ENVIRONMENT WAIKATO

Memorandum

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TO	D Palmer
FROM	N Selvarajah

SUBJECT: Wallace Corporation Waitoa site - Assessment of Environmental effects

WASTE WATER DISCHARGE TO LAND

This memo assesses the reliability of the prediction of the effects of the proposed land disposal of the waste water produced from the final treatment pond system on the soil, pasture and ground water and develops environmental indicators and monitoring programme for the key waste water characteristics.

The keys issues are identified as (a) hydraulic loading (b) nutrient loading (c) sodium and chromium build-up and (d) pasture performance.

Hydraulic loading (pp 54-55. HGCL, 1993)

Average daily volume of effluent:

It has been estimated that the average daily volume of effluent used for irrigation is 1485 m^3. This figure has been obtained from Table 6.7 using the total effluent produced from Wallace Corporation during the irrigation period. It is not clear whether the total effluent volume includes storm water and sewage effluent diverted into treatment ponds. The estimated daily sewage effluent production is 20.6 m^3 and the volume of storm water diverted into the ponds is not known.

Infiltration rates:

For the analysis following it has been assumed that average daily effluent volume (1485 m^3 d^{-1}) is irrigated onto land (84 ha) from late October to mid-June (212 d) at the rate of 6 ha d^{-1}. This rate will allow a 14 d irrigation cycle for every 6 ha. The spray application rate will be 7.4 mm h^{-1}. Waitoa and Waihou loams are identified as the major soil types in the land disposal area. The Waitoa loam is a poorly drained gley soil whereas the Waihou loam is well drained. The application rate (7.4 mm h^{-1}) has been determined by considering the infiltration rates of the Waitoa loam during unsaturated (8 mm h^{-1}) and saturated (4 mm h^{-1}) conditions. Consequently, the proposed application rate is likely to cause surface ponding under saturated conditions. The proposal acknowledges that surface ponding is likely but indicates that this would not cause any surface runoff of waste water into drainage channels because the land is flat.

Proper land disposal system should not cause any surface ponding. Frequent surface ponding can cause anoxic conditions in soil, which is detrimental for soil and pasture. Reducing soil-water conditions produce toxic substances due to the high presence of sulphur (S) and dissolved organic matter. It is recommended that an application rate of 5 mm h^{-1} should be practised, because this application rate is unlikely to cause any surface ponding even under saturated conditions. This rate is widely used for soils with a low infiltration rate (MAFF, Welsh Office Agriculture Department, 1991).

<u>Net hydraulic loading:</u>

The proposal assumes that half of the average annual rainfall of 1200 mm falls in the irrigation period (212 d) which equates to 2.8 mm d^{-1} and the evapotranspiration (ET) rate during summer months is 4-5 mm d^{-1}. From long-term rainfall records (1905 to 1980) available at Ruakura (NZMS, 1983), rainfall during the irrigation period is estimated as 928 mm, which is 78% of the average annual rainfall. According to this estimation, the daily rainfall equates to 4.4 mm d^{-1}. The evapotranspiration rate for the irrigation period should not be based on summer rates, because a large proportion of the irrigation period occurs during autumn and spring. The average ET rate for the irrigation period is approximately 2.6 mm d^{-1} (NZMS, 1983).

The proposal considers an irrigation rate of 1.6 mm d^{-1} based on a hydraulic loading of 22 mm per paddock per application (i.e. 22 mm/14 d). However, this memo calculates the hydraulic loading as 24.8 mm based on the irrigation figures given in the proposal (i.e. hydraulic loading = 1485 m d^{-1} / 60000 m^2). Thus the irrigation rate should be estimated as 1.8 mm d^{-1} rather than 1.6 mm d^{-1} as stated in the proposal.

Using the estimated average rainfall and evapotranspiration, the proposal predicts a net hydraulic loading at or below evapotranspiration (Rainfall (2.8 mm d^{-1}) + Irrigation (1.6 mm d^{-1}) - ET (4-5 mm d^{-1}) = Net hydraulic loading (0 mm d^{-1}) and consequently minimal leaching during the irrigation period. However, if 1485 m d^{-1} is irrigated onto a 6 ha area, the hydraulic loading per application should be 24.8 mm and hence the net hydraulic loading should be 3.6 mm d^{-1} (Table 1).

