neither actually said well you could give it a try and see what happens. I'm really glad I did what I did. (Another

asks how long it has been?) It's going on three years since I had all the amalgam fillings removed (woman, G2).

The potential for recovery stories to emerge as a dominant theme from the focus groups, was of particular concern to Cutress, as indicated in the Method Section, by his imposition of a two-year break between the potential volunteers' last visit to Dr Godfrey, and the focus group invitations being mailed. Most participants with recovery stories reported being well for much longer than two years, but this is a curious point in the debate. First, placebo literature does not specify a time frame for recovery endurance. Secondly, the two-year sampling criteria was not effective in ensuring the focus group participants had even begun to act on their mercurialism diagnosis, although for many it was well beyond two years. Thirdly, a time frame does nothing to separate a placebo effect from a placebo response. In the former, an observed effect occurs because of the placebo drug or procedure, while in the later, the observed response may occur from a natural or spontaneous remission that just happens to follow the placebo drug administration or procedure (Stewart-Williams (2004). Finally, in the case of health changes, a two-year period is likely to increase memory errors or biases in symptom reports.

Stewart-Williams' (2004) latest paper in a number published on *The Placebo Puzzle*, (for example, Stewart-Williams & Podd, 2004a; 2004b) differentiates between the "archetypal" placebo effect, where a 'sugar pill' produces a genuine recovery in a naive patient; and the current broader use of the term, where "a placebo effect is any genuine psychological or physiological response to an inert or irrelevant substance or procedure" (p. 198). He points out that any assessment of a placebo effect requires a "no-placebo control group", and without it there can be no assessment of the "proportion of the response is a genuine placebo effect" (p. 199).

Using Stewart-Williams' (2004) model, the attribution of placebo effects in deamalgamation and detoxification, cannot be made on focus group data. However, the apparently enduring nature of the health changes reported, still suggests that whether a placebo response, a placebo effect or genuine recovery, that deamalgamation and detoxification was followed by objectively observable, major health benefits in the lives of the majority of randomly

sampled medical patients, and not in the lives of those who have, over the same period of time, retained their amalgams.

### *Triangulation and Social Science*

If the present thesis accepts that for most of the focus group data supported the premise that mercury released from dental amalgam fillings has a causal role in some chronic health problems, how does this acceptance contribute to contestable explanations of mercury poisoning? It could be that for some people, the level of mercury that can cause an adverse reaction is so low that leached dental amalgam mercury added to mercury from all sources can produce an effect with symptoms of mercury poisoning. Another approach is to question the concept of the lowest observable adverse reaction.

One area of the mercury-poisoning phenomena that the present author has not seen explored in the literature, is the potential for the historical development the two professions, medicine and dentistry, and their territorial differences in relation to the body, to create in western medical practice, a “toothless body”.

To the focus group participants, the contradictions appear plain – why is mercury not safe in the environment but is safe in the mouth; is not safe inside a thermometer or preserving a vaccination, but acceptable in much larger quantities and leaching, in the mouth. For them it is difficult to see why illogical arguments are not apparent to pro-amalgam health professionals.

In the biomedical approach to health, historically the dental profession has laid claim to the oral cavity (Nettleton, 1988). It may be that the territorial division of the body, by doctors and dentists, hides the source of the contradiction. Dentists take “medical histories” then work safely around the medical/medication problems. Doctors may not see the toxic font in “healthy” restored teeth. The focus group findings would suggest that a more open and interdisciplinary approach might give rise to new medical findings about mercury sensitivity, and lower the limit for safe or tolerable levels. The best explanation for the situation at present is that doctors rarely consider a diagnosis of micromercurialism; dentists are closed to the possibility of

causing harm; and individuals have very different levels of tolerance to mercury.

### **Chapter Summary**

This chapter reports the qualitative exploration of the mercury poisoning experience for NZ people who have considered amalgam removal for health improvements. The study was an independent assessment of patients from one medical practice. There are four principal findings from the analysis of data from seven focus group discussions: (i) People who linked amalgams and health were not a homogeneous group with psychiatric illness, but fell into four distinct categories differentiated by their sets of symptoms, their fiscal resources, and their motivation. (ii) There was a major positive relationship between amalgam removal with detoxification, and the recovery of psychological and physical health, although the detoxification process was problematic. (iii) General medical practitioner or psychiatric consultations created problems in addition to the physical symptoms; and (iv) The placebo effect is not supported as an exclusive explanation for positive health outcomes.

## **CHAPTER FOUR: MERCURY AND VENUS – A STUDY OF WOMEN OCCUPATIONALLY EXPOSED TO MERCURY**

### **Introduction**

There is empirical evidence, presented in Chapter 1, that occupational mercury exposure may result in psychosomatic illness experience, and deficits or changes in affect, cognitive skills, psychomotor skills and sensory function. Meta-analysis has established exposure and test performance relationships for different domains with common neurobehavioural tests (Meyer-Baron, Schaeper & Seeber, 2002).

Studies specifically in dentistry have found adverse neurobehavioral effects from chronic low-level mercury exposure (Echeveria et al., 1995; Ngim et al., 1992; Shapiro, Cornblath, et al., 1982; Uzzell & Oler, 1986). Despite this, there is still no clear evidence in the literature from which to predict the long-term health outcomes for people such as dentists who may at one time have experienced neurobehavioural changes from occupational mercury exposure.

Ratcliffe, Swanson, and Fischer (1996) critically assessed the methodology and analysis of 164 mercury exposure studies and concluded that “the evidence for association between neurologic effects and inorganic mercury is irrefutable” (p. 238). Yet some uncertainty comes from there being very few follow-up studies, and from conflicting findings in those studies that do have a longitudinal aspect.

Albers et al. (1988), Letz et al. (2000), Frumkin et al. (2001), and T.Powell (2000), have demonstrated that there are some residual effects from occupational mercury exposure, but the possibility remains that some deficits are reversible once exposure ceases (see Cavalleri & Gobba, 1998).

In addition, women have been neglected in neurobehavioural studies of occupational mercury exposure. There are three reports specifically of women and occupational mercury exposure, and a limited number of studies that include both genders in the samples. Wood, Weiss and Weiss (1973) report

the medical case studies of two women who were exposed over many years, while calibrating glass pipettes. Uzzell and Oler (1986) report on 13 women who as dental auxiliary workers were exposed to mercury while preparing filling material. Triebig and Schaller (1982) report on a small sample that included two women, exposed at a chemical plant, and nine women exposed at a mercury-thermometer factory. In total there are data on fewer than 30 women.

The present study focused on a unique New Zealand occupation that lent itself to contributing to the scant knowledge in a number of these critical areas. Specifically, the mercury exposure was high-dose, chronic occupational exposure; the exposure was from practicing dentistry; the occupational group was women-only; and the cohort was at least thirty years on from the commencement of the mercury exposure.

In 1921, a New Zealand Government initiative established a state funded School Dental Service within the Department of Health, beginning a social experiment to curb dental disease in children. World War 1 army dentist, Sir Thomas Hunter, was the first Director of the Division of Dental Health, and he, "...threw himself into his new civilian task with military style efficiency..." founding "...his girls' army" (Brooking, 1980, 101-102).

The military link is important because the School Dental Service was run along military lines, complete with uniforms denoting rank, and with the lower ranks unlikely to question their senior officers' instructions. Only young women were selected, based on Hunter's sexist rationalisation that females would not have career expectations that could threaten the male-dominated dental profession (Middlemass, n.d., Brooking, 1980). They were trained to perform a limited range of conservative dentistry tasks and to promote good dental hygiene.

From 1921 until 1975 copper amalgam (CuAm) was the standard tooth filling material supplied to the School Dental Service, although in the latter years its use was restricted to deciduous teeth, and silver amalgam (AgAm) was supplied for the repair of decayed permanent teeth.

CuAm, supplied as a hard pellet, contained 30% copper and 70% metallic mercury. Pellets were prepared for use by 1) heating over a naked flame until the mercury bubbled out of the copper, 2) triturating with mortar and pestle to amalgamate the metals into a soft mix, and 3) hand-expressing the excess mercury droplets through a gauze cloth (Dental Materials Lecture Notes, Willis Street Dental School, 1969). The prepared mix contained approximately 50 percent each of copper and mercury. It should be noted that no form of protective clothing, including gloves, was worn, so the expressed mercury was in contact with the women's skin.

Handling metallic mercury was a risk factor in itself, but a greater risk came from breathing the mercury vapour. Frykholm (1957) described a series of experiments on mercury from dental sources. He demonstrated that when a pellet of CuAm was heated, the ambient air in a dental clinic environment reached peak levels of  $3000\mu\text{g Hg}/\text{m}^3$  air. In describing the practice of heating CuAm over an open flame, as was the New Zealand practice until 1975, Frykholm said, "In order to avoid too much mercury vapour being released, the copper amalgam should not be prepared in this way, but preferably under a ventilated hood with good exhaustion" (p. 76).

Silver amalgam was supplied as silver-tin-zinc and sometimes copper particles in powdered form and separate metallic mercury. This required weighing (5 parts silver to 6 parts mercury) and amalgamating the two components by mortar and pestle. Like CuAm this also produced a soft mix from which excess mercury droplets were hand-expressed through a cloth. Frykholm's (1957) experiments described this situation also, reporting  $400\mu\text{g Hg}/\text{m}^3$  in the air above the mix.

To contrast these peak exposures with contemporary occupational safety limits, Meyer-Baron et al. (2002) report the current German MAK<sup>24</sup> value is  $10\mu\text{g}/\text{m}^3$  and the generally accepted international value is  $25\mu\text{g}/\text{m}^3$  (International Programme on Chemical Safety, 1991).

Although biological exposure measures from individuals who worked in the School Dental Service are not readily available, it can be deduced that in the

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<sup>24</sup> Maximale Arbeitsplatz-Konzentration or maximum concentration in air

1970s, women employed in the School Dental Service were at risk of occupational mercury poisoning. In the course of a normal working month, a single operator would be expected to place 180-200 fillings, which is equivalent to 9 or 10 peaks of high-dose mercury vapour in the course of a working day, against a constant background level of mercury vapour in ambient air. Mitigating this was the work year being broken into school terms, so that women were out of their clinics for approximately nine weeks per year. This estimate of exposure is supported by Department of Health annual reports to Government, presented in Table 3 .

Table 3  
*Filling Output, by Staff and Year*

Year	No of Staff	Total No of Fillings	M per person
1974	1,356	2,589,019	1,909
1975	1,371	2,248,326	1,640
1976	1,319	2,202,169	1,670

Source: Appendices to the Journals of the House of Representatives (AJHR), 1975; 1976.

While most women worked in sole-practitioner dental clinics where the surgery was a small room, others worked with one or two colleagues also operating in the same room. For women working in this situation, the frequency of copper pellet heating was multiplied, and hence the ambient level of mercury vapour would have peaked more often.

In the 1970s some women of the School Dental Service became aware of the potential health risks from heating and handling mercury repeatedly throughout a working day. They expressed their concerns to their supervisors, known as Principal Dental Officers and Dental Nurse Inspectors, and to their doctors (Glass, 1981; R. Ritchie<sup>25</sup>, personal communication, March 16, 2004).

<sup>25</sup> Principal Dental Officer, Waikato District, in 1974, and later Ministry of Health, Dental Advisor.

In an editorial in the School Dental Service Gazette, responding to early suggestions that mercury posed a health threat for the workforce, Short<sup>26</sup> (1974) admonished the women for questioning work procedures published as standard operating instructions. He suggested that if there was evidence of mercury poisoning, it was because the women were not being careful in the handling of mercury, because the material *per se* was implied to be safe. Short states that the staff of the School Dental Service had been advised in an earlier School Dental Service Gazette editorial on:

Routine protective measures built into standard service techniques to ensure the hazard of contamination was maintained at the lowest possible level (p62); [and concluding] Avoidance of spillage, recovery of spilled mercury when accidents occur, and the maintenance of adequate ventilation and temperature controls in the clinics will be important factors. Monitoring programmes will do nothing to reduce hazards if the basic rules of mercury hygiene are ignored (p. 63).

By “ventilation and temperature controls” Short (1974, p. 63) was referring to the women working with their clinic windows open and minimizing the use of the electric-bar heaters supplied as standard space heating equipment. School Dental Clinics did not have extraction fans or any kind of air conditioning. Variation and fluctuations in New Zealand’s seasonal temperatures meant that the instructions were impossible to follow. The manual measurement of liquid mercury for silver fillings, the naked-hand expression of excess mercury from amalgam mixes, and the naked-hand clean up of accidental spills, in the absence of any protective clothing, demonstrates that even the most conscientious woman would still be at risk of mercury poisoning.

Glass (1981) claimed that there was a tendency for doctors (at that time) to attribute the women’s reported symptoms of anxiety or depression to hormonal factors. With Principal Dental Officers, who were almost exclusively male, taking a victim-blaming approach to the women’s health concerns, there was some time delay before the eventual identification of endemic mercury poisoning in the School Dental Service workforce.

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<sup>26</sup> Aubrey Short. Editor of the School Dental Service Gazette and one time PDO of the Willis Street Dental School, Wellington.

The delay in recognition may also reflect a general lack of appreciation of occupational risks from mercury in dentistry in the 1970s. Iyer et al. (1976) report a case of mercury poisoning in a male dentist, where a mood disorder and dropping instruments were not initially linked to occupational mercury exposure. Furthermore, Cook and Yeates (1969) reported the case of a dental chairside assistant who worked for 20 years before developing a kidney complaint and dying within 10 days, despite hospitalisation, extensive testing and non-effective treatment. Mercury was not included in her urine analysis, but was found to be the cause of her death at autopsy; and there are others with the same pattern, reviewed in Chapter 1.

By 1974, with the New Zealand Public Service Association's engagement of an occupational physician to make an assessment of possible mercury poisoning for the women, the Department of Health accepted the possibility of a causal link between mercury exposure from CuAm, and the women's health concerns. During 1974-75, all school dental clinics were air-tested for environmental mercury contamination. Nine hundred and thirteen women<sup>27</sup> were urine-tested for excreted mercury levels with three percent "off work for varying periods because their levels exceeded the maximum." (AJHR, 1976, E10, p. 40).

The main outcome from the mercury survey was that "...this work showed which dental procedures were giving rise to the elevated mercury vapour concentrations" (AJHR, 1975, E10, p. 33) and CuAm was withdrawn from use. Silver amalgam began to be supplied in an encapsulated form, prepared for use in a machine. These actions were thought to bring mercury hygiene practices into line with international safe practices, and mercury monitoring ceased. The last of the women to use CuAm are now in their sixth decade of life. There are few remaining data from, and no official reports on, either the women's urine-testing or dental clinic environment air testing programmes, save the brief reports in the AJHR for 1975 and 1976.

The present neurobehavioral follow-up study was proposed to assess any residual long-term effects from the generic mercury exposure that the young women experienced. From the literature it was thought that the most likely

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<sup>27</sup> No reason is given for the AJHR reference reporting on fewer than the total workforce.

area for persistent deficits was the psychomotor domain, with poorer mood also possible.

Of the few long-term studies of mercury-exposed workers, Kishi et al. (1993a) who assessed mercury miners on average 18 years after their exposure, found persistent coordination deficits in the all-male sample. Simple reaction time (SRT) scores were significantly poorer than the controls.

Albers et al. (1988) have raised the question of whether, in the psychomotor domain, neurotoxic damage from an earlier period is only revealed as people age. There is some literature supporting this idea, including evidence that peak frequencies in hand tremor shift after mercury exposure ceases (Langolf, Chaffin, Henderson, & Whittle, 1978).

Letz et al. (2000), and Frumkin et al. (2001), assessed men who had been occupationally exposed to mercury for a period of at least one year after 1956. On psychomotor tests they found finger tapping, SRT, and coordination (as assessed with the Grooved Pegboard), showed either a trend or a significant deficit, when compared to controls.

In the cognitive domain much of the research is linked to organic mercury exposure and demonstrates intergenerational deficits in cognitive development. Langolf and colleagues, in several studies, demonstrate that there are memory deficits in mercury exposed workers compared with non-exposed controls, and suggest that it has not been established that memory deficits assessed during occupational exposure, are reversible. (Langolf, Smith, Henderson, & Whittle, 1981; P. Smith, Langolf, & Goldberg, 1983)

Siblerud, Motl, and Kienholz (1994), explored the causal relationship between silver amalgam fillings and mood, following a report of a post mortem study by Eggleston and Nylander (1987) of a positive correlation between brain mercury and amalgam fillings. Siblerud et al. (1994) assessed multiple mood factors with 25 women with 10 or more silver amalgam fillings, and 23 age-matched women who had never had amalgam fillings, concluding that “amalgam mercury may be an etiological factor in depression, excessive anger, and anxiety” (p. 67).

Echeverria et al. (1995), comparing 19 mercury exposed and 20 unexposed dentists, found a significant dose-response relationship between urinary mercury and emotional lability.

T. Powell (2000), who assessed workers from a mercury processing plant five years after their exposure, found the most frequently recorded symptoms were those known to be linked to mercury poisoning, including body tremor, sweating, gingivitis, skin problems, memory and concentration problems, headache, fatigue and emotional lability. T. Powell had included two unrelated symptoms he referred to as bizarre, to check for malingering.

The aim of the present study was to test the null hypothesis: that there are no differences in health survey and neurobehavioural assessments between women who worked in the School Dental Service before the withdrawal of CuAm and matched women who were never occupationally exposed to mercury. This has the objective of determining whether there are any residual effects or unmasked evidence of the early mercury exposure. The independent variable, mercury-exposure, was operationalised as 'graduation from the Willis Street Dental School, Wellington, New Zealand, at least three years prior to the withdrawal of CuAm'. The dependent variables were a general and reproductive health survey and a neurobehavioural test battery.

## **Methodology**

### *Rationale for the Selection of Assessment Tools*

Neurobehavioural research into the effects of exposure to a neurotoxin has typically used an assessment battery comprising survey, standardised psychological tests, and psychomotor skill assessment tasks. With exposure to mercury specifically, there is no consensus on, nor standardisation of, an appropriate test battery. As has been customary then, a neurobehavioural test battery was developed.

There is also a requirement to screen for influences that may be confounding variables. These influences may be of environmental origin, related to other

historical occupational toxic exposures, arise from illness and accidental injury, or arise from behaviours linked to lifestyle choices.

Three existing generic NBTB informed test selection in the present study. The Neurobehavioral Evaluation System (Letz, 1991) and the WHO Neurobehavioral Core Test Battery (Friberg, 1991) were designed for clinical neuropsychological assessment in the event of individual mercury exposure. The Adult Environmental Neurobehavioral Test Battery (AENTB) (Ambler, Anger & Sizemore, 1995) was designed for clinical assessment or research. The AENTB has been peer reviewed (Ambler, Lybarger, Anger, Phifer, Chappell, & Hutchinson, 1994; Ambler, Rice & Johnson, 1996). All three of these test batteries take a broad-brush approach. Hence, while there is a trend towards concurrence on test domains, there is surprisingly little overall consensus on test composition. The only tests in common are the POMS (McNair et al., 1992), a symbol-digit substitution task, and a simple reaction time test.

In addition, the assessment of psychomotor skills and affect were strongly influenced by the most recent papers reporting long-term follow-up assessment of occupational mercury exposure (Frumkin et al., 2001; Letz, et al., 2000; and T. Powell, 2000). As these, and further studies, implicated reproductive health in problems related to occupational mercury exposure, and an increase in psychosomatic symptom reporting, so these aspects of health were also considered for the present study (Barsky & Borus, 1999; Brodsky, Cohen, Whitcher, Brown, & Wu, 1985; Cox, Breazna, Davidson, Meyers, & Clarkson, 1999; Frumkin et al., 2001; Meyers & Davidson, 1998; Schuurs, 1999).

The test selection process was compatible with that suggested in the Baker, Feldman, White, and Harley (1983) guide for developing an occupational, neurotoxic exposure test battery. They suggested that while the battery must be comprehensive, use standardised psychological tests and materials, and preferably tests with experimental validation for the toxin, it should take local conditions into account. Such an approach was successfully adopted by Sullivan (1993), in a University of Michigan doctoral dissertation that involved the cognitive testing of Amazonian village children exposed to elemental and organic mercury during local gold mining activity.

The final choice was related to the appropriateness of the assessment tools for both normal and pathological middle-aged New Zealand women. Consideration was given to issues of creating a good test environment in a range of locations, and establishing rapport with women who may have mixed feelings about participating in a neurobehavioural assessment. Further practical considerations influenced test selection, such as the time the battery might take to administer; the mobility of the testing apparatus; and the probable computer literacy of the sample.

Therefore selected tests are those key tests that cover the likely mood, cognitive and psychomotor functions, while exploring in more depth the areas already shown to have long-term mercury induced deficits. The rationale for inclusion or exclusion of specific domains and specific tests follows.

#### *Assessment Selection and Justification*

##### *General health and symptom experience*

A pragmatic approach was taken to assessing general health by collecting health experience and symptom data in a preliminary postal survey. This was seen as a practical way to reduce the subsequent length of the face-to-face neurobehavioural assessment session. It was thought that, in the interests of maintaining a positive testing environment that it was preferable to have participants consider and rate their symptoms or illness experience separately from the neurobehavioural assessment.

Health was surveyed in three ways: first as a global measure, and then as two sets of symptom data. A self-rated, single-question health scale was described by Idler and Kasl (1991) as a reliable indicator of current lifestyle health issues. This was included as the first question in a preliminary questionnaire (PQ). Participants rated their current health against a subjectively perceived ideal on a seven-point scale from “excellent health” to “terrible health”. Stephens (1996) found the scale differentiated clearly between groups of post-traumatic and non post-traumatic stress disordered police officers; and showed a moderate negative correlation with a symptom checklist.

Symptom experience was surveyed in two categories: in the past and in the present. This was intended to show whether the exposed group recalled any particular pattern of health problems during the time they were exposed to mercury vapour from CuAm, as well as their current symptom experience. The choice of the 33-items in the checklist and the five-point response scale was based on symptoms reported in medical case studies (see Chapter 1) and three symptom checklists that had been used in research where mercury-poisoning symptoms may have been present.

The first checklist was in use, by a Battelle Centers for Public Health, University of Washington, research team<sup>28</sup>, at the time the NBTB used in the present study was first being considered. The Battelle team were investigating the combined effects of mercury and nitrous oxide on practicing dentists. They had participants record in-depth medical histories by responding to a computerised questionnaire that comprehensively covered general health, reproductive health, injuries, medical conditions, medication and substance use, surgery, and mood. The 163-item checklist included frequency and severity of current and chronic symptoms. Participants were further involved with biological testing, keeping daily diaries of the use of chemicals in their practices, and finally, a neurobehavioural assessment<sup>29</sup> that was specifically developed for the Battelle study.

Although consideration was given to adapting the Battelle medical history computer programme, the choice in the present study of including the collection of symptom data in a mailed questionnaire, made any computerised questionnaire impractical. The anticipated participants could not be expected to have either computer literacy, or computer access. All the items selected for the present study were included in the Battelle checklist.

Secondly, Frumkin et al. (2001) had included a symptom assessment in a questionnaire that covered both general health and symptoms associated with mercury poisoning, in their long-term follow-up assessment of mercury exposed factory workers. Using a four-point scale, they found 12 of 15

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<sup>28</sup> Echeverria, Heyer, Bittner and colleagues

<sup>29</sup> *Behavioral Evaluation for Epidemiologic Research Test Battery* (Echeverria, Heyer & Bittner, unpublished), sent to the author of the present study following personal communication with Echeverria, during 1999.

symptoms showed statistically significant difference between the mercury exposed and control participants' health over the previous month. These items were included in the checklist for the present study, except where they were to be covered in mood or cognitive aspects of the test battery (for example, depression; memory trouble).

The third was a symptom list obtained from the medical centre where the participants in the *Biting the Silver Bullet* study (Chapter 3) were patients. This was a one-page excerpt from a *Bio-Probe Newsletter* (1993) (reprinted in Appendix G), reporting a meta-analysis of six unpublished studies of dental patients who had replaced their amalgam fillings. The list included 31 symptoms, the percentage of the 1569 patients covered by the studies who had reported the symptom prior to deamalgamation; and for each symptom, the number cured or improved patients, and the percentage cured or improved patients.

The main differences between these lists and the symptom list used in the present study came about because mood items, injury items, women's health issues and substance use, were to be assessed separately from symptoms in the present study, but were included to varying extents in the studies described above. Overall there were few differences between any of the studies in terms of what symptom experience was explored. Rather, the studies asked the questions differently, to suit their own aims. An example of this is the symptom 'headaches'. The *Bio Probe Newsletter* list divided this symptom into headaches and migraine headaches. The Battelle Centers for Public Health questionnaire had one symptom labelled headaches, with four response lines. These were for headaches on the day the participant completed the questionnaire, recent severity, recent frequency and chronic duration. Headaches were not a significant finding for Frumkin et al. (2001).

### *Reproductive health*

Reproductive health is what School Dental Service 'reunion organisers' identified, anecdotally, as the area they believe most needed research. They refer to their own adverse experiences around reproduction. This section has been included for that reason, and because it is a point of difference from studies of men occupationally exposed to mercury. In studies of

methylmercury exposure, the fetus, babies and children are considered to be the at-risk populations. Drasch, Schuup, Hofl, Reinke, and Roider (1994) for example, examined by autopsy, 108 children aged one-day to five years, and 46 fetuses, and compared the children's mercury concentrations from the kidney and cerebral corticies, with the dental status of their mothers. Their research signalled the need to restrict amalgam work in pregnant women. Mothers' mercury levels have been assessed by maternal hair testing to gauge the impact of environmental mercury pollution on their offspring (Boichio & Cernichari, 1998). The authors report wide variation in hair mercury levels, and no impact on fertility, but recommended neurobehavioural assessment of the children. Gardella and Hill (2000) have reviewed environmental teratogens, and list mercury as a confirmed environmental toxin in spontaneous abortion, although they note that most evidence is from methylmercury studies.

Frumkin et al. (2001), surveyed men occupationally exposed to mercury, and collected data on family reproduction history. They reported the findings of a brief checklist of reproductive outcomes including miscarriage, premature labour, stillbirth, low birth weight, and fetal malformation. Miscarriage and fetal malformation were reported as showing more than twice the occurrence in the exposed group than in the controls.

The present study therefore included reproductive health questions in the health survey, and followed the Frumkin et al. (2001) design. School Dental Service women, from an Auckland draft, who had participated in "key informant" focus groups for a questionnaire designed and pilot-tested for a women's reproductive health project (L. Jones & White, work-in-progress from 2001), generated additional categories. These were menstrual difficulties, conception difficulties, children's learning disorders, gynaecological investigations or surgery, and menopause experience.

While the list is essentially the framework of a women's reproductive health questionnaire, in the present study the scales are in a brief forced-choice format. This design was to quantify the issues and enable comparisons with controls, and was seen as a way of testing the validity of the anecdotal evidence.

## *Mood*

There were two approaches to assessment seen in mercury literature that impacted on the choice of test for affect. They were that mood assessment can be included in the symptom list in a preliminary questionnaire, or it can be incorporated into a test battery in the form of a validated clinical or research tool. Although there have been a wide range of tests used in mercury studies, depression, anger and anxiety are most often associated with events of mercury exposure (for example, Echeverria, et al., 1995; Siblingrud, et al., 1994). Hence, the common choices have been: The General Health Questionnaire (Goldberg, 1972, in Spreeen & Strauss, 1998); the Symptom Checklist 90 Revised (Derogatis, 1975, in Spreeen & Strauss, 1998); and the POMS (McNair et al., 1992). Tests less frequently used, but with significant results, were Beck Depression Inventories (Beck, Steer & Brown, 1996); and the State-Trait Anxiety Inventory (Spielberger, 1983)

The present study selected the POMS (McNair et al., 1992) for inclusion in the test battery. Previous studies and the generic NBTBs have most frequently selected the POMS for determining differences in affective responses between groups exposed or not exposed to mercury.

The POMS is a normed, standardised test that has two versions: a 65-item test and a 72-item POMS-Bi test. Both are lists of mostly single descriptor words (e.g. grouchy), with some two and three word mood expression (e.g. bad tempered, full of pep), for one of six sub-scales.

In the 65-item version, the sub-scales are tension-anxiety, depression-dejection, anger-hostility, vigour-activity, inertia-fatigue, and confusion-bewilderment. In this form the stimulus words are all descriptors of negative affect. The 72-item test, recommended in the manual for bipolar disordered or normal populations, also has six sub-scales, and the items measure the factors composed-anxious, agreeable-hostile, elated-depressed, confident-unsure, energetic-tired, clearheaded-confused. The two versions have 35 descriptors in common. The different descriptors in the 72-item version are words that extend the range of affect described within the subscales, so that there are six descriptors towards the negative aspect of each sub-scale, and

six descriptors towards the positive aspect of each sub-scale. The 72-item list was updated more recently so the descriptors are words in common usage.

The 72-item POMS-Bi was selected for inclusion in the NBTB after pre-testing both forms. Having positive as well as negative dimensions to the sub-scales was seen to give participants a list with face validity for their everyday lives, while still assessing anxiety, depression and anger. It had the additional visual benefit of being presented as a single, visually pleasant page, whereas the 65-item version was a dull blue booklet.

### *Sensory measures*

In the sensory domain, the main effects of mercury exposure have been linked to occipital cortex damage, and found in visual impairment including colour vision loss, (Cavalleri & Gobba, 1998; Kishi, Tozaki, & Gong, 2000; Schuckmann, 1979); and ocular changes (Roels, Gennart, Lauwerys, Buchet, Malchaire, & Bernard, 1985). Assessment of vision has been excluded from the present study, as this is one area that appears to be reversible, where the equipment would be difficult to transport, where there may be difficulty in providing or standardising the appropriate lighting conditions for testing for colour vision deficits, and where the cost of test materials such as the Farnsworth d-15<sup>30</sup> colour vision or hue tests or the L'Anthony colour vision test, were outside the fiscal resources available for a PhD thesis.

### *Cognitive tests*

Although neurobehavioural testing following mercury exposure has found a range of deficits related to cognitive function, these tend to be detected only when testing is at the time of exposure, as in chronic and on-going occupational exposure; or immediately following an acute, and usually accidental exposure.

