M.A. SPENCE PROSECUTION

EVIDENCE OF NADARAJA SELVARAJAH

Qualifications and Experience

1.1 My name is Nadaraja Selvarajah. I hold a Bachelor of Agricultural Science with honours majoring in Soil Science from the University of Peradeniya, Sri Lanka and a Doctor of Philosophy in Soil Science obtained from Lincoln University, New Zealand.

1.2 I have 12 years experience in teaching and conducting tutorials and laboratory demonstrations for undergraduates in Chemistry, Physics and Soil Science. During this period I have undertaken research into various aspects of Soil Science. Since December 1992 I have worked for the Waikato Regional Council as a Soil and Water Scientist within the Resource Information Group. Since July 1995 I have taken up the Programme Manager, Agriculture and Forestry position within the Resource Use Group.

1.3 My Soil Science research focused on soil nitrogen transformation (chemistry and soil microbiology) in agricultural soils. I have evaluated and developed methods for assessing nitrogen mineralisation and ammonia volatilisation potentials for New Zealand agricultural soils. I have presented 11 conference research papers in New Zealand, one in the U.S.A. (Seattle) and have also published a research paper in an international journal. Since I joined Waikato Regional Council I have performed several Environmental Impact Assessments on land-based waste treatment systems in the Waikato region and provided frequent technical advice to the Council related to effluent management including dairy farm effluent management.

Scope of Evidence

1.4 My evidence will assess and discuss the environmental impact of dairy farm effluent discharge into the ponded area at Mr Spence’s farm property located on Bowman Road, Mangapiko. I must emphasise that my evidence is based on the existing general information on the impact of effluent discharge onto or into land in New Zealand and overseas, site hydrogeological information and some site farm management information. I have not performed any onsite environmental monitoring investigations. In my opinion detailed field assessments are preferable to that of desk-top study approaches. However, if such a detailed field study were to be performed it should have been performed during the period of dairy farm effluent discharge into the ponded area. Moreover, due to the complexity associated with point-source pollution assessment, any detailed field investigation of groundwater contamination from a point-source of pollution requires several groundwater monitoring bore constructions and sampling and analyses of ground water, raw farm effluent and pond water quality. Considering the deep water table prevailing in the Mangapiko area such an investigations could have been very expensive. For example construction of a 50-60 metre depth monitoring bore will cost from $3000 to $4000.

2. Environmental effects of Mr Spence's untreated dairy farm effluent discharge to the ponded area

Effluent strength

2.1 Dairy farm effluent typically contains about 99% of water and the balance 1% as nitrogen (both organic and inorganic), organic carbon, phosphorus, potassium and sulphur. Organic carbon is present as dissolved and undissolved forms which contributes to a large proportion of Biochemical Oxygen Demand (BOD) when effluent is discharged, into soil or water. Dairy farm effluent also has a substantial amount of microorganisms such as bacteria, fungi and virus. Among the bacteria and virus the most significant forms from the environmental view point are the pathogens. Generally bacteria such as faecal coliforms or enterococci are used as indicators to assess the extent of faecal contamination of recreational or drinking water. The Drinking Water Standards for New Zealand suggest that no faecal coliforms should be detectable in 100 millilitres of water (Ministry of Health, 1995). The typical amount of faecal coliforms found in raw dairy farm effluent is 2×10^7 per 100 ml.

2.2 The 1993 resource monitoring record indicates that the number of cows milked on Mr Spence's property was 120. According to Mr Spence he milked only 70 cows during 1994 season and hence I have used the 1994 figure for effluent loading estimates. Assuming an effluent volume of 50 litres/cow (Agricultural Waste Manual, 1984) and a lactation period of 8 months a dairy farm with 70 cows is likely to generate about 336 kg nitrogen in the milking parlour. This estimate is based on the recent AgResearch effluent research which indicated that 0.04% of the dairy farm effluent is nitrogen.

2.3 **Potential effects of the discharge of raw dairy farm effluent into the ponded area on the pond and ground water quality**

Pond water quality

It appears that the major source of pond water could be from perched water table caused by the subsurface water flow from the rolling grass land surrounding the ponded area. Such a ponded area is likely to dry-off during summer season due to (a) evaporation, (b) downward percolation (c) little or no contribution from subsurface water flow and (d) low rainfall input. If the pond is not accessible by the grazing animals the quality of the water can be expected to be 'good', although the water may not be suitable for human consumption due to potential surface run-off of animal excreta into the pond during heavy rainfalls.

