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A STUDY OF THE BACTERIOLOGICAL QUALITY OF BOTTLED AND TAP WATER IN CEBU CITY, PHILIPPINES

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

Master of Environmental Management

at Massey University, Manawatu, New Zealand



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2014

Abstract

A study was conducted in the mega urban centre of Cebu City, Philippines between July and October 2013, with the aim of assessing the bacteriological quality of bottled and tap drinking waters. The study was performed during the warm, rainy season, when prevalence of diarrhoea linked to bacterial contamination of water supply is usually at its highest level in tropical countries. The bacteriological tests performed on the water samples were: isolation of *E. coli*, thermotolerant coliforms, total coliforms, and heterotrophic plate counts. In addition, sanitation programs applied by bottled water manufacturers and the local water system supplier were surveyed by means of a questionnaire. The study focussed on bottled water brands with the greatest combined market share in the study area, and the household taps surveyed were located in villages with the greatest number of local water supply concessionaires.

The results indicated the presence of bacteria in both bottled and tap water samples. A considerable number of bottled water samples from one brand were positive for heterotrophic plate count bacteria. On the other hand, positive tap water samples collected from one household were positive for *E. coli*, thermotolerant coliforms, total coliforms, and the HPC bacteria. Multivariable Poisson regression modelling indicated a significant variability in heterotrophic bacterial counts between production batches of bottled water. For the tap water samples, statistical analysis was not indicated because all contaminated samples belonged to a single household tap and were collected on one sampling occasion.

In regard to sanitation programs, the municipal water supplier and all except one bottled water manufacturer reported the application of Good Manufacturing Practice and Quality Control programs in the production plant. Interestingly, the only bottled water manufacturer which did not respond to the survey questionnaire manufactured the only brand consistently showing positive bacterial counts and failing the Philippine regulatory standards. It is concluded that a number of factors associated with bacterial contamination in the study area require close monitoring by bottled water manufacturers, water suppliers, and health authorities.

Preface

'Because water is life,

Water quality reflects the quality of life'

- From the Author

Acknowledgments

I wish to thank the following individuals and organizations for making this study a success:

- To my wife and daughter who showered me with love and inspiration while I am doing this Master's program in New Zealand;
- To the New Zealand Ministry of Foreign Affairs and Trade (MFAT) who provided me this Post-Graduate Studies scholarship through the NZAID/NZASA program;
- To my research supervisors Dr. Alex Grinberg and Prof. Nigel French. In particular, I would like to acknowledge my Chief Supervisor Alex Grinberg for his continuous support and guidance;
- To my colleagues, friends, and mentors in Palmerston North who supported me throughout my stay in New Zealand;
- To the Department of Science and Technology – Regional Office VII, Philippines who provided the microbiology laboratory facility and logistics for my data collection;
- And most of all, to the Lord God Almighty for the blessings of knowledge and wisdom to complete this research project.

Dedication

I dedicate this study to my mom who passed away while I am writing this thesis

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List of Abbreviations

ABWA	Asia Middle-East Bottled Water Association
ABWI	Australasian Bottled Water Institute
AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
APHA	American Public Health Association
AWWA	American Water Works Association
BAM	Bacteriological Analytical Manual
BGLB	Brilliant Green Lactose Broth
CAC	Codex Alimentarius Commission or Codex
CC	Total Coliform Count
CCP	Critical Control Point
CFR	Code of Federal Regulations
CFU	Colony-forming units
CPDO	Cebu City Planning and Development Office
DOST7-RSTL	Department of Science and Technology - Regional Office VII – Regional Standards and Testing Laboratory

EC	European Council
ECC	<i>Escherichia coli</i> count or <i>E. coli</i> count
EC medium	<i>E. coli</i> medium
EEC	European Economic Community
EFSA	European Food Safety Authority
EMB	Eosin Methylene Blue
EPA (US)	Environmental Protection Agency (United States)
ESR (NZ)	Institute of Environmental Science and Research (New Zealand)
EU	European Union
FDA (US)	Food and Drug Administration (United States)
FEFO	First-to-Expire, First-Out Policy
FGD	Focus Group Discussion
FSMS	Food Safety Management System
GHP	Good Hygienic Practices
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis and Critical Control Points
HPC	Heterotrophic plate count

