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WASTEWATER QUALITY RELATIONSHIPS WITH REUSE OPTIONS

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ABSTRACT

The trend towards reuse of effluent for land application of domestic and industrial wastewater is driven by the need to maximise limited water resources and benefit from the plant nutrients available in the effluent. Of significant impact upon the value of the wastewater for reuse is its chemical properties as well as biochemical oxygen demand and suspended solids. While the sewage treatment plant is expected to treat all wastewater received to a minimum environmental standard, no efforts are given to reducing the chemical load derived from uses of chemicals in the domestic household. That the regulation of industry and commerce far exceeds those of the combined effects of thousands of household is remiss of environmental regulators.

This paper examines the results of research into the more common sources of chemical additives to the wastewater stream. Twenty five potable water supplies are examined for their salt load, 20 liquid and 40 powder laundry detergents and five dishwashing products were used to simulate discharges to the sewer, measured for their phosphorus, salt and sodium concentrations. The results of the research indicate that choices in the products available for general use within the house can be made only where product labelling and consumer education is improved. Technical improvements in wastewater treatment are not the answer. The improvement in effluent quality will have significant beneficial effects upon land application areas and expand the range of reuse options available for commercial operations.

KEYWORDS

Detergents, phosphorus, reuse, salinity, sodium, wastewater

INTRODUCTION

The Australian investments in wastewater reuse will gather momentum over the next decade as changes to environmental legislation target point and non-point source pollution of fragile waterways, particularly those discharges to the irregular flows of inland river systems. The *Australian Guidelines for Sewerage Systems: Effluent Management* (ARMCANZ & ANZECC, 1997), the *Draft Guidelines for Sewerage Systems - Use of Reclaimed Water* (NH&MRC, *et al.*, 1996) and the "*Guidelines for Sewerage Systems: Acceptance of Trade Waste (Industrial Waste)* (ARMCANZ & ANZECC, 1994) are national objectives for improving the quality of water discharged from sewage treatment operations, whether that discharge is to the ocean, river systems or the land.

The largest proportion of Australia's population, located on the narrow coastal plain on the Pacific Ocean seaboard, discharges partly treated sewage (combined domestic and industrial wastewater) to the ocean. About 82% (1270 ML/day) of primary and secondary treated effluent from the New South Wales (NSW) coastal fringe communities is discharged to the ocean from 35 plants (Codd, 1997) Reuse of effluent or other by-products has been minimal. Large metropolitan areas, such as Sydney, reuse no more than a token amount (0.3%), while inland sewage treatment works (STW) reuse less than 7% of the effluent(Codd, 1997).

Akin to regulation in other countries, albeit with similar objectives, sewage effluent discharges in NSW are regulated by the Environment Protection Authority (EPA). The *NSW Protection of the Environment Operations (General) Regulation 1998* (NSW Government, 1998) and subsequent regulations provide the framework to license, monitor and enforce the improvement of the quality of sewage effluent discharges. The Load Based Licensing (LBL) scheme introduced in 1999 sets licence fees at a level determined on the load of pollutants discharged, rather than as previously, on pollutant concentration. Although viewed by many as a means of increasing revenue collection without the tools to adequately address current treatment mechanisms, the implications of the legislation will drive additional reuse projects. As an example, the Fee Rate Threshold Factor for phosphorus is set at 0.3 mg L^{-1}, a level not even the most modern sewage treatment works can meet, forcing local authorities to look to land application as a means of reducing the exorbitant cost of the load fee for phosphorus when discharged to waters.

While trade waste discharges from commercial and industrial premises into sewers are under greater scrutiny as local government councils implement licensing and monitoring programs, the larger proportion of discharges are from totally uncontrolled and unmonitored approved connections to the sewer. The domestic household is able to discharge, at will, a cocktail of chemicals at varying concentrations, together with biodegradable and non-biodegradable solids without any concern as to the ramifications of those discharges either on the treatment system or the expected final quality of the discharge water.

That only a small proportion of the total discharges to sewer are regulated is remiss of the authorities. While many local authorities suggest that it is not possible to regulate the household, there is an opportunity to scrutinise the products available for use within the home and limit the effects those chemicals have on the quality of the wastewater stream.