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<sup>30</sup> Desaturated

Langolf, et al. (1981) used psychomotor and cognitive tests to monitor, over the course of a year, sub-clinical effects from mercury with chloralkali factory workers. They found that short-term memory deficits showed subtle effects from mercury exposure were occurring. In a later paper, P. Smith et al. (1983) reported that their monitoring showed that psychomotor effects were reversible when mercury exposure ceased, but they had not been able to establish that memory deficits were also reversible; and this was recommended as an area for further study.

In selecting tools for the cognitive domain assessment, composite measures were favoured, where the time spent administering a test could be justified by the quality or range of data that may be contributed to the study. Intelligence tests were specifically excluded, as Kishi, Doi, Fukuchi, Satoh, Satoh, Ono, et al. (1993; 1994) suggest that little variation is found when participants have higher levels of education, as indicated by tertiary qualifications. Hence, intelligence may be a critical variable to cover in studies of mercury miners, but it has not been so in studies in dentistry, nor would be expected, with the population for the present study.

The California Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan, & Ober, 1983) was selected to test memory and the learning of verbal stimuli, based on its recommended use for chemical sensitivity (Hartman, 1995), its prior use with mercury, most recently by Frumkin, et al. (2001), and its equivalence with the Hopkins Verbal Learning Test (see Spreen & Strauss, 1998).

The CVLT is a standard test with known psychometric properties, and is available in an “Adult-Research” version. Participants are asked to memorise a 16-item list, where the stimuli are presented as a shopping list for ecological validity. As well as total scores for free recall, cued recall, recognition, recall following interference and delayed recall, the CVLT can also identify learning strategies though the scoring of serial effects, position effects, perseverations, intrusions and false positives in recognition: these further options were

designed to help clinicians plan therapy through identification of the location of specific brain damage<sup>31</sup>.

Spreeen and Strauss (1998) suggest that the CVLT correlates “moderately well with other standard measures of learning” (p. 301), including the Rey Auditory Verbal Learning Test on which it was based, and that was used in older mercury studies. An alternative test in neurobehavioural assessment is the Hopkins Verbal Learning Test (see Spreeen & Strauss, 1998). The main difference between the Hopkins Verbal Learning Test and the CVLT is the number of trials for learning. The CVLT uses five trials, and the Hopkins Verbal Learning Test uses three. The Hopkins Verbal Learning Test appears to be preferred where time is a critical issue in test battery administration. In the present study, as the CVLT was the main cognitive test, the longer time required to administer the CVLT Adult Research version was not seen as a deterrent to its use.

The Symbol-Digit Modalities Test (SDMT) (A. Smith, 1973) was selected as a composite test of cognitive skill and attention, requiring effective integrated visual scanning, and attention. The SDMT is a speed test, where the participant is required to insert the digit that matches a symbol from a 9-symbol-digit key onto a page of lines of random symbols. The SDMT has been widely used in mercury exposure assessment, and while this may partially justify its inclusion, further support comes from Spreeen and Strauss (1998) who suggest that the SDMT is possibly “the most sensitive test of cerebral integrity” (p. 255).

It has been suggested that using the SDMT alone favourably compares to using a combination of Letter Cancellation, Digit-Symbol, Trail-Making, and Choice Reaction Time tests. (for example, see four studies described in Spreeen & Strauss, 1998). Further, Spreeen and Strauss claim that the SMDT is the single best measure for detecting reduced information processing speed, and is preferred over reaction-time testing, the Paced Auditory Serial Addition Test (Gronwall & Sampson, 1974), the Stroop Test (see Lezak, Howieson, & Loring,

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<sup>31</sup> Personal Communication, Edith Kaplan, CVLT author, American Psychological Association Convention, Hawaii, July, 2004.

2004), Mini-Mental State Examination (Folstein, Folstein & McHugh, 1975), and Raven's Progressive Matrices (Raven, 1996), all tests used by various mercury-poisoning studies to assess for information processing problems.

The third composite cognitive processing, concentration and motor speed test was a computerised SRT test, as reaction time has well established sensitivity to toxic chemicals (Ambler et al., 1994; 1995). Simple reaction time was one of the tests recommended by all three of the generic neurobehavioural test batteries. Testing SRT has previously been in common use for assessing response speed and focussed attention in the event of occupational chemical exposures (Ambler et al., 1995). In the present battery, SRT was also the test chosen to "warm-up" participants to the testing session, being relatively brief, a test that the participants can successfully complete without an awareness of their relative level of performance, yet one that has good face validity for a cognitive assessment task.

#### *Psychomotor tests*

Throughout the mercury poisoning literature, reports of damage to the peripheral nervous system are common. The AENTB suggested that the inclusion of grip strength was indicated where physical impairment may be involved (Ambler et al., 1995). While both grip strength and grip fatigue conditions can be assessed, in the present study only grip strength was assessed, as one aspect of sensorimotor function. Grip strength testing, using a hand dynamometer, is a non-invasive task with gendered norms. Hartman (1995) describes grip strength measurement as a well-established task in neurobehavioural toxicology assessment.

The Grooved Pegboard is a complex visual-motor dexterity test and measures the time it takes a participant to reach for, grasp, rotate-to-match, and position 25 identical key-pegs into lines of target holes, that have the key slot randomly positioned. This test has identified statistically significant differences between mercury exposed samples and controls in long-term, follow-up studies (Frumkin et al., 2001).

Finger dexterity has been assessed in studies of mercury exposure, as a task requiring the placement of 100 pins into rows of snug holes. These tests are

known varyingly as the “one-hole test” (Echeverria et al. 1995; 1998); and the “pins-mins” test (Gonzalez-Ramirez et al. 1995). A tweezer dexterity test taps similar skills to the finger dexterity test, but with finer hand-eye coordination required when tweezers are used to pick up and place the pins. The tweezer version was selected for the present study to add an additional challenge to the skill required for the Grooved Pegboard.

The O'Connor Tweezer Dexterity test was included for a further reason, related to the practice of dentistry. In the School Dental Service, the women used tweezers for much of their detailed daily work, and some residual transfer of training may have occurred. With this test it may be possible to analyse scores from subsets of the mercury-exposed sample, for confounds with work history. There is an expected moderate positive correlation between scores on this test and the grooved pegboard.

Tremor is the single most cited symptom of mercury poisoning. There is, however, very little standardisation of technique or equipment. Early tests used visual criteria to establish tremor. In the 1970s and 1980s various study-specific devices were made, and while tremor was measured, there was no external validity to reported tremor levels. More recently a Danish device was developed that incorporated a two-axes<sup>32</sup> accelerometer in the tip of a pen-like instrument. (Galinski, Rosa, & Wheeler, 1990). While this gave an element of ecological validity, the device was limited by its incapacity to measure the third, vertical, axis.

The Tremorometer® supersedes previous two-axes measuring devices, by incorporating a three dimensional accelerometer (Tripp, 2002). With the tremorometer, assessment of tremor can record tri-axial finger tremor patterns, electronically. The Tremorometer measures the frequency, amplitude and intensity of tremor on three-axes, and is supported by a computer software package to provide summary statistical data and Fast Fourier Transformed power spectra.

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<sup>32</sup> Data, in Hertz, were generated in two axes in a horizontal plane: right-left and forward-backward directions

## *Malingering*

As the focus of the present study is a historic occupational toxic exposure, there is potential for reflection by the participants on the findings. It is not inconceivable, therefore, that demand characteristics could occur, particularly in the direction of a participant from the exposed group making less effort than they could. T. Powell (2000), in his study of Zulu workers who were supposedly affected by mercury and who were in litigation with their employer, included a test of malingering with pre-set exclusion criteria, to identify cases where inadequate effort appeared to have been made.

Vickery, Berry, Inman, Harris, and Orey (2001) reviewed tests of inadequate effort. Conclusions from the review were that there were a range of commonly used tests, but that few had been used in multiple studies. Some tests reviewed were not tests of malingering *per se*, but included measures of internal validity<sup>33</sup>. Vickery et al. reported that the most frequently selected, effective test was the Rey 15-item test (Rey, 1964, cited in Lezak, Howieson & Loring, 2004). Lezak et al. described the Rey 15-item test to be an effective test of malingering in clinical situations.

The Rey 15-item test is a brief short-term memory test that is presented as a very difficult task, effectively offering the malingerer an opportunity to underperform. It was selected ahead of a more complicated alternative, the Test of Memory Malingering, (Tombaugh, 1996). The Test of Memory Malingering takes 20 minutes to administer, compared with only five minutes for the Rey 15-item test. In a test battery scenario, the addition of a single measure of 20 minutes duration needs to contribute more than the suspicion of inadequate effort, when a briefer test has established validity. Both the Rey 15-item test and the Test of Memory Malingering could provide useful data on short-term memory, however there is a strong correlation between Test of Memory Malingering and CVLT scores, so there was no further advantage in including the Test of Memory Malingering.

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<sup>33</sup> For example, the Minnesota Multiphasic Personality Inventory

Ambler et al. (1995), have stated that for the tests described above, a combined exposed and control group sample of over 50 participants would detect a 10 percent difference with 95 percent power and  $\alpha = 0.05$ . Their assertion was based on a pilot study of the 14 tests in the Adult Environmental Neurobehavioural Test Battery, and a review of workplace literature by Anger (1990).

### *Rationale for the Sequence of Tests*

With the framework of the test battery described above, a rationale was developed for the sequence of presentation of the nine tests. Ambler et al. (1995) stress the importance of minimising the potential for participants to perceive they lack competence or skill in completing assessment tasks. This can be avoided by placing those tests, where there is an opportunity to reflect on performance, later in the order of presentation. In addition, the first test should have the appearance of being able to be competently undertaken, to give the participant confidence in their role as a research subject. The SRT test has simple stimuli, required only a key-tap response, gave no reaction-time feedback, and was reasonably brief, and hence it met the criteria for being placed first.

To help consolidate rapport, the tweezer dexterity test was placed second. It can be conceptually linked to the work of a dental nurse, where tweezers were used to transport small items from the work surface into the mouth (e.g. cotton wool items), so it was expected to have face validity for the exposed group. It was also expected to have novelty value as an activity for the control group.

The CVLT needed to be early in the sequence, so there would be an appropriate passage of time (at least a 20 minute delay that the participant was unaware of), before the long-delay memory recall and recognition tasks. Part 1 of the CLVT was therefore administered third.

At this point of the proposed battery, none of the tests had required the participant to write any responses. To vary the activities, the SDMT was selected in the fourth position. The remaining tests were mixed by task-type,

and length, to maintain interest and minimise fatigue in the participants. There was a logical progression from passive to active; from sitting to standing; and from speaking to writing or planned action.

The assessment of mood was placed third to last, to minimise any flow-on effect from surfacing negative feelings. No studies involving mercury have reported this as an issue, but the present study has taken a precautionary approach to the mood assessment placement in the test battery order. As a non-timed task that a participant should complete independent of the administrator, when placed near the end of the battery it provides the administrator an opportunity to pack up the completed materials, and to review the progress sheet to ensure the correct order had been followed and data recorded accurately.

The test of malingering was placed second to last. It was expected that if a participant had been responding with less than full effort, a response bias would be established and evident by the end of the session.

The final test, the Grooved Pegboard was placed last to be as far as possible from the other pegboard, the O'Connor Tweezer Dexterity Test. It was also anticipated from the test norms that it could be completed competently and quickly, and like the O'Connor Tweezer Dexterity Test, appeared to be high in novelty value: something that might aid motivation after a sustained period of testing. The final order, anticipated time and type of activity are summarised in Table 4.

Table 4

*Proposed Survey and NBTB: Sequence, Task and Time*

Order	Task	Type of task	Estimated Time
Posted prior to assessment	Preliminary Questionnaire	Questionnaire Screening	15-20 minutes
NBTB assessment	Set up, establish rapport Question and consent	Conversation Interview	10 minutes
1	SRT	Computerised	5 minutes
2	Tweezer Dexterity Test	Manual	10 minutes
3	CVLT part 1	Verbal	20 minutes
4	SDMT	Pencil & Paper	5 minutes
5	Tremor	Standing but passive	10 minutes
6	Dynamometer	Standing but active	10 minutes
7	CLVT part 2	Listening and responding	5 minutes
8	POMS-Bi	Pen & Paper	5-10 mins
9	Rey 15 item test	Pen & Paper	5 min
10	Grooved pegboard	Manual	5 mins
Total estimated time (excluding survey)			1 hour, 35 minutes

## Method

### *Sample*

A “total population” sampling method was used on a four-year cohort of graduates from the Willis Street Dental School, Wellington, NZ.

The military style training in the School Dental Service had consequences that are important for the present study. The first was that, following their graduation, the women did not choose their own place of employment. They were given “field-postings” that assigned them to a position in a School Dental Clinic, and this could be anywhere throughout New Zealand. Secondly, it was from this involuntary diaspora that a tradition developed, where draft (class) members maintained contact with each other and held draft reunions at various times.

The reunion tradition made it possible to locate potential participants through reunion-organizers, who were prepared to supply a list with their draft-members’ current addresses<sup>34</sup>. While none of the lists was a perfect record, each draft had only a few women, from the approximately 30-40 graduates, with whom they had lost touch completely; and each list had some women listed as resident outside of NZ.

In this way a near total population sample was possible for the four years selected, 1968-1971. Drafts from these years had the youngest women who, before the withdrawal of CuAm as a filling material, had had time to work through a three-year ‘moral bond’<sup>35</sup>. This was a point before which few women resigned but after which many resigned from the School Dental Service.

*Mercury and Venus* reports on 74 women: 43 ex-School Dental Service employees in a mercury-exposed group; and 32 matched controls. The

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<sup>34</sup> Thirty-year reunions meant draft contact lists had been recently updated, which was particularly helpful to the present study.

<sup>35</sup> As students were paid throughout their training, there was a three-year bond to the School Dental Service. There was no financial penalty for resigning early only the threat of no future employment. It was known as a moral bond.

mercury-exposed women volunteered from an identified population of 115 women who were living in NZ. Otherwise eligible women, who were resident outside NZ, were excluded. This was a 40.2 percent response rate, after deducting the eight mailed invitations to participate, that were returned by NZ Post as undeliverable<sup>36</sup>.

Control group volunteers were sisters and friends of participants from the mercury-exposed group. Of the 33 women who originally volunteered, 14 were sisters and 19 were friends. One sister withdrew completely before the assessment, leaving a total of 32 control group participants: 13 sisters and 19 friends. Their mean age was 0.8 years younger, and with a greater SD than the exposed group (see Table 5). This was a function of sisters volunteering for the control group, as they were naturally either younger or older than their exposed-group sister, whereas the friend-volunteers were close in age to the exposed group participant with whom they were matched.

Groups proved to be very closely matched for alcohol intake, tobacco intake and self-reported general health (see Table 5). Alcohol intake and tobacco smoking were measured on a five-point scale, where 0 = none or not at all, 1 = some or not much, 2 = moderately or only occasionally, 3 = quite a lot or quite often, and 4 = heavily or very frequently. State of health was measured on a 7-point scale, where 1=terrible, 2=very poor, 3=poor, 4=fair, 5=good, 6=very good, and 7=excellent.

Table 5  
*Matched Variables, by Group*

Variable	Exposed		Control	
	$\bar{x}$	SD	$\bar{x}$	SD
Age in years	52.19	1.20	51.39	4.54
Alcohol intake	1.76	0.95	1.78	0.75
Tobacco smoking	0.32	0.82	0.30	0.87
State of health	6.05	0.83	6.03	0.81

<sup>36</sup> Gone from the address on the reunion list, but with no forwarding address.

## *Materials*

### *Participant files*

A manila file was prepared for each participant, colour-coded by group to minimize later confusion on data entry. Files contained a progression log-sheet for dates of postings and receipt of material (such as the Preliminary Questionnaire), a checklist for the management of the NBTB appointment, a consent form, a POMS response form, a SDMT response form, a CVLT response booklet, and forms to record scores for other assessments. Also included was an envelope with a NZ\$10 petrol voucher to offset participants' opportunity costs (see Participant Data File, Appendix I).

### *Preliminary questionnaire*

A three-section preliminary questionnaire (PQ) was prepared. Section A surveyed general health, 33 illness symptoms and 11 reproductive health experiences. It included the six screening questions that were exclusion criteria for the NBTB, and the recreational drug use questions for comparing the match between mercury-exposed and control groups.

Section B surveyed environmental influences on the participants. These were quantified on a nine-category table of toxins and chemicals. Participants were instructed to respond in relation to the one-year period prior to the NBTB assessment.

Section C had separate versions depending on the participant's group. The control group were asked a single question on occupational mercury exposure. The mercury-exposed group were asked three open-ended questions about their memory of the mercury-poisoning episode in the School Dental Service in 1974 - 1975 period, and to complete a full work history survey covering all types of employment that might involve mercury exposure (see Volunteers' Preliminary Questionnaire, Appendix J).

### *The Neurobehavioural Test Battery*

A flipchart was prepared to guide the progress of tasks in the NBTB. It was a visual prompt for the NBTB administrator, and visual reminder of verbal test instructions for the participant. Cards were revealed one by one, beginning with a title page, a page that invited questions before signing the consent form, then an outline of each task in the NBTB, described below. The Rey-15 item test was presented as a flipchart page. (See Flipchart Instructions, Appendix K).

The SRT test was a computerised test. A 'NEC Pentium 5' laptop computer ran an SRT programme written for the present study by Loudon (2002). The programme commenced with a screen for entering the participant's unique identifier (ID number), then gave a menu for instructions, practice trials, main trials and exit. When exit was selected, the main trial data was saved as a discrete file under the participant ID number, recording response times in milliseconds (msec.) for the 60 main trials, the median, and mean with SD response time in msec. of the 60 main trials, and the mean response time with SD in msec. of the 40 trials remaining, when the fastest 10 responses and slowest 10 responses were removed.

The SRT programme consisted of 20 practice trials and 60 experimental trials, where a digit appeared on the laptop computer screen at random intervals between 0.5 and 5.0 seconds. Time in msec. was recorded for the delay between visual presentation of the stimulus digit and a key press.

The O'Connor Tweezer Dexterity Test (Lafayette Instruments) has been described. This required the pegboard and 100 pins, long-nosed straight tweezers, and a stopwatch. Times taken (in minutes, seconds and centi-seconds), to complete 50 and 100 pins for a single attempt, were recorded on the participant's NBTB record sheet.

The CVLT was the Adult-Research Version (Delis et al., 1983). It is an 11-page booklet of verbal memory tasks based on two 16-item shopping lists, referred to as the Monday list and the Tuesday list. Each list consists of 16 randomly mixed words: four each from four semantic groups. Of these, two groups (i.e.

eight words) were from shared categories (fruit, and herbs or spices); while the remaining eight items were from non-shared categories. In the Monday list these were clothing and tools. In the Tuesday list they were fish and kitchenware.

The CVLT booklet contained all the verbal instructions for the participant to progress through short-delay and long-delay recall tasks, an interference task, free and cued responses and a recognition task. A participant's responses could be recorded in the boxes provided in the booklet, where there were instructions for scoring.

The SDMT (A. Smith, 1973) was a three-page form. Page one was the cover sheet, where participant ID, date of birth and handedness could be recorded. Page three was the one-page of symbols and response boxes with a 9-digit key. Page two was a separating sheet of carbon paper. Participants were given a pencil and the form. They completed 10 practice digit-symbol exchanges, then had one minute by stopwatch for the main exchange task. All that was required for scoring was to remove the response page and carbon page to reveal that the reverse side of the cover sheet had the correct answers positioned alongside the participant's responses.

Two triaxial Tremorometer® units were used to record finger tremor patterns (Tripp, 2002). Both unit monitors displayed instructions to guide the operator and participant through the recording process, beginning with the entry of the participant's ID number. Data is saved to TremorLab®, a software package for tremor analysis, separately for each participant. The battery-operated units are supplied with a stand, a sensor (an micro-accelerometer) and a 135g weight. In addition, the assessment required Leukopor® 2.5cm tape, scissors and spare AA batteries.

Grip strength was tested using a Jamar Dynamometer®. This apparatus registered kilos-force applied to a hydraulic handgrip. The handgrip was adjustable for different sized hands, and had a safety cord to prevent it being accidentally dropped. The register required manual reading and resetting after each trial. Data was recorded on the participant's NBTB record sheet.

The POMS-Bi 72-item form was used (McNair et al., 1992). The test was on a single A4 sheet, and comprised three columns, each of 24 mood descriptors. Every word had four numbered response boxes that corresponded to the ranked frequency of experiencing the indicated mood. Participants were given a pencil and they could complete the form without discussing the responses with the researcher.

The Rey 15-item test was printed onto a flipchart card. As described by Spreen and Strauss (1998), the test card contained five rows, each with a progression of three common “symbols” (for example, 1,2,3; A,B,C). The preceding flipchart page introduced the task as a memory test. Participants were given a blank A4 page as a response sheet, and a pencil. A stopwatch was required to limit the viewing time of the stimulus material.

Grooved Pegboard (Lafayette Instruments) has been described. In addition to the pegboard and 25 identical key-pegs, a stopwatch was required. The response time in minutes and centi-seconds was recorded manually on the participant’s NBTB response sheet.

### *Procedure*

#### *Recruitment, pre-assessment postings and exclusions*

The recruitment of participants began with a mail-out of the information pack including a covering letter and a volunteer reply form (see Appendix L) to 123 women whose names and addresses were on the four draft-reunion lists. Those who volunteered were invited to identify a potential control group woman, who was to be either their sister or a friend close in age. The sisters and friends were then sent an information pack tailored to participation in the control group (see Appendix M). Potential volunteers who self-identified as Māori were offered the option of attending an information hui for whanau, but this option was not requested.

On receipt of a positive reply, each participant was given a unique identity (ID) number. The ID number was recorded on an *excel* spreadsheet of participants’ contact details and the volunteer reply form, but on every other document with

participant data, except the consent form, only the ID number appeared. The paper documents with both ID number and volunteer's personal information were separated and secured away from the assessment data. Volunteers from both groups were mailed a PQ and a postage paid reply envelope.

Pilot Testing of the NBTB preceded the NBTB assessment period. Five volunteers, who were family or friends of the author, and one of the thesis supervisors, participated in pilot administration of the NBTB, and in gauging the length of time testing entailed. The number five for pseudo participants was on the recommendation of Ambler et al. (1995).

Revisions made during this period were the exchange of the POMS 65-item test in favour of the 72-item test; and a change to the flipchart and verbal instructions for responding to the POMS, to clarify what response was required for confusing double-negatives, such "much unlike this" for item 13, untroubled.

Participants lived from North of Auckland to Wellington, with a scattering throughout the South Island. Assessing participants therefore involved multiple trips to Auckland, and throughout the Wellington – Kapiti Coast areas. In addition, two trips were made to the Wanganui – Taranaki region, three trips to Hawkes Bay, two trips to the Bay of Plenty, and single trips to the Gisborne / East Coast area, Wairarapa, Hamilton / King Country and to the South Island.

Non-responders to the first mail out were mailed a single follow-up letter and information pack where a second or subsequent trip to their location was planned. The second letter contained a support letter from Dr C. Feek, New Zealand Ministry of Health (see Appendix N).

The author of the present study undertook all data collection. A timetable was developed for travel to participants. Most assessments were in the participant's own home. Other venues included School of Psychology rooms on the Massey University campuses at Wellington, Palmerston North and Albany,

participants' workplaces, motel rooms<sup>37</sup> and one church hall. Assessment trips began in November 2002 and were completed by November 2003.

### *The NBTB assessments*

The assessments, all conducted in English, commenced with a period to establish rapport, during which the participant asked questions and signed the consent form. All participants were screened for hand and limb injury, occupational overuse syndrome (OOS), traumatic brain injury or concussion. Most participants had returned their PQ form before their NBTB assessment appointment, but those participants who had not done so, were screened before the assessment began.

Instructions and scoring for all participants were standardised (see Appendix O). The O'Connor Tweezer Dexterity Test, the CVLT, the SDMT, the Jamar Dynamometer, the POMS, and the Grooved Pegboard all have administration instructions and scoring procedures set out in their respective manuals or directly on a response sheet, as previously described. The SRT programme presented the participant with on-screen instructions, supplemented by verbal reinforcement for successive approximations to the optimal response style during the practice trials only. The reinforcement could include such comments as helped a participant who was not familiar with a laptop keyboard, to first use only one finger, to use only one key, and to keep their finger in contact with the key surface between a response and the onset of the next stimulus.

The Rey 15-item test was presented as a normal memory test, but in the verbal instructions it was stressed that this was a difficult task that could appear to be deceptively simple.

The Tremorometer does not have standardised testing procedures specifically so it can be adapted to the needs of a specific project. In the present study this was to record finger tremor patterns. A small sensor was taped to the first

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<sup>37</sup> Only where there was a room separate from the bedroom area.

finger, for recording trials on three positions for each hand. Each trial lasted 21 seconds with 100 recordings per second.

The positions tested related to tremors defined by Findley and Koller (1995, in Findley, 1996). The first trial was for “postural tremor”, a tremor that occurs when maintaining an action against gravity. The participant extended an arm in front, at shoulder height. The second trial was for “rest tremor”, a tremor that occurs with the hand inactive, and in a hanging-relaxed position. The third trial was for “action tremor”, and was measured as the voluntary action of the hand against gravity and holding a light load. In this case the participant repeated the posture position with an added 135g weight. (Findley, 1996, p. 123).

The NBTB visits to participants took on average between one and a half and two hours. At the conclusion of each session, participants were thanked and received the unexpected petrol voucher.

### *Ethics Approval*

The Massey University Human Ethics Committee approved the procedure, protocol number PN 01/125.

There were two approved variations to the protocol. The first was a variation to the NBTB, and the second was to send a follow-up letter to non-responders, with the Ministry of Health support letter.

## **Results**

### *Overview of Analysis*

There were multiple stages in the process of data analysis. A preliminary descriptive analysis using the Statistical Package for Social Sciences (SPSS) (Version 10, 2001) was used to explore distribution shape and missing values. Comparative distributions of grouped data from each test in the NBTB were explored using scatterplots and box plots: for median values, quartile values

and outlying scores. The consequences are discussed in the section of cases for exclusion, screening and missing cases.

For the PQ, cross-tabulation, Pearson's Chi Square and Mann Whitney U tests were performed on variables in Section A: the nominal and ordinal categories related to health and reproductive health. The symptom checklist was analysed in two parts: symptoms rated in the category 'past' were cross-tabulated separately from symptoms rated for 'present'.

For Section B, environmental influences were analysed for frequency of any specific influence reported. Other than references to Hormone Replacement Therapy, vitamins, and various but few individual drug regimens, there was no evident pattern or confound presented by the data. Hence it is reported no further.

For Section C, the recollection of the urine-testing period is presented, with qualitative responses to the open-ended questions. Common themes are illustrated by typical verbatim responses. Work history for the mercury-exposed group was used to calculate duration of exposure.

For tests in the neurobehavioural test battery, independent samples t-tests were used to compare test score means, and for subscales within tests such as the POMS and the CVLT. Levene's Test of equality of variances was applied at the  $p < .05$  significance level for equal variances in the choice of statistic. Pearson's correlation was conducted between tests by group, where two NBTB tests were expected to co-vary. A GLM ANOVA was used to analyse the tremor data but missing cases made using mixed measures problematic.

It should be noted that the planned analysis had included a step to control for type-1 error from multiple comparisons from the same participants, where the data were interval and ratio level data. This was to make a Bonferroni adjustment to the alpha level for accepting that between-group differences had not occurred by chance. Ambler et al. (1995) suggest that in studies with NBTB assessments, the adjustment should be applied separately to "functional groupings" (p.166), which in the present study included the cognitive, affective, and psychomotor domains.

As the following section shows, the only comparisons across the NBTB assessments that were significant at  $p < .05$ , were two POMS-Bi subscales, but a different, post-hoc treatment was planned for this measure, as the POMS-Bi has T-scaled clinical norms available. For results from the cognitive and psychomotor domains, it was irrelevant whether alpha was set a  $p < .05$  or more conservatively, with the Bonferroni adjustment.

### Exclusion, Screening and Missing Cases

One case from the mercury-exposed group was excluded from the analysis. A statement on the PQ indicated a possible confounding neuropsychological variable, and this was confirmed when many of the outlying scores seen in the descriptive data were tracked back to the participant.

Screening was undertaken for malingering, based on the Rey 15-item test data. Prior to the commencement of data collecting, a score of 12 from a possible 15 items correctly recalled, was set as the limit for a minimum acceptable score, but there were three cases in each group with scores of 11. For these six participants, other test scores did not fall towards the lower limits of any one other test, so the malingering threshold was redefined as a score less than 11. There was no difference in the distribution of scores between the exposed and control groups, and no outliers after the single case exclusion.

There were missing cases for several tests, although there were different reasons depending on the test. These are summarised on Table 6. Excluding the tremor test, no participant missed more than one test. Of 320 tests, the exposed group missed 11 individual tests and the control group missed seven. This represents a non-completion rate of 0.03% for the exposed group and 0.02% for the control group.

The tremor test was attempted with participants but various scenarios, from not being able to start the electronic Tremorometer programme, to the programme losing data that had been recorded, to one of the two units used recording data intermittently with any participant, led to a high rate of missing data. From exposed group participants, 42.5% have no tremor data recorded, while from the control group 30% have no data recorded.

Table 6

*Missing Cases, by Assessment Task*

Assessment	Exposed	Control	Reason
PQ	2	2	Not returned
SRT	3	1	Laptop failure.
O'Connor Tweezer Dexterity Test	2	2	All four completed 50 pins but stopped before 100 pins, through experiencing OOS pain.
CVLT	2	2	Participants declined
SDMT	0	0	
Tremorometer	17	9	Equipment malfunction
Grip Strength	0	0	
Rey 15-item test	0	0	
POMS-Bi	0	0	
Grooved Pegboard	2	0	No raw data recorded (administration error)

*Attribution of Quotations and Examples*

On the consent form, participants were asked to decide and state how they would like any example from their NBTB assessment or their PQ to be attributed. This was a decision most participants found to be difficult, so that when it was known what examples and quotations would appear in the present thesis, each of the participants who were quoted were sent a letter giving them a second opportunity to make the decision, without time pressure.

