IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of applications by **NEW ZEALAND DAIRY GROUP** to the **WAIKATO REGIONAL COUNCIL** for resource consents for the proposed Lichfield Project

EVIDENCE OF NADARAJA SELVARAJAH

1. INTRODUCTION

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.

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 5 conference research papers in New Zealand and have also published a research paper in an international journal. I have performed several Environmental Impact Assessments on land-based waste treatment systems in the Waikato region.

Scope of Evidence

1.4 My evidence will discuss New Zealand Dairy Groups' (NZDG) assessment of the proposed dairy factory wastewater irrigation system and its impacts on the environment at the Lichfield site. This assessment will comprise the following:

(a) Suitability of the site for waste water irrigation
(b) Hydraulic loading
(c) Nitrate in ground water - its health, environmental and economical effects
(d) Nitrogen loading rate
(e) Recommendations

2. Suitability of the site for waste water irrigation

2.1 The soil type (Taupo sandy silt loam) is suitable for irrigation due mainly to its high porosity and hydraulic conductivity. The soil is also capable of readily immobilising very high quantities of phosphorus applied through the proposed waste water irrigation. However, information is still required (a) on the possibility of surface runoff due to high rainfall or frost and soil clogging caused by sodium and slime accumulation in soil and (b) build-up of a perched water table under the soil layer due to the shallow depth of the underlying ignimbrite rock combined with a high net hydraulic loading ((rainfall + waste water) - evapotranspiration). Visual assessment of the soil profile indicates slight mottling, which is a sign of saturated soil conditions under prevailing environmental conditions at the site. Moreover, there is no information available on the destiny of the overland runoff at the site. Considering the high nutrient and biochemical oxygen demand (BOD) of the waste water, overland runoff of waste water into water ways could cause serious environmental consequences.

3. Hydraulic loading

3.1 The application rate proposed by the applicant is 6 mm/hour. Waste water will be applied for 2 days for approximately 4 hours/day. I consider the spray irrigation system proposed to be excellent in that it is very flexible and enables ready manipulation of loading rates or the duration of application. This is critical during high rainfall where irrigation is performed onto larger areas than usual.

3.2 One of the major driving forces for nitrate leaching is hydraulic loading. High hydraulic loadings accelerate the process of nitrate leaching. High hydraulic loading can also promote biological degradation of nitrate (i.e. denitrification) by reducing oxygen levels in the soil environment. Apart from plant uptake, the denitrification process also helps to reduce nitrate build-up in soil. Denitrification in soil occurs mainly where organic carbon is available. In pastoral soils, the soil layer below the root zone has little or no available organic carbon and hence the potential for denitrification is low in this layer. Consequently, nitrate leached below the root zone is available for ground water contamination. Based on the above process, in porous soils such as the Taupo sandy silt loam, a high volume of waste water application could outweigh the benefit of denitrification due to flushing nitrate away from the zone of denitrification. I will discuss the denitrification process in detail later in my evidence.

3.3 Nitrate is transported via soil water to the ground water aquifer. Such transportation is driven by gravity and diffusion. When there is a lack of soil water, downward movement of nitrate is restricted. Under natural conditions, rainfall assists the downward movement of nitrate. As the irrigated area will be used for grazing, further nitrate and urine-N (mainly urea) leaching will occur from urine patches. I emphasise that if the nitrate residence time in the root zone is to be increased, hydraulic loading per irrigation event has to be optimised to suit the soil type and plant root depth. I have estimated in the staff report that the annual net hydraulic loading (1252 mm) at the Lichfield site is 25% greater than that of the Hautapu (Bardowie) site. I consider the proposed hydraulic loading is too high due to the above reasons and recommend the applicant should either minimise waste water generation or increase the land area available for irrigation.

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

Health

4.1 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.

4.2 The current New Zealand drinking water standard classifies nitrate as a contaminant and specifies a maximum acceptable level of 10 mg nitrate-N/litre (Board of Health, 1989). Department of Health undertakes regular monitoring of community water supplies for nitrate in drinking water. Following an extensive assessment of the last two decades data on ground water nitrate in the Waikato region, Environment Waikato is committed to undertaking a ground water nitrate monitoring programme (Annual Plan 1994-95, Environment Waikato).