2.4 Mr Spence's milking parlour is located on a relatively elevated area which is approximately 60 metres from the pond. When the milking parlour is washed each washing could generate about 3500 litres of raw effluent. The effluent would have flowed along the drainage located between the pond and the milking parlour and a major proportion of the effluent would have entered the pond. A small proportion of the effluent (both solids and liquid), however, could be retained into/onto the soil in the drainage area (photographs Nos 1-7).

2.5 If the dairy farm effluent is to be discharged into an environment other than pasture, it must be treated using an approved treatment system by Environment Waikato prior to the discharge. Both two pond and barrier ditch treatment systems are approved systems to treat and discharge dairy farm effluent. These systems must have appropriate dimensions according to the herd size and must be sealed to minimise effluent seepage. In Mr Spence's case raw effluent was discharged into the ponded area without any pre-treatments. Consequently, continuous use of the ponded area as a raw effluent disposal facility would have resulted in severe surface water contamination and hence the *water* quality would have reached the quality of a typical dairy farm effluent treatment pond *effluent*.

2.6 Visual assessment during my site visit on 29 August 1995 indicated that there was no overflow of the pond to the adjacent paddock through the culvert beneath the raceway which was located on the southern aspect of the pond. Considering the heavy rainfall during the 1995 season (i.e. January-August 1995) (1141.5 mm compared to the rainfall normal from 1961 to 1990 of 888.0 mm) and no apparent overflow of the pond, it appears that there is a substantial amount of downward percolation of pond water into the ground. The rainfall data have been obtained for the Ngahinapouri area from the National Institute of Water and Atmospheric Research data-base since there have been no rainfall data available for Mr Spence's farm site. These observations suggest that the ponded area was not sealed and that when raw effluent is discharged into the ponded area it is likely to seep into geological materials beneath the pond.

2.7 **Ground water quality**

Bore logs obtained from Environment Waikato database within 1 km radius of Mr Spence's site indicate that most bores in the area are deep (i.e. 57-81 metres). The geological information available for some of these bores suggest that the geological material found in this area is predominantly pumice (e.g. a bore located on the corner of Bowman Road and Day Road (Map Ref. S15:100563) had pumice down to 73 metres). This observation confirms my assumption that the pond is likely to lose a substantial amount of water into the ground through percolation. The percolated water will eventually reach ground water table.

2.8 During the percolation of this contaminated water into soil, contaminants can move with percolating water. Depending on the nature of the flow pathways different contaminants can migrate downwards. Generally suspended solids are filtered before the percolation occurs. Under saturated conditions contaminants such as bacteria can also move with percolating water for a long distance. If there are preferential flow pathways most contaminants can migrate relatively longer distances in soils.

2.9 The ground water contaminants of major concerns here are ammonium-nitrogen, nitrate-nitrogen and bacteria. Generally nitrate-nitrogen is not present in raw dairy farm effluent. However, when raw effluent is applied into soil or water nitrate-nitrogen forms from ammonium-nitrogen through biochemical oxidation process. Ammonium-nitrogen is released initially from urea-nitrogen which is present in animal urine. Approximately 55% of the nitrogen ingested by dairy cow is excreted as urea-nitrogen and 35% as dung nitrogen and 10% is converted into milk protein. Decomposition of dung-nitrogen will also release ammonium-nitrogen. However, since dung-nitrogen is mainly undigested plant protein materials it requires several days for decomposition to release ammonium-nitrogen. Ammonium-nitrogen (NH_4^+) is a positively charged plant nutrient whilst nitrate-nitrogen is a negatively charged plant nutrient (NO_3^-). Since most soil particles are negatively charged, ammonium-nitrogen is readily adsorbed by soil hence it is less mobile compared to nitrate-nitrogen. Less adsorption of nitrate-nitrogen by soils means nitrate-nitrogen can move with percolating water. Ammonium-nitrogen moves in soil when the soil environment is saturated with ammonium-nitrogen. Under anaerobic conditions ammonium-nitrogen is stable. However, during aerobic conditions ammonium-nitrogen can be transformed into nitrate-nitrogen by soil bacteria.