In the following section<sup>38</sup>, some quotations appear with the participant's full name, some with their first name, some with a pseudonym, and some with a generic introduction only (see Appendix P, Attribution of Participants' Quotes, for a sample letter and a completed reply form).

### *Results of the Preliminary Questionnaire*

#### *Section A: General Health*

Self-rated health demonstrated that the exposed and control groups were equivalent at the time of assessment, based on how participants rated their health in relation to their ideal of excellent health. The mode for both the exposed and control groups was the penultimate score of 6, labelled "very good", on a seven point scale where 7 was labelled "excellent". The exposed group mean score was 6.05 and the control group mean score was 6.03, a non-significant difference. Table 7 reports the frequency of rating the different levels of health. The number of participants for each category is given, with the corresponding percentage of the group in brackets.

Table 7

*Self-Rated General Health, Frequency by Group*

Group	Terrible	Poor	Fair	Good	Very Good	Excellent	Total
Exposed	0 (0%)	1 (2.5%)	0 (0%)	6 (15%)	22 (55%)	11 (27.5%)	40 (100%)
Control	0 (0%)	0 (0%)	2 (6.6%)	3 (10%)	17 (56.6%)	8 (26.6%)	30 (100%)

Data on physical injuries in the past year were collected as a screening tool for impaired performance on the manual tasks in the NBTB. No participants recorded experiencing concussion, traumatic brain injury, hand injury or arm injury. "RSI or OOS" was reported by 32.5% of exposed group and 6.66% of the control group. All participants from the exposed group reporting OOS were

<sup>38</sup> And the remainder of the thesis.

from the medium or heavy mercury exposure categories. This is a significant between groups difference (see Table 8). The number of participants for each category is given, with the corresponding percentage of the group in brackets.

Table 8

*Physical Injuries, Frequency by Group*

Physical Injuries	Exposed	N=40	Control	N=30	$\chi^2$ sig
RSI/OOS	13	32.5%	2	6.66%	P < .01*
All other injuries	0		0		

\*Pearson's Chi-Square  $\chi^2$  (1, N=70) = 6.80, p < .01

Symptoms were analysed separately by time. Symptom experience “in the past” was defined as the time when the participant was in her late teens and early 20s. Of the 32 symptoms listed, the exposed group reported more symptom experience but no significant between-group differences were evident with a Mann-Whitney U Test. Present symptom experience included the six months prior to the completion of the PQ form. Of the 33 symptoms listed, again the exposed group reported the greater symptom experience. (Menopause was the additional symptom in the present symptom list.) Significant differences were shown on seven symptoms, and a further two showed a trend (p < .10). These nine strongest relationships are presented in Table 9.

*Section A: Reproductive / Women's Health*

Two women from the exposed group did not complete the reproductive health questions, as they reported that they chose not to have children. Participants were asked to record either yes or no to a checklist of items, and frequency data are reported in Table 10. For medical and surgical problems, the two women who were excluded for reproductive health were included again, as items in this checklist were women's health not reproduction. Frequency data are presented in Table 11. The number of participants for each category is given, with the corresponding percentage of the group in brackets.

Table 9

*Reported Present-Time Symptoms, by Group*

Symptom	Exposed %	Control %	Mann-Whitney Test
Arthritis	37.5	16.6	U = 443.5, p < .05
Bloating	55.0	26.6	U = 408.5, p < .03
Dry skin	62.5	46.6	U = 369.5, p < .01
Headaches	65.0	46.6	U = 403, p < .03
Metallic taste	32.5	10.0	U = 400, p < .02
Numbness	40.0	16.6	U = 437, p < .06 (trend)
Sleep Disturbances	70.0	46.6	U = 402, p < .04
Thyroid	15.0	3.3	U = 464, p < .07 (trend)
Unsteadiness	30.0	6.6	U = 427, p < .03

It can be seen in Table 10, that from the exposed group, of the potential maximum of 304 responses, there were 38 (12.5%); and from the control group, of the potential maximum of 240 responses, there were 14 (5.8%). However, conception difficulties and miscarriage problems contributed the most to the figures. Based on these two categories only, of the potential maximum of 76 responses, the exposed group recorded 17 (22.4%); and of the potential maximum of 60 responses, the control group recorded 6 (10%). Taken either as a ratio of all categories, or as a ratio of the two most frequently recorded categories, the exposed group experienced reproductive health problems at a level of more than 2:1. The number of participants for each category is given, with the corresponding percentage of the group in brackets.

Table 10

*Reproductive Health Outcomes, Frequency by Group*

Experience	Exposed	N=38	Control	N=30	$\chi^2$ sig
Conception difficulties	8	(21%)	2	(6.66%)	ns
Miscarriage	9	(23.68%)	4	(13.33%)	ns
Premature labour	1	(2.63%)	1	(3.33%)	ns
Stillbirth	2	(5.26%)	0	(0%)	ns
Low birth-weight baby	4	(10.52%)	1	(3.33%)	ns
Child with birth defect	7	(18.42%)	3	(10%)	ns
Child with learning difficulties	5	(13.15%)	2	(6.66%)	ns
Child with developmental delay	2	(5.26%)	1	(3.33%)	ns

Table 11

*Medical Diagnosis or Surgery, Frequency by Group*

Experience	Exposed	N=40	Control	N=30	$\chi^2$ sig
Hysterectomy	10	(25%)	2	(6.6%)	P < .04*
Breast or Ovarian Cancer	1	(2.5%)	0	(0%)	ns

\*Pearson's Chi-Square  $\chi^2$  (1, N=70) = 4.06, p < .04

## *Section C: Handling Mercury at Work*

### *Urine-mercury tests*

Responses by the exposed group participants only, in reporting their recollection of occupational urine-mercury testing, showed that 60% of the women did not remember being tested. The responses to the PQ urine-mercury testing question are summarised in Table 12

Table 12

*Recollection of having a Urine-Mercury Test, N = 40*

Response	Frequency	Percentage
Yes	15	(37.5%)
No	24	(60%)
Don't know	1	( 2.5%)

### *Urine-testing results*

Of the 15 women that did recall being tested, only two reported knowing the result, stating, "...my test result showed a very low level of mercury, [from memory about 32] does that sound right?" and, "Urine test 1974 – Results I think were in the mid 90's but weren't quite high enough to be stood down."

Four women reported having high urine mercury results but without knowing the result. A typical response to the request for results details would be:

I recall having frequent 24-hour urine testing. Somebody from the then Health Dept would arrive with a 'flagon' and 'funnel' and verbal instructions of 'pee in this for 24 hours'. This always coincided with morning tea in school staff room. Embarrassing and the brunt of many jokes. Next day flagon collected. Results were often not received or given a pass/failure mark. Few times a percent level was given where apparently a certain figure meant you were off work until level dropped.

I recall having special leave for several months and then opening up a closed clinic (names clinic). This clinic had been closed for some time and 2-3 weeks after resuming work my level was tested and apparently the highest it had ever been – borderline for ‘leave from work’ until level dropped (Sue).

The remaining women either reported low results or that they knew they had been tested but did not know the result. A typical response to the request for results details would be: “Had to supply a 24hr urine sample. No “stand down” time. No information on any result being negative” (Robin T).

The responses to the PQ for urine-mercury testing results are summarised in Table 13.

Table 13

*Recollection of Urine-Mercury Test Results, N = 40*

Result	Frequency	Percentage
High	4	10
Low	2	5
Don't Know	9	22.5
Not applicable	25	62.5

*Comments on mercury handling and unusual incidents*

In response to the PQ question for the exposed group only, on recollection of unusual incidents and comments on working with mercury, 18 participants left the section blank. Twenty-two participants commented on four dominant themes and two minor themes. The dominant themes were: waste mercury on work benches and the floor; the high frequency of spills; giving mercury to patients to play with; and not wearing protective clothing (neither gloves nor masks were supplied). The less frequently referred to themes related to waste (scrap) amalgam, and annual chest X-rays, implying that the latter was a test for mercury. Two participants referred to the sprinkling of lime (1) or sulphur

(1) in clinics that were to be closed for a period. Ten participants made comments that included at least two of the dominant themes.

Typical comments for spills, mercury on the floor, and/or waste amalgam included: "There was always mercury on ledges, on the floor etc. It was difficult to pick up therefore it would tend to stay there in little balls. I was continually handling mercury."

Another wrote: "I remember only the occasional spill on the front work bench at one clinic and when it ran down between the bench and the wall wondering how much more there would have been there."

Still others reinforced this experience:

It was easy for spills to occur and this happened regularly due to the difficulty of being able to contain it. Waste mercury ended up in the bin and then to the school furnace for burning. Spilt mercury ended up going through the floor. Excess amalgam was stored and supposed to be collected at the end of each school term. Often it was left for several years (Robin T).

One particularly unusual incident was reported:

I was at a sub-base (clinic named) and discovered in the cupboard an open shoebox full of AgAm scraps!! Which should have been sent off to Dominion Gold Waihi for reprocessing. I tipped it into the provided canvas bag and took it to the local post office – I handed it across the counter and before I could explain – the young man undid the string and the tag and emptied it across the counter!! Well, we both gasped! He had chunks of old filling material and beads of mercury spread everywhere and onto the floor! He said 'I thought it was money.' It was very heavy (Bobbi).

On playing with mercury, participants said:

Mercury spills often happened in the course of the day and were light-heartedly dealt with. Corners of the clinic often had small 'balls' of mercury in them through inadequate cleaners... children were often given balls of mercury to play with (Sue).

Remember when wringing mercury out of amalgam it always missed the jar and I used to have competitions with the school kids as to who could catch it off the floor (Jaine England).

I can only recall handling mercury with children – putting small amounts of mercury in old burr containers for them to play with. Occasional spillage onto the floor occurred; and from another,

Heaps of spills. Races with it (Rachel Heath).

On (not) wearing protective clothing, participants said, “Gloves or masks were never worn. When handling mercury quite often small amounts were wiped onto the floor when it spilled as you were putting it into the waste mercury jar.”

#### *Comments on Conversations with Superiors on Mercury as a Hazard*

In response to the PQ question for the exposed group only, requesting details of conversations or directives from their inspectors, 23 participants reported that no one had ever suggested to them that mercury was a hazardous substance.

Two typical responses were: “I had never been informed that mercury was a hazard. It was just part of the regular commodities in dentistry,” and, “I don’t remember any such conversations at all.”

Five women, including the four with high mercury levels, reported that a Principal Dental Officer or Dental Nurse Inspector<sup>39</sup> had, in the period after urine-testing had begun, made some comment about mercury as a hazard, to ensure clinics were well ventilated. Eleven participants left this section blank or wrote “nil”. A typical response was:

Because we worked in isolation, in those days it was difficult to get much feedback on the mercury tests. I thought it odd that there was no follow up. Some of us started ringing each other to see what happened

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<sup>39</sup> Referred to by participants as PDO and DNI

about their tests. Before that we rarely had contact with other nurses and only saw the inspectors once or twice a year. I don't recall much written follow up and I wondered why it was a 'oncer'. Usually any discussion in later years was downplayed. I mean there was a feeling the nurses who rocked the boat were "radicals". Most of us were a compliant lot and lived in fear of the PDO or DNI and reports!" (Bobbi).

Another participant who has kept all her inspection reports had checked these and responded that in the 24 reports written on visits to her clinic(s), only one mentioned mercury safety, and that was after the testing had begun. The report dated January 24, 1975, states only "Care with mercury discussed."

#### *Work history and mercury exposure*

There was wide variation in the style of recording of work history with mercury. Critical cutoff points were determined after reviewing the data. These were to categorise participants who had graduated from the Willis Street Dental School and resigned sometime between then and the end of the three-year moral bond, in one group labeled "low" exposure. Those who had worked through and beyond their bond, and up to 10 years, whether in the School Dental Service or in a private dental practice, were also grouped and labeled "medium" exposure. A third exposed group was comprised of those participants who had worked through their bonds and have, over their careers, worked more than 10 years in dentistry<sup>40</sup>. This was the "high" exposure group. All categories have exposure to CuAm from employment in the School Dental Service, with the medium and heavy exposure groups having a minimum of three years post graduation working with CuAm. The numbers in each category are presented in Table 14.

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<sup>40</sup> Work time in mercury-free dental practises was not included.

Table 14

*Mercury Exposure Based on Work History, N=40*

Exposure Rating	Frequency	Percentage
Low	9	22.5
Medium	16	40.0
High	15	37.5

### *The Neurobehavioural Test Battery Results*

#### *Psychomotor Tests*

##### *Simple reaction time*

For each participant, from 60 trials, reaction times in milliseconds were rank ordered and the slowest 10 and fastest 10 trials were excluded to minimise the effects of inattention and anticipation respectively.

Comparing the central 40 trials by mean scores there was no significant difference between the exposed group (M = 292.78, SD = 32.43) and the control group (M = 292.14, SD = 29.05),  $t = .08$ ,  $p = .93$  (two tailed),  $df = 67$ .

##### *O'Connor Tweezer Dexterity Test*

For each participant, the time in minutes and seconds for placement of 100 pins was converted to minutes and decimal fractions of a minute (min), and contributed to the group data. Levene's test for equal variances showed that data for exposed and control groups did have significantly different variance ( $F = 8.15$ ,  $p .006$ ) with the control group scores negatively skewed. With the assumption of unequal variances there was no significant difference between the exposed group (M = 6.24min, SD = 0.86min) and the control group (M = 6.66min, SD = 1:36min),  $t = -1.46$ ,  $p = .15$  (two tailed),  $df = 46.55$ .

### *Tremor*

A GLM ANOVA was conducted to examine the effect on tremor frequency, measured in Hz, from several independent variables. These were meter (two levels), position (three levels), hand (two levels), and mercury exposure (four levels). None of the IVs are repeated measures as there was too much missing data from meter 2 to impute the values necessary for a mixed measure ANOVA. There was a significant main effect found for meter and for position as presented in Table 15. There were no significant interactions. All participants were right-hand dominant.

A separate analysis with repeated measures for hand and for position was conducted on data from meter 1, because most of the missing data were associated with meter 2. There was a main effect for position and hand, with the right hand showing a significant decrease in frequency between the mean posture and rest positions (8.8Hz and 8.7Hz respectively) and the load position mean of 7.4Hz.

### *Grip strength*

For each participant, raw scores from three trials with each hand were averaged and scores recorded for dominant and non-dominant hands in kilograms force. Comparing the mean scores for the dominant hand, there was no significant difference between the exposed group (M = 28.96, SD = 6.79) and the control group (M = 28.88, SD = 4.24),  $t = .06$ ,  $p = .95$ , (two tailed),  $df = 71$ . Comparing the mean scores for the non-dominant hand, there was no significant difference between the exposed group (M = 27.89, SD = 5.25) and the control group (M = 27.77, SD = 4.85),  $t = .10$ ,  $p = .92$ , (two tailed),  $df = 71$ .

Table 15

ANOVA: Mean Tremor Frequencies (Hz), No Repeated Measures

Variables	Frequency		F	p	$\eta^2$
	Mean (SD)	df			
<b>Meter</b>					
Meter 1	8.08 (0.99)	1, 195	33.17	<0.001	.16
Meter 2	6.84 (1.71)				
<b>Position</b>					
Posture	7.93 (1.63)	2, 195	8.57	<0.001	.09
Rest	6.78 (1.35)				
Load	7.53 (1.44)				
<b>Hand</b>					
Right	7.38 (1.62)	1, 195	0.16	.69, ns.	<.01
Left	7.45 (1.48)				
<b>Exposure</b>					
None	7.61 (1.58)	3, 195	0.91	.44, ns.	.02
Low	7.38 (1.48)				
Medium	7.32 (1.35)				
High	7.07 (1.66)				

*Grooved Pegboard*

Scores for the Grooved Pegboard were recorded in seconds and centi-seconds for time taken to place correctly all 25 pegs in the board. Comparing the mean scores, there was no significant difference between the exposed group (M = 69.01, SD = 9.26) and the control group (M = 68.28, SD = 10.75),  $t = .31$ ,  $p = .76$ , (two tailed),  $df = 70$ .

A Pearson's  $r$  test was used to correlate the mean scores on the Grooved Pegboard with the O'Connor Tweezer Dexterity Test. This showed that for the exposed group, the scores had a moderate correlation,  $r = +.50$ , while the control group had a weaker correlation,  $r = +.32$ .

## *Cognitive Tests*

### *California Verbal Learning Test*

Participants were scored on multiple dimensions of learning. These included: the initial unprompted recall of the first list presented, the Monday list (T1); the sum of correct free-recall words after five presentations of the Monday list (T1-5); the total number of words learned as recalled after the fifth presentation (T5); the unprompted recall of a second list, the Tuesday list; the immediate free-recall of the Monday list following interference from the Tuesday list; and cued recall of the Monday list.

Following a delay of not less than 20 minutes, data were collected on the free and cued recall of the Monday list; and a recognition task where Monday list words were identified. None of the different dimensions showed any significant difference between the exposed group and the control group (see Table 16). On two dimensions, immediate cued recall and long-delay free recall, Levene's Test showed there could be no assumption of equal variances. The *t*, *p* and *df* statistics were therefore based on the assumption of unequal variances.

In the initial learning trials (five repetitions of a "Monday" shopping list) the control group showed a slightly better learning rate, as measured in correct responses, than the exposed group across all five trials, and on the interference "Tuesday" shopping list.

This pattern of difference reversed following a 20 minute delay period, and for the free and cued recall and the final trial, recognition, the exposed group scored slightly better than the controls. There was a trend showing that the exposed group performed better than the control group on free and cued recall, immediately following the Tuesday interference list. However, none of the results in the CVLT was significant.

Table 16

*Descriptive Statistics for the California Verbal Learning Test*

	M	SD	t	p	df
Monday Total T1-5					
Exposed	60.38	7.26	-.25	.81	67
Control	60.83	7.75			
Monday T1					
Exposed	8.59	1.89	-.40	.69	68
Control	8.77	1.98			
Monday Recall T5					
Exposed	13.95	1.72	-.45	.65	67
Control	14.13	1.63			
Tuesday					
Exposed	7.05	1.95	-1.10	.26	67
Control	7.57	1.91			
Monday Immediate Free recall					
Exposed	12.67	2.34	.34	.74	67
Control	12.47	2.60			
Monday Immediate Cued Recall					
Exposed	13.54	1.82	1.73	.09 <sup>41</sup>	50.98
Control	12.60	2.50			
Monday Long Delay Free recall					
Exposed	13.18	2.14	1.71	.09 <sup>42</sup>	48.89
Control	12.07	2.96			
Monday Long Delay Cued Recall					
Exposed	13.61	1.92	1.32	.19	65
Control	12.90	2.47			
Delayed Recognition					
Exposed	15.00	1.31	1.03	.31	64
Control	14.66	1.40			

<sup>41</sup> Levene's Test of Unequal Variances (F= 6.51, *p* .01)

<sup>42</sup> Levene's Test of Unequal Variances (F= 5.63, *p* .02)

### *Symbol Digit Modalities Test*

A score for the number of correct symbol-digit exchanges per participant was calculated by subtracting errors from number of completed. Comparing the mean scores there was no significant difference between the exposed group ( $M = 38.1$ ,  $SD = 4.64$ ) and the control group ( $M = 36.47$ ,  $SD = 6.71$ ),  $t = 1.23$ ,  $p = .23$  (two tailed),  $df = 71$ .

### *Rey 15-item Test*

Three scores were recorded for each participant: number of symbols correctly recalled (max 15), number of rows correctly positioned (max. 5) and number of symbols positioned in the correct row and column (max. 15). The third of these is reported, as it had the greatest potential for error.

Comparing the mean scores for the number of symbols positioned in the correct row and column there was no significant difference between the exposed group ( $M = 13.39$ ,  $SD = 1.83$ ) and the control group ( $M = 13.47$ ,  $SD = 1.98$ ),  $t = -.175$ ,  $p = .86$  (two tailed),  $df = 71$ .

### *Mood*

#### *The Profile of Mood States*

For each participant, raw scores were separated into six subscale scores. Total score per subscale was calculated on Microsoft Excel 2000 using the formula:  $Ts = \text{sum}(p1 \text{ to } p6) - \text{sum}(n1 \text{ to } n6) + 18$ , where  $Ts$  = total score,  $p$  = positive stimuli and  $n$  = negative stimuli. This gave a subscale  $Ts$  range between 0 and 36, where 0 is the lowest mood score and 36 is the highest mood score. Two subscales, the Agreeable-Hostile and Composed-Anxious, showed significant differences between groups. The exposed group was more agreeable and more anxious than the control group, as presented in Table 17.

Table 17

Scores on the POMS-Bi Subscales, Range 0 (low) to 36 (max.)

Subscale		Exposed Group	Control Group	t	p (Two-tailed)
Agreeable ----- Hostile	$\bar{x}$	28.76	26.22	2.09	.04*
	SD	(4.99)	(5.89)		
Composed ---- Anxious	$\bar{x}$	24.61	27.72	2.26	.03*
	SD	(5.86)	(5.78)		
Elated ----- Depressed	$\bar{x}$	25.27	25.72	-0.33	.74
	SD	(5.59)	(5.94)		
Confident ----- Unsure	$\bar{x}$	24.07	25.31	-0.84	.40
	SD	(6.25)	(6.24)		
Clearheaded- Confused	$\bar{x}$	28.27	28.66	-0.33	.75
	SD	(5.51)	(4.41)		
Energetic ----- Tired	$\bar{x}$	22.12	20.93	0.78	.44
	SD	(6.26)	(6.59)		

\*sig.  $P < .05$  (df = 71)

## Discussion

### *Summary of Results*

Between-group results supported the acceptance of the null hypothesis in all but the survey results for one physical injury, seven current symptoms and hysterectomy experience; and for all but two subscales of the mood assessment of the NBTB.

It was notable from the outset of analysis that the two groups of women, one of whom was occupationally mercury-exposed and the other not, were equivalent on many measures, including those thought to be important to ensure the groups were matched: age, alcohol intake and cigarette smoking. In addition, perceived health showed that the women's self-assessment of health against a perceived ideal was that they were equally in very good health.

In some way, the single measure of health set the pattern for the entire study, with some important exceptions. The first of these was the women's experience of RSI or OOS, which was listed, not as a symptom of ill health, but under physical injuries that might make it difficult to complete the NBTB. Exposed group women were more than five times as likely to have OOS than control group women.

In general health the between-groups' recollections of past health were very similar, with the exposed group reporting more symptoms than the controls, but where not one of the 33 symptoms showed a significant difference in the between-groups analysis. With current health however, the exposed group still reported more symptoms than the controls, but seven symptom categories were significantly different from the control group and a further two showed a trend towards a significant difference. In women's reproductive health, the exposed group had a significantly greater frequency of hysterectomy, with 25 percent of participants having had the surgery, versus 6.6 percent of controls.

In the NBTB the groups performed remarkably similarly across all the tasks with no evidence of malingering. In the POMS the exposed group were significantly more agreeable on the Hostile-Agreeable scale and significantly

more anxious on the Composed – Anxious scale than were the control group. There may be effects for tremor, particularly within the exposed group, in the form of lower frequency tremor in the dominant hand at rest, but missing data, from equipment failure, prevented the findings from being more conclusive.

### *Discussion by Domain*

#### Health

The general health measure gave the first indication that the respondents to the invitation to participate were *well* women. Over 70 percent of both exposed and control groups rated their health as very good or excellent. From the control participants this suggests that women in their early 50s enjoy good health and that all the participants perceive their health to be near their ideal.

This finding of equivalent perceived health indicated a within and between group homogeneity that is very important to consider in the interpretation of the results, in the absence of data for the exposed group from the period when they worked with CuAm. If the woman had reported their health to be “good” or even below the mid-point on the scale, there could have been a suggestion that there was some concerted effort on the part of the mercury exposed women to present their group as being worse off from having worked for the School Dental Service. However, with the women all reporting very good to excellent health and no evidence of anything but full effort, then concern turns to the non-responders.

It would be useful to know if the exposed group participants are representative of all the women from the four-year work cohort. If the symptoms of mercury poisoning, such as erythema, are enduring, then it is possible that those whose lives have been affected, did not volunteer, while those who were in good health, felt able to do so. If this were the case then there is a possibility that the data are biased in favour of the exposed group volunteers achieving scores that are better than the non-responders could have achieved. Accepting the null hypothesis for the NBTB then, would be in error because of sampling bias.

Data on physical injury were collected as a screening tool, and showed that the mercury-exposed participants were more likely to now have RSI or OOS than the controls (32.5% versus 6.6%). In the exposed group, none of the nine women in the 'low' exposure category reported having OOS, while six of the 10 women in the 'medium' exposure category and seven of the eight women in the 'high' exposure category did, indicating a pattern where the longer a participant worked in dentistry, the greater their chances of developing OOS appear to be.

Although the design of the present study is quasi-experimental, in that one group received a treatment – occupational mercury exposure – and one group did not and were an equivalent control group, it is still not possible to attribute every significant finding to the IV mercury exposure. In the first DV to show a significant difference, OOS experience, the problem becomes apparent.

It was the medium and high mercury exposed women who reported OOS, and peripheral and sural nerve damage is associated with occupational mercury exposure, but these are also the respondents who have been working the longest with vibrating mechanical devices too, in the form of "the dental drill". In considering the importance of a significant OOS finding, mechanical vibration must be considered as a confounding variable.

None of the participants from either group thought that their OOS would prevent them from undertaking the motor assessments, but two from each group were unable to complete the one task that required sustained fine-motor activity. The two exposed group participants were from the 'high' exposure level. Albers and colleagues have established that peripheral nerve damage is associated with occupational mercury exposure (Albers, Cavendar, et al., 1982; Albers, Kallenbach, et al., 1988; Levine, Cavender, Langolf, & Albers, 1982), and this does raise the possibility that mercury exposure may predispose a person to OOS.

As a consequence of the reported very good health, there were few of the 33 listed symptoms of ill health reported in the PQ, in the general health survey.

Dry skin was the only symptom to feature strongly both in the past and in the present experience for the exposed group<sup>43</sup>. It was one symptom that came close to significance in the between-groups Mann-Whitney U test on past health, and of all symptoms was the least likely to have been a chance finding, with a significant between-group difference at  $p < .01$ , for present symptoms.

Dry skin is a symptom of micro-mercurialism and acrodynia so the possibility is that there was a link to mercury exposure. Frequent unprotected skin contact with elemental mercury, from the use of CuAm, and the manual mixing of silver amalgam, marks out the School Dental Service women from other dental personnel.

It is also possible that when seeking relief from dry skin symptoms, occupational mercury exposure has not been considered in a causal relationship by medical doctors, and identified as an occupational hazard before now. One participant described a skin problem, not dry skin *per se*, which she experienced but that was never diagnosed, while she was working in the School Dental Service:

I came down with a strange illness which resembled scarlet fever. I had a rash all over my stomach - fine spots and a scarlet face with white around my mouth. Blood test said it was not scarlet fever.” (Bobbi)

Frykholm (1957) reported on 29 cases of allergy to mercury from dental amalgam. “15, (seven of them dental nurses) had skin symptoms in the form of various kinds of eczema.” (p. 62). He refers to a “female dentist (with) a tendency to inflammation ... and rosacea-like eruptions on her face.” (p. 64); and in another case to “eczematous reaction” around the mouth. The participant’s episode is consistent with these descriptions. It is not to suggest a belated diagnosis for the participant, but the point can be made that the exposed group women were not likely, for even serious acute or chronic dry skin problems, to have a medical practitioner explore metallic mercury allergy as a cause.

Sinclair and Thompson (2004) surveyed New Zealand dentists on their self-perceptions of “hand dermatoses” (p. 38), and found one third of their

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<sup>43</sup> Participants did not have to report the physical extent of their dry skin problem.

respondents had experienced skin problems in the previous year. In current dental practice there are many potential sources of skin irritants, including mercury, latex gloves, acrylics and caustic detergents, so it is disappointing to find that Sinclair et al. (2004) did not report whether those experiencing skin problems came from mercury-use or mercury-free clinics. Their paper does not assist in the analysis of the dry-skin findings for the exposed group women, and appears to miss an opportunity to present evidence for the safety of mercury use in the dental practice for dentists, for this symptom.

Of the six other symptoms reported with a significant between group difference, the pattern is that the symptoms are predictable from the literature on mercury exposure, and from the medical definitions of mercurialism, but for three symptoms at least (arthritis, bloating and headaches) in mid-life women these could be confounded by many other causal influences. The numbness in the extremities, unsteadiness and metallic taste are classic signs.

Thyroid symptoms, where the between-group difference was reported at the level of a trend towards significance, were an interesting finding, in that when mercury is implicated in immune system dysfunction, thyroid problems in particular are raised. In the *Biting the Silver Bullet* study, anecdotal evidence that could be supported by medical records, showed hyperthyroidism in remission following deamalgamation and detoxification. That there were multiple women from a sample of 40 reporting thyroid symptoms (of an undefined nature) and clearly more than the control group, coupled with medically supported anecdote and some existing literature, suggests that perhaps there is the beginnings of scientific support for this uncommon symptom to be linked with mercury exposure.

Where health problems specifically for women were concerned, from the 'past symptoms' list, menstrual difficulties were rated more by the exposed group than controls, but this did not feature in the present symptom reporting. This raised an issue for having used a past-present symptom checklist. It was not until data were available that it became apparent that for some symptoms, and menstrual difficulties or carpal tunnel syndrome are examples, a major medical intervention such as surgery might have confounded comparisons over time.

One quarter of the exposed group had a hysterectomy. This was the only significant finding in the section on reproductive health. Perhaps there was an important difference in women's health from mercury for the exposed group women when they were young, and the consequence was surgery. It would explain why there was no equivalent (menopausal) menstrual difficulty pattern in the present symptoms.

It was recorded in the introduction that a common topic of discussion at draft reunions was reproductive health, and indeed some women from an Auckland draft are exploring this. The data from the present study were nominal level, and only begin to quantify a relationship. However, when read in conjunction with existing literature (Schuurs, 1999; or Brodsky et al., 1985), or any of the methylmercury studies, reproductive health merits further study.