Table 1. Estimation of net hydraulic loading

	Estimation in the proposal	Current estimation
Av. rainfall	2.8 mm d^{-1}	4.4 mm d^{-1}
Av. ET	4-5 mm d^{-1}	2.6 mm d^{-1}
Application rate	1.6 mm d^{-1}	1.8 mm d^{-1}
Net hydraulic loading	0.0 mm d^{-1}	3.6 mm d^{-1}

It must be emphasised that since the irrigation is intended to be carried out daily during the entire proposed irrigation period (212 d), it is appropriate to assess the 'actual' daily hydraulic loading. It has been estimated that out of 212 d, 73 d will receive > 1 mm d^{-1} rainfall (NZMS. 1983) and hence approximately 928 mm rainfall is distributed during 35% of the irrigation period which on average is about 12.7 mm d^{-1}. Thus during the > 1 mm d^{-1} rainfall events, the net hydraulic loading is estimated as 11.9 mm d^{-1} (i.e. (12.7 mm + 1.8 mm) - 2.6 mm).

Use of precipitation index (PI) (pp 41-42, HGCL. 1993):

A precipitation index approach to the management of net hydraulic loading does not allow for stringent control over surface runoff or rapid leaching losses. This is because the one day hydraulic loading (i.e. 24.8 mm) is distributed for 14 d and hence the application rate is 1.8 mm d^{-1} (in reality the entire 24.8 mm waste water is irrigated within 24 hours). Such a loading is likely to cause minimal environmental effects only during dry periods. However, during wet periods PI can be used effectively to manage net hydraulic loading. The conventional engineering approach to waste water irrigation is to use land as a 'filtering system' hence it encourages greater hydraulic loading on well drained soils. Thus PI for well-drained soil is estimated several folds higher than that for poorly drained soils. Such an approach accounts for surface runoff, but ignores nutrient leaching from top soil. Nutrient leaching is a dynamic and cumulative process with increases in hydraulic loading causing greater nutrient leaching. For a given hydraulic loading the extent of leaching varies according to the soil type, soil moisture conditions and the nutrient content of irrigation water (Scotter, 1993). Irrigating waste waters have more deleterious effects on the receiving environment than irrigating pure water because dissolved nutrients can move with waste water in the soil profile.

When waste water containing nutrients is irrigated onto dry soil the nutrients are absorbed into small soil pores and the potential nutrient leaching is reduced even if there is a high rainfall following irrigation. However, when waste water is applied onto wet soil the nutrients are absorbed mainly in large pores resulting in a high leaching potential (Tillman et al., 1991). Thus a high rainfall event following irrigation can leach most of the nutrients that are located in the macropores. It is emphasised here that proper use of PI will only prevent surface runoff, but it does not guarantee minimal leaching loss. This is because PI considers only the preceding rainfall for 4 days and it does not account for post irrigation rainfall. Consequently, any good waste water irrigation practice should adopt conservative hydraulic loading rates. Irrigation should be planned according to the season and the ability for soils to assimilate the applied nutrients.

In my opinion the PI limit (PI = 82) granted in the Water Right (W2390) is extremely high. According to this high PI limit, the approximate total rainfall for 4 d prior to irrigation will be 100 mm (25 mm d^{-1}). With the irrigation of 24.8 mm the total loading will be 124.8 mm. When the ET for these 5 d is considered (2.6 mm d^{-1}) the net hydraulic loading will be approximately 110 mm. Even if the extreme ET values are used (e.g. summer ET of 5 mm d^{-1}), the net hydraulic loading for 5 d will be approximately 100 mm. Assuming a soil pore volume of 50%, the leaching depth will be 200 mm (i.e. only 50 mm depth is available in every 100 mm soil column for the water to occupy). If the top 200 mm soil is fully saturated then the leaching depth will be 400 mm (i.e. assuming little or no irrigated water is held in the 200 mm depth saturated soil column and the balance of the 200 mm dry soil column has 50% pore volume).