4.3 Several comments have been made by Dr. Barnett (section 7 of his evidence) in relation to the human health effects of ground water nitrate. I strongly disagree with the statements made by him for the following reasons:

(a) The reference to the World Health Organisation (WHO) statement "*...only 2.3% of all cases appear to be associated with nitrate levels of between 10 and 20 mg* *of nitrate-N per litre water...*" itself admits that there is risk involved for infant health in consuming water with nitrate-N levels between 10 and 20 mg/litre. Note that the 10 mg nitrate-N/litre standard was set in 1962 by the WHO and U.S. Public Health Service (USPHS). In 1978 the National Academy of Sciences reexamined this standard. The study team concluded (cited by Aldrich, 1980):

> It appears therefore that a level of 10 mg NO_3-N/l (the current U.S. Public Health Service drinking water standard) affords reasonable protection to the majority of newborns against methemoglobinemia derived from nitrate-contaminated water supplies. Purely from the perspective of preventing methemoglobinemia, there is little evidence to support a more stringent drinking water standard. On the other hand, use of water containing 20 mg nitrate nitrogen per liter or more seems likely to increase significantly the number of infants at risk, unless extensive public education programs alert the appropriate populations to avoid ingestion of high nitrate waters by young infants.

More recently, at a nitrate contamination conference Weisenburger (1991) concluded:

> Currently, there is insufficient evidence to permit raising the drinking-water standard above 10 ppm nitrate-nitrogen, whereas there are some indications that the standard provides the necessary safety factor to prevent most acute and chronic health effects of ground water contamination. Any decision to change the standard must await the results of further research.

(b) The reference to Burden's (1982) review paper on nitrate contamination of New Zealand aquifers "*...Burden (1982) reports that at the time of publication of his review no cases had ever been reported in New Zealand...*" is misleading. The statement was taken out of context because Burden (1982) states the following in his review:

> 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).

I must draw your attention to a recent reported infant death case related to nitrate in ground water in New Zealand. Following a prescription the 6 month old infant (who had vomiting and diarrhoea) received glucose and an electrolyte prepared using contaminated ground water (27 mg nitrate-N/litre) at her home in the Franklin area died after developing symptoms related to methaemoglobinaemia (Mr. T. Long, Franklin District Council, pers. comm.).

(c) 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...".

4.3 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).

4.4 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). High nitrate levels in grass can also affect grazing animal health. Recently, deaths of cows linked to high nitrate in grass have been reported in the Waikato region. In this case blood nitrate levels exceeding 25 mg/litre were detected (Ms. A. Dewes, Otorohanga Veterinary Services, pers. comm.).

Environment and economy

4.5 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.

4.6 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 the NZDG is 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.

4.7 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 increasing nitrate loading into 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.

5. Nitrogen loading rate

5.1 Determination of a nitrogen loading rate for any land treatment system is a vital part of water quality management to avoid excessive leaching of nitrate into ground water. I know several land treatment systems in New Zealand where high nitrogen loading rates have resulted in severe ground water contamination. When land treatment systems are combined with grazing, the concept of waste treatment is often questionable, because animal `waste' is created on land which requires further treatment. It is well known that each cow urination event will leave nitrogen equivalent up to 1000 kg N/ha. Due to the complex nature of nitrogen cycling it has been difficult previously to determine an appropriate nitrogen loading rate for a grazed pasture system.

5.2 Fortunately, many years of soil research overseas and in New Zealand have resulted in a better understanding of this complex bio-chemical process. Consequently, we are in a better position to determine environmentally and agronomically sustainable nitrogen loading rates for different farming systems. Using the existing information on nitrogen research, in Europe and the USA, stringent legislation and policies have been set for nitrogen loading rates for land application of waste and nitrogen fertiliser use.

Nitrogen transformations other than denitrification

5.3 Using the existing information, I agree with the estimates of nitrogen removal through animal products and ammonia volatilisation made by the consultants for NZDG. I do not agree with the lowest possible range for clover fixation of nitrogen (0 kg N/ha/year) provided by the consultants. I have discussed this in detail in the staff report. However, the maximum predicted clover nitrogen fixation (60 kg N/ha/year) by the consultants is possible under the given conditions. My conservative (`purposely low') estimate is 40 kg N/ha/year.