### *The Psychomotor Domain*

In the NBTB the psychomotor domain tests overall suggest that, apart from unresolved issues around fine tremor, the two groups are remarkably similar. If there had been deficits or reduced skill at the time of the mercury exposure, then these have recovered. Transfer of training was demonstrated with the exposed group scoring better than the controls where dexterity included the need to manipulate tweezers, giving the exposed group a minor but not significant advantage in performing one task.

It is possible with some psychomotor tests that the greater range of age of the control group (42-62 years) had an influence on the scores, where the younger participants may have performed better than those closer to the mean age, or older women may not have been performing as well those closer to the mean, so in addition to between-group differences, clinical norms were used for comparison where they were available and appropriate for New Zealand women.

In the grip strength task, for example, the available norms cover Canadian children and teenagers rather than adults, so are less appropriate. With the Canadian 18-19 year age group, the greatest mean grip strength for women was 32 (SD 3.0) kilos force for the dominant hand and 27.5 (SD 3.0) kilos force

for the non-dominant hand (Mathiowetz, Wiemer, & Federman, 1986). This compares favourably with the New Zealand mid-life women, where the mean grip strength for the dominant hand for both groups was 29 kilos force (rounded) and for the non-dominant hand, 28 kilos force. If one assumes that teenagers are stronger than mid-life women, then the New Zealand women performed very well, albeit with a greater SD.

The situation was not as favourable for the tweezer dexterity task where the norms suggest that a median score for adult women was 5.7 minutes. The exposed group mean score was 6.24 minutes, while the control group mean was 6.66 minutes. This is a non-significant between-groups difference. The norms would suggest that both groups are closer to the 30<sup>th</sup> percentile of the norm range than the 50<sup>th</sup> percentile (Instruction Manual, O'Connor Tweezer Dexterity Test, undated).

All participants chose to attempt the O'Connor Tweezer Dexterity Test, a test that required sustained fine motor skills. As mentioned earlier, two participants from each group did not complete the 100-pin placement as they experienced OOS pain after several minutes and stopped. Transfer of training was suggested, in the justification of tests, as a reason to expect that on this one test, the exposed group should achieve better times than the controls. While this was the case, perhaps the large number of the exposed group to report OOS kept the difference from being statistically significant.

The grooved pegboard scores were able to be compared with norms and to scores from published mercury exposure studies such as Mathiesen et al. (1999) or Frumkin et al. (2001) who report on mercury exposed and control group men in a long-term follow-up studies. The norms show that the mean score for women aged 40–49 years, using the dominant hand was 69 seconds, and 74 seconds for 50-59 year old women.

Men from the control group in the Mathiesen et al. (1999) study were significantly faster than the mercury exposed group, completing the grooved pegboard in 70.9 and 75.8 seconds respectively. Men from the control group in the Frumkin et al. (2001) study were also significantly faster than the mercury-exposed men. Their mean times were 75.5 and 81 seconds respectively. The mean score for the control group in the T. Powell (2000)

study was 69 seconds, and he attributes the highly significant difference to at least one extreme score included in the 117 seconds mean score for mercury-exposed workers.

The New Zealand women had mean scores of 68 and 69 seconds in the control and exposed groups respectively. In both groups the times for the task are near the expected time for women performing at the 50<sup>th</sup> percentile of the norms; and equal to or faster than both the control and mercury exposed men in the comparable studies.

While the grooved pegboard has been suggested as being highly sensitive to neurotoxic effects, so too has reaction time. In the Mathiesen et al. (1999) study, SRT had significant between group differences with controls faster than the exposed group men, 225 and 238 msec. respectively. In the present study there was no significant difference, with the control group barely faster at 292.1 msec. and the exposed group at 292.7msec. While the mean scores for both groups of women were slower than the mean scores of the chloralkali workers and controls, this could be a function of the different forms the tests took; or computer operating speeds. Both assessments were computer-generated stimuli with a key press response. The present study used a laptop computer with Microsoft 2000NT, while Mathiesen et al. do not report what operating system they used.

The mercury literature does record three unexpected findings related to SRT and hand-eye coordination. Ritchie et al. (1995) found that older dentists had faster SRT than their comparison group of younger dentists. Piikivi et al. (1984) found that mercury-exposed chloralkali workers, who had been part of a mercury monitoring programme since 1957, and had low levels of mercury in urine, had significantly slower times on a hand-eye coordination task than those with higher biological indicators of exposure. Piikivi and Hannenin (1989) found that, in a 9-test NBTB, chloralkali workers performed better on the hand-eye coordination task than the controls, but only on that task.

The discussion in Ritchie et al. (1995) covers only data that “confirms previously reported studies” (p. 813), so they did not suggest any reason why older dentists might have had faster SRT in their study. Piikivi et al. (1984) suggest that mercury monitoring fails to identify those workers who will

develop symptoms related to mercury exposure. However, in their later paper, Piikivi and colleagues suggest that a lack of motivation on the part of their control group may explain the poorer performance by the controls, but that alone did not explain why the effect was seen on only the hand-eye coordination task.

It is difficult to say that motivation alone, or a chance finding, has resulted in mercury-exposed workers performing better than controls on SRT-type tasks in three studies. There is a need to review the assessment tasks in more detail than was possible in the papers by Ritchie et al. (1995) and Piikivi and colleagues. Perhaps this is an area needing further replication. The use in the present study of a computerised SRT programme, with variable interval presentation of stimuli, and having the mean scores based on the central 40 from 60 trials, gives confidence in the reliability of the data over almost every SRT finding where there has been no description of the procedure.

Tremor assessment and the interpretation of the results were problematic. During the first three months of neurobehavioural testing the tremorometer purchased for the project, referred to as meter 1, collected full sets of data for each participant, but failed often and unpredictably to upload data to the Tremorlab software programme, sending the message that “programme integrity failed” and the programme had to be reinstalled. As meter 1 held only one data set at a time, on each occasion that this occurred, the participant’s set of data was irretrievably lost. The manufacturer sent a replacement (exchanged) unit, referred to as meter 2, but this meter rarely collected a full set of data, with the data missing from apparently random cells. Meter 2 did hold multiple sets of data, and data summaries could be recorded manually from a summary screen.

Although it was assumed that only the data handling instructions had been improved between meter models, and the manufacturer confirmed the algorithm for the tremor measurement was identical, it was apparent that the two meters were giving two different patterns of data. This showed first in the full set *vs.* missing data set pattern, then when the data were checked using descriptive statistics, the SD of the mean tremor frequencies (Hz) were different in data sets from meter 1 and meter 2. The SDs from meter 1 were

always <1.0 Hz, while the SDs from meter 2 were always >1.0 Hz. Further, the mean frequencies were consistently lower with meter 1 than meter 2.

With this knowledge, various approaches were taken to interpreting the tremor findings. To answer the question of difference between exposed and control groups, t-tests were carried out on the whole data set, finding that there were no significant differences on any of the three hand positions or between hands. However the exposed group did have overall lower mean frequency tremor in all positions and on both hands, with a trend towards a significant difference on the “right load” at  $p = .08$ . Right load had the greatest number of valid cases included in the data set.

To accept this finding requires an assumption that the randomisation of participants between the two meters implicitly controls for the differences between meters affecting the results. Eight exposed and nine controls were tested with meter 1, and 19 exposed and 17 controls were tested with meter 2.

To check this assumption, and to explicitly control for meter, separate meter t-test analyses of mean tremor frequencies (Hz) were conducted. This showed clearly that the pattern of differences between meters was in mean frequencies as well as SDs. Again all exposed group hand positions had lower mean tremor frequencies than the control group, with the right rest position showing a significant difference with meter 2, the left load position significant with meter 2, and the right load just short of significance with meter 2.

This suggested a need to test the question of differences between mean tremor frequencies by both groups and by meter, and hence a GLM ANOVA was performed without repeated measures. This showed the differences were almost entirely due to the main effect from meter. There was no main effect for group, nor any interactions that were not linked to meter. The meter explained .16 of the variance.

The remaining question then was the influence of different levels of exposure on mean tremor frequency scores. Correlations of mercury exposure levels and tremor mean frequency before the main effect of meter was controlled for, showed a unilateral tremor in the right hand at rest, in mercury exposed women who had worked the longest.

In the tremor data the strongest influences on mean frequencies were the meters themselves, and the hand-position, both with significant main effects. This has been a frustrating finding because without meter failure confounding the data, there were patterns such as the bandwidth of mean frequencies corresponding to earlier findings from Biernat et al. (1999), where frequency slowed with chronic mercury exposure. This appears to be supported, but with unreliable data. Alternatively, Chapman et al. (1990) suggest that under light load conditions and mercury exposure, frequency is higher and has narrower range of peaks, and this is the opposite pattern to the present study.

The entire exposed group reported using their right hand as their dominant hand, from their training days, even if they had been left-handed before that time. If this is considered with the exposed group experience of physical contact with the metallic mercury through wringing excess mercury from filling mixes, then the same finger that the sensor was attached to and was showing the lowest tremor frequency, with a light load, was the finger that had the greatest unprotected contact with mercury.

Tremor is an interesting area for follow-up study, and in particular to explain the exposed groups' right hand tremor. The pattern for those with greater exposure can be seen to fit with tremor literature. However, a condition labelled "white finger" is known as an occupational risk for pneumatic drill workers, where prolonged mechanical vibration damages the nerve and blood supply to the fingers. It may be that mercury is not a causal agent after a long delay, and that holding the dental drill is implicated.

Although the present study was testing the null hypothesis, and the data suggest this should be accepted for the tremor variable, the tremorometer unit failures present too much of a confounding influence to either accept or reject the hypothesis on this test. The right hand frequencies under load conditions are suggestive of a specific adverse enduring effect from work in the School Dental Service, but a causal link to mercury exposure, mechanical injury or some other variable cannot be made with the present data.

## *Mood*

The spread of scores between subscales on the POMS-Bi shows a pattern for the total sample of a homogenous group of women. The predicted results from previous mercury studies, from Vroom and Greer (1972) onward, where anger, anxiety and depression were evident in mercury-exposed groups, were not found. In the present study, the exposed group was significantly more anxious on the Composed - Anxious subscale; but against the prediction, the exposed group was not more depressed. On the Hostile-Agreeable subscale, rather than being more hostile<sup>44</sup>, the exposed group was significantly more agreeable.

In addition to the between-group comparison, the group mean scores can be compared to the norms<sup>45</sup> for the POMS-Bi. (McNair et al., 1992) These are expressed as T-scores, whereby raw scores from different scales are converted into scales where each “has a mean of 50 and a SD of 10”, from a range of 0-100 (Guilford and Fruchter, 1978 p. 478, in Lorr & McNair, 1982).

In the Composed – Anxious subscale, where the exposed group mean score was 24.61, (SD = 5.86) and the control group mean score was 27.72, (SD = 5.78), the norms suggest 23 as the mean T-score, so that even if there was a significant difference indicating the exposed group may be anxious, both groups are still above the mean T-score this subscale.

Taking the same approach to the Agreeable – Hostile subscale where there was also a significant difference between the exposed group mean score of 28.76, (SD = 4.49) and the control group mean score of 26.22, (SD = 5.89), the agreeable exposed group fall on the mean of 29, while the control group are below at a T-score of 46. Using the norms, it could be suggested that the control group were hostile, rather than the exposed group being especially agreeable.

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<sup>44</sup> “Hostile: the descriptor for grouchy, annoyed or angry feelings.” (McNair, 1982, p. 3)

<sup>45</sup> Norms for USA college students

However, there may be a third variable, linked to personality or temperament, which was influencing this, and presumably then, the other subscales. It was the perceived wisdom of the staff of the Division of Dental Health, in the Department of Health, that women applying for training for careers in the School Dental Service should appear agreeable and friendly. These were virtues that would be important in a woman who would need to gain rapport and the confidence of small dental patients undergoing painful procedures (R. Ritchie, personal communication, 16 March, 2004).

As well as being agreeable, the military structures of the School Dental Service bred anxiety. School dental service staff were routinely subjected to inspection of the standard of their work, the state of their clinics, their record keeping and the state of their uniform and appearance. The inspectors' visits were always unannounced – using the military element of surprise to keep the staff vigilant, or perhaps, in a constant state of anxiety about performance. One participant had commented about inspectors' visits in the PQ, saying that she lived in perpetual fear of the unannounced calls. That this was not an individual with an anxiety problem was reinforced by other anecdotes. One participant explained how a coded inter-clinic telephone message system was developed to signal the arrival and progression of an inspector around a district. This suggests that while trait anxiety may have been higher in the exposed group, a conditioned emotional response to assessment situations could also have developed.

Agreeableness has been suggested as a personality trait for dentists. Murry and Butler (1988) found that 20 percent of dentists in a study of toxic influences from the dental clinic environment, scored highly on the CAQ<sup>46</sup>, a finding interpreted as a good proportion being “warm hearted and personable” (p. 57). They add that such extremely high scores “may indicate an unhealthy and overriding need for approval by others” (p. 57). Furthermore, in studies of occupational stress in dentistry, it has been shown that dentists want to be liked by their patients but perceive they are disliked (L. Jones, 2002) and that this is a continuing source of occupational stress. Murry et al. also report that close to 30 percent had very low scores indicating “unsatisfying relationships” (p. 57) and “a high level of anxiety” (p. 58).

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<sup>46</sup> Clinical Analysis Questionnaire – a mood and personality scale.

From these findings, if further studies of dental personnel were undertaken, both current mood, and some state-trait assessment, such as the State-Trait anger and anxiety inventories (Spielberger, 1983), may generate more useful data.

In comparing the mean scores for the Elated – Depressed subscale with the norm of 24, the exposed group mean score of 25.27, (SD = 5.59) and the control group mean score of 25.72, (SD = 5.94) were one T-score above mean of 50. For the Confident – Unsure subscale, the norm was 22, so that the exposed group mean score at 24.07, (SD = 6.25) and the control group mean score at 25.31, (SD = 6.24) were again both above the T-score mean of 24.

On the Clearheaded – Confused subscale, again a non-significant finding in the present study, the exposed group mean score of 28.27, (SD = 5.51) and the control group mean score of 28.66, (SD = 4.41) were well above the mean T-score of 25. Finally, on Energetic – Tired subscale, the exposed group mean score 22.12, (SD = 6.26) and the control group mean score 20.93, (SD = 6.59) straddle the T-score mean which is 21 on this subscale.

It was useful to have clinical norms in addition to the between-group t-tests, because from the study data it could appear as if the population of mid-life NZ women, whether exposed to mercury or not, were somewhat tired and anxious, with the exposed group also being apparently super-agreeable, based on the assumption that the higher the POMS-Bi score, the more favourable the mood of the participant. However, as the norms show, the subscales may be the same point-length but the values within the scales are not comparable without the T-scaling adjustment.

It could have been useful too, to compare the findings of the present study with other studies of mercury exposed subjects, but this is not possible as in all other cases where the POMS was used, the POMS 65-item version. When the pilot study highlighted the advantages of the POMS-Bi for a normal sample, it seemed to outweigh the advantages of a meta-analysis.

On balance, after considering whether or not having chosen a lesser-published version of the POMS limited the extent to which the question of affect and

mercury exposure was answered in the present study, the POMS-Bi was still seen as the instrument of choice in the NBTB for the specific population. If anything influenced the data it may have been the response format, but this was explained clearly with a YES / NO response guide, and there can be confidence that the data reflect the current state of the sample at the time of assessment. There was evidence of mood change during the occupational poisoning episode in the School Dental Service (Glass, 1981), and there is now evidence that the effect has not been enduring.

In the affective domain the findings are that the POMS-Bi was the instrument that was the best choice for the NBTB, the significant and non-significant between-group findings are consistent with norms and suggest that no real problem exists in the sample, but that there must be caution in generalising from this to the broader population of mercury exposed women, because of the characteristically *well* woman sample.

The last aspect to be considered is whether these findings can be generalised to the population of women who worked in the School Dental Service. On that count there must be some reservation. The sample was a well-woman sample, by their own report. However, if symptoms of erythism have endured, there may well have been, among the non-responding women, some clinically depressed, highly anxious, or shy women, who would be very unlikely to volunteer for something the information sheet called neurobehavioural testing, taking up to two hours.

Supporting this, as a consideration of how representative the exposed group volunteers were, are anecdotes from participants and questions to the author of the present thesis, during the assessment period. Successive participants would ask whether specific draft-mates had also volunteered for the study. While these questions were not answered, they built a picture of a group of non-volunteering women that the participants were concerned about, and invariably depression, or some social withdrawal, was given as the reason one person was concerned about another. There was a strong accord within drafts about who may be suffering from depression or anxiety or social phobia. However, the present project design did not include any way to target specific people, so the question of how representative the sample was of the cohort, remains challenged but unanswered.

### *The Cognitive Domain*

It was notable that when the women were introduced to the learning task, and when the flipchart announced the CVLT as a learning task, women from both groups exclaimed that they had bad memories and they did not expect to do well. In the CVLT only one participant did not begin chunking before the first cued recall, and most had begun pairing like-category items during the second reading of the Monday list. Some participants demonstrated that verbal repetition of groups of words was helpful during recall, and while the repeated words were recorded, they did not alter the total recall scores, a correctly recalled word is scored only once per trial. An example would be, "...Parsley, chives, um I said nutmeg didn't I? Parsley, chives, nutmeg, and I know there's another herb, um...". Repetition was not considered to be a performance problem, but a memory aid, and it was evident, equally, in both exposed and control participants.

Most participants scored very well on the recognition task, which was the final test of verbal learning. At this point, Monday list words were randomly mixed with Tuesday list words, phonetically similar words from Monday-list categories, items with a similar use, and unrelated items. Where there were errors it was that a Monday list word was missed, rather than any of the distracters being selected. Hence only the correct recognition score has been reported, and in this, the exposed group performed slightly better than controls, but with no significant difference. The exposed group mean was 15 words correct from a possible 16; and the exposed group mean was 14.66 (SD 1.31 and 1.40 respectively).

The participants took the opportunity to say that in a real-life situation they wrote lists or notes for shopping, and have developed strategies to cope with retaining important information. There were no extraordinary developments in delivering the CVLT and no apparent reason not to accept the null hypothesis. If there are short-term memory loss or verbal learning deficits with acute mercury exposure, these were not evident in the present sample.

The digit-symbol substitution task was straightforward to administer and score. All participants completed the test, and none displayed any difficulty in the requisite rapid visual processing skills and task switching to make rapid

motor responses. The mean number of correct responses achieved by both the exposed and control groups in the one-minute test, was at the level expected in 90 seconds for people with normal or above average IQ. The exposed group were marginally faster than the controls, achieving a mean score of 38.10 correct responses (SD = 4.64) while the control group's mean score was 36.47 correct (SD = 6.71), but like the CVLT tasks, where the exposed group has performed better than the controls, this difference could have occurred by chance. The SDMT is a common test in neurobehavioural batteries, so the lack of between-group difference supports the acceptance of the null hypothesis.

#### *Biological Measures of Mercury.*

There were neither biological monitoring results from the 1970s nor any urine or hair samples from the present for the women in the study. Considering that much of the mercury exposure literature has sought to quantify a dose-response relationship (see Meyer-Baron, Schaeper & Seeber, 2002), or an effect-size relative to dose (see Meyer-Baron, Schaeper, von Thriel & Seeber, 2004), this would seem to make the task of establishing an exposure model for the present study quite difficult. However, as there is no doubt that the women of the School Dental Service were chronically exposed to high levels of metallic mercury and vapour, the absence of biological data, past or present, are not seen as a major limitation. The present study has relied on estimates of exposure based on known mercury vapour levels from heating CuAm (Frykholm, 1957; Glass 1981), from inspection reports, from Department of Health annual reports and the women's own recollections.

It would be expected that for those not presently working in mercury-use dentistry (as opposed to mercury-free practice), mercury levels would be equivalent to the normal population. Letz et al. (2000), in their longitudinal study of chloralkali workers, found that at the 18 year post-occupational exposure, urine samples had non-significant mercury levels between exposed and control groups, and they reported not collecting urine samples for their 30 year follow up because of the previous low levels.

### *Further Study of School Dental Service Women.*

For future studies there are files in National Archives, that the present author has read (and no doubt more that have not been uncovered) giving some identifiable data on up to 70 women who had urine tests showing mercury levels above 30 µg/l, recorded in the 1970s. The data are spread over many files, and would require some effort to collate, but do include names<sup>47</sup>, year of graduation, first clinic posting following graduation, and, for some women, urine-mercury test results. While surnames and work address may be changed or out of date, with the support of the Dental Therapy Association and drafts' reunion networks, perhaps 50 or more women could be traced.

From the Mercury and Venus study there is a need to clarify the suggested biases resulting from 1) apparently mainly well women volunteering and from having no information on non-volunteers; and 2) the women not knowing what the results of their urine test taken in the 1970s was. Two further studies are suggested. The first is a brief follow-up study to ask non-volunteers if they would give their reasons for their decision. This would require further ethics committee approval as it may be seen as hounding women who have already had two formal opportunities to make contact with the author. The second study is an investigation of women from the School Dental Service that were employed at the same time, but where urine-mercury levels are known.

### **Chapter Summary**

The principle finding of this study is that the sample of women who were previously employed to use CuAm filling material in the School Dental Service, and therefore were chronically exposed to high levels of metallic mercury vapour, do not appear to be neurobehaviourally compromised by their early career choice, now that they are aged in their 50s.

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<sup>47</sup> Maiden surnames, and married names where the woman married while employed in the School Dental Service.

The study has found that in general health, while the exposed group perceived themselves to be in very good health, as did the control group, the mercury-exposed women were reporting seven symptoms from a list of 33 to a significantly greater extent than the control group (headaches, metallic taste, dry skin, unsteadiness, bloating, arthritis, and sleep disturbances). The symptoms that they are reporting are consistent with aspects of the medical definition of mercury poisoning, and with the vague signs of slow-onset mercurialism reported in medical journals. General health problems may be a residual effect from occupational mercury exposure.

Reproductive health for the exposed group was significantly worse, and the rate of hysterectomy was significantly higher, than in the control group. Combined with the pattern of the exposed group's frequency of reporting other reproductive problems, this is one area of great concern and warrants further investigation.

With physical injury the exposed group had a significantly greater incidence of OOS. With tremor, although faulty meters seriously biased the data, there were main effects for hand and position. Arthritis was one of the significant symptoms. Together these may indicate some residual peripheral nerve damage that would be consistent with mercury exposure, but they may also signal long-term damage from the use of mechanical drills, or interaction with mercury exposure predisposing the women to peripheral nerve damage from the vibration. It is an area that needs further investigation.

Mood changes are one of the consistent findings of mercury poisoning studies, and the exposed group showed significantly different levels of anxiety and agreeableness from the controls; although both groups scored above the clinical norm for their age and gender. The pattern is more consistent with personality variables in career choice than it is with residual effects from mercury poisoning, but this must be considered with the choice of assessment tool. The POMS-Bi may have been a less reliable indicator of negative affect, and the decision to replace the POMS 65-item following the pilot study has made it impossible to compare POMS results across occupational mercury studies. The choice of assessment tool for affect would need to be a consideration of any future study.

On other psychomotor tests there are few differences between the exposed and controls in the present study, and the scores or timings achieved in tasks is comparable with other studies and with clinical norms where available. The tests were conducted without problem, and were tests chosen and recommended by other neurobehavioural researchers. There is no support for enduring effects and no support for age unmasking effects in this domain.

Memory was a domain where the women perceived themselves to be weak but the data did not support their subjective concerns. Although P. Smith, Langolf, & Goldberg (1983) suggested that there may be enduring effects on verbal memory, this has not been demonstrated in the present study.

The greatest limitation of the present study is seen, in retrospect, to be the sample. It may well be representative of the four-year cohort, but anecdotal evidence suggests that findings should be interpreted as though there was a strong bias in favor of well women volunteering, and those known to have mood disorders in particular, not volunteering. If there had been different results on the POMS, perhaps indicating anxiety, depression, or fatigue, there may have been correlated lower scores on psychomotor tasks and a very different picture from the one of women barely affected at the present time.

As a final word in this chapter, from a broad neurobehavioural and health perspective, there were few concerns about the exposed group. General health, reproductive health, possible peripheral nerve damage and some aspects of mood warrant further investigation. If such investigations were designed, the sample, tremor and mood assessment instruments, and an exposure model that included evidence of past biological measures would need to be considerations.

## **CHAPTER FIVE: CROWN AND BRIDGEWORK – A NEW CRITICAL DISCOURSE**

### Introduction

This chapter begins with a summary of the findings of the studies in Chapters three and four. Then, because one of the ways that each side of the debate attempts to get leverage is to dismiss as flawed, studies that the “other side” promotes, each study has been critiqued as if one was either the pro-amalgam or anti-amalgam debater. From this comes a synthesis of the way that, when read together, the two studies from the present thesis contribute to the debate.

In the following section the analysis moves up a level to discuss how the findings relate to the wider aims of the present thesis and contribute a psychological perspective on the debate. The metaphorical crown from dentistry in the chapter’s title is the proposed model that is presented to explain how both sides of the debate may have elements of scientific truth that are not mutually exclusive. There is a gap between the positions that can be filled by the model, and further, by anchoring the model in each side of the debate, it forms a bridge.

The model is applied to a number of contestable or contentious points introduced in Chapter 2, where the debate was set out, to assess the extent to which it addresses these points of science and of politics.

### **Summary of The Findings**

#### *Biting the Silver Bullet*

In the qualitative study, *Biting the Silver Bullet*, all of the participants had been medically diagnosed with mercury poisoning through urine-mercury testing, where their results were over 50 µg/l. These people were found to represent not one homogeneous sample of sick or psychiatric patients who had blamed their ill health on their dental amalgam fillings, but represented four distinct scenarios as medical patients. One category comprised those participants who

were sick when they were given the mercury poisoning diagnosis and were still sick, forming in retrospect a kind of control group. Another category had participants who had been chronically ill and were now well. A third, smaller number, could be categorised as having a primary diagnosis other than mercury poisoning, and the fourth was a well-person group.

The category divisions were related to the various presenting medical conditions that the participants had, as medical patients, and these in turn related to the way participants had come to consider, then believe, that there was a link between mercury from their dental amalgam fillings and their health or ill health. Not all the participants had believed there was a link when they went for their first consultation, nor did they all act to minimise mercury exposure on receiving their urine test results. The well-person group had a predetermined position on the safety of dental amalgam and would have proceeded to replace their amalgam fillings whatever the urine tests results had been.

The overwhelming majority of those who had undergone deamalgamation and detoxification reported enduring health gains. Those who had not removed their amalgams reported that their health problems were still present and becoming worse. A small number of participants who had a different and serious primary diagnosis, such as cancer or hyperthyroidism, had not begun their conventional medical treatment (for example, chemotherapy), because their conditions were pronounced by their specialists to be in remission.

Selection criteria for the random sample were designed (not by the present author) to minimise any placebo effect from clouding evidence of a real relationship between any treatment for high levels of mercury in urine and the participants' return to health. A placebo effect from a belief in the efficacy of deamalgamation was not supported as an exclusive explanation for the reported health gains.

There is an assumption in the present thesis, that the diagnosis of mercury poisoning for focus group participants, based on their presenting symptoms and subsequent high mercury-urine levels was medically warranted. Similar patterns of symptom report, biological testing, and diagnosis, in medical case histories, make this assumption. It is important here, when considering the

placebo effect, because the placebo effect implies that no real treatment occurred, or an irrelevant procedure took place, or perhaps no real illness preceded treatment. In the present study, after the diagnosis, two important physical and quantifiable changes had occurred, plus there would have been a change to a third variable known to be associated with metal fillings.

From deamalgamation there was a cessation of continual mercury exposure from dental amalgams as these were removed or replaced, and consequently there was a reduction then cessation of galvanic activity in the mouth. For those participants who had complied with a detoxification procedure, that was a third treatment. As deamalgamation and detoxification were strongly correlated with health recovery in the focus groups' narratives, and health recovery had endured for more than two years, this led to the conclusion that something other than the placebo effect was causally linked to the participants' positive health status. It could be the deamalgamation and detoxification, as the participants generally believe, but that is not to say that it could not be something else, for example, a psychoneuroimmunological effect, spontaneous remission, or as a small number of the participants had considered, the result of prayer.

The dominant group themes showed that there are medical patients in New Zealand who experience a gradual decline into multifaceted ill health. This was the category of chronically ill participants that are now well. The participants who had experienced this decline reported that their doctors tended not to take a holistic view of symptoms and that they had not found a diagnosis or effective treatment with routine and extensive testing. At some point before the urine-mercury test indicated that they had a body burden of mercury in excess of internationally accepted LOAEL, most would have been prescribed antidepressant drugs, that when taken were reported to make participants feel worse, and there would have been the suggestion of psychosomatic symptomatology or that the patient was a hypochondriac.

It is not the task of a qualitative study to say whether the participants were or were not hypochondriacs. That is for the medical practitioner or the patients themselves to know. In the focus group discourse the participants said that because the attitude of some doctors was to label them rather than find the correct diagnosis, they had to monitor their own symptoms and trust in

themselves that they were not “mad” but sick. Relationships and careers were lost during the period of decline and ill health, making the cost of treatment difficult for some, especially as amalgam replacement is not covered by medical insurance. Suicide was considered as an option by perhaps a third of the participants in this category, all of whom demonstrated enduring good health.

This is where the application of sound focus group theory is important. With the majority of participants over seven groups all reporting a similar pattern of experience, then the researcher can have confidence that there were too many stories for all of them to have been coincidental, or entirely due to the placebo effect.

Survey techniques have produced findings that support the focus group health recovery themes. Since the L. Jones (1999) study, Lindh, Hudecek, Danersund, Eriksson, and Lindvall (2002) have surveyed over 700 Swedish people with ill health linked to dental amalgams. They found that more than 70 percent reported improved health and general well-being, following deamalgamation and detox. They cite the L. Jones paper, also suggesting that there is more to the health recovery data than can be dismissed by calling it a placebo effect.

Focus group participants, after putting behind themselves many years of struggle with ill health, did want an avenue to express their concerns or convictions that Government health policy needs to change in relation to what tests, drugs and treatment are publicly funded. The general theme underpinning the discussion was the need for a national health policy that encourages and subsidises mercury testing, and contributes to amalgam removal when it is medically indicated. As a preventive measure many wanted to ban mercury in dentistry.