Any waste water irrigation administered on grazed pasture should attempt to confine the applied waste water nutrients and the existing soil nutrients within the top 200 mm soil where most pasture roots are located. Plant uptake of nutrients is used as the major nutrient removal mechanism and hence the nutrient leaching below root zone has greater potential to contaminate ground water. Considering an ET of 2.6 mm d^{-1} the proposed 24.8 mm hydraulic loading will result in 22.2 mm net hydraulic loading. If the soil is unsaturated, this loading will result in 45 mm leaching depth, and 90 mm under saturated conditions. Thus the proposed hydraulic loading is acceptable when little or no rainfall is received. Since the effect of rainfall is very significant on the extent of potential nutrient leaching, the use of low PI values will minimise nutrient leaching. MAF recommended a PI limit of 20 and 70 for the Waitoa and Waihou soils respectively. It is recommended here that a PI limit of 20 should be applicable to both soil types. Visual assessment of the irrigated land indicated that there is a very high presence of weeds associated with a significant absence of clover species in the pasture. Such a shift in vegetative composition occurs when pasture is subjected to excessive hydraulic loading, because clover-ryegrass species are very sensitive to saturated soil conditions and weeds spread rapidly in the space created by the death of grass cover.

It is also recommended that a soil survey be performed and a soil map produced for the proposed irrigation land. Although two different soil types with contrasting hydraulic properties have been identified in the proposal, it is not known what proportion of the area these soils occupy in the property. For a successful and sustainable waste water irrigation practice the knowledge of the soil types and their land area are vital.

Nutrient loading

The waste water generated at Wallace Corporation is a good source of essential plant nutrients. It contains considerable amount of macronutrients such as N, P, K. Ca, Mg, and S, and micronutrients such as Cl, Fe, B, Mo, Na and Mn. Thus land disposal of this waste water is considered very useful for pasture production. The waste water also contains a substantial amount of Na and Cr and the land disposal of these two elements are addressed in the latter part of the discussion.

Nitrogen:

According to the Water Right the maximum annual N application rate is 400 kg ha^{-1}. The current annual N loading rate is 392 kg ha^{-1} and the proposed future rate is 300 kg ha^{-1}. Nitrogen management is very important under a grazed pasture system. The conventional N loading rate determination based mainly on the amount of crop uptake and N removal in animal products is inappropriate under a grazed system. Under a grazed pasture system, whilst high soil N build-up leads to high nitrate leaching losses, high N content in pasture leads to greater N ingestion by grazing animals and consequently higher excreta-N loss through urine (Jarvis et al., 1989). It has been well documented that presence of grazing animals is the driving force for nitrate leaching in soil (Selvarajah, 1993). This is because cow urine spots contain up to 1000 kg N ha^{-1}. Although it is well known that increasing N application results in increased dry matter production, the resultant increased stocking rate or high plant N content can lead to greater N loss through leaching from the system. The amount of N removed through production (i.e. milk protein) is relatively small in the entire N flow in a grazed system. For example, at a stocking rate of 2.7 cows ha^{-1} the annual N removal through milk production is estimated as 55 kg ha^{-1}. This accounts for only 10.6% of the total amount of N ingested by the cow (520 kg N ha^{-1} y^{-1}).

It has been estimated that for the Waikato region under the worst weather conditions (i.e. high rainfall) about 100 kg N ha^{-1} y^{-1} is required for a sustainable dairy clover-ryegrass pasture system (Selvarajah, 1993). This estimate considers an annual input of 200 kg N ha^{-1} through clover-N fixation. Consequently, a grazed pasture system that comprises of little or no clover population is unable to obtain this 200 kg N through symbiotic N fixation. Thus for a grazed pasture system that comprises only ryegrass, about 300 kg N y^{-1} can be applied.