This paper addresses the need to control the inputs to the wastewater stream as a strategy for improving effluent quality and reducing the effects of nutrients and salts on the land application area. Improvements in effluent quality will extend the reuse options available to the engineer, reducing potential losses in soil hydraulic conductivity, avoiding plant nutrient deficiencies or toxicities or minimising the impact of salt on the irrigation area. The areas most easily addressed are those of potable water quality, water conservation and restriction in product availability on the supermarket shelves.

INPUTS TO WASTEWATER STREAM

The quality of the potable water, that is treated reticulated water, available to the general community varies considerably with geographic location. Influences of raw water quality include those of catchment geology, catchment management and sediment controls, land use within catchments and groundwater inflows to the raw water storage. Treatment of the water supply by the agencies to remove suspended solids (TSS) and reduce the harness for aesthetic purposes results in an increase in the total dissolved salt (TDS) concentration, in particular that of sodium.

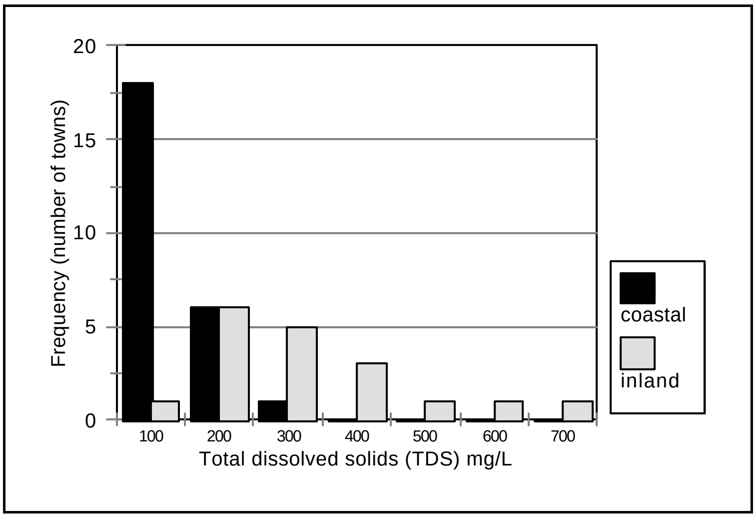

Figure 1 Comparison of concentration of salts in potable water supplies for coastal and inland catchments

Figure 1 indicates the relative differences between water quality, with respect to TDS for 25 major town water catchments compared with 18 inland catchments, as monitored in 1999. Long term weathering of the coastal catchments has removed many of the soluble solids and results in a softer water with fewer chemical impurities.

Inland water supplies are usually very hard waters that require considerable chemical additives to remove calcium and magnesium salts. Iron and manganese salts are often a serious problem in inland waters.

An implication of potable water quality on reuse options is given in Table 1, where the contribution to the overall sodium balance derived from the potable water source is given for four major towns in NSW. These masses of sodium chloride equivalent are the starting point for water being used as wastewater inputs, even though the concentrations are beyond the ability of engineers to manipulate at an economic cost.

Table 1. Contribution to sodium budget from domestic sources for four major towns in NSW (tonnes NaCl equivalent per year for 5 ML discharge per day)

Location	**Potable water**	**STW effluent**	**Domestic Input**
Coffs Harbour (coastal)	32	338	306
Armidale (Tablelands)	127	330	203
Moree (inland)	148	394	246
Dubbo (inland)	283	589	306

When water is used in domestic and commercial premises, chemicals are added to the water from washing persons and clothes, from food preparation and cleansing of utensils used for that food preparation, and as a carrier to remove solids (faeces, paper, soil) from the house to the sewer, thence to the sewage treatment plant. The impact of this use of the water decreases the quality of the wastewater depending upon specific use and chemical inputs. Figure 2 indicates the changes to water quality, with respect to sodium salts from potable water to effluent discharged from the STW after treatment (Patterson, 1994). The increases in sodium average 63 mg L^{-1}, and are equivalent to about 158 kg ML^{-1} of sodium chloride (common salt).