### *Mercury and Venus*

The quantitative study, *Mercury and Venus*, explored the long-term effects of occupational exposure to high levels of mercury, for a cohort of women who worked in the NZ School Dental Service before the withdrawal of CuAm in 1975, and matched women who were never occupationally exposed to

mercury. The results of a general health and reproductive health survey, and the scores from a neurobehavioural test battery, were analysed for between-group differences.

From the survey, some general and reproductive health issues surfaced, and in particular that the exposed women had a significantly higher rate of hysterectomy, a significantly higher reporting of seven of the 33 symptoms of ill health, and a significantly higher reporting of OOS.

The null hypothesis was accepted for the findings from the neurobehavioural test battery as there were no differences that could stand up to a critical evaluation. However, exploring the findings in a larger frame of reference showed that in considering some aspects of the study in combination, such as OOS (an injury), tremor (a symptom of mercury poisoning) and arthritis (a symptom of ill health) there could be a suggestion that working in the School Dental Service had had an adverse impact on the women's health, but not necessarily from the mercury. The findings brought into question mercury and the long-term physical impact of the use of electric, mechanical devices.

There are some limitations to generalizing from the findings to either the empirical understanding of occupational mercury exposure, or other women who worked with CuAm. One limitation is that little was recorded about the 1970s mercury poisoning episode. It is known that some women who worked in the School Dental Service did have symptoms of erythema that medical practitioners saw as linked to hormonal factors, not occupational exposure to mercury, and that some were prescribed antidepressant drugs (Glass, 1981).

While the sample did report symptom experience from when they were young women, there was no significant pattern to the past symptoms, when compared to the control group. There is no way of knowing if the exposed group participants individually had even sub-clinical symptoms of mercury poisoning that might have been reversed with the passage of time. Certainly they show evidence of mercury-related symptoms now, with present symptoms similar to generic symptom experience during chronic episodes of mercury exposure (e.g. headaches, metallic taste, dry skin, unsteadiness and sleep disturbances).

This could be said to support a theory that symptoms of mercury poisoning are gradually unmasked with increasing age, rather than symptoms being reversible. However, as it was not known if there were symptoms to be reversed in this sample, the finding is inconclusive. It may be more accurate to say that there is some evidence to suggest that after 30 years there are health differences between the exposed women and controls, and that the differences are typical symptoms for mercury exposure. These may be becoming more of a concern with the women's increasing age.

Considering that the women experienced chronic exposure to very high levels of mercury vapour and to daily skin contact with elemental mercury, they appear to have fared very well in relation to occupationally exposed workers in other industries when follow-up long-term assessments have been made with very similar neurobehavioural test batteries. The women in the School Dental Service were supplied with copper amalgam, a product that had been discredited in the 1920s in Europe. They were ill informed about the risks of mercury vapour and skin contact with mercury, blamed for developing symptoms, and only tested when union intervention forced the issue. The main difference from other occupational studies is that the participants came from worksites where even 30 years ago, urine testing was a routine precaution against any individual worker developing clinical signs of mercury poisoning, and workers' records were kept for posterity, making longitudinal analysis possible (Albers et al, 1988; Letz et al., 2000; Frumkin et al., 2001).

It is concluded that the mercury-exposed women who participated in the study performed in most areas of assessment and their report of perceived health, as well as the control group women. It is difficult to generalise from such a well-women sample to those women who did not volunteer for the study, without knowing how representative the participants were of the cohort. The main limitation of the study is that there may be something inherent in a mercury-exposed population, related to erythema, which inhibited some exposed women from volunteering. Without knowing more about why some women did not volunteer, or the representativeness of the exposed sample, it is difficult to generalise the findings more broadly to all women who worked with CuAm.

## General Discussion

The aim of the general discussion is to show that although the two studies in the present thesis may have each begun with different epistemological assumptions that led to the use of different methodology, when read together they have a complementarities in their findings, that lead logically to a new interpretation of the central debate, and hence to recommendations for future research, and for public policy; and to assist the dental patient give informed consent, for a procedure they have confidence in.

It will be argued that the debate itself, and the need for stakeholders to position themselves as either pro-amalgam or anti-amalgam, is fallacious<sup>48</sup> and the time for debate has passed. The debate began as a political and professional power struggle and has morphed into a failure of constructive dialogue between interested scientists and the broad dental community, including personnel and patients. The 21<sup>st</sup> century has heralded the “post-normal” scientific paradigm<sup>49</sup>. Where once it was normal for society to accept scientific developments and authority, now applied science and technology must be acceptable to prevailing public values.

In NZ, an Environmental Risk Agency is charged with the task of risk assessment in the post-normal climate. Scott and Tipene-Matua (2004) describe the agency’s role as assessor of technical risk, using empirical scientific methods, and also assessor of cultural, social, and ethical influences on the scientific understanding of risk, using social science methods, so that contentious issues should not become political issues.

There is no major scientific uncertainty, outside the dental profession, about mercury toxicity. The reviewed literature shows a consensus on the neuropsychological sequelae from exposure, the acceptance of the need to minimise exposure to mercury, and the need to detoxify after exposure either by a drug regime or the passage of time. Rather, debate on the safety of mercury in dentistry has always existed, but was contained in the realms of

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<sup>48</sup> The fallacy of false alternatives.

<sup>49</sup> The term “post-normal” is used without reference in Dew and Fitzgerald, 2004.

professional dominance. When Mackert (1991) referred to “the amalgam wars” (p. 54), in his review of dental amalgam, he was unintentionally acknowledging that while the debate is centred on the use of mercury in filling materials, it was also embedded in the control of the ideology of professional practice, the legal and economic realms of dental practice, and of occupational health and safety.

Two overarching themes will be developed to support that position. Following a discussion of methodology, the *Biting the Silver Bullet* and the *Mercury and Venus* studies will each be reviewed from the pro-amalgam and anti-amalgam perspectives, as this shows how scientific methodology has itself become a problematic in the debate, and how this has limited the opportunities for resolution until now.

Second, if there is a unified scientific explanation for the neurotoxic or health effects from mercury exposure, then the data from either or both studies should fit the explanation. In this theme, a new model, the Tolerance to Mercury Continuum (TMC) is presented with a discussion that challenges the way that exposure levels have been modelled, the way symptoms are validated and hence the way that poisoning is established. Competing discourses in the debate are explored and resolved with the TMC model.

### *Problems and Uses of Methodology in the Debate*

In the Introduction and Chapter 1, it was suggested that psychology could contribute to the debate, using the qualitative methodology of critical health psychology and the quantitative methods of experimental psychology. Until the national publication of study in Chapter 3, *Biting the Silver Bullet*, (L. Jones, 1999) and in an international academic journal (L. Jones, 2004a), all scientific mercury research was underpinned with the empirical, logical positivist assumptions of quantitative methodology. For dentists, qualitative methods are in the realm of non-science. In New Zealand this is demonstrated by the New Zealand Dental Association web page declining to acknowledge that a New Zealand study has been peer-reviewed and published. Cutress, who initiated the study, ignored its findings in a recent review paper (Yip & Cutress, 2003) by narrowly accepting only epidemiological and clinical evidence.

Brown (1991) suggested that there are four generic research designs that are suitable for mercury research in human populations. These were correlational, case-control and cohort studies (both using observational methods); and the experimental intervention.

Brown (1991) dismissed correlational studies, specifically those that have included biological assays of blood and urine mercury, or comparing populations with and without amalgam as weak designs, fixed in one point in time and unable to demonstrate cause and effect.

On case-control studies, Brown (1991) suggested that these are only useful for chronic illnesses where there has been a long period between exposure and disease, and that the disease is rare in the population. He considered that the symptoms of mercury poisoning make selecting cases for a case-control study almost impossible. Where tremor or mild renal problems exist there may be few cases, but these people are not likely to be easily identified in the population. By contrast, depression and fatigue are not rare, but few cases will be caused by mercury. However, Brown does endorse cohort studies, in particular where it is possible to establish the history of the exposure and adverse effects. He acknowledged that there are ethical problems with experimentation using toxic substances.

In his conclusion, Brown (1991) suggested the best-evidence on amalgam safety should come from experimental in vivo animal studies or interdisciplinary human studies where dentists are involved with, for example, toxicologists, and including statistical, behavioural and medical expertise.

The NZDA (2003) considered the importance of research design in their guidelines to members on evidence-based dentistry. Evidence-based practice is a contemporary trend in medical and nursing fields where the rationale is that technology and techniques are ever-changing, so that theories, therapies, equipment or tests that sit outside or on the border of what is science-based practice, may quickly be incorporated into mainstream practice. Best-evidence based practice requires the dentist to be able to access good, critically evaluated information. According to the NZDA, this information is available primarily on MEDLINE.

So as to give the readers of the New Zealand Dental Journal (NZDJ) an understanding of research, NZDA (2003), as did Brown (1991) for American Dental Journal readers, suggested which research designs were appropriate for members to use as evidence. A “well done systematic review of two or more randomised controlled trials” (p. 31) is the gold standard; with the randomised control trial second and a cohort study third. The list does include “a dramatic uncontrolled experiment”, “the opinion of respected authorities,” and at the bottom of the list but not in the accompanying glossary of research design terminology, “Someone once told me...” (p. 31).

NZDA (2003) is an interesting paper because a survey of the NZDJ readership found that almost 50 percent of respondents had reported that scientific articles in the journal were *not* useful to their continuing education, but nearly 70 percent did respond positively to inclusion of summaries and reviews of articles from other journals being included, perhaps suggesting that the readers prefer to be told what is the best-evidence, and that their Bachelor’s degree does not prepare them for the critique of scientific material.

For a dentist in general practice, looking for best evidence on the use of amalgam, the debate has a further and somewhat unusual feature. In western market economies, where there is doubt that a product or material is safe for the general public, one might expect *proof of safety*<sup>50</sup> from those who are involved with its promotion or sale. For example, when margarine was developed in the 19<sup>th</sup> century it was rejected as a safe, edible butter substitute in New Zealand, and the state controlled its sale by Act of Parliament. It was not *proven safe* and freed from criminal legislation until 1972 (Fitzgerald, Wylie, Crump, & Campbell, 2004).

With mercury in dental amalgam, since its acceptance by the American Dental Association over a century ago, the burden of *proof of risk* has been left to academia and dissenters from the party line. There was no scientific proof of the safety of amalgam fillings in the 1880s, and there has been none since.

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<sup>50</sup> The term “proof” is used to mean a very high level of confidence, rather than to suggest that science can prove absolutely, safety or risk.

The split in dentistry was on pragmatic economic grounds, so the first amalgam war was about ethics and professionalism *vs.* the capture of a market for quasi-professional services. It was an ideological watershed in dental materials warfare. The contemporary debate is more overtly about public health and scientific research methods.

Brown (1991), and the NZDA (2003), present important papers, because they give the clue that it is the interpretation of research that has resulted in dental associations like the NZDA claiming that there are no valid scientific studies to show that mercury in dentistry is a human health risk. This has created many tensions in the debate.

For example, one contemporary and contestable area arising from a lack of consensus on the validity of scientific research, is the meaning of the release of mercury from fillings, and in particular the potential for this mercury leaching to be causing the plaques and tangles associated with Alzheimer's disease.

Hahn and colleagues (Hahn, Kloiber, Vimy, et al., 1989; Hahn, Kloiber, Leininger, et al., 1990) have performed *in vivo* studies of mercury release from dental amalgams placed in molars of a sheep and a monkey, and they claim that there is considerable evidence for neuronal damage from dental amalgam. Further studies in chemistry supported and extended these findings. These include studies of rats exposed to mercury vapour; and of brains of deceased human Alzheimer's disease sufferers. The authors conclude that it has been demonstrated that trace element imbalance with elevated mercury is associated with Alzheimer's disease (Cornett, Ehmann, Wekstein & Markesbery, 1998; Cornett, Markesbery & Ehmann, 1998; Hock et al., 1998; Pendergrass, Haley, Vimy, Winfield, & Lorscheider, 1997). Their work was described in Chapter 2.

From Brown's (1991) or NZDA (2003) papers on the best designs for amalgam research, these teams are apparently using appropriate methods. The findings have causally implicated mercury from filling amalgam in a serious degenerative disease process, and papers have been published in MEDLINE listed journals. Experts have reviewed their papers presumably before

publication and published reviews afterwards, supported the findings (for example, Lorscheider, Vimy & Summers, 1995).

Amalgam protagonists however, do not accept this evidence. Wahl (2001a) for example, says the mercury detector used in one study misread the airflow and overestimated the amount of mercury released from fillings; in another there were mistaken assumptions about the relationship between the type of food being chewed and intra-oral mercury flow from amalgams – suggesting here but nowhere else in the mercury literature, that some food may inhibit mercury release. Where rat studies were conducted and showed lesions similar to AD following mercury exposure, the rats were said to have vastly different mercury exposure than humans ever could.

On the other hand, a dental research team, with experts from outside dentistry, conducted two AD studies with very different results. In the Nun Studies, also discussed in Chapter 2 (Saxe, et al., 1995), used a longitudinal design and demonstrated no association between the dental status of 129 Nuns, and AD. This was based on the correlation between an index of dental amalgam status and eight cognitive tests. Dental reviews of this work are favourable (see Eley, 1998; & Wahl, 2001a), who refers to them as “controlled human studies” (p. 699). This is somewhat misleading, especially for a critic of methodology in studies with anti-amalgam findings. The Nuns’ institutional life may have given them minimal difference in environmental influences; but there were not any control group participants. Saxe and colleagues followed the Nun Study with an autopsy study involving some of the deceased nuns, but Haley ([www.altcom.com](http://www.altcom.com), accessed 29.01.2005), highlighted the flaws in Saxe et al’s. papers, from an anti-amalgam perspective.

In his review, *The Future of Dental Amalgam*, for the British Dental Association, Eley (1998), dismissed any research that implicated mercury as a neurotoxin for dental personnel, specifically including Echeverria et al. (1995), Foo et al. (1993), Gonzales-Ramirez et al. (1995), Ngim et al. (1992), Shapiro, Sumner and Spita (1982), and Uzzell and Oler (1986). These papers were covered by one very short paragraph. All had flawed methodology. Later in his review, under the heading of neurotoxicity, he described the first Nun study at greater length than these six studies that did show cognitive or other impairment, using generalised claims such as, “(The nuns) were all exposed to

identical environmental conditions and consumed the same food” (p. 49), and concluded that there is, “no evidence of any effect of mercury from amalgam on cognitive function” (p. 50).

What the examples of the Nun studies or the animal studies show, is how amalgam research provides a forum for the debate to be continued. Any study may be carefully designed to answer some specific question raised by earlier work, but the precision required for empirical work does open the way for disagreement about the choice of variables, operational definitions, the appropriateness of test instruments or statistics and the like, as it is not easy to create the perfect controlled conditions for a human study. To some extent it can be said that the application and interpretation of scientific method is overtly prolonging the debate, although this must be combined with the covert agendas of the interest groups behind the critiques and publications.

#### *A Pro-Amalgam Perspective on Biting the Silver Bullet*

With the present work, protagonists may dismiss findings from a qualitative study. Neither Brown (1991) nor NZDA (2003) suggest qualitative methods are an appropriate way to examine issues from the debate, because the search is for a robust causal relationship between mercury and health risk. There has never been much published outside of lay information sources (for example, magazines) on the patients’ perspective, other than the M. Thompson et al. survey of public opinion on amalgam, and the implications for dental practice (M. Thompson et al., 1997), and the Swedish studies, reviewed in Chapter 1. However since the L. Jones (1999) study, Lindh et al. (2002) have used survey techniques to gather patient data on amalgam-linked illness.

An example of a medical practitioner’s suspicion and misunderstanding of qualitative methods occurred when the proposal for the present study was submitted for approval to the Bay of Plenty (Crown Health Enterprises) Ethics Committee. It was at first declined. The committee agreed to meet the present author at their next meeting, where a medical practitioner committee member expressed concern that findings of the study might be used to endorse certain medical practices such as the administration of chelating drugs before a mercury urine test. When it was explained to the committee that in focus

groups, people ‘tell their stories’ and present a narrative of how they understood or believed certain experiences occurred, and that the discourse analysis generates themes which can inform existing scientific positions, they gave their consent. The medical practitioner had to be reassured that the merit of the method was not an attempt to prove that any particular experience was an appropriate medical practice, but an attempt to understand the commonalities of it, and to triangulate this understanding with the conflicting evidence from the debate.

In addition, in a television interview when the study was first published (L. Jones, 1999), the then President of the NZDA, J. Annan, told a *Holmes Show* journalist, Chris Wright, that the study was not based on science because there was no control group; despite control groups not being an issue in focus group research. Such a criticism does not discredit the study, but does demonstrate the way ignorance is able to interrupt the open communication of scientific findings.

*An Anti-Amalgam Perspective on Biting the Silver Bullet*

Here antagonists could say that the health recovery stories of deamalgamation and detoxification demonstrate the link between amalgam fillings and ill health, and the clear need for political intervention to protect the public from the pro-amalgam scientists and the majority of the dental profession. After all, this is what case studies in medical journals have been claiming intermittently for years. Since the publication of *Biting the Silver Bullet* findings, two further papers have been published. Lindh et al. (2002), support the findings, with a 796 patient retrospective study; and Nerdrum, Malt, Hoglund, Oppedal, Gundersen, Holte, et al. (2004), who focussed on personality as the cause of symptoms, not the result of a toxic exposure, and their study supported the *status quo*.

In support of the antagonists’ position is that the participants in *Biting the Silver Bullet* were volunteers from a random sampling procedure, and there could equally have been many voices from people who believed they were misdiagnosed, or who had undergone deamalgamation to no effect. Disgruntled medical patients and non-believers, of whom there were two (but they did not attend a focus group), would have had as much reason to

volunteer as those who believed that their diagnosis of mercury poisoning had eventually led to their reported recovery of health. In addition there were well-person volunteers, who had previously had heavily filled dentitions, and were not expecting health gains. They were an unanticipated group that showed that the pool of potential participants was broader than just the once chronically ill or perhaps mentally ill patient. This added weight to the findings, as it could be suggested they were generated from a cross section of NZ society. The final claim could be that the sick who had not had the recommended dental treatment, had not found cures elsewhere. They could be framed as a quasi-control group for quantitative analysis.

Pro-amalgam America Dental Journal author Mackert (1991), in criticising a study of allergic reactions to an amalgam patch test, claimed that 3 percent was the probable figure for a positive skin response to contact with a 1 percent solution of mercury. Without debating the form of the solution, or if three percent equates well to the overused word *rare* for allergic responses, the 21 participants<sup>51</sup> from the focus group study, who claimed complete health recovery, are also three percent of the original 700 medical patient population from which the participants were sampled. Even if every other medical patient had not had the same positive experience, three percent did report recovery.

Lindh et al. (2002), who reported more than 70 percent recovery, did conclude that symptom profiling may be the way to separate those who will recover from those for whom amalgam removal and detox had a less than remarkable outcome. As with the Lindh et al. work, from the anti-amalgam perspective, there is support for the anti-amalgam position from the present study.

#### *A Pro-Amalgam Perspective on Mercury and Venus*

If protagonists were to examine the design using either Brown's (1991) or NZDA (2003) guidelines, then as a cohort study with matched controls, it should pass the first hurdle. As the null hypothesis was accepted for the NBTB, they might suggest that women who worked for the School Dental

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<sup>51</sup> There were more with recovery stories, but others had detox. problems or pre-existing conditions that for this argument, exclude them.

Service need no longer worry that their early career choice has had a negative long-term impact on their health. High-level exposure to mercury was, after all, safe in the long term. Current practices with mercury hygiene must lead to the conclusion that dentists and their patients are safe today.

In the detail of the method, the sample size was greater than other studies where NBTB effects have been found (for example, Siblingud et al., 1994; or Uzzell & Oler, 1986), the neurobehavioural test battery covered domains where effects were predicted by previous studies (for example, Echeverria et al., 1995; Ngim et al., 1992), and tremor assessment notwithstanding, many of the standard assessment tools had been used in multiple other mercury studies, and the data collection phase was unproblematic. The main problems were in quantifying the early mercury exposure and eliminating confounding factors from the intervening years, but this would have been more of a problem had there been a range of between-group differences.

Comparing the findings to the long-term follow-up studies of T. Powell (2000), Albers et al. (1988), Letz et al. (2000), or Frumkin et al. (2001), the exposed group participants in the present study fared very well. Comparing them as a group to the controls, the groups were almost indistinguishable. This supports the protagonists position that mercury is a safe material for dental personnel to work with (providing they practice good mercury hygiene), and hence for their lesser-exposed patients.

#### *An Anti-Amalgam Perspective on Mercury and Venus*

There would be a problem for antagonists if all the focus on the study were on the acceptance of the null hypothesis. Antagonists would expect some consideration to be given to the significant findings of the neurobehavioural assessment, the possible reproductive health problems that occurred around the time of exposure, and some important ongoing between-group health current differences. An example could be mood differences. The exposed group was a more anxious group, and anxiety is a known symptom of mercurialism, but in the present study it has been discounted as a major finding, perhaps incorrectly.

Further, antagonists could be critical of a potentially confounding variable in the general health of the sample. Both groups of women rated themselves as having “very good” health, although the exposed group had recorded experiencing seven of the 33 listed symptoms to a significantly greater extent than the controls. Clearly, as the *Mercury and Venus* study was intended to identify any adverse neurobehavioral effects from copper amalgam, the significant current health findings might become inadvertently overlooked in accepting the null hypothesis.

### *Summary of the Debaters’ Possible Critiques*

Empirical research has been the amalgam debater’s battleground in the development of the dominant ideology on the safety of mercury in dentistry. In reviewing a range of studies it appears that the epistemological tensions between different quantitative methods have worked to entrench rather than advanced the knowledge with which the dental practitioner or the dental patient makes informed decisions about the treatment they are giving or receiving.

There are strengths and weakness in all mercury studies, regardless of the perspective the reader is taking. There is a place for critical health psychology and participatory research methods in neurotoxicology, where there is recognition of vested interests in the construction of certain knowledge, or when the dominant discourse serves the function of supporting vested interest groups in society. In addition, the critical health psychology perspective has an interventionist agenda, and aims to generate practical findings or address specific health issues (for example, see the mission statement, International Society of Critical Health Psychology, 2005)<sup>52</sup>.

There is also a place for the robust cohort study. If adverse neurobehavioural effects from, for example, mercury in dental fillings, were reversible when exposure ceases, then this would be good for dental practitioners and the public alike to know. The knowledge could ameliorate, in some way, the risk of an informed choice to have amalgam fillings or to work in an amalgam-use

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<sup>52</sup> [www.ischp.massey.ac.nz](http://www.ischp.massey.ac.nz)

practice. The *Mercury and Venus* study did not directly demonstrate this because there was no way to quantify neurobehavioural health from 30 years ago, although by deducing that some women may have had observable or sub-clinical effects from the nature of the occupational exposure, then the study can be seen to support a 'reversibility theory'.

### **Mercury Poisoning Revisited**

Without taking sides in the debate, there is evidence from the scientific literature that there is a pattern to the course of events that occurs on exposure to mercury, including minimal exposures. At the biological level some mercury is not absorbed (for example, exhaled mercury vapour), and some is stored, but can be eliminated by excretion from the tissues over time. A small amount of circulating mercury crosses the BBB before it is oxidised, and this is harder to eliminate. Symptoms from stored mercury have a gradual onset, may occur at a sub-clinical level or at first may be mistaken for other conditions (for example, depression). When a medical diagnosis is made, usually from 'spot' urine testing, there is a treatment plan that involves eliminating or reducing the source of exposure and either giving chelating drugs to mobilise and excrete stored toxins, or waiting for the passage of time to allow natural elimination to occur. Return to normal health is expected.

This pattern was evident in the medical reports of children with acrodynia, with accidental community exposures like the artists' collective, and in occupational exposures like the chloralkali factory maintenance men. Recovery of health is what the chronic ill health category of participants of the *Biting the Silver Bullet* study reported, and was an outcome (albeit without proof of early symptoms) for the exposed group from the Mercury and Venus study.

In summary, it can be seen that, depending on one's position in the debate, existing studies, including the two studies in the present thesis, can be used by debaters to support and entrench their positions. However, by further examining possible critiques and commonalities, a consistent scientific understanding can be found about the experience of mercury poisoning and recovery from the effects, and that will now be discussed.

## Tolerance to Mercury: A New Critical Discourse

### *Alternative Conceptualisations: Beneficial and Adverse Effects*

There have been conceptualisations of the effects of mercury exposure besides the negative view that mercury is always toxic, as expressed in the WHO's statement that there is no safe exposure level (Friberg, 1991). Beneficial effects from mercury exposure have been claimed across time and culture. Metallic mercury and mercury salts are used in Aiuvedic medicine. Mercury was a treatment for syphilis, from the 16<sup>th</sup> to the 20<sup>th</sup> centuries, Thimerosal is currently used as a preservative in eye drops and vaccines, and calomel was used in antiseptic skin creams. Mercury had a contraceptive use, as the active ingredient in spermicidal jelly, and was used as a fungicide on hospital bandages and dressings. In these applications, adverse effects were employed for beneficial outcomes. In addition, although not medicinally beneficial, mercury has been used in cosmetics such as skin whitening creams and blue eye shadow products<sup>53</sup>.

Claims that mercury has beneficial effects, do not negate the potential for negative effects, or demonstrate the benefits were real. With the syphilis treatment came speculation that mercury was the cause of madness and the death of a number of prominent and royal people. Thimerasol does function as a preservative in vaccines, but is implicated in infant autism, and calamine lotion today does not have the ingredient after which it was named<sup>54</sup>.

Not all studies of mercury within dentistry have found neutral or negative effects. Ritchie et al. (1995) reported that SRT was faster in older dentists (M = 241 msec.) than younger dentists (M = 271 msec.) when one might predict that they would be slower; and Brodsky et al. (1985) reported that fertility appeared

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<sup>53</sup> When the author was conceptualising the *Mercury and Venus* project, she was told that in the 1970s, the Department of Health and the NZDA executive considered that the *real reason* that some women in the School Dental Service had high urine-mercury levels was not their occupational exposure, but their overuse of spermicidal jelly and blue eye shadow products (R. B. Guise, personal communication, November 28, 1998; February 24, 2005).

<sup>54</sup> Calomel, the original base of calamine is a mercury compound

to increase (up to the level of exposure equivalent to placing 40 amalgams per week) in the dentists in their large study. Having said that, the Ritchie et al. study and probably both studies were, of course, flawed!

A beneficial effect from mercury is more likely to be an oxymoron. In western countries, the health industry has removed mercury from most sources except vaccines. Mercury has been replaced in new medical equipment such as thermometers and sphygmomanometers. In Boston (MA), the Boston Public Health Commission has a domestic thermometer exchange programme, where families can exchange mercury thermometers for a non-mercury type; such is that city's concern for the risk from broken mercury-thermometers (Shoemaker & Ghaemghami, 2003).

Adverse effects from mercury, or mercury poisoning as a western medical construct, are diagnosed as erythism, mercurialism, and acrodynia. These syndromes are the result of responses to mercury exposure, although they may be referred to as diseases. Acrodynia is called "pink disease" and adverse mood and psychomotor effects are called erythism. With the wide variation in presentation of effects, for legal purposes in occupational health monitoring and safety, various arbitrary exposure limits have been set. These are operationalised as mercury-in-air levels or biological markers, at pre-determined cut-off points for risk, (for example, TDI, TLV, or LOAEL as described in Chapter 1).

With the vagaries of storage and excretion and of presentation of effects, these definitions may not serve the public or occupationally exposed worker well. Rose (1992) has suggested, in relation to disease processes, that, "Disease truly forms a continuum of severity," and that it is those who have to manage the disease process who "require a system of unambiguous labels" (p. 10). It is proposed that the adverse effects from exposure to mercury, conceptualised in a way that is similar to Rose's disease severity, can be informative for the public and for management charged with the task of containing risk.

### *The Tolerance to Mercury Continuum*

The basic premise of the Tolerance to Mercury Continuum (TMC) is that there is always some biological response to mercury exposure – a negative health impact or neurobehavioural change. The predisposition to any response is spread along a continuum, from no observable adverse effects (high-end TMC), to total incapacitation (low-end TMC), in an untested assumption of an approximately normal distribution. The TMC can be seen in a strong negative relationship with risk of mercurialism (or technically, micro-mercurialism for low-TMC people) on exposure to mercury.

The key issue in mercury poisoning, and obstacle in resolving the debate in dentistry, is the dose-response relationship; that is, the relationship between the nature and extent of an exposure and the subsequent expression of symptoms. With mercury, there is no universally accepted “scientific” dose-response relationship (see Richardson, 1995, or the meta-analyses of Meyer-Baron et al., 2002; Meyer-Baron et al., 2004). Empirical studies that meet rigid criteria from a logico-positivist paradigm continue to fail to establish anything more than a dose-response guideline for the monitoring and management of mercury exposure in occupational settings. This should not impact on the medical or neurobehavioural assessment of individual health.

There appears to be, at the level of analysis of the individual, a wide range of sensitivity to mercury and tolerance to mercury across specific groups and within populations. Some people appear to be able to live and work with chronic mercury exposure and not to have observable detrimental effects on their health, or they experience changes only at a sub-clinical (unobserved) level. Some dentists, mercury miners, chloralkali factory workers and the like, would appear to be at this high-end position on the TMC. At the opposite end are people who are allergic to mercury. Their allergic reaction aids in diagnosis. Another, perhaps three percent, of people appears to be unable to tolerate even very low doses of exposure to mercury and would be at the low-end position on the TMC. These people may endure years of unrecognised mercury poisoning. Between the unaffected and the allergic (incapacitated and chronically ill) positions, may be a normal distribution of degrees of reaction. These ordinary people may have sub-clinical or clinical symptoms, but even

those occupationally exposed to mercury, are unlikely to attribute signs and symptoms that they experience, to mercury exposure.

A TMC, unlike a dose-response relationship, is not confounded by other contestable aspects of the debate including the storage versus excretion of mercury problem, or development of tolerance or sensitivity. For any individual, their proclivity to store or excrete cannot be known except from autopsy. A urine test measures mercury excreted by the kidneys. A blood test shows what level of mercury is circulating. Hence, what tests do is confirm exposure has occurred with an excretion level at one point in time, not what level of mercury is causing an adverse response. Test results become an aid to diagnosis, but are a poor measure of individual body burden and an unreliable indicator of symptoms.