It has been estimated in the proposal that there will be substantial reduction in total-N concentration in the waste water (i.e. from 415 to 80 g m^{-3}). It is not clear how such a reduction will be achieved bearing in mind the increased waste water loading (see pond treatment systems). Assuming such a lower N concentration is achieved, for an average daily waste water flow of 1485 m the N loading will be 118.8 kg d^{-1}. On an application per area basis this will be approximately 20 kg ha^{-1}. Considering the instantaneous N loading, this loading rate is considered to be agronomically and environmentally acceptable. Each paddock will be irrigated at least 15 times (14 d cycle) during the irrigation period. It should be cautioned here, however, that irrigation should not be performed during rainy days and the recommended PI (20) should be adhered to throughout the irrigation period. Consequently, the pumping and pond systems may need to be upgraded to meet the greater irrigation and storage requirements respectively during wet periods. Alternatively, a higher PI can be used with a lower application rate as long as the net hydraulic loading remains constant (i.e. 44.8 mm) (e.g. Table 2). If irrigation has to be performed when PI > 20 mm, hydraulic loading can be estimated by subtracting PI from net hydraulic loading. As recommended before the application rate during wet weather conditions should not exceed 5 mm h^{-1}.

Table 2. Different combination of net hydraulic loading parameters

PI	Hydraulic loading	Net Hydraulic loading
20 mm	24.8 mm d^{-1}	44.8 mm
30 mm	14.8 mm d^{-1}	44.8 mm
40 mm	4.8 mm d^{-1}	44.8 mm

Combining a higher PI (> 20) with lower irrigation application rate will help to reduce the loading on pond system during wet weather conditions.

Nitrate:

(i) Introduction

The presence of NO_3-N in ground water provides an indication of ground water contamination. According to the NZ drinking water standards the maximum acceptable level for NO_3-N is 10 g m^{-3} (Board of Health, 1989). Bottle fed infants less than 6 months old consuming water containing NO_3-N reported to have developed a disease called methaemoglobinaemia ('blue baby' syndrome). Overseas studies report many such cases with several cases resulting in death (Winton et al., 1974). To date, no cases have been reported in New Zealand, although methaemoglobinaemia is not classified as notifiable disease by the NZ Health Department. However, the symptoms for the Sudden Infant Death Syndrome ('cot death) are similar to that of blue baby' syndrome, implying that there may have been methaeomoglobinaemia cases in NZ which have never been noticed. In adults consumption of drinking water with high NO_3-N levels have been linked to gastric cancer and hypertension cases (quoted by Burden, 1982).

Apart from being a potential health hazard, due to subsurface flow of ground water into streams, or rivers, NO_3-N in ground water can pollute waterways causing algal blooms and may subsequently affect aquatic life such as fish. Many waterways in the region are used for recreation and unwanted algal growths can affect the revenue gained by tourism. High NO_3-N flow into the sea combined with P availability has also been considered as one of the main factors for toxic algal blooms reported frequently around the globe and recently in New Zealand. Moreover, if the environment is degraded, unnecessary trade barriers can be imposed by overseas trading partners on the export of food products from New Zealand. Currently, many European trading partners are spending billions of dollars in the management of their environment, hence the high cost of production. In New Zealand the cost of production is relatively low principally because there is an 'environmental subsidy' attached to the total cost of production, i.e. the cost of environmental degradation is not considered in the production of export food products. Many European trading partners believe that countries which trade with EC should maintain similar environmental standards, hence a 'realistic' cost of production. It should also be emphasised that New Zealand has a good marketing potential because of its clean and green image overseas. Every effort should be made to maintain this image because once such an image is lost it is difficult regain. One of the major problems with NO_3-N is that contaminated ground water is difficult to clean up.

(ii) Nitrate leaching

It has been recommended in the proposal that the irrigation will be performed from Pond 6 in the future. Currently waste water for irrigation is derived from Pond 3. More than 95% of the TKN (total kjeldahl nitrogen) (TKN = organic-N + NH_4-N) is available as NH_4-N (ammoniacal-N). Very frequently it is 100% of TKN! Since all the nitrogen in the waste water is in mineral form (i.e. NH_4-N) (there are two mineral-N forms found in ground water and soil: NH_4-N and NO_3-N) the potential for N removal through immobilisation (microbial assimilation of N) and denitrification loss will be minimal - meaning that the main N removal mechanism has to be either through plant uptake or ammonia volatilisation. Soil test results clearly show that among the mineral-N species NO_3-N (nitrate-N) is more dominant (78% of the total mineral-N is NO_3-N)) than NH_4-N (Table 8.7. HGCL, 1993). This finding is expected on these soils which have a high nitrifying capacity (oxidation of NH_4-N to NO_3-N) due in part to their volcanic origin. This high nitrifying capacity emphasises the requirement for stringent hydraulic management for these soils; mismanagement can lead to severe NO_3-N leaching losses which will result in ground water NO_3-N elevation.