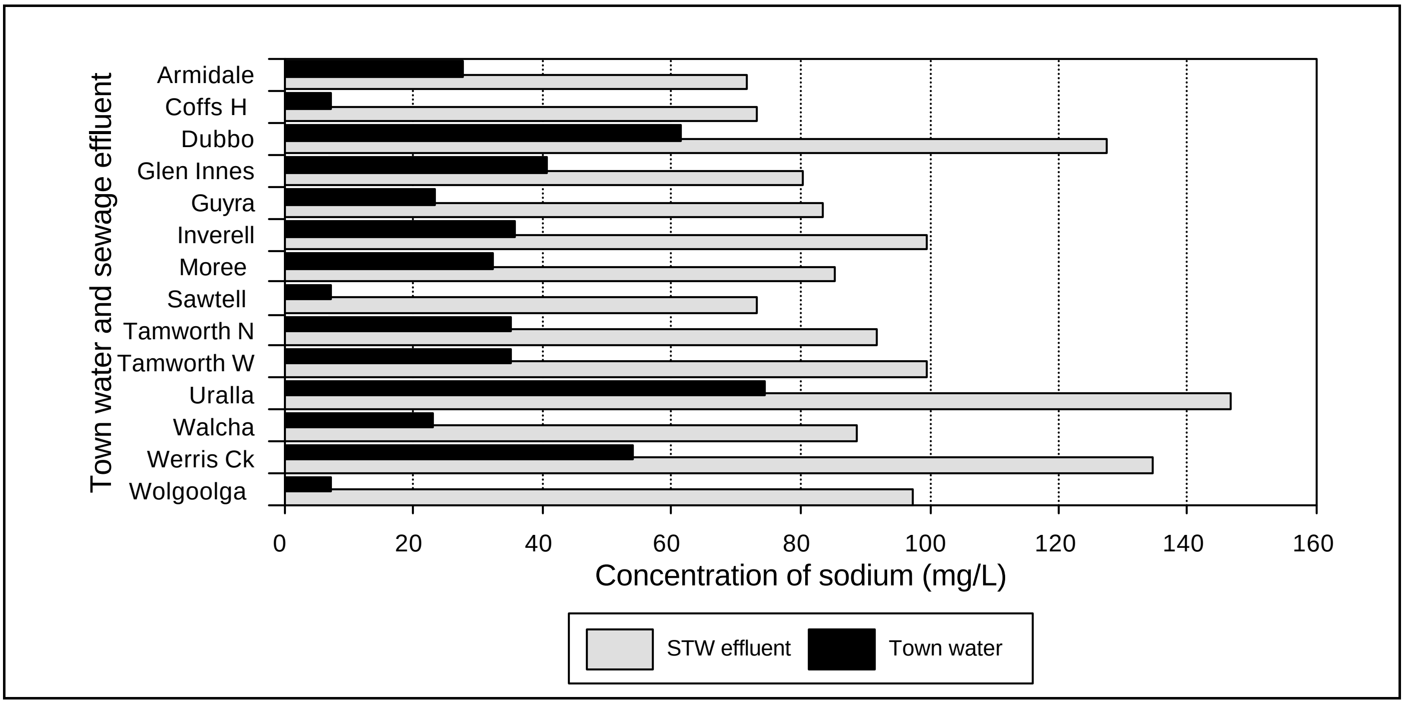

Figure 2 Changes to water quality, with respect to sodium, as a result of use in a town's water system

Table 1 indicates the additional burden of sodium salt on the wastewater, the difference being the contribution from chemical additives (including food sources) during use of the water and generation of wastewater. None of these towns has a significant industrial sector. The purpose of the calculation at 5 ML wastewater is to indicate the concentration of salt applied in the volume of water required per hectare of irrigation each year.

LIQUID TRADE WASTE DISCHARGES

Liquid trade waste discharges are those wastewaters which enter the sewer at a legal connection within the premises. Commercial food processors, fast food outlets, laundries, factories and other establishments with a potential to discharge greases and oils, high organics loads or other high suspended solids loads are required to be registered with the local authority. An example of a general acceptance guideline for trade waste discharges to sewer are given in Table 2 as taken from Armidale City Council's Liquid Trade Waste Policy (ACC, 1996). Councils are able to set their own guideline values outside national guideline values where they have an "appropriate scientific basis to nominate alternative criteria" (ARMCANZ & ANZECC, 1994). Discharges of industrial type wastes are excluded from sewer discharges and should not enter the wastewater stream, although illegal connections do occur.

Table 2. Criteria for a sample of the parameters covered by trade waste discharges agreements.

Parameter	Guideline value	Parameter	Guideline value
pH	7 - 9	Temperature	less than 38^oC
BOD_5	max. 300 mg L^{-1}	COD	less than 1500 mg L^{-1}
Total suspended solids (TSS)	max. 300 mg L^{-1}	Total Grease and Oil (TOG)	up to 100 mg L^{-1}
Phosphorus (TP)	max. 20 mg L^{-1}	Sulphate (as SO_4)	100 mg L^{-1}

(Source: ACC, 1996)

The operators of premises licensed under the liquid trade waste policy must install the necessary equipment, such as grease-trap arresters or oil separators, filters and settling tanks to ensure the discharge meets the criteria. Regular monitoring at the discharge point is required to confirm agreed limits are met. Other specific restrictions apply to heavy metals and organic compounds such as pesticides, flammable substances and infectious medical wastes.