The medical model assumption is that a high mercury urine level following any exposure, for example over 50 $\mu$ g/l Hg requires medical intervention, because high excretion is associated with high risk, while a low result, for example below 50 $\mu$ g/l Hg, does not. This is an oversimplification of test result interpretation. There is the potential for a test result to fit more than one quadrant of a 2x2 variable design, where the variables are storage and excretion. High excretion may mean high storage and hence high risk; but it could result from low storage if a person has a metabolism that is efficient at excreting toxins, and hence low risk. Low excretion may mean low storage and hence low risk; but it may also result from high storage if a person has a metabolism that is inefficient at excreting toxins, hence indicating high risk.

Neither does the level of excretion give a reliable indication of the source of exposure, because most exposure is chronic in nature and, using the bath metaphor from the focus group study, the body will gradually store increasing levels of mercury, like a bath that is gradually filling while the tap is dripping. Antagonists may argue that a urine test, following the administration of a chelating drug, will give a more reliable indicator of stored mercury, but again, just as there is no dose-response relationship, neither is there an excretion-response relationship, other than the likelihood that the higher the test result, the greater the chance of observable symptoms.

In this thesis, from the focus groups, the language of allergy was raised as an alternative to the use of biomarkers for diagnosis. However, lay and medical definitions were different. One participant expressed the issue of allergy tolerance issue like this:

I think there's a balance there really I mean for some people just my impression is that amalgams, some can handle amalgams, their systems can handle amalgams, but some people can't, and in my wife's case you know, it was particularly notable in her experience, her health has vastly improved as a result of getting her amalgams removed (man G7).

Allergy definitions in medicine may focus on severe reactions such as anaphylactic shock<sup>55</sup> (Frykholm, 1957), rather than the lay approach that at various levels of exposure there may be differing individual responses. With mercury in dentistry, what has been generally acknowledged is the rare 'shock' response, and a local oral lichenoid reaction adjacent to an amalgam fillings (Bergdahl, Ostman, Anneroth, Perris, & Skoglund, 1995). A clarification or shift in the discourse could ease some of the tension between the protagonists and antagonists in the mercury debate. This would require an appreciation of a possible range of severity in individuals who are allergic only in lay-terms, or rather, who react adversely at any level of mercury exposure, as becomes possible with a TMC.

This also leads to a reframing of the central question in the mercury poisoning debate - whether mercury is a safe material to use in dentistry - into two alternative questions. The first is, can the minimal-but-unremitting mercury exposure for people with dental amalgams, and low-dose but chronic mercury exposure for people working with mercury in dentistry, be tolerated in addition to mercury exposure from all sources? Applying the TMC, the answer is yes it can, no it cannot, and all points in-between.

The second question is, given the same mercury exposure scenarios, can people reverse negative effects and detoxify by reducing some aspect of their

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<sup>55</sup> Allergic reactions are classified by proximity to the allergen, local and systemic signs etc. Discussion of allergy is beyond the scope of the thesis, but may be of interest for some readers to pursue.

exposure, and the treatment of either the passage of time or with chelating drugs? The answer to this is most likely yes. A further question of either increasing or decreasing individual tolerance does not appear to have been discussed in mercury literature, but either is hypothetically possible.

### *Dentists Should be the First to Show Symptoms*

Reference was made in the *Biting the Silver Bullet* study to various dentists, doctors and specialists saying to focus group participants that they personally had amalgams and they were not succumbing to mercury related illness. The implication was that micro-mercurialism is a myth. This argument goes on further with dentists, who claim that their occupational exposure is greater than their patients, and therefore their patients could not get ill if they do not. The pro-amalgam support comes in part from the image of the healthy practicing dentist (Wahl, 2001a). The author of this thesis has heard this argument herself from dentists, since becoming interested in the debate, as the evidence that supports their beliefs that mercury is safe for them to use.

While both groups, dentists and patients, may have some low-level constant exposure if they have their own leaching mercury-based fillings, and patients may get a booster dose during a filling removal or placement appointment, the dental personnel using mercury-based filling material are assumed to have more constant and on-going mercury exposure through inhalation of mercury in their workplace air. Even with encapsulated silver amalgam mixes, D. Jones, Sutow and Milne (1983) have shown there is mercury vapour in the ambient air around objects or places such as the amalgamator, the patient's mouth and waste mercury storage containers.

Frykholm (1957) measured the levels of mercury vapour near patients' mouths, and measured time in minutes following insertion of silver fillings. While it is the patient who inhales (and exhales) the higher levels of mercury vapour, and for a longer time following the insertion of a filling, Frykholm conceded that dental workers may have more frequent lower and shorter peaks in background exposure to mercury vapour than their patients.

Nevertheless, the pro-amalgam argument is flawed. There is a hidden assumption underpinning the protagonists' perspective in the debate, and that

is, that on the critical variable of tolerance to mercury, dental personnel are typical of the general population. That is something that is not known. Even if there is a normal distribution of tolerance in the general population, it is possible that a subset, such as a small occupational group, does not cover the continuum. From dentists' own claims, one could suggest that dentists are more tolerant to exposure and hence are high on the TMC; but whether this is some natural disposition or an acquired tolerance is speculation.

Further, when comparing tolerance to mercury in the general population and in the population of dental personnel, it is possible that in addition to an assumed over representation of dentists at the higher end of the TMC, the formal education of dental students can be conceptualised as a process that selects out of dentistry, students who are low on the TMC.

Compare a high-end TMC dental student and a low-end TMC dental student, both of whom are beginning to work with amalgam, and with the low-end TMC student unwittingly experiencing erythism. In a profession that denies that occupational mercury exposure causes adverse reactions, and with a medical profession that is slow to recognise mercury poisoning, it is not likely that the student suffering lack of concentration, fatigue, depression, social withdrawal, reduced cognitive capacity, and the like (i.e. erythism), will pass successfully through the arduous years of study required for dentistry. It is more likely the student will choose to withdraw from study, or simply fail to maintain the grades to pass. In this way, without attributing student dropout to exposure to mercury, it could be argued that the dental profession may actually be comprised of high-end TMC individuals, or those who can acquire tolerance, if this is possible.

Using a TMC model, it is possible to argue that dental patients drawn from the general public who are at the low-end of the TMC (highly mercury-sensitive) may develop health problems from a very low-dose exposure (for example, amalgam fillings in addition to background exposure), before high-end TMC dental personnel. In this scenario, the first to experience adverse reactions would not be practicing dentists but the low-end TMC patients.

Further, it can be noted that while the opinion of the professional bodies of western dentists is that their members are not suffering adverse effects from

mercury exposure, they do describe dentistry as one of the more stressful professions (Annan, 2001). The curious thing about the manifestations of occupational stress in dentistry, such as the higher rates of suicide than other health professionals, depression, irritability, and low self-esteem (Alexander, 2001), are that these are not only outcomes of occupational stress, but equally are components or outcomes of erythism.

In the absence of research to the contrary, it may be that the correlation between affective disorders and occupational stress can be linked to the causal influence of mercury. In this case low-end TMC patients may still be the first to exhibit serious consequences of dental mercury exposure, but there may also be dental personnel through the mid-range of the TMC who are experiencing symptoms such as being quick to anger, feeling anxious and/or depressed, having problems concentrating (see Alexander, 2001), and experiencing gradual onset low frequency tremor. Dental personnel in this situation may have little critical self-awareness of their changing moods, or if they acknowledge mood and tremor problems, they will not attribute them to erythism.

The occasional incidence of acrodynia in children, and mercurialism in dental personnel, has led to medical journals publishing reminders to medical practitioners to consider mercury poisoning in unusual cases (for example, Von Muhlen Dahl, 1990). From this, and the focus group discourse, it can be deduced that erythism is not high on western medical practitioners' list of possible diagnoses in the presence of some symptoms of erythism presented as occupational stress. Although endemic, mercury is not recognised, as lead is, without a novel source in environmental poisonings. From this, an extension to the proposition made in Chapter 3 can be made. There it was suggested that the medical gaze (Foucault, 1975), is restricted to a *toothless body* for patients: dental fillings were not seen as a source of toxins. In insidious occupational poisonings, the medical gaze has no peripheral vision, so toxins in the work environment are not considered when treatment is planned for common complaints such as depression, fatigue, anxiety and the like, that may be the presentation of erythism.

## *Contraindications of Amalgam Use and the Tolerance to Mercury Continuum*

Amalgam manufacturer, Caulk, had amalgam safety data on a web page that can no longer be accessed, but is copied in Appendix C. This was for their product, Dispersalloy. The safety data listed contraindications: amalgam in children under six years, removal or placement for pregnant women, those with renal disease, as a root filling material, in contact with other metals (for example, gold work), and for those with known allergy to mercury. Common knowledge will show these are largely ignored in New Zealand, although they apply equally to any amalgam product. Caulk also warned that, "Mercury may also be a skin sensitiser, pulmonary sensitizer, nephrotoxin and neurotoxin" ([www.caulk.com](http://www.caulk.com)., accessed February 18 1998).

In New Zealand, children and pregnant women receive amalgam fillings. The NZ Ministry of Health wrote to NZ registered dentists in 1997, with concerns over informed consent on the placement or removal of amalgam fillings for pregnant women, suggesting alternatives should be considered. Alternatively, Ferguson and Whyman (1998) in a NZDJ paper on dental treatment for renal diseases, did not mention mercury as a nephrotoxin or that amalgam may be contraindicated. These are reasons to think the attitude to mercury use in NZ dentistry rests on the erroneous belief in the safety of mercury. An understanding of the TMC as a risk model, could make it easier for patients and dental personnel alike, to make more informed choices about amalgam.

The contraindications of amalgam in children, during pregnancy, and with the onset of renal disease, suggest that there are different periods of the lifespan when an individual's position on the TMC may change. In particular it may change with age, with pregnancy status, with different medical conditions, or with immune system dysfunction. Only Taskinen, Kinnunen, and Riihimaki (1989) discuss this possibility. They report a medical case study of a 60-year old woman who was apparently unaffected by her amalgams until she had a three-month treatment programme to construct and fit a metal dental bridge. The woman had several old amalgam fillings drilled out, some existing amalgams ground down, and new amalgam to support the bridge. During this work she became progressive unwell. First symptoms centred on her mouth – sore throat, salivation problems, stomatitis – but dizziness and headaches followed, as did respiratory problems, tremor and loss of grip strength. None

of these conditions responded to conventional treatment, and like the *Biting the Silver Bullet* participants, she had numerous 'clear' diagnostic medical tests. Finally urine analysis revealed very high mercury levels, and with the doctor and dentist cooperating, the woman regained her health, plus gold and amalgam-free dental work.

### *The 'Well' Woman Sample and Clinical Cases*

The previous discussion has largely focussed on erythism in low-level but chronic exposure in dentists, but for the TMC model to go further in addressing safety concerns, the sample from the *Mercury and Venus* study must be considered, because the exposed group were *well* women.

First, like the assumption made about dental students, some self-selection out of dentistry may have occurred during training for the School Dental Service, giving a workforce of women who would be towards the higher end of the TMC, especially for inhaled mercury vapour. In the 1969 student intake, for example, one of the four "drafts" sampled, 40 women began the training, and two years later, although none failed the final exams, only 33 graduated<sup>56</sup>. This dropout rate is surprising because of some specific influences on women who were selected.

From the various Health Districts, the expected numbers of resignations during the training period determined the number of students sent to train, as employment was guaranteed (R. Ritchie, personal communication, 16 March, 2004). Occupational socialisation stressed that the young women, who passed a 1:5 selection process, were in the School Dental Service for five years. The women were told they were a special group, as evidenced by their being trusted to work through a three year 'moral bond' in return for being paid a salary during training; unlike student teachers at the same time, who were paid less during training, and had a binding financial contract to repay their wages should they resign before teaching for three years. The dental students lived and worked together, like military recruits. Students could not 'drop out' but rather had a formal process of interview and resignation. Anecdotally two

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<sup>56</sup> Anonymous information, School Dental Service Gazette, 1971

themes recur to explain resignations. Some women fell pregnant; and some women “couldn’t cope”. Both of these would make a student appear to be unsuited to the work and be given leave to resign.

Secondly, most women who graduated did work through their three-year bond, although others who resigned before this time had no penalty for doing so. In the *Mercury and Venus* study sample, 22.5 percent of the exposed group did not work beyond the three-year bond, but interestingly 37.5 percent worked 10 years or more in dentistry. This could show a general tendency for those remaining in dentistry to be towards the high-end of the TMC, because, given what is known about mercury vapour from heating copper amalgam, one would expect there would be more reported symptoms than there have been, at least in the category of ‘the past’. While this supports the idea that those who stay in dentistry are either high-end TMC or develop tolerance, the reverse cannot be claimed.

There are alternative explanations to a low-end TMC position for young women not continuing in that employment, and one, for example, is the social norm in the 1960s and early 1970s of women moving from career to home when they married. Another was that this was the first chance to leave with no ‘moral’ guilt.

It has been stressed that the exposed group in the *Mercury and Venus* study were generally well women, albeit that 25 percent have now had hysterectomies, or perhaps because they had them. There was equivalent within-group variation in general health, as measured by standard deviations from mean scores in both the exposed and control groups, but the data were not screened for individual participants who may have had clinical symptoms.

#### *Applying the Tolerance to Mercury Continuum to Individuals*

Dental personnel who have the lived experience that mercury is safe accept dental associations’ pronouncements of safety. Individuals, and antagonist health professionals, may have the lived experience of unsafe use, or accept evidence of adverse effects that their pro-amalgam peers do not. The TMC opens a way for both groups to be correct in their belief in their own

experience, and wrong in dismissing the others' position, but for the TMC to be accepted, there may need to be something other than self-reported symptoms, or the acknowledgement that in any group of people with similar mercury exposures, there will never be a predictable dose-response relationship.

Shapiro et al. (1982) tested nearly 300 participants at a dental congress for stored mercury by X-ray fluorescence (XRF), a non-invasive in vivo technique that measures heavy metals in bone (Bloch & Shapiro, 1981). Shapiro et al. applied the exclusion criteria of "neuropsychological conditions known to affect test scores" (p. 1147), before dentists with either high or low wrist-mercury levels were included in a neuropsychological study. One might suggest that dentists were excluded for having the very conditions that Shapiro et al. were looking for, and rather than be excluded, the dentists with neuropsychological conditions could have been included, perhaps as a separate group. (Dentists on antidepressant medication, for example, would have been excluded, despite depression being a relevant adverse response to mercury exposure.) However, the XRF test did show a range of tissue mercury results from 66 percent undetectable, to 20 percent above  $20\mu/g$ <sup>57</sup>, including 13 percent over  $40\mu/g$ . For the TMC, this suggests a skewed distribution with a clear high-end mean value. There were 23 volunteers in the high-mercury group of whom 30 percent had sub-clinical or clinical electrophysiological evidence of peripheral nerve damage, including slowed motor and sensory nerve conduction speeds and carpal tunnel syndrome<sup>58</sup>.

Two matters arise from this. The first is the potential for a technique like X-ray fluorescence, a safe method of measuring body burden rather than excreted mercury, to be part of a quick-screen tool to determine an individual's place on the TMC. The second is the problem of how to account for clinical cases in group research. These will be discussed below.

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<sup>57</sup> The least detectable level with X-ray fluorescence.

<sup>58</sup> This could have a mechanical vibration and/or a mercury component, as was suggested for tremor in the *Mercury and Venus* women.

### *Implications for Clinical Cases*

In discussion following a seminar presenting preliminary findings of the *Mercury and Venus* study (L. Jones, 2004b), J. Leathem (personal communication, 23 June, 2004) suggested that clinical cases would be lost in the data, and signalled the usefulness of *not* excluding anticipated outliers, but exploring them more closely. This is consistent with the Radley and Chamberlain (2001) notion that medical theory should be built on cases and not the other way around, where the case has to fit the theory, as has become western medical practice.

Hanninen, in a review of her 25 years of research, predicted that behavioural toxicologists would develop a myriad of test batteries that would make it confusing to compare findings across studies. That prediction appears to be accurate. She also predicted that very little attention would be given to individual variation in responses to toxic exposures, seeing this as a methodological problem (Hanninen, 1985). There has been almost no attention to individual variation in occupational mercury exposure studies, while almost total attention given to the search for a dose-response relationship. As has been mentioned earlier, the dose-response relationship is a useful approach for setting occupational exposure limits, but it is of little use to the person experiencing adverse effects, who, if they could get the correct medical diagnosis, may be put on a path to recovery.

Ambler, Rice and Johnson (1996) reviewed research designs for neurotoxic studies, and in particular measurement techniques, for the summary session of a conference on the "Assessment of mercury neurotoxicity through psychometric and neurobehavioural testing". They acknowledged a need for something other than dose-response data in risk assessment, especially in cases of mercury exposure. They saw the identification of mercury poisoning as a challenge for doctors. The medical profession generally was said to be unaccustomed to accepting that mercury can cause adverse effects at low levels of exposure. Ambler et al. reminded researchers that to hold sway with doctors, they must consider the clinical implications of their data and not just the statistically significant findings.

### *Screening for Mercury Tolerance*

Ely, Fudenberg, Muirhead, LaMarche, Krone, Buscher, et al. (1999), used Bloch and Shapiro's (1981) X-ray fluorescent technique in a longitudinal study comparing urine and XRF mercury levels in a study population with changing levels of exposure to mercury. They claim that:

The mercury wars have continued for over 150 years because of the continued failure of mainstream medicine to understand MM (micro-mercurialism) and two of its principal characteristics: retention toxicity and bone storage." (p. 554).

Ely et al. (1999) accept that the body can excrete the mercury it is exposed to, to some indeterminate level, but when exposure increases, from environmental influences or from new dental amalgam fillings, a point is reached where the body begins to retain mercury. From this point, Ely et al. say that urine mercury levels show a "featureless" range, while XRF shows a "distinct bimodal distribution" of mercury stored in bone. Their theory is that once the body begins to store mercury, a cascade of changes occurs; the most important being the deactivation of enzymes responsible for mercury excretion. Mercury storage, termed "retention toxicity", is said to be the predisposing condition for the symptoms of micro-mercurialism (all p. 556).

Other techniques that may be useful for operationalising the TMC include the patch test for mercury allergy, tremor monitoring, and colour vision monitoring. Hay (2002) referred to mercury allergy patches that were "a preparation of silver amalgam (1% in soft white paraffin)" (p. 82), applied to the skin (see Figure 3). However, in talking to Hay (personal communication, 27 January, 2005), he reported that, in NZ in 2004, the patch tests were NZ\$2000, that a person needed to be referred to, then wait years on a public hospital waiting list to get one; and that they were not available anywhere other than in a hospital setting where an allergologist could read them. This would appear to exclude them at present from use as a screening tool in everyday dental practice.



Figure 3. Amalgam patch test with allergic response.

Photograph supplied by Hay, from Hay (2002). Reprinted with permission of the Editor, New Zealand Dental Journal.

Tripp's tremorometer has the potential to be used for monitoring finger tremor, and to establish a mercury-tremor biomarker other than the anticipated change that occurs with mercury exposure in tremor frequency (Tripp, 2002). Tremorometer malfunction prevented this from being explored in the *Mercury and Venus* study, although some break or 'stall' in the sinusoidal wave pattern initially gave rise to speculation that there could be a "mercury footprint" (see Figure 4). The upper trace shows a sample of an exposed participant's right hand at rest. Recordings are at 200 per second, over a 20 second period. The yellow vertical bands mark the section presented in line two, and the single cycle illustrates the stalled normal wave pattern that was observed in exposed group participants' data, but not with controls.

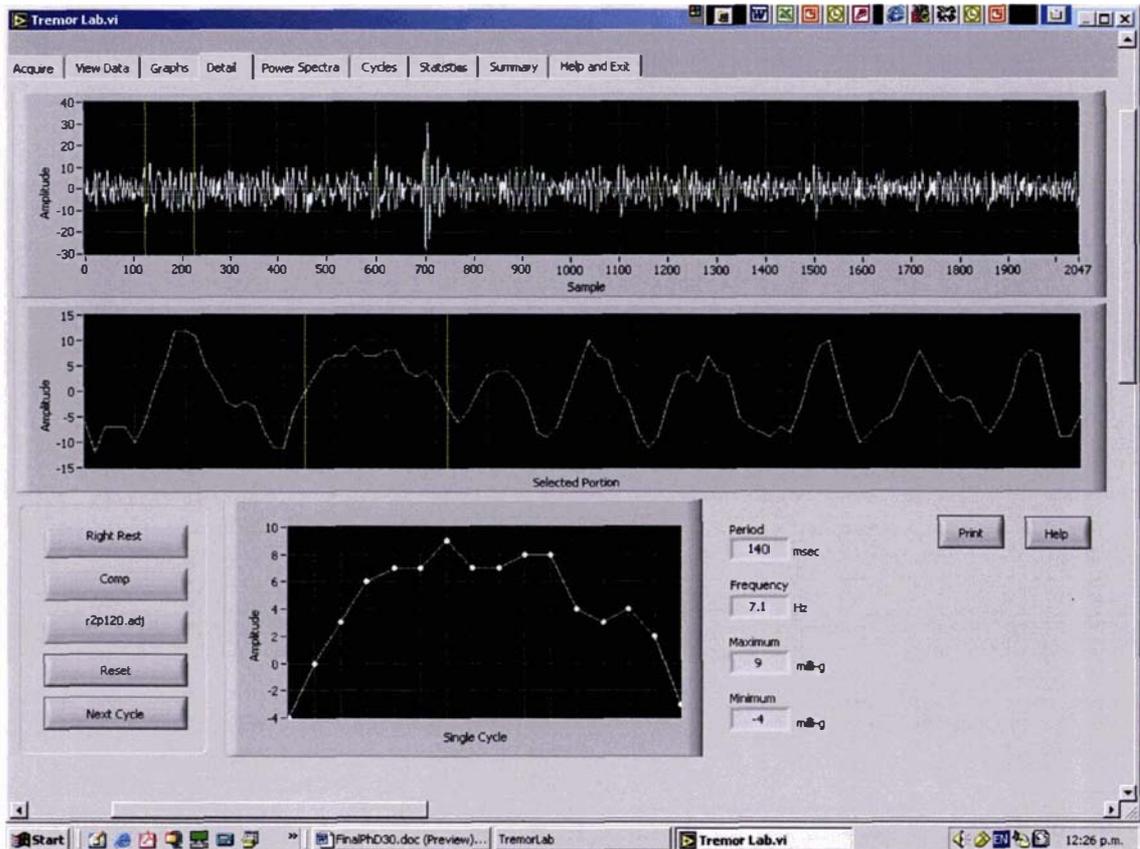


Figure 4. Exposed participant's right hand rest tremor sample, illustrating a patterned observed only in exposed group data.

Sensory domain assessment was outside the scope of the present thesis, but colour vision loss has been documented in occupational mercury exposures (Cavalleri & Gobba, 1998). For the assessment of colour vision, the Farnsworth desaturated hue panel (d-15) is recommended in the Adult Environmental Neurobehavioural Test Battery, for persons involved with accidental mercury spills (Ambler et al., 1995; Sizemore & Ambler, 1996).

All the techniques described above are non-invasive and painless, and X-rays in the XRF technique notwithstanding, safe. The tremorometer and the Farnsworth d-15 are portable. Perhaps there could be an avenue for medical and dental professions to maintain a monitoring programme for sub-clinical effects from occupational exposure; and to test patients more often for mercury sensitivity, if there was an indication that the person may be low on the TMC.

Some focus group participants in the *Biting the Silver Bullet* study, referred to their doctors subjecting them to a wide range of tests, but none for mercury tolerance. X-ray fluorescence, tremorometers, d-15 panels or allergy-patch technologies could be more commonly used to establish a low TMC position, as an alternative to the current urine tests, or when treatment for chronic ill health is not effective, for example when prescribed antidepressants make depression seem worse.

### **Recommendations for Further Study**

#### *Further Study to Test the Tolerance to Mercury Continuum*

A clear finding from the reviewed literature and from the first study, is that, for whatever reason, medical doctors do not commonly pursue micro-mercurialism as a possible diagnosis for either chronically ill patients or dental personnel, with the relevant symptoms. A recommendation for future study would be the development of a longitudinal mercury-monitoring programme, based on the TMC. A study of current dental personnel and dental patients, using a modified neurobehavioral test battery, and including technologies to give a measure of stored mercury, could explore methods to quantify the range of effects across the TMC. It could also be useful to know, specifically, more about the characteristics of high-end TMC dentists and low-end TMC patients.

If a programme could be developed that monitored mercury tolerance in individuals, then it could help to ensure that employers have safe mercury practices, under Occupational Health and Safety regulations. It could reassure employees who are occupationally exposed to mercury, that their personal tolerance to mercury was not exceeded. Dental personnel, for example, could be monitored at set periods from entry into dental school, and throughout their working lives. It is acknowledged that a mercury-monitoring programme would be more useful for occupational mercury exposures, than for dental patients wanting to making informed treatment choices, as some changes occur only after some poisoning has occurred.

### *Reproductive Health*

Given the statistical significance of the differences between mercury-exposed and control group women from the *Mercury and Venus* study, on experience of hysterectomy; and the pattern of negative experience in the exposed group on reproductive survey questions generally, a multidisciplinary investigation into the reproductive health of copper amalgam exposed women is recommended. Although the present data were generated with quantitative measures, the follow-on study could suit a critical health psychology approach, and including research partners with women's health, medical (obstetric or gynaecological) and epidemiological expertise.

### *Tremor Norms*

Tremor norms appear to be important for understanding both normal tremor and the impact of a variety of toxins. They could be used in dentistry for comparative purposes, and other occupations using toxic substances. It is recommended that adult tremor norms for posture, rest, and load conditions be established. Tremor literature, mainly from non-dental occupational mercury exposures, suggests that tremor assessment has the greatest potential for objective diagnosis of pre-clinical micro-mercurialism. There are no existing adult norms, only reported tremor patterns, and these may not be applicable if taken out of context. This recommendation is despite the limitations to the present thesis resulting from the dismal performance of the state-of-the-art technology in tremor assessment, because addressing equipment reliability and validity this is something that would have to be overcome before future tremor work was commenced.

### *Politics and Public Health*

The last issue is the influence of politics around the use of toxic substances. The two studies in the present thesis looked at populations with arguably different levels of mercury exposure, but mercury in dentistry is not just a problem for individuals or at-risk groups. Tonnes of waste amalgam are causing environmental pollution. In the amalgam debate, amalgam protagonists do say that amalgam is becoming a less popular material. That

does not change anything for its toxic properties, but a gradual decline in amalgam use would be good for dental patients, dental personnel, the environment, and the food chain. Amalgam is ultimately a global problem.

In the NZ School Dental Service, a patient or parent wishing to exercise their informed choice to not have amalgam fillings finds there is an additional barrier to amalgam-free oral health, and that is the cost. One must pay for children to have mercury-free dentistry. Moreover, parents of child or youth patients must pay, not just the difference between the amalgam filling and the non-amalgam filling, but for the complete cost of examination and treatment. Routine conservative dentistry is relatively expensive, so mercury-free dentistry may not be an option for many families.

To this end, a final recommendation from the thesis is to the Ministry of Health, to implement in New Zealand, the Health Canada criteria and regulations for amalgam use. This is asking for dentistry to act on amalgam manufacturers' own contraindication list. Removal of amalgam from the School Dental Service should be first, because the present policy is discriminatory on the basis of cost of treatment, and the segment of the population that is likely to opt for the more expensive non-amalgam treatment options.

Underpinning this recommendation is Rose's (1992) model for prevention of risk in public health. Rose argues that a change of policy may appear to target help the few people who are at greatest risk – in this case those low on the TMC, but reducing mercury exposure across the population does more than that. Rose suggests policy that reduces exposure, does the greatest good for those who make up the larger group of people around the mean. With mercury exposure, these are people who could be experiencing unrecognised or sub-clinical adverse effects, and whose quality of life may be only slightly compromised by their tolerance to mercury. They will also benefit, albeit to a lesser degree.

The possibility that a generation could grow up never having mercury exposure from dental sources would be an important public health measure. First, dental and public health researchers could evaluate the impact of a

policy to systematically reduce mercury exposure, and feed this information back as evidence for best practice to the dental profession.

Secondly, the recommended policy is consistent with New Zealand's Environmental Risk Management Agency's (ERMA) precautionary principle for public health (ERMA, 2002). Ninnes (2004) describes the precautionary principle as meaning:

That one does not release a substance into the environment if there is uncertainty as to whether it will cause harm to humans and the environment. This is in contrast to the risk assessment approach where such a substance is released into the environment and assessment of the risks it poses are developed: (p. 72).

Mercury from dentistry is already being released into the environment, but less would be released with the new policy. As the quantity of mercury that causes harm is uncertain – or from this thesis, the tolerance of the population is uncertain, then a precautionary approach to dental amalgam use is warranted. Further, Pearce (2004) reinforces the principle, from an epidemiological perspective in public health. Where there is any doubt, he asserts, public health policy should err on the side of safety.

### **Conclusion - The Debate Revisited**

The debate has been about the safety of mercury in dentistry, but the arguments have been underpinned with issues of power and ideology, and the dominant pro-amalgam group effectively controls the practice of dentistry. This includes what dental students are taught about mercury, and hence what members of dental associations tell their patients; but in the age of electronic information, patients know more, and want more than assurances based on authority and conflicting science.

Protagonists say there are safe levels of mercury exposure. The World Health Organisation says not. From the readings of original studies, to the extensive reviews, to the most recent pro-amalgam paper (Bates, Fawcett, Garrett, Cutress & Kjellstrom, 2004), and the most recent anti-amalgam paper (Mutter, Naumann, Sadaghiani, Walach & Drasch, 2004), to the findings of the two

studies in the present thesis, it is the author's contention that there is too much individual variation in dose-response relationship to say there is any safe level, but if tolerance could be measured, people could be located on some point of a TMC. All points have some risk, but there is a point where occupational exposure results in non-observable changes; and a point where minimally exposed people can become ill. The TMC is a framework from which informed choices could be made.