Note that the ground water sample obtained recently (December, 1993) from Piezometer 1 (P1) had a NO_3-N concentration of 45.0 g m^{-3} which is 4.5 higher than the NZ drinking water NO_3-N limit. Other piezometers are showing similar, but less severe $N0_3$-N pollution (e.g. P4= 7.3 and P5 = 10.6 g NO_3-N m^{-3}). The reason for the absence of NO_3-N in P3 is the high presence of iron (Fe) in this ground water. High concentrations of iron in ground water are caused by anoxic conditions in the aquifer. Under anoxic conditions Fe is mobile due to its reduced form, i.e., Fe^{2+}. This Fe^{2+} can reduce NO_3-N in ground water during denitrification. It has been observed that all the piezometers sampled contained ground water with >0.1 g Fe m^{-3}. At these levels there should be a significant reduction in ground water NO_3-N. Thus the high presence of NO_3-N in the ground water indicates the extent of NO_3-N contamination despite the reducing conditions existing in these ground waters. Moreover, NO_3-N in shallow aquifers in the Waikato region generally increases during autumn and early winter due to the increased recharge followed by leaching of NO_3-N accumulated over the spring and summer (Selvarajah et al., in prep.). Consequently, ground water NO_3-N measured during summer is generally lower than that of other seasons. Since the above piezometer readings have been obtained during summer, even higher NO_3-N levels can be predicted in ground water for other seasons.

It must also be noted that P1 is located close to Waitoa River. Ground water flows towards the northeast, and depending on the rate of subsurface flow, ground water NO_3-N may enter the Waitoa River at significant rate. It is recommended that additional piezometers be installed on the north-eastern side of Paddock 52 and to the north of J D Wallace Ltd site. These piezometers will be used to monitor ground water NO_3-N levels adjacent to surface water bodies.

Farm N management strategies:

Farm management should be aware of the high annual N application rates through waste water irrigation and hence take account of other N inputs. Paddocks which receive waste water from Wallace Corporation should not be used for other forms of N application. This includes dairy-shed effluent irrigation either directly or indirectly from effluent storage facilities or oxidation ponds, fertiliser-N application, receiving and using N based waste water from other waste water sources (except for Wallace Corporation) and using stock feed (e.g. silage, hay or concentrates) brought from other farms or suppliers unless there is an acute shortage of stock feed.

It has been anticipated in the proposal that the two dairy farms will be combined as one farm and oxidation pond systems will be used for dairy shed effluent treatment and storage. It is not clear at this stage whether it is planned to use the existing system or expansion of the existing system. It should be verified whether the existing Water Right for the pond operation and the existing pond capacity is adequate to receive waste from both farms. Moreover, an irrigation programme is required for the disposal of dairy shed effluent from the pond systems. Currently, Environment Waikato allows 150 kg N ha^{-1} loading for dairy shed effluent. The land area required depends on the size of the herd. For example, a herd size of 200 requires approximately 4 ha for dairy shed effluent irrigation assuming a milking period of 270 d. It is recommended here that when two farms are combined there is no need to construct a new pond system; instead the effluent must be irrigated onto land allocated for this purpose. If irrigation of dairy shed effluent is carried out throughout the year, only a temporary holding system is necessary as a contingency measure for pump failure or wet weather conditions.

Another vital N management practice is the control over cultivation practices. Since ploughing during warm periods is considered as a major source of ground water NO_3-N (Francis et al., 1993), any form of cultivation should not be performed on the irrigated land. If ploughing should be performed for the reestablishment of the grass cover, it should be performed during dry weather in July or August to minimise mineralisation from soil organic-N and subsequent leaching of NO_3-N. Since the irrigation is not performed during these months the period appears the best time for any cultivation.