Denitrification

5.4 The factors influencing denitrification have been explained in detail in the staff report and the reports provided by the consultants for NZDG. Denitrification is mainly a biological process where under oxygen deficient conditions bacteria reduce nitrate into nitrogen (N_2) and nitrous oxide (N_2O) gases in the presence of available organic carbon.

5.5 There exists a small but significant difference between the denitrification estimates provided by the DRI. Whilst Dr. Barnett estimates the lowest possible denitrification loss as 150 kg N/ha/year, Dr. Russell estimates it as 120 kg N/ha/year. However, both consultants estimated the maximum possible denitrification for the Lichfield irrigation site as 220 kg N/ha/year.

5.6 With the available information, my estimate of denitrification for the proposed nitrogen loading rate is 65 kg N/ha/year. I consider that the denitrification losses provided by the DRI are substantially high. I have discussed this in detail in the staff report. My current discussion will assess the technical information provided by Dr. Russell in his evidence.

5.7 When referring to denitrification losses from conventional grazed dairy pasture systems Dr. Russell states,

> ...for a dairy farm in the Waikato denitrification losses amount to about 30 kg/ha annually (Steele, 1982). He, and his co-workers, had measured maximum rates of up to 120 kg/ha in the Te Kowhai soils.

The paper by Steele (1982) actually reads as follows:

> Field measurement of denitrification in Te Kowhai soils suggested a maximum possible nitrogen loss of 120 kg N/ha/year, but the average figure is probably less than 30 kg N/ha/year (Limmer, 1981).

It is clear from Steele's (1982) statement that denitrification losses in a dairy pasture system with Te Kowhai soil is estimated as less than 30 kg N/ha/year, and this value does not apply to the entire Waikato area as implied by Dr. Russell. The high denitrification rate in the poorly drained gley soils (e.g. Te Kowhai soil) is expected due to prevailing reducing conditions. The high losses sustained from Te Kowhai soils cannot be used to estimate the denitrification loss from the Lichfield site. This is because the Lichfield soil (Taupo sandy silt loam) is well drained.

5.8 My estimate for denitrification from a grazed dairy pasture system (which does not receive any waste water) is 10 kg N/ha/year (as nitrogen and nitrous oxide). This estimate has been made from the daily denitrification loss estimates (as nitrous oxide) obtained from a research report by Sherlock *et al*. (1992).

5.9 As indicated by Dr. Russell, denitrification is much higher in grazed systems receiving waste water with high available carbon. The field trial performed by him at Hautapu indicated that an estimated 110 kg N/ha/year of applied nitrogen could be denitrified from 1495 kg N/ha/year applied through dairy factory waste water irrigation.

5.10 According to the above study about 8% of the applied nitrogen was lost through denitrification. Using this figure for the Lichfield site could overestimate denitrification. This is because:

(a) the Hautapu site comprises a high proportion of Te Kowhai soil which has greater denitrification potential than the Taupo sandy silt loam.

(b) The waste water used at the Hautapu trial contained a substantial amount of nitrate due to nitric acid use in the factory. Nitrate in irrigated waste water enhances the denitrification rate. At the Lichfield site nitric acid will not be used, therefore there will be no nitrate present in the waste water at Lichfield. The nitrogen form present in the proposed waste water will be protein. Nitrate does not readily form from protein in the waste water.

(c) Denitrification is a temperature driven reaction. In a meat processing waste water irrigation project Russell *et al*. (1993) concluded that at soil temperatures below 12^{o}C denitrification is *not* an important nitrogen removal mechanism. Soil temperatures at the Lichfield site are expected to be less than 12^{o}C, for several months of each year.

(d) The denitrification estimate at Hautapu did not consider low denitrification rates at night. The estimate assumed that day time losses were equal to night time losses, and

(e) A high proportion of the denitrification measurements at the Hautapu site were made during summer.

5.11 Despite the above reasoning I consider that 40 kg N/ha/year of the applied nitrogen (400 kg N/ha/year) will be denitrified at the Lichfield site. I have also estimated denitrification in ground water as 14 kg N/ha/year (rounded to 15 kg N/ha here). Thus my estimate of total denitrification at Lichfield site is 65 kg N/ha/year which includes denitrification from grazed pasture.

5.12 Despite a strong possibility of overestimation of denitrification by Dr. Russell at the Hautapu site, he has indicated in his evidence that he now believes that he *underestimated* denitrification at the Hautapu site. His reasons were:

(a) The methods he used to assess denitrification precluded the measurement of denitrification during spray irrigation.