Protagonists say amalgam is inert, but clearly it leaches mercury and is toxic. They say amalgam does not cause disease. Unless micro-mercurialism or erythema are called diseases this may be technically true, but it is misleading nonetheless. It may cause adverse reactions.

The argument over whether dentists' good health demonstrates the safety of mercury is not straightforward, and dentists may not be as unaffected as they would like to believe. That said, dentists might be a biased sample when considering tolerance to mercury, and the safety of mercury.

Protagonists say mercury is cost effective as a filling material, but cost effectiveness is irrelevant in a safety debate. If social and environmental costs are considered, even the original claim may be incorrect. Similarly, any suggestion that alternatives to amalgam may have health risks is irrelevant to the safety of mercury in amalgam. There are biocompatibility tests for both amalgam and the newer materials, and more use could be made of them. Patients do have extraction as an option to choosing filling materials that may cause them harm. That amalgam is becoming less popular is also irrelevant, especially for those who already have a heavily filled dentition.

Protagonists say there are no scientifically valid studies to show harm from mercury, and that it has an excellent safety record. This is simply wrong and misleading. Mercury has been extensively reviewed and is without a good safety record. It may be true that papers presenting amalgam as a risk get published in journals other than dental and medical journals, although medical journals have published numerous case studies showing micro-mercurialism as an under-recognised disease. Dentists will not know if their patients have adverse effects from amalgam fillings, if doctors overlook the potential for significant mercury exposure to come from amalgam fillings.

Returning to the comments (introduced in Chapter 2) by Kedgley, that were reported by Whyman (2003) on the NZDA website as asking:

If metallic mercury is so toxic that it requires special handling and storage precautions before it is made into tooth filling material, and the waste product including leftover scraps of filling and the bits the patient spits out are too toxic to be flushed into the sewers, then how can it be all right in the warm, slightly acid saliva bath in a patient's mouth? ([www.nzda.org.nz](http://www.nzda.org.nz), 2003).

Perhaps an explanation can be found in the genetic predisposition to a place on the TMC. Some people appear not to show adverse reactions to some level of mercury in their mouths. This is not a 'proven fact' and it does not necessarily make it 'all right' because it oversimplifies the issue.

If the TMC is linked to genetics, then the whole 'nature-nurture' dichotomy should be considered. That is: there is a genetic predisposition to tolerance, and an interaction with mercury in the physical environment, public policy, general health, and technology. Assuming that there is a normal distribution of places on the TMC, it is logical to expect that where low-level mercury pollution exists in the environment, or a quantifiable level of mercury is established in the food chain, this may result in an elevated health risk for around three percent of a population, and a lesser but real risk across the whole population. When an additional burden is added through an optional use of mercury in dentistry, the percentage of severely affected will increase and more people may experience milder impairment without much potential to be aware of the cause.

Mercury in amalgam may be safe under some circumstances, for some people, some of the time, but may still require handling precautions and environmental controls. The neglected aspect of the explanation then, is the role of free will. If people are concerned about their personal tolerance, they can make an informed (or uninformed) choice not to accept amalgam fillings.

The contribution that the present thesis makes to the overall debate on the safety of mercury in dentistry is that for both the dental patient considering informed consent and the dental personnel placing amalgam fillings, some will

be affected and some will not, but there is no clear-cut case, as either the protagonists or antagonists in the debate would espouse. There is a good chance that dental personnel who have lasted, for example, 10 years in their profession, will not be affected at a clinical level. They may feel they are working with a safe product while they are practicing good mercury hygiene, but there is more they can do to ensure their own and their patients' safety, including being more open to understanding the reality of the low tolerance position.

For an estimated three percent of the NZ public (120,000 of the 2005 population) who may be allergic to mercury or be low on the TMC, there is a very high physical, social and economic cost in accepting amalgam. The majority of the population appear to have some tolerance to the level of risk for experiencing the adverse effects of low-level chronic mercury exposure but they may never know the sub-clinical impact that mercury from fillings is making on their lives.

The End. Rinse and Spit.

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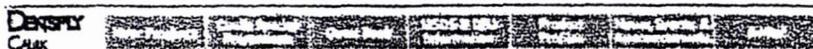
**APPENDICES**

**APPENDIX A**

**Dental Amalgams and Health Experience**

## **APPENDIX C**

### **Amalgam Manufacturer's Contraindication of Amalgam Use**



## DIRECTIONS FOR USE

# Dispersalloy<sup>®</sup>

### Tablets and Powder

A dispersed phase admix amalgam, containing lathe-cut particles and silver/copper eutectic spheres.  
 Caution: U.S. Federal law restricts this device to sale by or on the order of a dentist. For dental use only.

#### Composition

	Powder (for 100g.)	Tablets
Silver	69.5 g	.270 g
Tin	17.7 g	.069 g
Copper	11.8 g	.046 g
Zinc	1.0 g	.004 g

#### Indication for use

Dispersalloy<sup>®</sup> should be used in stress bearing restorations (Class 1 and 2), when other restorative materials or restoration techniques are not indicated.

#### Contraindication

The use of amalgam is contraindicated:

- In proximal or occlusal contact to dissimilar metal restorations.
- In patients with severe renal deficiency.
- In patients with known allergies to amalgam.
- For retrograde or endodontic filling.
- As a filling material for cast crown.
- In children 6 and under.
- In expectant mothers.

#### Side Effects/Warning

Prior to use, read the MSDS information and product instructions for this item.

Exposure to mercury may cause irritation to skin, eyes, respiratory tract and mucous membrane. In individual cases, hypersensitivity reactions, allergies, or electrochemically caused local reactions have been observed. Due to electrochemical processes, the lichen planus of the mucosa may develop.

Mercury may also be a skin sensitizer, pulmonary sensitizer, nephrotoxin and neurotoxin.

After placement or removal of amalgam restorations, there is a temporary increase of the mercury concentration in the blood and urine.

18/02/98 08

Author's Note: Emphases in the original.

**APPENDIX D**

**New Zealand Dental Association, Dental Amalgam FAQ Page**

## Dental Amalgam



There are alternatives to amalgam fillings, but are they as cost effective, safe or durable? Read on for the facts on 'silver fillings'.

### What is dental amalgam?

Dental amalgam is a blend of metals such as silver, copper and tin. Mercury binds these metals together, providing a strong, hard, durable 'silver' filling for your teeth. Dental amalgam is less expensive than other materials.

### Do amalgam fillings release mercury?

If you have amalgam fillings, mercury vapour may be released when you chew vigorously or grind your teeth. The amount of vapour released from fillings is extremely small. There is no valid scientific evidence that associates this tiny amount of mercury vapour with any health problems.

### Is the mercury in my amalgam fillings safe?

The mercury used in fillings is safe for most people. Authorities such as the British Dental Association, US Public Health Service, FDI World Dental Federation and World Health Organisation state that amalgam has been used for more than 150 years in millions of patients and no controlled studies have shown adverse health effects, except for rare cases of mercury allergy.

### I've heard that people are cured from illness when amalgam fillings are removed - is this true?

Stories of overnight cures from serious diseases have never been supported by sound scientific evaluation. If you are concerned about your amalgam fillings your dentist will be happy to discuss the benefits and risks of replacing them.

### What are the alternatives to amalgam fillings?

Composite fillings are tooth coloured and can be used for front and back teeth. Large composite fillings generally don't last as long as amalgam, but this should be weighed up against their excellent appearance and any concerns you may have about mercury release. Composites are effective if they are not very wide, and only involved one or two surfaces of the tooth.

Gold or porcelain inlays and overlays are very effective filling materials due to their strength and long term durability. They are more expensive than other materials.

To find out which treatment is best for you, and the costs involved, talk to your dentist.

[return to consumer homepage](#) | [NZDA Homepage](#)

## **APPENDIX E**

### **Biting the Silver Bullet: Recruitment Package**

## Bay of Plenty Environmental Health Clinic letterhead

Date

Dear Patient

Here is an information pack about a study investigating the experiences of people who have linked their dental amalgams and their health. It is the first stage of a broader study investigating issues in mercury poisoning

I support this research and I have agreed to have this information sent to you. The researchers are looking for people to talk about their experiences. Are you interested?

If you are interested, please **reply to the researcher** only using the volunteer reply form. **I will not be told whether or not you volunteer.**

As you will see from the information pack the research will take place in several different locations. Volunteers will be asked to attend a group discussion that will last for about one hour. **Your contribution will mean that the issues they go on to investigate will be generated by people with experience of mercury poisoning. At present the planned research is based on assumptions - not everyday experience.**

All participants will be given a petrol voucher, to acknowledge their contribution.

Remember, I am not personally involved in this research. Please send you volunteer reply form and get further information directly from the researcher.

Yours sincerely

Mike Godfrey

## DENTAL AMALGAMS AND HEALTH<sup>1</sup>

### **A qualitative study exploring the experiences of people who have considered dental amalgam removal for health benefits**

Wellington Polytechnic has been contracted to undertake a study of dental amalgams and health experience, by the New Zealand Academy of Oral Toxicology and Medicine. The work will be carried out from a social science perspective, by Linda Jones, who is currently developing a research proposal to follow up a group who were occupationally poisoned by mercury in 1974.

If you would like to know more about this research after reading the enclosed information pack, please contact

Linda Jones M.A. (Principal Investigator)  
Social Science Health Researcher / Lecturer  
School of Nursing Health and Environmental Sciences  
Wellington Polytechnic  
Private Box 756  
Wellington

(04) 801 2794 ext 8530 (24hr phone for messages)

This information package contains

- **Information for Volunteers** pages
- *Dental Amalgam and Health Volunteer Reply Form*
- an addressed, prepaid reply **envelope**
- a **list** of contact addresses

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<sup>1</sup> This research has the approval of the Bay of Plenty Ethics committee. and the Wellington Polytechnic Research and Ethics Committee You may contact the Bay of Plenty Ethics Committee at PO Box 241, Whakatane, tel (07) 307.3999, and the Wellington Polytechnic Research and Ethics Committee at Private Box 756, Wellington, tel (04) 801 2794.

# DENTAL AMALGAMS AND HEALTH

## INFORMATION FOR VOLUNTEERS

from Linda Jones, Principal Investigator

### What is the research about?

This research will document the experiences of people who have linked their health problems with their dental amalgams. We know there are people who link their amalgam fillings and their health, but we don't know how they experience the process of getting a diagnosis or treatment or what their long term health outcomes are.

We would like you to come to a discussion group, where your contribution will become part of a report on dental amalgams and health experience. You will also be able to influence the direction taken in a wider research project which is planned to trace and assess a group of school dental nurses who were occupationally poisoned by mercury in 1974. You will be asked to discuss issues such as:

- what has led you to link amalgam fillings with your health?
- what experiences do you share with other people in the discussion group who have also made this link?
- what issues do you think are the most important for researchers or policy makers to understand about dental amalgam
- why some people choose to have their fillings removed

### What will volunteers have to do?

First, say yes - there are very few people who have the link between amalgam fillings and health confirmed by a medical practitioner. We need a good response to establish patterns and common themes in the amalgam experience.

Second, participate in a discussion group with five to eight people who may have had similar experiences to you. Everyone in the discussion group will have been to the Bay of Plenty Environmental Health Clinic more than two years ago, but beyond that we need to be told by you.

### When and where will the groups meet?

Group dates and venues depend on the response. I hope to get two groups in each of the following venues. The discussion will last approximately one hour. Good parking and light refreshments are available, and the researcher will give participants a five dollar petrol voucher to help with travel costs.

Tauranga Motor Inn, (conference room) Tauranga	Wednesday 15 September
Wiley Court Motor Lodge, (conference room) Rotorua	Friday 17 September
Anglesea Conference Centre, Hamilton	Monday 21 September
The Albany Campus of Massey University, Albany	Tuesday 22 September
Auckland College of Education, Epsom, Auckland	Wednesday 23 September

### **Can you withdraw from the study?**

Yes, you can withdraw at any time, for any reason.

### **Points to note**

#### ■ **informed consent**

All participants will be required to sign a form acknowledging that they consent to being part of this study, and that they know what the study is about.

#### ■ **confidentiality**

Participation in the project is strictly confidential. Your name will never be used in any report about this study, nor will your identity be disclosed in any other way. At the end of this study, all the raw material collected during from discussion groups will be destroyed.

#### ■ **ethics approval**

This study has the approval of the Bay of Plenty Ethics Committee, and the Wellington Polytechnic Research and Ethics Committee.

**Please fill in the attached *Volunteer Reply Form* and return it in the prepaid, addressed envelope.**

**DENTAL AMALGAMS AND HEALTH  
CONTACT ADDRESSES**

**PRINCIPAL INVESTIGATOR**

Linda Jones  
School of Nursing Health and Environmental Sciences  
Wellington Polytechnic  
Private Box 756  
Wellington  
tel (04) 801 2794 ext 8530 (24hr phone for messages)

**ETHICS COMMITTEES**

The Chairman  
Bay of Plenty Ethics Committee  
PO Box 241  
Whakatane  
tel (07) 307.8999

Dr P Wood  
Research and Ethics Committee  
Wellington Polytechnic  
Private Box 756  
Wellington  
tel (04) 801 2794 ext 8723 (24hr phone for messages)

## DENTAL AMALGAMS AND HEALTH

### VOLUNTEER REPLY FORM

Please complete and return this form in the attached envelope by August 28.  
You should receive confirmation and details of your discussion group during  
the first week of September.

Yes, I want to participate in the *Dental Amalgams and Health* discussion groups.

**YOUR NAME** \_\_\_\_\_

**YOUR CONTACT PHONE NUMBER** \_\_\_\_\_

**YOUR ADDRESS** \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Have you had any amalgam fillings removed?** YES NO  
(circle one)

**My preferred venue is** Auckland -Albany Auckland -Epsom  
(circle one)  
Tauranga Hamilton Rotorua

**My preferred weekday time is**  
(circle one or more)

early afternoon / late afternoon / early evening  
or any of these times

**APPENDIX F**

**Biting the Silver Bullet: Group Conformation and Consent Form**

**DENTAL AMALGAMS AND HEALTH  
CONFIRMATION FORM**

Your are invited to participate in a group discussion on

<b>DATE</b>	<b>Thursday, 17 September 1998</b>
<b>TIME</b>	<b>5.00 pm</b>
<b>PLACE</b>	Wiley Court Motor Lodge 345 Fenton Street <u>Rotorua</u>  (ph 07 347 7879)

**Things to note**

Your group discussion will be lead by **Linda Jones** with a secretarial support person.

- There is plenty of parking.
- Collect your petrol voucher at the session.
- Please bring the attached Consent Form

If you have any questions please contact:

**Linda Jones (Principal Investigator)**

tel 04 801 2794 ext 8530 (if I am not available or you get the after hours message, still dial the extension number and you can leave a message at any hour)

**DENTAL AMALGAMS AND HEALTH  
PARTICIPANT CONSENT FORM**

Please bring this form with you to your discussion meeting.

**I have read the information sheet about *Dental Amalgams and Health* and I have had the opportunity to discuss this study and to ask questions which have been answered to my satisfaction.**

**I understand that participation in this study is voluntary and that I may withdraw my consent at any time.**

**I understand that my participation in this study is confidential and that no material which could identify me will be used in reports.**

**I understand that this research has been approved by the Bay of Plenty Ethics Committee and the Wellington Polytechnic Research and Ethics Committee.**

**I, \_\_\_\_\_ consent to participate in this study.**

**Signed:**

**Date:**

If you have any questions please contact:

**Linda Jones (Principal Investigator)**

tel 04 801 2794 ext 8530 (if I am not available or you get the after hours message, still dial the extension number and you can leave a message at any hour)

## DENTAL AMALGAMS AND HEALTH

**Thank you** for taking part in the discussion group. Your time and effort are appreciated and will contribute to the ultimate completion of this project. Having finished the interviews, I am very pleased the project used focus groups and not questionnaires, as you (all) have raised many issues we would not have thought to ask about; but also because in the planning we had made assumptions about the potential participants being some kind of uniform group as far as beliefs about amalgam were concerned, and of course you are a diverse group of people. It has been a privilege to hear your stories and opinions.

The information you have shared will remain confidential. As yet the tape recordings have not been destroyed but they will be as soon as they are transcribed.

I will be sending the Bay of Plenty Ethics Committee a summary of the research findings at the end of November. If you would like a copy too, please contact me at:

The School of Nursing Health and Environmental Sciences  
Wellington Polytechnic  
Private Box 756  
Wellington

or leave a phone message on

(04) 801 2794 ext 8530 (24hr phone for messages)

Linda Jones  
Principal Investigator

Dental Amalgams and Health Project.

## **APPENDIX G**

### **Bio-Probe Newsletter: Micromercurialism Symptom List**

### SELECTED HEALTH SYMPTOM ANALYSIS OF 1569 PATIENTS WHO ELIMINATED MERCURY-CONTAINING DENTAL FILLINGS

The following represents a partial statistical symptom summary of 1569 patients who participated in six different studies evaluating the health effects of replacing mercury-containing dental fillings with non-mercury containing dental fillings. The data was derived from the following studies: 762 Patient Adverse Reaction Reports submitted to the FDA by the individual patients; 519 patients in Sweden reported on by Mats Hanson, Ph.D.; 100 patients in Denmark performed by Henrik Lichtenberg, D.D.S.; 80 patients in Canada performed by Pierre Larose, D.D.S.; 86 patients in Colorado reported on by Robert L. Siblingud, O.D., M.S., as partial fulfillment of a Ph.D. requirement and 22 patients reported on by Alfred V. Zamm, M.D., FACA, FACP. The combined total of all patients participating in the six studies was 1569.

% OF TOTAL REPORTING	SYMPTOM	NUMBER REPORTING	NO. IMPROVED OR CURED	% OF CURE OR IMPROVEMENT
14%	ALLERGY	221	196	89%
5%	ANXIETY	86	80	93%
5%	BAD TEMPER	81	68	89%
6%	BLOATING	88	70	88%
6%	BLOOD PRESSURE PROBLEMS	99	53	54%
5%	CHEST PAINS	79	69	87%
22%	DEPRESSION	347	315	91%
22%	DIZZINESS	343	301	88%
95%	FATIGUE	705	603	86%
15%	GASTROINTESTINAL PROBLEMS	231	192	83%
8%	GUM PROBLEMS	129	121	94%
34%	HEADACHES	531	460	87%
3%	MIGRAINE HEADACHES	45	39	87%
12%	INSOMNIA	187	146	78%
10%	IRREGULAR HEARTBEAT	159	139	87%
8%	IRRITABILITY	132	119	90%
17%	LACK OF CONCENTRATION	270	216	80%
6%	LACK OF ENERGY	91	88	97%
17%	MEMORY LOSS	265	193	73%
17%	METALLIC TASTE	260	247	95%
7%	MULTIPLE SCLEROSIS	113	86	76%
8%	MUSCLE TREMOR	126	104	83%
10%	NERVOUSNESS	158	131	83%
8%	NUMBNESS ANYWHERE	118	97	82%
20%	SKIN DISTURBANCES	310	251	81%
9%	SORE THROAT	149	128	86%
6%	TACHYCARDIA	97	68	70%
4%	THYROID PROBLEMS	56	44	79%
12%	ULCERS & SORES IN ORAL CAVITY	189	162	86%
7%	URINARY TRACT PROBLEMS	115	87	76%
29%	VISION PROBLEMS	462	289	63%

## **APPENDIX H**

**Participant's File (Excluding Standard Test Response Booklets)**

ID

	Date		Date data entered	Originals archived
Invitation rec				
PQ sent				
PQ received				
NBT App sent				
Consent form				
Matched control details				
SRT				
Tweezer test				
CVLT				
POMS				
Tremor				
Dynomometer				
DSMT				
Rey 15 item				
Pegboard				

Notes

**DEXTERITY**

**GRIP STRENGTH**

<b>RH</b>				
<b>LH</b>				

**PEGBOARD**

**SYMBOLS – MEMORY TEST**

**Mercury and Venus: a long-term follow-up neurobehavioural assessment of women occupationally exposed to mercury.**

**CONSENT FORM** - To be signed at the assessment session.

I have read the "Information For Volunteers" and have had the details of the study explained to me. Any questions I had have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand I have the right to withdraw from the study at any time until the findings are analysed, and to decline to participate in any particular tasks.

I understand that the information will be used for Linda Jones' PhD thesis and the publications or presentations arising from this.

I agree to participate in this study under the conditions set out in the Information for Volunteers sheet.

**And either** (cross out the one that does not apply)

1. My participation in the assessment session is on the understanding that **only the pseudonym that I have written here** will be used if an example from my assessment is used in any publication or presentation of the results.

Pseudonym \_\_\_\_\_

**or**

2. My participation in the assessment session is on the understanding that **my name (iwi etc.) will be used** if an example of my assessment is used in any publication or presentation of the results.

**Signed:**

**Name:**

**Date:**

**APPENDIX I**

**Volunteers Preliminary Questionnaire**

## Volunteers' Preliminary Questionnaire

This questionnaire has a cover page and three sections.

Questions in Section A collect information on general health and life experiences. Section B collects information on environmental influences that have to be considered when analysing the neuro-behavioural assessment results. Section C covers work-history, mainly in the School Dental Service, but it is also for any "comparison group participants" who have ever worked with mercury.

Please complete all three sections.

*Please note:* There are some injuries that could make it difficult for you to complete the neurobehavioural assessment tasks e.g. hand injury or recent concussion. If something you have marked in the questionnaire indicates this, I will personally contact you to discuss your options.

*Informed consent reminder:* Completing and returning this questionnaire gives consent for the information to be used in the research. You sign a separate consent form for the neurobehavioural assessment. You can withdraw from the study for any reason up to the point where the findings are analysed.

*Participant number:* On receipt of your completed questionnaire, I will assign you a personal record number that will be used throughout the project, and this cover page will be separated from your answers.

Thank you for your involvement in this research.

- Participant's Name
- Date of Birth
- Personal Record Number



**Section A General Health and Life Experiences**

**A1.** Compared to a person in excellent health, how would you rate your health at the present time? Circle ONE number.

- Terrible.....1
- Very poor.....2
- Poor.....3
- Fair.....4
- Good .....5
- Very good.....6
- Excellent.....7

**A2.** Circle yes or no to show if you have suffered any of the following physical injuries in the last year?

Concussion	yes	no
Traumatic brain injury	yes	no
Dominant hand injury Including finger(s)	yes	no
Non-dominant hand injury as above	yes	no
Arm injuries	yes	no
RSI or OOS	yes	no

A3. Circle the appropriate number for your drinking and smoking during the last year.

0 = not at all

1 = some or not much

2 = moderately or only occasionally

3 = quite a lot or quite often

4 = heavily or very frequently

Alcoholic beverages	0	1	2	3	4
Tobacco	0	1	2	3	4
Marijuana	0	1	2	3	4

A4. Circle the appropriate number next to each of the following items to show how much each has bothered you. *The list is continued on the next page.*

0 = not bothered at all OR never had this

1 = bothered me a bit OR not much

2 = moderately bothered OR occasionally have this

3 = bothered quite a bit OR quite often have this

4 = extremely bothered by this OR frequent problem

	Past: Late teens and early 20s	Present: In the last six months
Allergies	0 1 2 3 4	0 1 2 3 4
Arthritis	0 1 2 3 4	0 1 2 3 4
Asthma	0 1 2 3 4	0 1 2 3 4
Bloating	0 1 2 3 4	0 1 2 3 4
Blushing / hot flushes	0 1 2 3 4	0 1 2 3 4
Blood pressure problems	0 1 2 3 4	0 1 2 3 4
Carpel Tunnel Syndrome	0 1 2 3 4	0 1 2 3 4
Chest pains	0 1 2 3 4	0 1 2 3 4
Constipation	0 1 2 3 4	0 1 2 3 4
Diabetes	0 1 2 3 4	0 1 2 3 4
Dizziness	0 1 2 3 4	0 1 2 3 4
Diarrhoea	0 1 2 3 4	0 1 2 3 4
Dry skin	0 1 2 3 4	0 1 2 3 4
Epilepsy	0 1 2 3 4	0 1 2 3 4
Fibroids	0 1 2 3 4	0 1 2 3 4
Gum problems	0 1 2 3 4	0 1 2 3 4
Headaches	0 1 2 3 4	0 1 2 3 4
Indigestion	0 1 2 3 4	0 1 2 3 4
Kidney problems	0 1 2 3 4	0 1 2 3 4

	Past: Late teens and early 20s	Present: In the last month
Menstrual difficulties	0 1 2 3 4	0 1 2 3 4
Metallic taste	0 1 2 3 4	0 1 2 3 4
Numbness, anywhere	0 1 2 3 4	0 1 2 3 4
Ringing in the ears	0 1 2 3 4	0 1 2 3 4
Sinus problems	0 1 2 3 4	0 1 2 3 4
Skin infections	0 1 2 3 4	0 1 2 3 4
Sleep disturbances	0 1 2 3 4	0 1 2 3 4
Smear test abnormal	0 1 2 3 4	0 1 2 3 4
Sore throats	0 1 2 3 4	0 1 2 3 4
Thyroid problems	0 1 2 3 4	0 1 2 3 4
Ulcers in the mouth	0 1 2 3 4	0 1 2 3 4
Unsteadiness	0 1 2 3 4	0 1 2 3 4
Vision / eye problems	0 1 2 3 4	0 1 2 3 4
Menopause		0 1 2 3 4

**A5** Circle **yes** or **no** if you have ever experienced the following:

**OR if you have chosen a pregnancy-free lifestyle,  
go down to A6 and leave A5 blank.**

Conception difficulties	yes	no
Miscarriage	yes	no
Premature labour	yes	no
Stillbirth	yes	no
Low birth-weight baby	yes	no
Child with birth defect	yes	no
Child with learning difficulty	yes	no
Child with developmental delay	yes	no

**A6.** Circle **yes** or **no** if you have ever experienced the following:

Hysterectomy	yes	no
Breast cancer	yes	no
Ovarian cancer	yes	no

**Section B Environmental Influences**

**B1.** Circle the appropriate number if in the last year, you have come in contact with, worked with, or used, any of the following?

- 0 = not used at all OR never
- 1 = used a bit OR not much
- 2 = used moderately often OR moderate amounts
- 3 = used quite often OR quite a bit
- 4 = always using this OR frequent contact

Please give details where applicable e.g. date(s), type of chemicals, or drug brand names. Continue on the reverse side of this page if needed.

Details please

Orchard and garden sprays	0 1 2 3 4	
Solvents and paint-products	0 1 2 3 4	
Industrial or anaesthetic gases	0 1 2 3 4	
Spermicidal jelly	0 1 2 3 4	
Asbestos	0 1 2 3 4	
Electric batteries	0 1 2 3 4	
Radiation	0 1 2 3 4	
Vitamin supplements	0 1 2 3 4	
Prescribed or pharmacy only medication	0 1 2 3 4	

## **Section C Mercury handling at work**

Please note that there are separate Section Cs depending on which group you are in. This is the last page for women in the comparison group. School Dental Nurses go to C2 on the next page.

### **COMPARISON GROUP ONLY.**

**C1** Circle **YES** or **NO** if you have ever worked with or handled mercury? If Yes, please give details.

YES

NO

- **Thank you for your help.**

**You will shortly receive an assessment appointment by post. Please contact Linda Jones if it is not convenient. Ph 04 801 2794 x 6530 or School of Psychology, Massey University, PO Box 756, Wellington.**

**SCHOOL DENTAL NURSE GROUP ONLY**

**C2** Circle **YES** or **NO** in answer to the question: Do you remember being "tested for mercury" back in the 1970s?

YES

NO

If Yes, please record the type of test, the approximate date(s), results, and details of any "stand down" time or treatment you received.

**C3** In this study I assume that mercury-handling practices were much the same for everyone working under “standing instructions”, including measuring liquid mercury, heating mercury-copper pellets, wringing mercury out of amalgam mixes, handling, and storing waste mercury.

However, during your time as a school dental nurse, do you remember any unusual incidents related to mercury, e.g. mercury spills? Please comment this or other aspects of working with mercury you think should be considered.

**C4** Please record any details you can recall, from conversations with your PDO or DNI about mercury as a hazard, or events like your clinic being tested for mercury levels. Continue on the reverse if necessary.

**C5 Work history in dentistry from training to the present.**

Please complete the table for employment as a School Dental Nurse / Dental Therapist with the Department of Health, **AND** subsequently with CHEs, private dental practitioners, hospital dental departments etc.

Do not give details of the years when you were not working with mercury. Continue on the reverse if necessary.

Example	Dates and duration of employment	Place / type of school or employment	Did this clinic have a pre-school roll?	Was the clinic in a fluoridated area?
→	March '69-Sept 71	Intermediate clinic: Hawera	a small one – 20 maybe??	no

- **Thank you for your help.**

**You will shortly receive an assessment appointment by post. Please contact Linda Jones if it is not convenient. Ph 04 801 2794 x 6530 or School of Psychology, Massey University, PO Box 756, Wellington.**

## **APPENDIX J**

### **Flipchart Instructions**

**Mercury and Venus:**

**A long-term follow-up  
neurobehavioural assessment of women  
occupationally exposed to mercury.**

**Preliminary Questionnaire and the  
Neurobehavioural Assessment**

Any questions?

**Consent form**

**Collect this before proceeding**

**Reaction Time**

Follow the instructions on the screen.

There is an opportunity to practice before  
the main task.

### **Dexterity**

This is a task you do with your dominant hand, and using tweezers.

There is an opportunity to practice before the main task.

### **Verbal learning**

This is a learning task where you listen to a long list of words to see how many you can learn under various conditions.

After the list is read I will write down what you say.

### **Symbol-Digit Exchange.**

This is a writing task where you have a limited time to match symbols and digits from a key-code. You do get several practice trials before the time starts.

## **Tremor**

In this task you have a little sensor taped to your finger. Three x 20-second recordings are made on each hand. I'll give you verbal directions as we work through the different hand positions.

## **Grip Strength**

In this task you will grip a “dynamometer” that records the strength of your grip. There are no practice trials, but you get three grips with each hand.

## **Memory Test**

In this task you have 10 seconds to memorise fifteen different symbols, then a limited time to reproduce them on paper, preferably in the right order.