Other nutrients and pasture health:

Soil test results in the proposal (Table 8.7, HGCL, 1993) clearly show that there is an excessive amount of Ca, P, K, S and Mg present. Consequently, for pasture production there is no more land application of these nutrients required for a few seasons. Such a high presence of these nutrients in soil reflects on the elevated levels found in pasture (Figure 8.2, HGCL. 1993). However, in the case of soil or plant build-up of Ca, P, K and Mg there is generally no adverse effect on soil fertility, plant and animal health or ground water contamination. Several years of P build-up in soil can eventually cause P leaching. However, the two soil types are classified as yellow brown loams which have one of the highest P retention capacities among New Zealand soil types. Moreover, the proposed annual P loading (56 kg ha^{-1}) suggests that even long-term application will leach little or no P into ground water.

Although the proposed annual nutrient loading rates (Table 8.5, HGCL, 1993) show that there will be a reduction in K (from 130 to 37 kg ha^{-1}) and P loadings (from 64 to 56 kg ha^{-1}), there is no estimation performed on future loading for Ca and Mg. According to the proposed Ca loading, it is estimated here that the annual loading will increase from 13.8 (at present) to 112 kg ha^{-1} which is an increase of 712%. The increase for Mg is estimated here as 742% (i.e. from 8.9 to 75 kg ha^{-1}). A reduction of sulphur (-54% change) has been reported in the proposal. The current estimation shows that sulphur increases from 163 to 187 kg ha^{-1} y^{-1} which is a 15% increase. The increase in cation nutrients such as Ca and Mg is considered favourable for soil conditioning when considering the future increase in sodium. Calcium and magnesium build-up in soil is not harmful for the soil environment. However, the increase in S is a concern because there has been already a build-up of S in soil with the current and lower S content of the waste water. Sulphur in SO_4-S form can leach in soil. However, since the high SO_4-S in ground water is considered as no threat to health or environment the proposed level is allowable. Under reduced conditions SO_4-S is reduced to form HS or S^{2-} forms. Presence of these S forms in ground water imparts a bad smell. Under such conditions pasture performance is also affected. Reduced conditions are caused mainly by excessive irrigation and poor drainage of waste water. As emphasised before, hydraulic management is very critical for irrigating waste water.

As far as micronutrients are concerned (i.e. Zn, B, Mn, Fe, Cl and Mo) no loading levels are proposed except for boron (B). Excessive application of B in soil will be toxic to pasture. The proposed annual loading rate of B (1.1 kg ha^{-1}) is acceptable since up to 1 kg B is recommended for B deficient pastoral soils. Generally pasture grown on yellow brown loams in the Waikato show B deficiency. It is recommended to provide information on the proposed loading rate of other micronutrients (e.g. Mo, Cd, Fe, Mn, Mo, Cu and Se). The micronutrients listed here are all beneficial for good pasture performance. Apart from Mo and Zn other micronutrients are naturally available in high levels.

Sodium (Na)

It has been proposed that the annual loading rate of Na is 1068 kg ha^{-1} which is 642 kg ha^{-1} higher than the current loading rate. Excessive land application of Na is deleterious for soils with a high clay content. High Na levels in soil will destroy soil structure which is essential for soil aeration and drainage. When clay minerals are dispersed by Na they clog soil pores causing poor drainage. The success of the proposed irrigation system depends mainly on good soil drainage conditions. Although yellow brown loams are less affected by high soil Na levels than many other New Zealand soils, caution must be taken in applying such large quantities of Na Although the proposed SAR (sodium absorption ratio) is 33% less than the current SAR levels, the mass loading of Na can outweigh any benefit that is obtained by having other cations such as K, Mg and Ca. It must also be noted that Na can be more deleterious to soil structure when applied with waste water which has a pH > 9.0. However, in the case of the proposed waste water quality, the pH is unlikely to exceed 8.5. Due to the high presence of Na it is important to keep the waste water pH below 8.5 throughout the irrigation period.

