# Household Chemical Impact on Effluent Re-use

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SUMMARY

The wastewater stream produced from domestic residences is a cocktail of chemicals over which the sewage treatment works (STW) operator has no control. Unlike trade waste disposal from even the smallest commercial operations, as controlled under National Guidelines, individual domestic households are immune from restrictions for disposal of household products to sewer, while the cumulative effects are totally ignored. A visit to the local supermarket will indicate the range of chemical compounds likely to enter the wastewater stream in variable quantities and unknown combinations.

This research project examined a sample of common household products and compared the likely effects of the entry of these chemicals to the wastewater stream upon re-use options. The products, specifically inorganic chemicals used mainly for "cleaning" and "disinfecting" included laundry detergents, washing-up detergents, bath soaps and general cleaning products. A comparison with the documented concentrations of chemicals in common foodstuff was explored as a means of identifying particular chemical species. Grab samples from the kitchen sink, shower and bath water provide an insight into the quality of wastewater generated.

A questionnaire survey of 111 households in the Armidale area gathered information on the use of the domestic wastewater as a vehicle for removing various wastes from the house. Specifically designed to collect data on septic tank systems, the range of information is applicable to sewered households indicating such detail as the type of laundry products purchased and the method of disposal of cooking oils.

Large quantities of highly alkaline and sodic compounds are common in laundry detergents. These salts produce an effluent which leads to elevated levels of total dissolved salts (TDS) and high sodium adsorption ratios (SAR), impinging upon soil properties from the salinity and sodicity effects in the disposal area. As an example, simply by choosing low sodium laundry detergents, a community could reduce, at no cost, more than 40% of the sodium load entering the sewers.

A comparison of domestic wastewater quality to trade waste requirements indicates that the household is immune from any form of regulation. Washing up water with a temperature of 60$^{o}$C, 2300 mg $L^{-1}$ Total Oil and Grease (TOG) and pH 10.65 far exceeds that able to be released by the commercial sector which is restricted to maximum temperature 38$^{o}$C, 100 mg $L^{-1}$ TOG and pH 7.0 to 9.0. The numerically greater number of households depositing uncontrolled wastewater may provide a greater impact on the sewage treatment plant than uncontrolled commercial operation. Education of householders in the wise use of sewers may overcome many overloading systems as well as reduce the concentration of undesirable chemical in the wastewater.

As re-use schemes increase in public favour and attract discounts for load based licensing schemes, the root cause of potential degradation of the disposal area rests in the products available on the supermarket shelves. While phosphorus and nitrogen receive notable publicity the potential loss of soil structure, hydraulic conductivity and imbalanced fertility from the uncontrolled use of sodium rich chemicals in the household is ignored. Improved regulator and consumer awareness is required to prevent long term loss of two valuable resources, the water and the soil. The recommendations from this project are for regulation of household cleansing agents and consumer education in improving the quality of wastewater before it arrives at the treatment plant. The community benefits will arise from increased efficiency of treatment, reduced licence fees and greater environmental protection.

KEYWORDS: household chemicals, laundry detergents, load based licence, re-use, salinity, sodicity, sodium, sodium adsorption ratio, trade waste criteria

# 1 INTRODUCTION

Wastewater, from either single dwellings or urban residential developments is a source of contamination of the hydrologic cycle. Numerous solutions are available, with varying degrees of success, to reduce the impact of disposal of treated wastewater (effluent) on the environment. For septic tank systems, primary treatment separates particles as a function of density. Materials less dense than water accumulate as scum to seal the chamber off from the atmosphere and producing a septic (anaerobic) environment, while materials more dense than water settle to the bottom as sludge. Effluent overflows are directed to a soil disposal trench for final purification and return of the water to the hydrologic cycle. A further refinement to on-site systems incorporates an aeration chamber between sedimentation and disposal, reducing biochemical oxygen demand ($BOD_5$) and further solubilising organic materials. Final disposal is usually by surface irrigation of a landscaped area around the house. While composting toilets treat toilet wastes, grey water disposal is usually by land application without treatment.