<b>A</b>	<b>B</b>	<b>C</b>
<b>1</b>	<b>2</b>	<b>3</b>
<b>a</b>	<b>b</b>	<b>c</b>
<b>Δ</b>	<b>O</b>	<input type="checkbox"/>
<b>i</b>	<b>ii</b>	<b>iii</b>

### **Feelings**

This task requires you to fill in a form, by rating a range of feelings for this week, including today. Fill in the block underneath the number that you felt like.

0 = NO much unlike this      1 = slightly unlike this

2 = slightly like this      4 = YES much like this

### **Pegboard**

This is a timed task involving thinking and manipulating small objects. You will go straight into the task, after I demonstrate how to do it.

**APPENDIX K**

**Recruitment Package for School Dental Nurses**

15 October 2002

Dear

**Mercury and Venus: a long-term follow-up neurobehavioural assessment of women occupationally exposed to mercury.**

Introductions first. My name is Linda Jones. I am a full-time lecturer in the School of Psychology at Massey University, Wellington. I wish to invite graduates of the Wellington School for Dental Nurses to participate in my PhD research, looking to see if there are any long-term consequences of having worked with copper amalgam.

The aim of the research is to assess and compare mercury exposed women, and non-exposed women on a range of measures that are sensitive to the effects of mercury in the brain.

This pack contains information on:

- ▶ What volunteers will be asked to do
- ▶ Volunteers' rights and confidentiality information
- ▶ Funding and ethics approval statements
- ▶ How to volunteer; and
- ▶ Asking a non mercury-exposed sister or friend to volunteer with you.

If you have any questions, please contact me, or just send back the volunteers' reply form, and possible assessment date form, in the envelope provided. I look forward to hearing from you.

Yours sincerely,

## **Mercury and Venus: A long-term follow-up neurobehavioural assessment of women occupationally exposed to mercury.**

### **INFORMATION FOR VOLUNTEERS**

#### **What is the research about?**

I began this doctoral research (PhD) after reviewing research on people who were exposed to mercury in their work, and finding evidence that suggests that working with mercury has the potential to cause long-term damage to the central nervous system (CNS). Mercury is a toxic chemical with no guaranteed “safe” exposure level according to the World Health Organisation. It crosses the blood-brain barrier that normally prevents toxins reaching the brain. My research is designed to examine behaviours that are linked to brain functions that are susceptible to mercury damage, to show if school dental nurses, and in particular those who worked with copper amalgam, have any lasting CNS problems from their occupational use of mercury.

You may be thinking, “I’m fine, it didn’t affect me,” or alternatively you may be wondering if changes in for example, your memory, are natural aging or perhaps related to mercury. Either way, to answer the question it is important to assess a cross-section of women who trained and worked with mercury. The best group would be women who are at least thirty years on from their initial occupational exposure. I have contacted or been contacted by several drafts’ reunion organisers who have given me their current address lists, and this is how I have been able to contact you.

I will be looking for **group patterns**, not individual results to get a big picture of the long-term effects of occupational exposure to mercury. Because group patterns are analysed, and because it is an important part of the scientific research method, the dental nurses’ group will need a comparison group of women who have never worked with mercury, to also be assessed. The best comparison group volunteers are dental nurses’ sisters, or close-in-age women friends. Age, education level, gender, and to some extent family history, are the important considerations in matching the exposed and comparison group women. There is a place on your “Volunteer Reply Form” for you to identify someone who might volunteer for the comparison group.

#### **What will volunteers have to do?**

Your contribution will be to participate in an assessment involving a variety of tasks where mercury may have affected the CNS of dental nurses but not the comparison group women. The assessment tests are called neurobehavioural tests because they have the potential to show how any damage to the nervous system has affected behaviour – which includes thinking, feeling and physical actions. The tasks I have chosen should detect and measure mercury effects at a “sub-clinical” level, which means at a level where people may not be aware of developing deficits. The tests are done in a single session that may take up to two hours.

The tests cover aspects of:

- ▶ memory and learning
- ▶ attention, concentration, and mood
- ▶ reaction-time
- ▶ health experiences
- ▶ hand-eye coordination
- ▶ tremor and hand grip-strength

Most tasks are standard psychology tests requiring you to check boxes of key words, or report your answers. The reaction time test is computerised. The tremor measure requires you to have a thimble-sized sensor taped to your finger for about one minute per hand. The remainder of the assessment requires you to do simple manual tasks. There are no invasive tests; and no biological samples are required.

Prior to the assessment session, you will be sent a preliminary questionnaire on work history, other environmental influences, and health experiences. The reason for this is to look for patterns of health experience, and influences on your assessment scores. Some injuries or health experiences may mean it would be difficult for you to complete the manual tasks. If there is any reason why you should not participate, I will contact you personally.

The assessments will take place between November 2002 and March 2003, at Massey University (Wellington, Palmerston North and Albany), and I will travel to other locations that are handy to where volunteers are living. Actual dates and venues for the assessment sessions will be planned when the volunteer replies are returned.

### **Volunteers' Rights**

You have the right to be given information about the research. There is a consent form that you will be asked to sign to say you understand the research, and although it will be sent in advance of the assessment appointment, you can ask questions and look at the test materials before signing it on your assessment day.

You also have the right to be identified or not be identified in my PhD thesis, or in any presentations or publications based on the research, as you choose. If you have had an experience that might add to the analysis or illustrate the discussion of the results, you can say which you prefer - to provide a pseudonym, or have the "story" attributed to you. There is a place on the consent form to state your preference.

After you have volunteered you have the right to withdraw from the study at any time until the findings are analysed; or you can choose to not answer some of the questions.

You have the right to have your data stored securely and confidentially. The assessment scores will be analysed by computer. At the point of data-entry, record numbers not names will be used. Data will be retained for five years in secure storage, in the School of Psychology, Massey University, Wellington. This complies

with the University's Policy on Research Practice (section 2.2). At that time data will be destroyed through the University's secure document-destruction system.

In any location where I arrange assessment sessions, if anyone is interested, and I am particularly thinking of Maori women and their whanau, we can organise an information hui where this information and anything else you would like to discuss can be done by us talking about the research.

#### **Other Issues:**

▶ **Funding.** This research is partly funded by Massey University, School of Psychology, as part of my employment, and partly funded by me as a PhD candidate.

▶ **Ethics Approval.** This project has been reviewed and approved by the Massey University Human Ethics Committee, PN Protocol 01/125. If you have any queries about the conduct of this research, please contact Professor Sylvia Rumball, Assistant to the Vice-Chancellor (Equity and Ethics) telephone 06 350 5249, email [S.V.Rumball@massey.ac.nz](mailto:S.V.Rumball@massey.ac.nz)

▶ **Feedback on the research.** A summary of the findings will be sent to all volunteers, and to the Ministry of Health. The PhD thesis will be deposited in the Massey University Library where it can be read or borrowed. I intend to publish the findings in scientific journals, whether they show something or nothing, to add to the scientific knowledge on the consequences of occupational exposure to mercury.

▶ **Comparison group.** Dental Nurses, please try to identify a woman who may volunteer for the comparison group. My first preference is for a sister, then a woman friend about your age and education level. Discuss the project with them, and if they are interested, please send me their name, address, and relationship to you, on the reply form, and I will then send them a volunteers' information and reply pack.

▶ **Support.** I will assist you to locate suitable counselling or support groups, should you find participating in this research creates problems for you.

**Your Volunteer Reply Form and postage-paid envelope are attached.**

**Thanks for reading this material. I look forward to your response.**

**Linda Jones  
School of Psychology  
Massey University  
PO Box 756  
Wellington**

**Phone: 04 801 2794 x 6530  
Fax: 04 801 0492  
Email: [L.M.Jones@massey.ac.nz](mailto:L.M.Jones@massey.ac.nz)**

**Mercury and Venus: A long-term follow-up neurobehavioural  
assessment of women occupationally exposed to mercury.**

**VOLUNTEER REPLY FORM**

Please complete and return this form, and the attached "assessment timetable planning information" form as soon as possible. A prepaid, addressed envelope is enclosed. You should receive the "preliminary questionnaire" within a week of my receiving your response.

Yes, I want to participate in study investigating the long-term consequences for School Dental Nurses, of occupational exposure to mercury.

**YOUR NAME**

**PHONE NUMBERS**

**Home**

**Cell**

**Work**

**YOUR POSTAL ADDRESS**

**YOUR EMAIL ADDRESS**

**YOUR SISTER'S OR FRIEND'S NAME (state relationship)**

**HER POSTAL ADDRESS**

**I HAVE TALKED TO HER ABOUT THE RESEARCH  
(CIRCLE ONE)**

**YES**

**NO**

## **APPENDIX L**

### **Recruitment Package for the Control Group**

24 January 2003

Dear

**Mercury and Venus: a long-term follow-up neurobehavioural assessment of women occupationally exposed to mercury.**

Introductions first. My name is Linda Jones. I am a full-time lecturer in the School of Psychology at Massey University, Wellington. Your friend Linda Jones gave me your name as someone I can invite to be a “matched volunteer” for her, in my PhD research, looking to see if there are any long-term consequences for School Dental Nurses of having worked with copper amalgam filling material.

The aim of the research is to assess and compare mercury exposed women, and non-exposed women on a range of measures that are sensitive to the effects of mercury in the brain. You would be in the comparison group.

This pack contains information on:

- ▶ What volunteers will be asked to do
- ▶ Volunteers’ rights and confidentiality information
- ▶ Funding and ethics approval statements, and
- ▶ How to volunteer.

If you have any questions, please contact me, or just send back the volunteers’ reply form in the envelope provided. I look forward to hearing from you.

Yours sincerely,

## **Mercury and Venus: A long-term follow-up neurobehavioural assessment of women occupationally exposed to mercury.**

### **INFORMATION FOR VOLUNTEERS**

#### **What is the research about?**

I began this doctoral research (PhD) after reviewing research on people who were exposed to mercury in their work, and finding evidence that suggests that working with mercury has the potential to cause long-term damage to the central nervous system (CNS). Mercury is a toxic chemical with no guaranteed “safe” exposure level according to the World Health Organisation. It crosses the blood-brain barrier that normally prevents toxins reaching the brain. My research is to examine behaviours that are linked to brain functions that are susceptible to mercury damage, to show if school dental nurses, and in particular those who worked with copper amalgam, have any lasting CNS problems from their occupational use of mercury.

Your sister or friend may be thinking, “I’m fine, it didn’t affect me,” or alternatively she may be wondering if changes in for example, her memory, are natural aging or perhaps related to mercury. Either way, to answer the question it is important to assess a cross-section of women who trained and worked with mercury. The best group would be women who are at least thirty years on from their initial occupational exposure. I contacted or was contacted by several dental nurse “draft reunion” organisers who gave me their address lists, and this is how I was able to contact your sister / friend. I trust that she talked to you about the project before sending me your name and address.

I will be looking for **group patterns**, not individual results to get a picture of the long-term effects of occupational exposure to mercury. Because group patterns are analysed, and because it is an important part of the scientific research method, the dental nurses’ group scores will need to be compared to scores from a group of women who have never worked with mercury. This is where you come in. It would be very helpful if you would consider volunteering to be in the comparison group.

#### **What will volunteers have to do?**

Your contribution will be to participate in an assessment involving a variety of tasks where mercury may have affected the CNS of dental nurses but not the comparison group women. The assessment tests are called neurobehavioural tests because they have the potential to show how any damage to the nervous system has affected behaviour – which includes thinking, feeling and physical actions. The tasks I have chosen should detect and measure mercury effects at a “sub-clinical” level, which means at a level where people may not be aware of developing deficits. The tests are done in a single session that may take up to two hours.

The tests cover aspects of:

- ▶ memory and learning
- ▶ attention, concentration, and mood
- ▶ reaction-time
- ▶ health experiences
- ▶ hand-eye coordination
- ▶ tremor and hand grip-strength

Most tasks are standard psychology tests requiring you to check boxes of key words, or report your answers. The reaction time test is computerised. The tremor measure requires you to have a thimble-sized sensor taped to your finger for about one minute per hand. The remainder of the assessment requires you to do simple manual tasks. There are no invasive tests; and no biological samples are required.

Prior to the assessment session, you will be sent a preliminary questionnaire on work history, other environmental influences, and health experiences. The reason for this is to look for patterns of health experience, and influences on your assessment scores. Some injuries or health experiences may mean it would be difficult for you to complete the manual tasks. If there is any reason why you should not participate, I will contact you personally.

The assessments will take place between November 2002 and March 2003, at Massey University (Wellington, Palmerston North and Albany), and I will travel to other locations that are handy to where volunteers are living. Actual dates and venues for the assessment sessions will be planned when the volunteer replies are returned.

### **Volunteers' Rights**

You have the right to be given information about the research. There is a consent form that you will be asked to sign to say you understand the research, and although it will be sent in advance of the assessment appointment, you can ask questions and look at the test materials before signing it on your assessment day.

You also have the right to be identified or not be identified in the thesis or in any presentations or publications based on the research as you choose. If you have had an experience that might add to the analysis or illustrate the discussion of the results, you will be asked which you prefer: to provide a pseudonym, or have the "story" attributed to you. There is a place on the consent form to state your preference.

After you have volunteered you have the right to withdraw from the study at any time until the findings are analysed; or you can choose to not answer some of the questions.

You have the right to have your data stored securely and confidentially. The assessment scores will be analysed by computer. At the point of data-entry, record numbers not names will be used. Data will be retained for five years in secure storage, in the School of Psychology, Massey University, Wellington. This complies

with the University's Policy on Research Practice (section 2.2). At that time data will be destroyed through the University's secure document-destruction system.

In any location where I arrange assessment sessions, if anyone is interested, and I am particularly thinking of Maori women and their whanau, we can organise an information hui where this information and anything else you would like to discuss can be done by us talking about the research.

**Other Issues:**

▶ **Funding.** This research is partly funded by Massey University, School of Psychology, as part of my employment, and partly funded by me as a PhD candidate.

▶ **Ethics Approval.** This project has been reviewed and approved by the Massey University Human Ethics Committee, PN Protocol 01/125. If you have any queries about the conduct of this research, please contact Professor Sylvia Rumball, Assistant to the Vice-Chancellor (Equity and Ethics) telephone 06 350 5249, email [S.V.Rumball@massey.ac.nz](mailto:S.V.Rumball@massey.ac.nz)

▶ **Feedback on the research.** A summary of the findings will be sent to all volunteers, and to the Ministry of Health. The thesis will be deposited in the Massey University Library where it can be read or borrowed. I intend to publish the findings in scientific journals, whether they show something or nothing, to add to the scientific knowledge on the consequences of occupational exposure to mercury.

▶ **Support** I will assist you to locate suitable counselling or support groups, should you find participating in this research creates problems for you.

**Your Volunteer Reply Form and postage-paid envelope are attached.**

**Thanks for reading this material. I look forward to your response.**

**Linda Jones  
School of Psychology  
Massey University  
PO Box 756  
Wellington**

**Phone: 04 801 2794 x 6530  
Fax: 04 801 0492  
Email: [L.M.Jones@massey.ac.nz](mailto:L.M.Jones@massey.ac.nz)**

**Mercury and Venus: A long-term follow-up neurobehavioural  
assessment of women occupationally exposed to mercury.**

**SISTERS AND FRIENDS VOLUNTEER REPLY FORM**

Please complete and return this form, and the attached "assessment timetable planning information" form as soon as possible. A prepaid, addressed envelope is enclosed. You should receive the "preliminary questionnaire" within a week of my receiving your response.

**Yes, I want to participate in the comparison group of the study investigating the long-term consequences for School Dental Nurses, of occupational exposure to mercury.**

**YOUR NAME**

**PHONE NUMBERS**

**Home**

**Work**

**Cell**

**YOUR POSTAL ADDRESS**

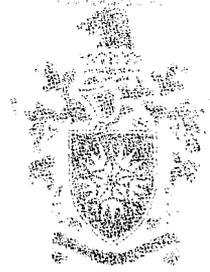
**YOUR EMAIL ADDRESS**

**YOUR SISTER OR FRIEND'S NAME (state relationship)**

## **APPENDIX M**

### **Non-Responders Second Invitation with Ministry of Health Support Letter**

January date 2003.



**Wellington Campus**  
Private Box 756,  
Wellington,  
New Zealand  
Telephone: 64 4 801 2794  
Facsimile: 64 4 801 2692

Dear ex-dental nurse

**It's not too late to volunteer!**

I wrote to you before Christmas about my PhD research with women who used copper amalgam: "Mercury and Venus: A long-term follow-up neurobehavioural assessment of women occupationally exposed to mercury."

I got a good response for a mailed request for volunteers, but not so good compared to the numbers of participants I need for a scientifically strong outcome. With a larger group of women I can use statistics to answer questions like: "Is there a relationship between the length of time a woman worked, and evidence of mercury effects?" as well as looking for differences between ex-dental nurses and their sisters or friends.

Because I don't know why you didn't respond, I'd like to give you some more information, in the hope you will still volunteer. I am planning trips around the country from mid January to the end of March, and would be happy to see you then.

First, if you graduated from "Willis Street" in Wellington before 1972, then that will have given you sufficient exposure to copper amalgam for the purposes of this study.

Second, if you don't want to ask a sister or friend to volunteer with you, you can still participate. We can find a "matched" comparison group woman for you.

Third, we don't *just* want people in excellent health. People with chronic conditions are also welcome to volunteer.

Finally, attached is a supporting letter from the Ministry of Health. Dr Feek, and Peter Hunter the dental advisor (now retired) have followed the development of this project since I began work on it four years ago. They support the research as a way to start to follow up the mercury-poisoning episode of the mid-1970s.

I have enclosed another reply form and assessment timetable, for your convenience. Please contact me if you have any questions. I look forward to hearing from you.

Yours sincerely

Linda Jones

Ph. 04 801 2794 x 6530

email [L.M.Jones@massey.ac.nz](mailto:L.M.Jones@massey.ac.nz)



**APPENDIX N**

**The Neurobehavioural Test Battery Administration Protocol**

## **The Neurobehavioural Test Battery Administration Protocol.**

Instructions and actions are in normal typeface; verbal instructions to the participants are in italics. Instructions are supported by an A5 “task flipchart” that shows the progress through the tasks, and by turning the pages, ensures the assessor includes all the tests. The flipchart pages show a lay-persons title for the task, or name of the instrument; and the key instruction for the participant, in the event that they understand better with visual, in addition to verbal directions.

### **1. Establishing Rapport / Setting Up Equipment.**

#### Administration

Normal conversation as is appropriate

#### Flipchart Message

Mercury and Venus:

A long-term follow-up neurobehavioural assessment of women occupationally exposed to mercury.

## **2. Consent Process**

### Administration

Suggest moving into the formal proceedings if the participant is ready. Invite focussed questions and offer the consent form for reading and signing.

### Flipchart Message

Any questions?

**Consent form - sign this before proceeding**

## **3. Simple Reaction Time**

### Administration

The first NBTB task is a computerised task, with the instructions on-screen. The laptop computer has all applications closed except the SRT programme, and the destination file for the results. The participant has the laptop placed in front of them and they are asked to follow the written instructions.

Answer questions or demonstrate using the mouse if required, for the participant to independently work through the menu. During the

practice trials, comment on best practice, which included the participant deciding one key, not take their finger off the key between presentations of the stimuli, and staying focused on the screen.

### Flipchart Message

*Reaction Time*

*Follow the instructions on the screen.*

*There is an opportunity to practice before the main task.*

### Scoring.

The scores for all 60 VI stimuli are recorded in milliseconds and transferred by the programme to an excel spreadsheet for later analysis.

## **4. O'Connor Tweezer Dexterity Test**

### Administration

The participant is seated comfortably at a desk or desk height table, with the tweezer dexterity test board placed 30cm from the edge of the table and angled towards the side of the dominant hand - first in front of the examiner, then after the demonstration, in front of the

participant. The participant can adjust the angle of the board for their comfort.

### Flipchart Message

#### *Dexterity*

This is a task you do with your dominant hand, and using tweezers.

There is an opportunity to practice before the main task.

### Instructions and concurrent demonstration

*“The board in front of you consists of 100 holes each large enough to hold one pin. Pick up one pin at a time with the tweezers, and fill the holes by placing one pin in each as fast as you can. Pick up the pins by the end opposite or farthest away from you. Use only the hand in which you hold tweezers.”* Examiner demonstrates saying, *“Pick up the pin rather lightly so it will fall into the vertical position by itself, all ready to drop in the hole – like so.”* Examiner places a pin in the upper left hand corner. *“That is the best way. You see, if you hold the pin tightly like this,”* examiner demonstrates, *“or pick it up by the middle,”* examiner demonstrates, *“or pick it up by the wrong end like this,”* examiner demonstrates, *“it takes an awkward twist of the wrist to get it in, but picking it up rather lightly from the farthest end, this*

*way, it goes and naturally.*” Examiner continues to fill three more holes in the correct manner.

*“There are enough pins in the tray so that if you drop one or two on the floor you will still have enough left. Do not stop to pick them up. The holes are to be filled from left to right,”* (for a right-handed participant, or right to left for a left-handed participant) *“then each row is to be completed before the next row is started”*.

The examiner can suggest that, *“some people like to rest their elbow on the table but it is not compulsory.”* The participant must then practice by placing ten pins only, and fill the top line of ten holes. Then the examiner tips the pins out, allows a moment for the participant to prepare, ensures the stopwatch is set to 00.00 and says, *“Ready, go.”*

### Scoring.

The length of time required to fill all the holes in sequence is made in minutes, seconds and tenths of a second. Time begins when the instruction is given to “go” and ends when the last pin is placed.

## **5. The California Verbal Learning Test.**

### Administration

The CVLT booklet contains all the instructions for an examiner. The participant's record number only will be recorded on the cover.

### Flipchart Message

#### *Verbal learning*

This is a learning task where you listen to a long list of words to see how many you can learn under various conditions.

**After the list is read I will write down what you say.**

### Scoring

The CVLT booklet also has a guided scoring system.

## **6. Symbol-Digit Modalities Test**

### Administration

The “paper and pencil” form of the Symbol-Digit Modalities Test was used. The participant’s I.D. record number only will be recorded under examine the information. The form contains all the instructions for the participant, including a series of trials before the main test.

### Flipchart Message

### Instructions and demonstration

### Scoring

## **7. The Tremorometer**

### Administration

The I.D. number of participant is recorded on the Tremorometer. Tape is wound once around the index finger of the participant’s dominant hand, then around the sensor, to hold it in place. Instructions read from the Tremorometer monitor, guiding the assessor through three recordings: posture, rest, and load. The

sensor is then removed from the dominant hand and the process is repeated with the non-dominant hand.

### Flipchart Message

#### **Tremor**

In this task you have a little sensor taped to your finger. Three x 20 second recordings are made on each hand. I'll give you verbal directions as we work through the different hand positions.

### Scoring

The file is uploaded into the TremorLab programme, and the TremorLab software analyzes the data.

## **8. The Dynamometer**

### Administration

Explain that the first two actions are to do is check on the comfort of the grip, and adjust when necessary, and ensure the dynamometer cannot be accidentally dropped, by having the participant loop the safety cord over their wrist. When the grip is comfortable the participant remains comfortably standing, feet shoulder width apart.

## Flipchart Message

### Grip Strength

In this task you will grip a “dynamometer” that records the strength of your grip. There are no practice trials, but you get three grips with each hand.

### Instructions and demonstration

*“I’m going to explain what we do with the dynamometer. You will hold it with your arm relaxed at your side (first in the dominant hand) and when you are ready, grip hard by squeezing as firmly as you can. You will not feel the sensation of movement. Hold the maximum pressure that you can while I count five seconds, then relax your grip, but keep hold of the handle. After you have done that I will get you to raise your arm like this (demonstrates holding arm out in front) so I can read the dial, then we will repeat the exercise for a total of three readings for each hand. Any Questions?” (Answer them) “OK, ready, grip ,1,2,3,4,5,relax.”*

### Scoring

Each of the three trials the kilos force data are read from the dynamometer dial, and entered on the file record sheet. When data have been entered on SPSS, summary scores will be calculated for each hand.

## **9. CVLT part 2.**

Near this point, if 20 minutes has elapsed, the long delay section of the CVLT is administered. It is introduced at the end of the previous task by saying, "Now, we just have some more shopping to do before the next activity."

There is no flipchart message for the CVLT Part 2.

## **10. Profile of Mood States**

### Administration

The participant is given the POMS response sheet, with their I D. number in the place marked for a name. This is a self-administered, "paper and pencil" format record form that contains all the instructions for the participant. However the examiner will still read the following instruction to be sure the participant understands the task.

## Flipchart Message

### **Feelings**

This task requires you to fill in a form, by rating a range of feelings for this week, including today. Fill in the block underneath the number that you felt like.

NO 0 = much unlike this 1 = slightly unlike this

YES 2 = slightly like this 3 = much like this

### Instructions

*“This page contains a list of words that describe the feelings people have. Please read each one carefully. Then fill in ONE space to the right, like a lotto ticket, that best describes how you have been feeling during the past week, including today. The numbers refer to these phrases: 0 = much unlike this; 1 = slightly unlike this; 2 = slightly like this; and 3 = much like this.”*

The potential for double negatives to be confusing is explained, using the example of the word “untroubled”. It is suggested to the participant that where confusion arises, she should ask herself, *“Have I felt like this, yes or no? If yes, the correct response will be either 2 or 3. If no, the response will be either 0 or 1.”*

After the participant has been given the opportunity to ask questions, they will fill in the sheet without further interruption.

### Scoring

Raw data is transferred to an excel spreadsheet set up with the formula for each of the six subscales. Within each subscale the positive stimuli scores are added, negative stimuli words scores are deducted and a constant of 18 is added to the total to ensure that the final score will be above 0.

## **11. The Rey 15 Item Test**

### Administration

The participant is given a sheet of paper, blank except for their I.D. number recorded at the top, and pen. The test is explained as a difficult memory task. They will see for only ten seconds, the stimulus card that is on the flipchart, after which they will be given up to one minute to try and reproduce the symbols and patterns

### Flipchart Message

## Memory Test

In this task you have 10 seconds to memorise fifteen different symbols, then a limited time to reproduce them on paper, preferably in the right order.

### Instructions

The examiner says, *“This is a memory test. It is a very difficult memory test, but I want you to give it your best. What I’m going to do is show you a card with **fifteen different designs**. You will get ten seconds to study the card then I will turn the card over. After I turn the card over please draw as many of the designs as you can remember - and arrange them in the same way as they were on the card - that is you draw them just as they appear on the card. Again, this is hard, so do the best you can .”*

### Scoring

Three scores are entered in SPSS for the number of correct symbols also in the correct position. This will be a score from 0 to 15.

## **12. Grooved pegboard.**

### Administration

The participant is seated comfortably at a desk or desk height table. The pegboard is placed in the mid-line position, so that the board is at the edge of the table and the indentation containing the pegs is farthest away from participant.

### Flipchart Message

#### **Pegboard**

This is a timed task involving thinking and manipulating small objects. You will go straight into the task, after I demonstrate how to do it.

### Instructions and demonstration

This description is for participants whose dominant hand is their right hand. Instructions are reversed for left-handed participants. The dominant hand trial is first, followed by a non-dominant hand trial.

*“This is a pegboard and these are the pegs.”* (Indicates each while speaking.)

*“All the pegs are the same. They have a groove, that is, a round side and a square side and so do the holes in the board. What you must do is match the groove of the peg with the groove of the board and put these pegs into the holes like this.”* (Demonstrates filling the top row while speaking, then removing the pegs and putting them back in the tray.)

*“When I say go, begin here,”* (indicating the top-left hole) *“and put the pegs into the board as fast as you can. Fill the top row completely from the left side to the right side. Do not skip any holes. Continue to move down one row at a time, filling each row the same way you filled the top row. Any questions? As fast as you can then ready, go.”*

As suggested in the manual, participants may be encouraged to work faster, or instructed to keep their “other” hand on their lap during the trial if they show a tendency to want to use both hands.

### Scoring

The length of time required to perform each trial is made in seconds. Time begins when the instruction is given to “go” and ends when the last peg is placed. A second score is the number of “drops”. Drops do not include intentionally placing, or intentionally setting down and repositioning of the peg in order to manipulate it. As pegs can be placed incorrectly, a third score is the number of pegs correctly placed in each trial. If any trial takes longer than five minutes, the

participant is instructed to end the trial and a score of "1" = incomplete, is recorded for that trial.

### **13. Closing the Session**

The participant is given the opportunity to comment or question at the conclusion, then thanked and given the envelope with thanks form Massey University.

## **APPENDIX O**

### **Attribution of Participants' Quotes**



10 November 2004

Dear Rachel

**Mercury and Venus Research – Quote from PQ#136**

You may or may not remember but when you signed the consent form to participate in this project, I said that if I wanted to directly quote anything from our meeting or the questionnaire, then I would write and ask how you want me to refer to you.

I have chosen to include the quote below, from your questionnaire, to illustrate a point. At present none of the quotes are attributed to anyone but say, "One participant explained it like this..." or "A typical comment was..." (or similar) and then the quote. Quotes are indented and italicised to set them apart from my writing.

I will leave the introduction to your quote like that, but I can add either a pseudonym, or some part of your name, if you wish. Please let me know by 30 November at the latest. After that, if I have not heard from you, your quote will have only the generic introduction.

My expectation is that most people will be happy to have only the generic introduction. However, if you feel you would like your quote to be attributed to you in some way, then that is your right and I will see to it.

The Mercury and Venus study has been completed for some time, but I have not yet submitted my PhD thesis for examination, so I have not released any results as yet. Attributing the quotes is one of my last tasks before submitting, so the summary will be available next year.

Your quote is,

*"Heaps of spills Races with it."*

Best Wishes

Linda Jones

#105

**Mercury and Venus Project – Quotes.**

Please cross out whichever two do not apply, and supply names (and iwi) where appropriate.

1. I prefer to have the generic introduction such as:

~~A typical comment was... "your quote" Or As one participant said ... "your quote"~~

2. Please refer to me after my quote as the pseudonym:

~~\_\_\_\_\_~~

3. Please refer to me after my quote by the following part of my name:

"Sue"

Please return to Linda in the stamp-addressed envelope provided.

Thank you