Measurement and Control of Odorous and Polluting Gases from Wastes

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Abstract

Management of odorous and polluting gases from wastes is a world-wide challenge. Gaseous losses of nitrogen and sulphur from stored manure and sewage biosolids can be considerable, and these gaseous are offensive and undesirable. Hence, it is necessary to quantify these gas emissions from waste to determine the impact on air quality as well as to find out the efficient and effective control measures.

A field observation indicated that amendment of dairy manure with natural materials, such as soil and wood shavings can reduce gaseous emission. To understand the mechanism for reduction of gaseous emissions and to select an optimum natural medium, laboratory incubation studies were conducted to measure the gaseous loss of ammonia (NH_3) and hydrogen sulfide (H_2S) from stored manure and biosolids under aerobic and anaerobic conditions for a period of about 7 weeks. Natural materials such as soil, untreated pine bark, sawdust and wood savings, were evaluated for their potential to reduce these gaseous emissions.

Ammonia emission rate was typically peak within two days of the experiment and declined rapidly under aerobic and anaerobic condition from stored manure and sewage biosolids. NH_3 emission was higher during aerobic than anaerobic incubation but in the case of biosolids the difference was very small. The total nitrogen loss due to NH_3 emission was very low. It was around 1.23% from manure and 1.87% from biosolids under aerobic incubation. Around 49 mg NH_3 was emitted from a kg of cattle manure during aerobic incubation and it was 1155 mg from biosolids.

H_2S emissions were higher during anaerobic than aerobic incubation from manure and biosolids. Around 9.2 mg H_2S was emitted from a kg of manure and it was around 150.7 mg from biosolids under anaerobic incubation.

All materials tested were found to have an effect on the NH_3 and H_2S emission. However, pine bark and top soil amendment reduced the emission efficiently. NH_3 emission was reduced by 78% under anaerobic condition when 20g bark was amended

with 100g manure and it was around 56% in biosolids. Soil amendment reduced the NH_3 emission by 50% in manure and 46% in biosolids.

Pine bark reduced the H_2S emission by 80% from manure and by 83.5% from biosolids. Top soil amendment reduced the H_2S emission by 50% from manure and 79% from biosolids.

Therefore, the addition of natural materials, such as pine bark and soil, as amendments to manure and biosolids during storage offers potential for reducing emissions of NH_3 and H_2S.

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Chapter 1 Introduction

1.1 The issue

Emission of odorous and polluting gases from wastes is a world-wide problem as it causes nuisance to public and impacts air quality. The gaseous emissions from wastes can also cause environmental health problems (e.g., ammonia and hydrogen sulphide) and also are implicated in global warming (e.g., methane) and the depletion of the stratosphere ozone layer (e.g., nitrous oxide).

In New Zealand, large quantities of wastes are produced from the agricultural industries (e.g., dairy shed waste) and sewage treatment plants (e.g., biosolids) each year. New Zealand's 4.5 million dairy cows and 4.7 millions beef cattle (Statistics New Zealand, 2002) excrete about 130 million kg of dung and 92 million litres of urine. New Zealand's agriculture is dominated by pastoral livestock systems, and pastures are generally grazed year-round. The return of N to the soil in the form of extremely concentrated animal dung and urine patches can lead to losses of N through nitrate leaching and gaseous emissions (Haynes and Williams, 1993; Luo *et al.*, 1999; Bolan *et al.*, 2004a), thereby causing environmental degradation and reduction in N use efficiency (Ledgard *et al.*, 2003). Nitrogen leaching and gaseous emissions from animal excreta are likely to be highest during wet winter period compared to those in other seasons (Luo *et al.*, 2000; de Klein *et al.*, 2001). To reduce this problem improved winter management practices, including the use of stand-off pads have been introduced. Under this system excreta are collected, stored and returned to pasture as manure. It is likely that excreta would be stored for extended periods prior to field application. During storage, the turnover of organics and nutrients may change the excreta composition significantly, and the loss of dry matter, due to conversion of C, N and S compounds into gaseous forms, may be considerable (de Klein and Ledgard, 2001).

Biosolids is a nutrient rich organic material resulting from the treatment of sewage sludge. Biosolids production has increased in recent years. New Zealand currently produces around 77,000 dry tonnes per annum (NZWWA, 2003) and this amount will be increased by at least another 10,000 tonnes in 2011 (Speir *et al.*, 2003).

Therefore, intensive animal operations, including dairies and cattle stand-off pads, and sewage waste management systems are likely to produce emissions of odorous gases, such as NH_3, H_2S, volatile organic compounds (VOCs), and "greenhouse" gases including nitrous oxides, carbon dioxide and methane. Studies of these emissions are important, not only to assess the degree of odour nuisance, but also because some components are known to have detrimental effects on animals and humans.

1.2 Odour release and measurement

The human olfactory sense organ is highly sensitive and capable of distinguishing about 10,000 different odours, some at extremely low concentrations (Amore *et al.*, 1964). Odour is perceived by our brains in response to chemicals present in the air we breathe. Humans have a sensitive sense of smell and can detect odour even when chemicals are present in very low concentrations. Most odours are a mixture of many chemicals that interact to produce what we detect as an odour (Stuetz *et al.*, 2001).

When chemical contaminants discharged to air from either natural or man-made sources are detected by the olfactory senses then the individual is said to have perceived an odour. Because the olfactory nerve cells are directly connected to the brain, an exposed individual can often have a strong and immediate response.