(b) No measurements were made during rainfall.

(c) Denitrification is the key mechanism in nitrogen removal from the system apart from nitrate leaching.

5.13 I strongly disagree with his reasoning for the following reasons:

(a) Denitrified gas (nitrous oxide) was collected using chambers soon after irrigation ceased. This step is more than sufficient to simulate soil conditions during irrigation events since the soil would have been under saturated conditions soon after irrigation.

(b) Although rainfall could enhance denitrification due to saturated soil conditions, the loss should not be compared with that occurring during waste water irrigation. This is because rain water does not contain dissolved organic carbon and nitrate ions like dairy factory waste water. Moreover, dairy factory waste water is warmer (30°C) than rain water and hence lower denitrification will occur.

(c) During high rainfall or irrigation nitrate could be flushed down below the zone of denitrification (generally the root zone). This will reduce the nitrate available for denitrification.

(d) I am not convinced that apart from nitrate leaching denitrification could be the second highest nitrogen removal mechanism at the Hautapu site. My field studies (and many other laboratory and field studies on ammonia loss from soils) show that soil with a pH more than 7.0 will sustain a substantial amount of ammonia loss from ammonium present in soils (Selvarajah, 1991; Selvarajah *et al*. 1993). One such soil (Kaharoa sand) that had an elevated pH level (7.08) sustained an ammonia loss of 46% of the applied urea-N during a very warm spring. The soils at the Bardowie site have a pH more than 7.0 and I suspect that the losses sustained through ammonia volatilisation will be substantial at this site. The soil pH at the Bardowie site has steadily and slowly increased over the last 10 years due to waste water application.

5.14 I must emphasise that for dairy farms in the Waikato region ammonia losses from grazed pasture are generally low due mainly to the presence of highly buffered soils. These soils when maintained at their native pH levels (background) will have low ammonia loss potentials. The soils at the Lichfield site have an average pH of 5.6 and hence the ammonia volatilisation potentials for the site is likely to be low.

5.15 Dr. Russell has estimated denitrification using an indirect method. The method of estimation was not stated anywhere in his evidence or reports. However, I presume that the estimate was based on ground water nitrate data obtained at the Bardowie site since 1982 (both drainage water and ground water).

5.16 I have discussed in detail in the staff report the high uncertainties attached to nitrate leaching assessment using ground water nitrate levels and the hydrogeology of the Bardowie site. In my opinion such estimates require accurate hydrogeological data without which any prediction made on nitrate leaching should be viewed with caution.

5.17 If the drainage water nitrate levels were used to indirectly estimate the amount leached at the Bardowie site such estimates will have the following uncertainties:

(a) At the Bardowie site only a part of the irrigated area is pipe drained into the Mangaone stream. Consequently, the drainage area may not represent the entire farm.

(b) My understanding about the farm drainage is that farmlands are drained only when they cause saturated conditions. I suspect that at the Bardowie site the drained area comprises poorly drained Te Kowhai soil which has a very high denitrification potential.

(c) Typical farm drainage systems used on farms do not collect the entire soil leachate.

5.18 In his evidence Dr. Russell argued that the applied nitrate (nitrate resulting from nitric acid use at the factory) is rapidly and effectively removed through denitrification. I agree with him that nitrate present in the waste water has a higher probability to be denitrified in soil or even in the waste water itself. I do not, however, agree that he could expect the same denitrification at the Lichfield site. This is because as I indicated before there will be no nitrate present in the waste water.

5.19 The denitrification loss Dr. Russell estimated for the Bardowie site was up to 72% of the applied organic nitrogen (determined from the estimates in his evidence 3.11). He indicates that his conclusions are supported by numerous New Zealand and overseas studies. To the best of my knowledge there are no studies that have reported such a high denitrification loss under the given conditions.

5.20 Dr. Russell quoted (evidence 3.13) a laboratory study conducted in New Zealand by Kettles *et al*. (1994). I should emphasise that interpretation of any data obtained from laboratory oriented studies should be considered with extreme caution.

5.21 Following a discussion with one of the authors (Dr L. Schipper, Landcare Research) of the above paper I have discovered that the objective of the study was to examine the changes in soil properties for waste water irrigated and non-irrigated sites. The measurements of denitrification in this study were made under room temperature conditions (25^{o}C) and consequently very high biochemical reaction rates are expected. I was cautioned by the co-author that the results of this study should neither be used as an estimate of denitrification potential nor as an estimate of the absolute denitrification loss for a given system.