IBWA	International Bottled Water Association
IMViC	Indole, Methyl Red, Voges-Proskauer, Citrate
ISO/IEC	International Organization for Standardization / International Electrotechnical Commission
LTB	Lauryl Tryptose Broth
MCWD	Metro Cebu Water District
MPN	Most probable number
MR	Methyl Red
MTFT	Multiple-Tube Fermentation Technique
NSF (US)	National Sanitation Foundation (United States)
OECD	Organization for Economic Cooperation and Development
PCA	Plate Count Agar
PCR	Polymerase Chain Reaction
PET	Polyethylene Terephthalate
Phil. DOH	Philippine Department of Health
Phil. FDA	Philippine Food and Drug Administration
PNS	Philippine National Standards
PRP	Prerequisite Programs

PVC	Polyvinyl Chloride
QMS	Quality Management System
SMEWW	Standard Methods for the Examination of Water and Wastewater
SOP	Standard Operating Procedure
SSOP	Sanitation Standard Operating Procedure
TTCC	Thermotolerant Coliform Count
UV	Ultraviolet radiation
VBNC	Viable but non-culturable
VP	Voges-Proskauer
WEF	Water Environment Federation
WHO	World Health Organization

Glossary of Terms

AIC	the 'Akaike Information Criterion' used as index of the relative quality of a statistical model for a given set of data which provides a measure for model selection; the lower the AIC, the better is the fit of the model for a given data set
Allochthonous	microorganisms which are not normally found in the source water and, hence, only introduced via contamination
Autochthonous	microorganisms that occur naturally in the source water
Bacteria	single-celled prokaryotic living microorganisms comprised of either beneficial, spoilage, or pathogenic (disease-causing) members
Batch	a specific quantity of a product intended to have uniform quality and character, within specified limits, and produced under the same manufacturing cycle and order
Biofilms	microbial communities resulting from aggregation of bacterial cells that are attached to surfaces and enclosed in their self-produced exopolysaccharide matrix
Bottle	a vessel made of plastic or glass used to contain a water sample
Bottled water	commercially available drinking water delivered in various bottle packaging formats

Brand	the name of a product uniquely identified and commercially manufactured by a particular company
Concessionaire	a person or business who is given the right to operate, sell, or use something on property or resource (e.g. water) owned by someone else
Effervescence	producing or emitting small bubbles of gas in a liquid
Household	one or more persons living in the same dwelling place or house
Indicator organism	microorganism which fulfil a set of criteria that indicates the presence of other organisms especially pathogens
Lot	a collection of units of a product or a specific identified portion of a batch supposedly produced under identical manufacturing conditions from which a sample is to be drawn
Oligotrophic	environments that have low nutrient concentration
Pathogen	microorganism that causes a disease
Poisson distribution	statistical probability distribution of counts that randomly occur in a given interval of space or time
Potable	drinking water that is safe and wholesome for human consumption

Prototrophic	No specific nutritional requirements but mostly inorganic compounds
Psychrotrophic	Adapted to lower temperatures of 25 - 30°C
Residual chlorine	the amount of chlorine remaining in the water after a given contact time of oxidizing organic matter
Sample unit	the individual portion or container (individual bottles) of water taken as part of the sample and from which one or more analytical units is drawn for analysis
Sample	total number of individual sample units (bottles) drawn from a lot which will be tested in accordance with a specific sampling plan and method(s)
Sampling occasion	the period of time where all samples from all water types are collected
Sampling	the activity of collecting samples from the field based on the sampling plan and schedule
Store	a commercial establishment selling goods (e.g. bottled water) to the public
Tap water	drinking water delivered through valves, spouts, or faucets usually at the end of a municipal pipe distribution system such as in households

Turbidity	the haziness or cloudiness of a liquid caused by high amounts of individual particles
Unit of sampling	the volume of water taken as required for a particular sample unit (e.g. 500ml of tap water or 500ml packaged bottled water brand)
Village	the smallest administrative division in the Philippines, also known as 'Barangay'