2.10 In the case of excessive effluent discharge onto land an anaerobic layer of effluent prevails where most dung-nitrogen is present. As the solids are filtered and contaminated water percolates ammonium-nitrogen and bacteria are transported downwards. As the wetting front advances ammonium-nitrogen is oxidised to nitrate-nitrogen form creating a more mobile ground water contaminant. There have been several field studies conducted overseas on the extent of dairy farm effluent treatment pond seepage. The only field seepage study conducted in New Zealand was that commissioned by Environment Waikato (Ray *et al*., 1995). This preliminary investigation showed that a 'sealed' anaerobic dairy farm effluent pond in the Waikato region can leak approximately 1000 litres of effluent per day. The implication of this study is that effluent discharged to unsealed land can leak much greater volume of contaminant into ground water. Most overseas seepage studies demonstrated that although the environmental impact of seepage is minimal for soils with predominantly high silt or clay, the effects could be serious in coarse geological materials. For example an eight year old dairy farm effluent treatment pond located in coarse soils discharged nitrate-nitrogen at 100 mg/litre level (Korom and Jeppson, 1993).

2.11 In my opinion the geological and hydrological nature of Mr Spence's site provides an environment that is conducive for surface discharged effluent to contaminate ground water. Considering the deep water table on site, it can be argued that the only contaminant that is likely to reach ground water is nitrate-nitrogen. I emphasise that under unsealed conditions with the presence of coarse geological materials effluent can create a contaminant plume which will also contain faecal microorganisms. For example a ground water investigation conducted at a Whiritoa site showed that ground water drawn from 50 metre depth was contaminated with faecal coliform bacteria. Preliminary studies showed that the source of contamination may have been the natural wetland 150 metres upstream the borehole. The wetland water was contaminated with faecal materials from grazing animals upstream of the wetland.

2.12 From the viewpoint of nitrate-nitrogen contamination there is a potential for majority of the effluent-nitrogen to be converted into nitrate-nitrogen. In my opinion such a nitrogen input is not environmentally sustainable. My estimate for nitrate leaching in the Hamilton Basin area with predominantly dairy pastoral farming is approximately 60 kg nitrogen/ha/year (Selvarajah *et al*., 1994). Such a contamination occurs from non-point sources such as animal urine patches. The estimate of 60 kg nitrogen/ha/year from grazed dairy pasture is considered as high because this estimate was made for worse environmental conditions (i.e. high rainfall). A recent field study conducted at Ruakura indicated that an annual leaching of 12 and 74 kg nitrate-N/ha/year occurred to date from grazed dairy pasture without fertiliser nitrogen application (Ledgard *et al*., 1996). The study implies that leaching of nitrate-nitrogen can vary greatly depending on the weather conditions, however, on average 43 kg nitrate-nitrogen/ha/year could leach from grazed dairy pasture system in the Waikato region.

2.13 Leaching of nitrate-nitrogen from grazed dairy pasture system has been observed by many New Zealand and overseas soil scientists. It has been widely acknowledged by the scientific community that regardless of adopting best management practices there will be ground water contamination due to nitrate-nitrogen leaching from the grazed dairy pasture system. The best management practices will help minimise the extent of the contamination, not avoiding it. A compilation of the ground water quality information by Environment Waikato indicates that in the Hamilton Basin where dairy and dry stock are the predominant land uses, more than 50% of the 92 bores sampled had nitrate-nitrogen levels above drinking water quality standard (Selvarajah *et al*., 1994). These observations imply that adverse environmental effects can result with the leaching of estimated 43-60 kg nitrate-nitrogen/ha/year under grazed dairy pasture system. Such an effect is referred to as 'non-point source of pollution'.

2.14 In the case of Mr Spence's system it is considered as a 'point-source of pollution' hence the pollution is confined to relatively small area with greater intensity of pollution, causing a plume effect. According to my estimates on an annual basis of the 336 kg nitrogen discharged, there will be at least 200 kg nitrogen potentially available for leaching.

2.15 I would argue that even if Mr Spence's effluent discharge is considered as onto pasture or bare ground, high nitrogen loading rate combined with poor nitrogen removal mechanisms will still result in high nitrate contamination. The examples for excessive effluent discharges onto pasture or bare grounds are evident from the photographs obtained by Mr Stacey Bunting on 1 December, 1994 (photo numbers 12-15) on 22 March, 1995 (photo numbers 22 and 23) and on 29 August 1995 (photo numbers 26-32). I know several land treatment systems in New Zealand where high nitrogen loading rates have resulted in severe ground water contamination.

2.15 The ponded area was irregular in shape, however, the approximate dimensions were 65 m x 15 m and hence it was estimated that the ponded area could be about 975 m^2. These measurements were obtained by Mr Martin Keep, Environmental Field Officer, Environment Waikato on 24 April 1996. Assuming a disposal area of 975 m^2, the annual loading rate is estimated as 22 times greater than that is prescribed in the Environment Waikato's dairy farm effluent rules (i.e. 336 kg N instead of 15 kg according to the rules).