5.21 Similarly, the research paper from the USA quoted by Dr. Russell (evidence 3.14) should not be used for comparison with the proposed Lichfield site. This is because the paper reported denitrification losses under flooded conditions. Note that under extreme anaerobic conditions (which occurs under flooding) the paper reported a denitrification loss of 60-70%, whilst under unsaturated conditions Dr. Russell estimated similar rates (72% maximum as determined from his estimates).

5.22 Based on the information provided by NZDG, and other information available on the topic, I conclude that the denitrification value provided by DRI is overestimated. Such an estimate has resulted in an underestimation of nitrate leaching. As set out in Table 1 below I estimate the amount of nitrate leached at 400 kg N/ha/year loading rate as 275 kg nitrate-N/ha/year. Preliminary results from a recent trial (Ledgard, 1994) examining the effect of different fertiliser nitrogen application rates on ground water at Ruakura showed a substantial increase in soil water nitrate levels (at 1 metre depth) for soils receiving 360 kg N/ha/year. For soils receiving 0 and 220 kg N/ha/year there was little or no difference in soil water nitrate levels.

5.23 The above results support the recommended nitrogen loading rate (150 to 200 kg N/ha/year) provided by AgResearch for a dairy pasture system (Ledgard *et al*., 1994). These authors suggest that *for environmental reasons, the recommended nitrogen loading rate should be used as a maximum limit for fertiliser nitrogen applications*.

5.24 According to my estimate the predicted nitrate leaching loss is 175 kg N/ha/year for 300 kg N/ha/year loading rate. This is 3 times greater than that occurring under a clover-based pasture system in the Waikato (Selvarajah *et al*., 1994). However, the predicted nitrate leaching loss for the Lichfield site is comparable with the maximum leaching loss from a land-based dairy shed effluent system (maximum loading rate of 150 kg N/ha/year).

Table 1. Nitrogen balance

Nitrogen Transformation Processes	**Anchor Products Estimate**	**Staff Assessment**	**Recommended**
	Input 400 kg N/ha/year		**Input 300 kg N/ha/year**
Products (milk + maintenance)	75	75	85
Ammonia volatilisation	25	25	25
Denitrification	190	65	55
Clover-N fixation	+60	+40	+40
Leaching loss under clover based pasture systems	-	60	60
Non leaching N losses	290	165	165
Nitrogen available for leaching	170	275	175

5.25 I must stress that the difference between a land-based dairy shed effluent system and the proposed waste water irrigation system is the land area used for `waste' treatment. For example, the expected leaching loss from a typical dairy shed effluent treatment system (6 ha @ 150 kg N/ha) is 1050 kg N/year. In contrast, the leaching loss predicted from the Lichfield site (218 ha @ 300 kg N/ha) is 38150 kg N/year. Considering the large mass loading of nitrate entering ground water, intensive monitoring is required at the Lichfield site to ensure ground water quality is not adversely affected.

5.26 The lack of information on the hydrogeology of the Lichfield site precludes an estimate of ground water nitrate changes likely to occur following the proposed waste water irrigation.

6. SUMMARY

6.1 Considering the high volume of waste water generation at the Lichfield site I recommend that the applicant should either minimise waste water generation or increase the land area available for irrigation.

6.2 The nitrogen loading proposed by NZDG (400 kg N/ha/year) is considered to be excessive for the system proposed. The proposed nitrogen loading rate was based heavily on anticipated high denitrification losses. I have discussed in my evidence that such high denitrification is not possible for the proposed system, and hence involves high environmental risk.

6.3 I stress that the information provided on the receiving environment is very poor and hence it is difficult to predict the environmental effects and recommend monitoring sites for ground and surface water sampling.

6.4 The recommended nitrogen loading rate for the proposed irrigation system is 300 kg N/ha/year. I have identified that even at this rate of application there will be leaching losses of nitrate and subsequent ground water contamination. However, these effects are likely to be minor. Thus the rate is considered to be environmentally and agronomically sustainable despite the lack of information on the receiving environment. According to the recommended annual nitrogen loading rate the land area available for waste water irrigation should be increased from 164 ha to 218 ha.

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