The major Na based chemicals that are used at J D Wallace rendering plant are caustic soda (NaOH) and Sodium metabisulphite ($Na_2S_2O_5$) and at Eureka Hides and Skins Ltd salt (NaCl) and sodium sulphide (NaS). It is recommended that alternative non-Na based chemicals should be used as much as possible. For example, potassium hydroxide (KOH) is a good substitute for NaOH. The main source of Na is, however, the substantial amount of salt (NaCl) used at the Eureka Hides and Skins Ltd site and every effort should be taken to recycle the use of salt solution (brine) without discharging into the treatment ponds. It has been estimated here that the estimated Na loading for the next 20 years will be 21360 kg ha^{-1}. When mass loading is considered this quantity is considered as high. It is recommended that the management should take every effort to minimise Na loading.

Chromium (Cr)

It has been proposed that due to the wet blueing process, the use of Cr will increase substantially. The proposed increase in Cr is 375% (i.e. from 0.04 to 0.19 kg ha^{-1} y^{-1}). The present Cr levels in waste water irrigation are similar to those in the proposed waste water (0.05 g m ^{3}) (Tables 8.3 and 8.4, HGCL, 1993). Considering the greater amount of Cr used in the future it is assumed here that better Cr recycling at the blueing plant and Cr reduction in the pond treatment systems will be achieved to reduce Cr levels in waste water. The current pond system does not appear to change Cr levels in waste water between Ponds 3 and 6. Present waste water irrigation is derived from Pond 3 whilst the proposed irrigation will be performed from Pond 6, both of which have similar Cr levels recorded (< 0.05 g m^{-3}) (Appendix 3, HGCL, 1993). Thus it is essential to improve the sedimentation process of Cr in the pond systems to reduce the proposed loading rate. Sedimentation of Cr depends on retention time of waste water in the pond systems.

Chromium application to soil is a safe way of disposing small quantities of this heavy metal. The measured lowest soil pH is 5.6. Under this pH regime Cr will be in Cr^{3+} form and is relatively immobile. However. Cr^{6+} form is relatively mobile and hence considered toxic. Chromium is safely adsorbed to soil particles at high soil pH. When soil pH falls below 4, Cr becomes mobile. It is considered that the proposed rate of Cr application is unlikely to cause any Cr toxicity to soil or plant health. The average Cr level found in the irrigated soils is 15.9 mg kg^{-1} dry soil. Assuming the soil samples are obtained from 0-15 cm soil depth and the bulk density of soil 1.1 g cm^{-3} the amount of Cr present in a one ha area is 26.2 kg. The background level for Cr for these soils is not known. However, the background level of Cr can be determined or soils from an adjacent area which did not receive any irrigation up to the present time. Without this information it is difficult to comment on the extent of the accumulation of Cr in soil. The proposed annual loading rate of Cr is 0.19 kg ha^{-1}. It has been estimated that assuming Cr is held in the surface soil, after 100 y of similar irrigation practice the mass of Cr found in these soils will be 45.2 kg ha (26.2 + 19 kg ha^{-1}).

Considering the long-term cumulative build-up of heavy metals in soils such as Cr and the long-term operation of Wallace Corporation, any reduction in Cr loading will reduce the risk of high accumulation of Cr in soil. Chromium levels can be reduced further in the waste water through better sedimentation techniques employed at the pond treatment systems.

Pond operation

It has been indicated in the proposal that Pond 1 should be desludged to accommodate the extra volume of waste received in the future. Desludging is also necessary for a good performance of any anaerobic pond system. Consequently, proper sludge management is considered to be important. It is recommended that Wallace Corporation should prepare a proper sludge management programme prior to the intended increased operation. A registered pond treatment specialist should inspect all 6 ponds for treatment efficiency and waste water retention capacity. If required ponds should be desludged before the increase in the operation. During desludging sediments can be agitated and care should be taken to avoid irrigation waste water loaded with increased levels of chemical components. It appears that the sludge may not be suitable for land disposal and it can be transported, treated and disposed by a licensed waste disposal company.

Recommendations and Monitoring

Hydraulic loading:

(a) Accurate estimation of waste water volume (m^3 d^{-1}) is required with consideration to storm water and sewage discharge into the pond systems.

(b) The proposed hydraulic loading 22 mm (pp 54, HGCL, 1993) should be re-evaluated as 24.8 mm.