DOMESTIC DISCHARGES

Unlike the trade waste discharger, the domestic household is not restricted in the quality of wastewater discharged to the sewer. The total range of products available through the supermarket, plant nursery retailer (pesticides), home maintenance store (household paints and chemicals), and pharmacy (medicines) is likely to enter the wastewater stream in its removal from the household. While it is not possible to relate examples from each of these sources in this document, the example of laundry and kitchen detergents provides an insight into the marketing and consumption of products by the domestic household.

Contribution of chemicals from diet

The contribution of food products which decompose during wastewater treatment is significant. Foodstuffs such as cheese, processed flour, nuts and peas, corned beef and hamburgers provide valuable sources of phosphorus, nitrogen and sodium. It is most unlikely that an individual's eating habits will be changed to favour improved environmental considerations of wastewater treatment.

Survey of household detergents

A major source of chemicals to the wastewater stream is through the use of laundry detergents and fabric softeners, cleansing chemicals, soaps, abrasives, strong chemical disinfectants and strong acids and alkalis. A survey of laundry and kitchen detergents was used to accurately determine the contribution of phosphorus, sulphur and sodium to domestic wastewater. The implications of phosphorus and sodium concentrations in the wastewater are addressed here.

A range of laundry products, representing products from highly advertised brand names to the lesser known products, was purchased from supermarkets in Armidale in August 1999. Five dish washing detergents, 40 laundry powders and 20 liquid laundry detergents were selected. Each detergent was mixed at a concentration recommended by the product manufacturer, equivalent to the full wash water volume (150 L for a top loading automatic washing machine, 30 L for a dishwasher and 13 L for a standard kitchen sink).

There was no attempt to assess quality of the wash by its stain removing capabilities. An assumption was made that the manufacturer had determined the quantity of powder or liquid from independent testing. The liquid sample was analysed for pH, electrical conductivity, soluble phosphorus, sulphate, and the major cations (sodium, calcium, potassium and magnesium).

Phosphorus content

Two labelling initiatives are used in Australia to market products as "low phosphorus". It is unclear as to the environmental objectives these labelling symbols attempt to address. The industry standards have no legislative support and breaches of the standards do not appear to attract any repercussion.

The symbol **NP** is used to identify products which have *no added phosphorus*, although *levels below 0.5% may be present*. It is unclear as to whether the manufacturers source ingredients based upon low levels of phosphorus or whether the phosphorus in the ingredients is irrelevant to their operation. It is clear, however, that 0.5% equates to 5000 mg kg^{-1}, not an insignificant amount.

Of the six powder detergents labelled **NP**, one brand produced a wastewater with a phosphorus concentration of 6 mg L^{-1}, all others were less than 1 mg L^{-1} (average 0.3 mg L^{-1}). Each of the three liquid detergents labelled NP was less than 0.4 mg L^{-1} (average 0.15 mg L^{-1}).