The lowest concentration of a substance that can be detected by 50% of the population is termed its odour threshold (Bernd and Koster, 1998). This is not an absolute value but is statistically calculated from a sample of individual responses. Published odour thresholds vary due to differing measurement techniques and improvements in measurement technology. Threshold values of some common odorous substances are given in Table 1.1.

When the odour level exceeds the threshold level, nuisance is said to be occurring. Agricultural and industrial processes involving organic materials can be responsible for many odour complaints. Historically, activities likely to cause nuisance odour have been situated away from populated areas. However, urban spread means that previously isolated activities gain access to neighbours whose quality of life can be affected by unpleasant odour. Therefore, many agricultural and waste treatment industries face the challenge of odour management.

Table 1.1 Odour threshold and quality of some common odorous substances (Haug, 1980).

Compound	Threshold ($\mu g\ l^{-1}$)	Quality
Acetaldehyde	4	Pungent, fruity
Allyl mercaptan	0.05	Strong garlic, coffee
Ammonia	37	Sharp, pungent
Crotyl mercaptan	0.029	Skunk like
Dibutylamine	16	Fishy
Dimethyl sulphide	1	Decaying vegetables
Hydrogen sulphide	0.47	Rotten eggs
Skatole	1.2	Faecal

Clean air is an important part of a healthy, sustainable environment. It is also protecting people from offensive smells that can affect their daily activities and well being. New Zealand will continue its initiative in protecting its environment from the harmful effects of contaminants including air pollutants and will place increasing importance on whole ecosystem biological criteria to maintain bio diversity. So minimisation of odour emission from sewage treatment works and the agricultural industry, thereby protecting the air quality is one of the most significant challenges for New Zealand in future.

Gaseous emission processes from wastes and the factors affecting such emissions have not been fully studied. Understanding the gas emission processes and quantification are necessary to develop best management practices (BMP) and techniques to reduce such emissions as well as evaluating the efficiency of abatement technologies. General approaches to estimate the strength or intensity of odours include:

a. Sensory methods that involve collecting and presenting odour samples to human panelists (diluted or undiluted) under controlled conditions, e.g., dynamic olfactometers.
b. Measurement of concentrations of specific odorous gases (directly or indirectly).

1.3 Odour management and control

New Zealand regulations on discharges to air were covered by the Clean Air Act, 1972. The second schedule of this act defined activities that required 'Clean Air Licences'. These licences were based on 'best practicable means' of control and administered by the Department of Health. Municipal waste treatment processes did not require a license under this act (MfE, 1995).

The Resource Management Act (RMA) introduced in 1991, established a set of principles and guidelines for issuing resource consents for any activity, which were based on the effect of the activity on the environment. Regional authorities are responsible for administering the RMA and produce a 'Regional Air Plan'. According to RMA (1991) contaminants include any substance or energy or heat that either by itself or in combination with the same, similar or other substance or energy or heat when discharged onto to into land or into air, changes or likely to change the physical, chemical or biological constitution of the land or air onto or into which it is discharged. While the RMA provided temporary relief (control) for existing discharges, municipal waste treatment plants also have a duty to 'avoid, remedy or mitigate adverse effects' (MfE, 1995).

Some odour can be reduced by optimising control of reticulation and treatment processes and good treatment design, but technologies are required to effectively control odour emissions. Amendments of natural materials have become a popular method for treating odours because they are relatively inexpensive, and do not involve handling hazardous chemicals. Odorous compounds such as H_2S, mercaptans and NH_3 are adsorbed to the medium and then oxidised biologically to harmless compounds such as carbon dioxide, water, mineral salts and biomass. Common media used as amendments include soil, sand, peat, compost, bark, activated charcoal and combinations of these (Luo *et al.*, 2004).

1.4 Research objectives

The overall objective of the study is to quantify the gaseous emissions of NH_3 and H_2S from organic by-products and examine the potential value of natural materials in mitigating gaseous emissions. The specific objectives of this study include:

- Carry out a field study using natural materials to observe the ability to control gas emission from a cattle manure bunker.
- Determine the NH_3 and H_2S emission from biosolids and cattle manure.
- Understand the process for gaseous emission and aeration affect on gaseous emissions from biosolids and cattle manure.

- Evaluate the effect of amendment of biosolids or cattle manure with natural materials on the NH_3 and H_2S emissions.

1.5 Thesis layout

This thesis consists of six chapters. In Chapter 1, the environmental and health issues relating to gaseous emissions from organic wastes such as manures and biosolids are discussed. In Chapter 2, the literature relating to odour, its environmental effect and treatment is reviewed, with particular emphasis on measurement techniques and control measures. A field observation study was conducted to monitor gaseous emissions from manure bunkers, which indicated that the amendment of dairy manure with natural materials, such as soil and wood shavings can reduce gaseous emissions. The results from this study are described in Chapter 3. To understand the mechanism for the reduction of gaseous emissions and to select an optimum natural medium, laboratory incubation experiments were conducted to measure gaseous loss of NH_3 and H_2S from stored manure and biosolids under aerobic and anaerobic conditions. The suitability of natural materials such as soil, untreated pine bark, sawdust and wood shavings for treating NH_3 and H_2S were investigated in this study. Chapter 4 describes the materials and methods used in this laboratory investigation. In Chapter 5, the results of these investigations are presented and discussed. Chapter 6 gives the major conclusions from this study and the future research directions.