2.16 I conclude that the use of the ponded area at Mr Spence's farm for raw dairy farm effluent discharge would have caused severe surface water and ground water contamination within the Mangapiko catchment.

3. Appendix

Nitrate in ground water -its environmental, health and economical effects

Health

(a) Methaemoglobinaemia

3.1 For many years nitrate has been considered as a contaminant. Many human diseases have been linked to the presence of nitrate in drinking water (e.g. methaemoglobinaemia or `blue baby syndrome', gastric cancer, hypertension). It has been proven conclusively that infants less than 3 months old are very susceptible to nitrate in drinking water. This is because they have not developed normal haemoglobin in blood which is predominantly a protein material that helps to transport oxygen from the lungs to other organs. Young infants have a high proportion of `faetal haemoglobin' which binds readily with *nitrite* (NO_2) produced from nitrate (NO_3) in the digestive system. Consequently, the oxygen supply in the body is reduced and when not treated results in death. 3.2 The current New Zealand drinking water standard classifies nitrate as a contaminant and specifies a maximum acceptable level of 11.3 mg nitrate-N/litre (Ministry of Health, 1995). Except for a recent case which was suspected to have been associated with ground water contamination of nitrate in Pukekohe, no other methaemoglobinaemia cases had ever been linked with nitrate contamination in New Zealand. However, Burden (1982) states the following in his review on nitrate contamination of aquifers:

> To date, no cases of methaemoglobinaemia have been reported in New Zealand but this could, at least in part, result from the fact that methaemoglobinaemia is not classified as a `notifiable' disease by the New Zealand Health Department. Bottled-fed infants (~3 months) are also predisposed to the Sudden Infant Death Syndrome (cot death), a

condition of oxygen starvation, from which about 3 per 1000 infants from most Europeanised societies die (Money 1978). Many explanations for the occurrence of the syndrome have been offered but none appear satisfactory. Because of the similarity in symptoms it is possible that methaemoglobin levels may predispose infants to the Sudden Infant Death Syndrome (WHO 1978).

(b) Other human diseases caused by nitrate

Studies related to carcinogenic substances require many years of systematic research involving accurate analytical methods. It should be noted that it took a considerable amount of time, expense and effort to prove nicotine was a carcinogenic substance. Although I agree that there is no *firm* evidence to link nitrate in water with cancer, until researchers prove conclusively that nitrate in drinking water does not cause cancer we cannot afford to take such a risk. Burden (1982) quoted that N-nitroso compounds which could be formed from nitrate were proven to be carcinogenic in various species of laboratory animals. He indicates,

> "...there is no reason to suppose that humans are resistant to these substances...".

3.3 I must emphasise that since the publication of Burden's (1982) review there have been more diseases identified that have possible links with nitrate in drinking water (e.g. leukaemia, non-Hodgkin's lymphoma (NHL)). More diseases have been linked with dietary exposure to N-nitroso compounds (e.g. cancers of the stomach, oesophagus, nasopharynx and urinary bladder and brain tumours in children) (Weisenburger, 1991).

3.4 **(c) Animal health**

Nitrate in drinking water or food materials could seriously affect animal health as well. The Australian and New Zealand Environment and Conservation Council drinking water limit for stock water is 30 mg nitrate-N/litre (ANZECC, 1992).

Environment and national economy

3.5 Apart from being a potential risk for health, ground water nitrate can also reach rivers and streams through subsurface flow. This can result in algal blooms and the subsequent loss of aquatic life and degraded aesthetic appearance of rivers and streams. Many of these waterways are used for recreation which bring a substantial amount of revenue into the region from tourists. Thus protection of these waterways from nutrient enrichment is vital.

3.6 More importantly a country's food quality is judged mainly by its environmental standards and conditions. New Zealand has always been considered as `clean and green'. Such a global view has given extra access to the international market for food products. This could also mean that our food products could fetch higher prices due to the world wide demand for ‘clean and green’ products, which in turn means that there is little or no need for New Zealand to adopt unsustainable practices to obtain profit. I believe that our dairy companies are well aware of these benefits like any other food export industry and make every effort to *maintain* or *enhance* the existing environmental conditions in New Zealand.

3.7 Until more research work is done to prove nitrate effects on health and environment, I do not consider it appropriate to contemplate or even debate nitrate contamination of the environment. The lessons learnt from the USA and Europe indicate that the long-term risk to human health and national economies associated with ground water nitrate pollution, far outweigh the short-term financial benefits.

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