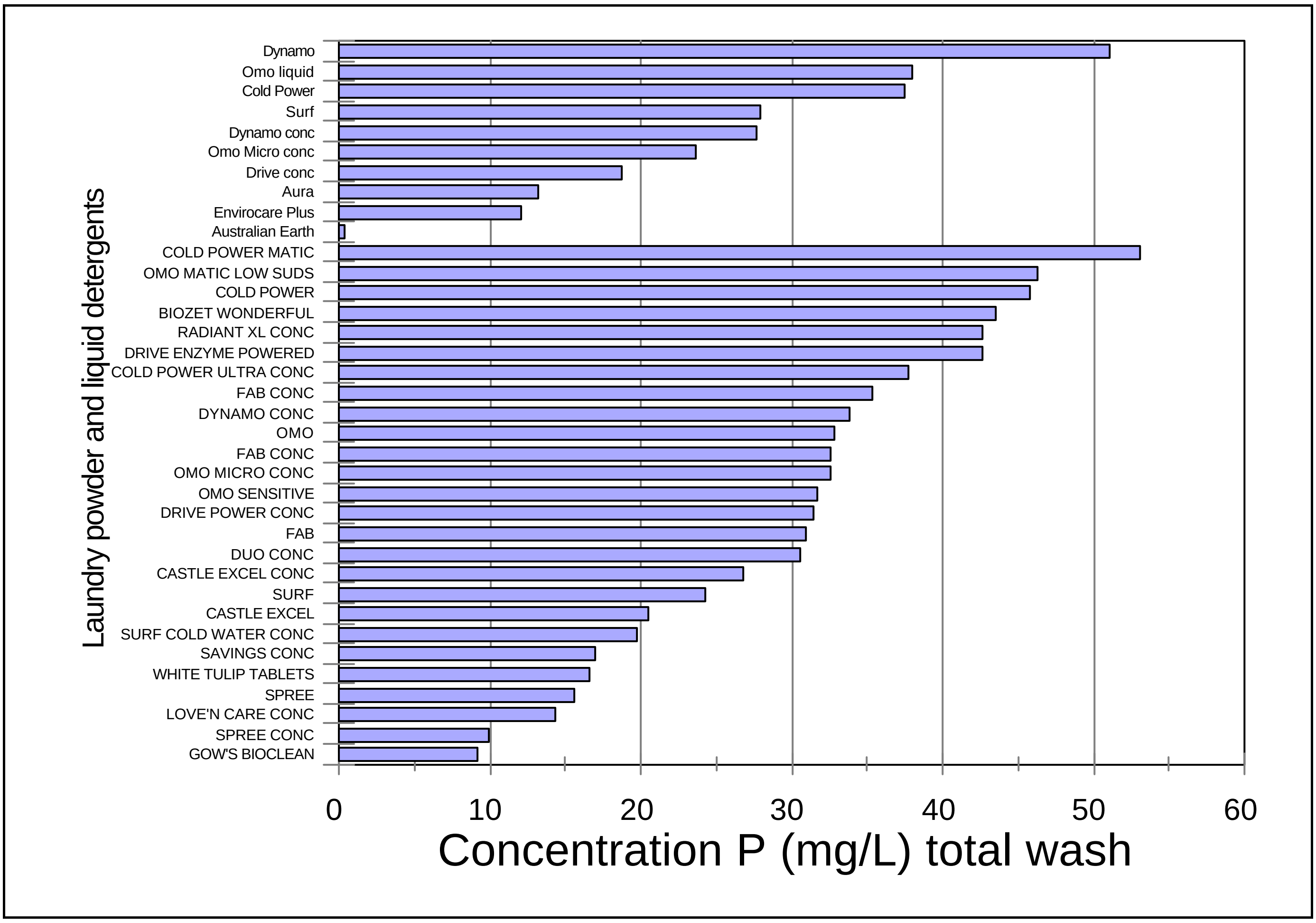

Figure 3 Concentration of phosphorus in liquid (l/c) and powder (u/c) detergents labelled **P**

The Symbol **P** denotes "*the product complies with agreed industry standards on phosphorus which impose a maximum content of 7.8 g per wash*". Figure 3 denotes the products labelled with this symbol and indicates the highly variable phosphorus concentration in the laundry wash water from these products. A phosphorus content of 7.8 g P per wash is equivalent to a concentration in the full wash load of 50 mg L^{-1}.

A third group consists of products either stated that their products contained "no phosphorus" or were "phosphorus free". The measured concentration of phosphorus for these products, was, with the exception of one product (7.9 mg L^{-1}) less than 0.3 mg L-1.

Dishwashing detergents

The four machine dishwashing detergents had 88.8, 61.9, 41.4 and 0.17 mg P L^{-1} of wash water compared with 0.1mg L^{-1} for the hand dishwashing liquid.

Sodium concentrations

Sodium salts present a significantly different problem to phosphorus in that they are always soluble and cannot be removed from the wastewater except by reverse osmosis. Sodium salts are used in laundry powder detergents as a "manufacturing agent", or in simple terms "filler". While sodium sulphate assists the manufacturer in processing operations, its function ceases from that point and becomes a significant source of sodium and sulphur in wastewater.

Many other components of laundry products use sodium as the cation because of the benefits of solubility. However, the contribution of sodium to the wastewater stream is generally not reported. It is uncommon for sewage plant operators to monitor sodium and often reuse options place considerable emphasis on BOD_5, total suspended solids (TSS), nitrogen, phosphorus and total salts while ignoring the effects of sodium.