(c) A PI of 20 should be used for both soils throughout the irrigation period or if a higher PI value is used the hydraulic loading should be reduced accordingly (follow the example in Table 2 of the memo).

(d) The net hydraulic loading should not exceed 44.8 mm (i.e. PI (20 mm) + hydraulic loading (24.8 mm)) for a 14 d irrigation cycle.

(e) No surface ponding or surface runoff should be apparent during the entire irrigation operation.

(f) A daily record of waste water flow from J D Wallace Ltd, Eureka Hides and Skin Ltd and Wallford Meats NZ Ltd to pond systems should be maintained.

(g) A daily record irrigated waste water flow should be kept.

Nutrient management:

(a) Nitrogen loading should not exceed 300 kg N ha^{-1}.

(b) Dairy shed effluent should not be applied onto waste water irrigation area.

(c) Fertiliser N use or other N based waste water should not be applied in areas which receive 300 kg N ha^{-1} through waste water irrigation.

(d) Stock should not be fed by stock feed from external sources (e.g. silage, hay. concentrates) other than the pasture from the irrigated area which receives 300 kg N ha^{-1} waste water irrigation.

(e) Ploughing irrigated areas is permitted only during the dry weather in July or August.

(f) Except for N all the other chemical elements levels in the waste water mentioned in the proposal should not exceed the proposed levels. If these levels are exceeded an appropriate additional land area should be used for irrigation.

(g) No new chemicals are introduced in the system without prior notification to EW.

(h) The irrigation water should be characterised for the following properties every month for the first two years and then on a quarterly basis:

pH, SS, BOD, Organic-C, TKN, faecal coliform, total coliform, nitrate-N, nitrite-N, ammoniacal-N, Ca, Mg, Na, K, DRP, TP, CI, sulphite, sulphate, total-S, total-Fe, total-Mn, Cr (III), Cr (VI), total Mo, Co, Se, Zn and B.

Sodium:

(a) The proposed Na loading rate should be reduced either through the use of substitute chemicals (e g KOH for NaOH) or more efficient recycling of brine. Another alternative is to use an additional land area for irrigation to reduced mass loading.

Chromium:

(a) The proposed Cr loading rate should be reduced by more efficient Cr recycling at the blueing processing site or better pond treatment. Alternatively, additional land area can be used for irrigation to reduce mass loading of Cr.

Pond systems:

(a) All pond systems should be inspected by a registered waste treatment specialist for (i) loading capacity (ii) retention time (iii) treatment efficiency and (iv) desludging requirement prior to the increased operation.

(b) A suitably qualified person should be in charge for the pond management who should maintain the following records:

(i) daily influent volume for Pond 1 and 3

(ii) daily effluent discharge volume for Pond 6

(iii) sludge management (all ponds)

(iv) daily pH, conductivity and DO measurement (all ponds)

(c) The first 5 pond effluents should be characterised on a quarterly basis for first two years for the parameters outlined for irrigation waste water.

(d) The effluent from J D Wallace Ltd, Eureka Hides and Skins Ltd and Wallford Meats NZ should be characterised on a quarterly basis for the parameters outlined for irrigation waste water.

Ground water quality monitoring:

(a) Another two piezometers are required in addition to the eight proposed piezometer sites: one on the far northern side of J D Wallace Ltd (close to Pond 6) and the other in paddock 52.

(b) Piezometers should be monitored as proposed in the proposal with the inclusion of faecal coliform.

(c) Bore samples (Bore 1, 2 and 4) should be monitored on a quarterly basis (March, June, Sept and Dec) for Mg, Ca, Na, K, Mn, Fe (acid soluble and total), Cr, CI, SO_4-S, pH, conductivity, HCO_3, nitrate-N, nitrite-N, ammoniacal-N, dissolved organic-C and DRP. Bore sample should be analysed separately without obtaining composite samples from all bores.

Soil testing:

(a) According to the programme outlined in the proposal with inclusion of analysis for Se, Mo, Cd, Mn, Fe, Cr (III) and Cr (VI).

Information required prior to the hearing

(a) Soil mapping for the irrigated area

(b) Separate Nitrate-N, Fe (acid soluble) and ground water level values for the 3 bores.

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