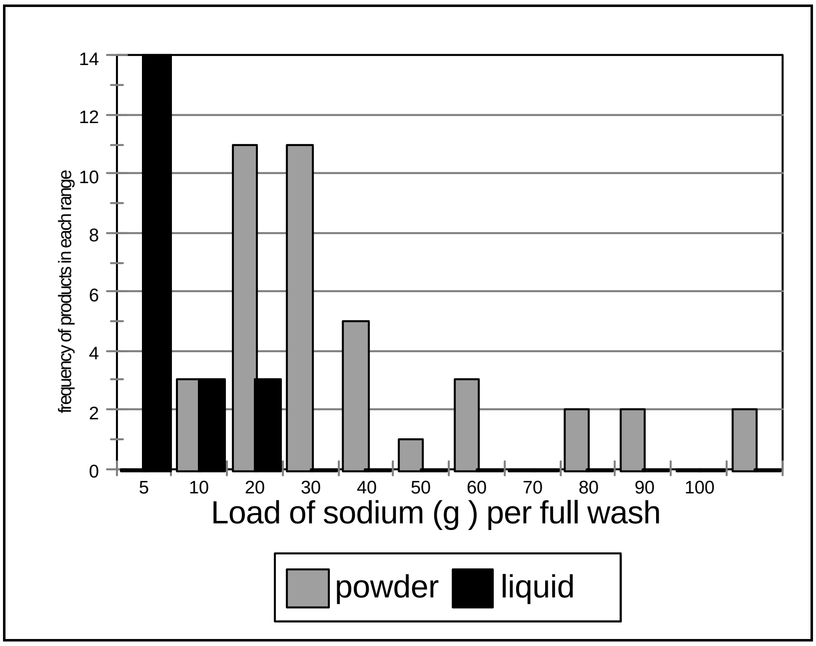

Figure 4 Load of sodium (g) per wash for liquid and powder laundry detergents.

The laundry products were measured for their contribution to sodium in the wastewater. Significant quantities of sodium are discharged with the wastewater (63 mg L^{-1} above the potable water background). What is not generally known is that by selection, low sodium products are available. There is no packaging information provided on the relative proportions of the elements contained in the laundry products. The consumer cannot make an informed choice.

Figure 4 indicates the range of sodium loadings from a full wash load for the products measured. A volume of 150 litres of water has been assumed for the total wash volume (Patterson, 1999).

Changes to wash water pH

Significant increases in pH of the wash water are partly due to the impact that high pH has on the ability of the detergent to remove stains. Soil and grease are more easily removed at high pH. The problem with high pH is the effect that any residuals may have on the person wearing the garment and the deterioration in cloth life with washing in higher pH liquids. The effects of high pH on the sewerage infrastructure should be examined.

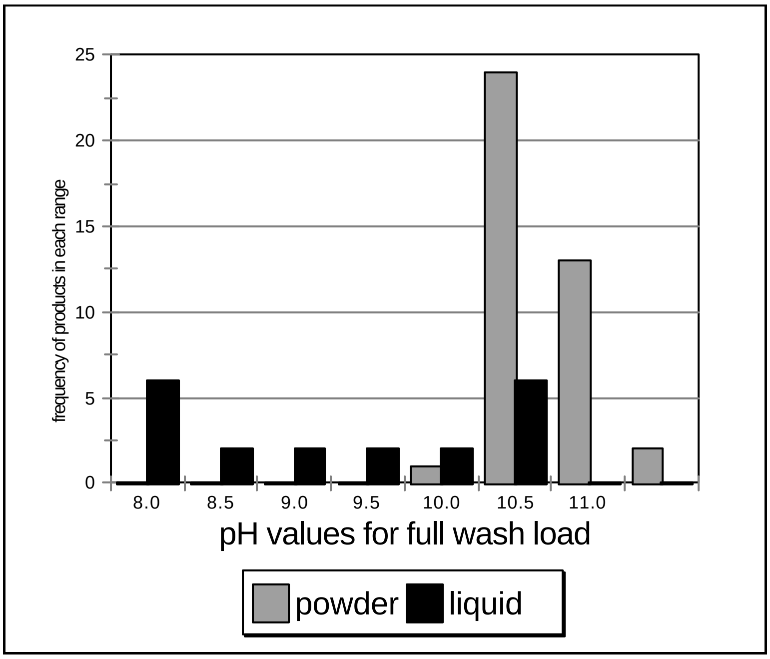

Figure 5 pH of liquid and powder laundry detergents

Many products make the consumer aware of the need for "caution" and "keep out of reach of children". However, advertising that a product which increases pH above 10.7 as suitable "for sensitive skin" is blatant misrepresentation of the effects that such elevated pH has on any human skin.

Of the dishwashing products tested, a powder resulted in the highest pH (11.55) recorded.

Of the 65 products tested, only 11 had a pH less than 9, the limit set by Armidale City Council for trade waste discharges. In most cases, laundry water discharges would not be permitted from commercial operations but are unregulated for general households.

DISCUSSION

The suitability of effluent for reuse options is determined not only by economic factors of climate, location and volume available, but more importantly by the chemical and biological properties of the effluent. That all wastewater chemistry is not regulated appears inconsistent with attempts to regulate commercial enterprises through liquid trade waste agreements. The domestic household is, at present, immune from any restriction on wastewater discharges to sewer and has a vast range of chemicals available for everyday use.

The potable water supply input to the wastewater stream is often disregarded in assessing likely future reuse options. Additional sources of sodium, used to reduce hardness (calcium and magnesium salts) may impose specific management issues on land application areas. Figure 1 shows the significant difference in total salt load with catchment location. Sustainable reuse options diminish with increased salt load as detrimental effects of salt and sodium impinge upon soil hydraulic conductivity and plant nutrient balances.

Attempts to reduce the phosphorus load of wastewater by the use of labelling with easily identifiable symbols P and NP can be misleading. Phosphorus is a valuable plant nutrient and where land application reuse options are undertaken, the phosphorus can be assimilated by plants and immobilised in the soil. However, phosphorus loading rates common to NSW sewage effluent are about twice the sustainable level for normal irrigation. A reduction in product phosphorus levels by 50% would have significant overall benefits in balancing nutrient loading. From the labelling of laundry products, it is not possible for the consumer to make such a choice, as is shown by the diverse range of phosphorus concentrations in Figure 3. The large disparity between load based licence limits of 0.3 mg L^{-1} and the 50 mg L^{-1} offered as the "industry standard" suggests that industry can significantly improve its role in phosphorus reduction using current technologies.

The large shifts in wastewater pH with the use of laundry detergents and the large buffering capacity provided by the combined dissolved salt load does not appear to concern wastewater treatment agencies. The effect of the high pH (mostly over 10, as shown in Figure 5) on biological degradation within the treatment system and its the effect upon the physical infrastructure should concern those agencies.

The sodium load from laundry products is of concern. Sodium salts, essentially always soluble and unable to be removed under typical wastewater treatment conditions, pass through the treatment process and impinge upon soil and plant relationships in land application areas. Over time, sodicity effects will reduce the value of those reuse projects and increase the risk of environmental harm. More adequate regulation, improved education and more specific product labelling are essential elements in improving effluent quality

CONCLUSION

The potential reuse of sewage effluent in sustainable projects hinges on the long term build up of chemicals and salts within the land application area, as well as the potential for plants to harvest those chemicals. The current rationale for most wastewater treatment is on engineering solutions after the wastewater enters the sewage treatment plant, almost no effort is given to improving the wastewater quality to this point.

The options for sustainable reuse projects are related to the quality of the effluent, and the environmental risks associated with land application for a variety of crops and activities. Domestic households currently enjoy unrestricted access to the sewer for the disposal of all manner of substances, a privilege not afforded the liquid trade waste licensee. That households should have access to a range of chemicals which significantly impinge upon wastewater quality is in need of review.

With increased phosphorus loads, soil phosphorus sorption capacity is reached in a shorter period and additional land will be required. A reduction of 50% in phosphorus load will achieve a more sustainable irrigation operation under Australian conditions. The removal of “fillers” on laundry products will significantly reduce the mass of sodium delivered to the reuse project.

Simple measures are available which can significantly reduce the chemical load of the incoming wastewater, but the politically unsavoury task of regulating householder consumption is unlikely to proceed. Therefore, product labelling to accurately reflect the product’s ingredients, much in the same way as food labelling has improved over recent years, must be implemented with a view to improving wastewater quality. Products which have a significant negative impact upon wastewater quality should be identified and appropriate education programs developed to inform the general public of the effects upon reuse potential of the effluent. The desirable product labelling should be developed between the manufacturers and the reuse operators, not by either alone.

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