Urban areas depend upon engineered solutions to wastewater treatments in centralised sewage treatment works (STW) with disposal of effluent by ocean outfall or discharge to a river. Removal of solids, $BOD_5$, nitrates and phosphates and a reduction in faecal coliforms is usually a requirement of Environment Protection Authority (EPA) licensing. Other than efforts to reduce phosphorus under the NSW Phosphorus Action Plan (NSW Public Works, 1984) and re-use guidelines (NSW Recycled Water Coordination Committee, 1993) little is done to reduce chemical loading of the domestic wastewater stream prior to arrival at the STW. Recent development of trade waste policies by local government authorities from guidelines prepared by AWRC (1992), provides the mechanisms for reducing concentrations of solids, greases and chemicals from commercial premises. Armidale City Council adopted their trade waste policy in February, 1996 (ACC, 1996). No comparable domestic requirement is in place in Australia, indeed it appears that domestic sewers are immune from restrictions on disposal. Neither are there guidelines for acceptable household practices for sewer disposal nor any constraints upon the sale of products which will ultimately end up in the sewer. AWRC (1992) outlines requirements for effluent management but does not address management of the wastewater quality before it arrives at the STW. Even the phosphate action plan is an industry self-regulation for which community support is scant while the concept of bio-degradability only applies to degradation of the primary components of products.

In previous work, the author (Patterson, 1994) demonstrated a significant reduction in saturated hydraulic conductivity where domestic wastewater was disposed of by surface irrigation onto a variety of soils. Reduction of the sodium load, as measured by the sodium adsorption ratio (SAR), was critical to sustainable effluent re-use on land. With the increasing trend towards sustainable sewage management, options for re-use of secondary and tertiary treated effluent are expanding beyond traditional pasture irrigation. Therefore, other than new systems to better treat wastewater, such as biological nutrient removal, chemical precipitation of phosphates and heavy metals, an education program to achieve a reduction in chemical use within the household is the only economically sustainable option.

This project examined several areas of household wastewater generation with respect to the chemical load from normal household activities and compared the discharge of wastes to the compliance criteria for trade waste disposal. Specifically, dishwashing and laundry products were examined as a significant source of chemicals, while typical food products were reviewed as sources of major nutrients.

# 2 RESEARCH METHODS

## 2.1 Surveys of Household, Supermarkets, Trade Waste Disposal

A survey of households was undertaken using a questionnaire designed for single dwellings connected to septic tank, to determine the range and frequency of substances and chemicals disposed of to the wastewater stream. Data were obtained from two major supermarkets in Armidale, detailing the sales of powder and liquid laundry and dishwashing detergents sold over a one week period. For purposes of confidentiality the supermarkets cannot be named. The data obtained give a relative value of product preferences and quantities over the period. The author has provided contract analytical services to commercial operations in Armidale for quantifying trade waste discharges. Data from those sources have been used to compare current trade waste requirements with household discharges.

### 2.2 Chemical Analysis of Laundry Detergents

A range of powder and liquid laundry detergents was purchased and a sample of each was mixed with water at the same concentration as from a normal wash, that is, mixed at the rate recommended by the manufacturers for a normal wash in a top loading automatic washing machine. The volume of water used was equivalent to 200 litres, the volume from the complete cycle of wash, rinse and spin rinse. For each sample the pH and electrical conductivity (EC) change was recorded and the concentration of sodium measured by atomic absorption spectrometry. The weight of sodium per wash was calculated for each product.

### 2.3 Reference Materials for Foodstuffs

Published materials (Thomas and Corden, 1977*;* NHMRC, 1991) were used to tabulate daily foodstuffs with major constituents which then, through the food chain, pass to the wastewater stream with minor abstractions and losses.

### 2.4 Data Collection in the Home

Data were collected by grab sampling from appliances such as washing machine, dishwashing machine, hand washing in kitchen sink, bathwater and shower water to quantify temperature, pH, EC and Total Oil and Grease. Estimates were made of quantities of some components such as solids and greases entering the household wastewater stream from normal household activities.

## 3 RESULTS

### 3.1 Kitchen Survey

A total of 111 households were surveyed, of which 17% were connected to Armidale's sewer, the remainder utilised on-site treatment. The former was the only group to report the disposal of tea leaves and food scraps into the wastewater stream. The latter separated food scraps, tea leaves and oils from the kitchen wastewater and disposed of them by composting. No household reported having a garbage grinder attached to the kitchen sink. Common practice in the kitchen was for vegetables to be washed and peeled in the sink, the soil and some scraps entering the wastewater stream. Grease traps were not common (<10%) for septic tank connections and rarely used on sewered houses.

In the kitchen, 24% of the surveyed group had installed dishwashing machines, averaging 7 washes per week. Dishwashing machines average about 30 litres per full wash cycle. Where dishes are scraped rather than rinsed prior to washing, about 210 litres of water will be used in dishwashing task each week, plus hand dishwashing of the larger utensils when necessary. The most popular brand of detergent used by the households was "Finish".

Where hand dishwashing was done, an average of 16 full basin loads was completed. The average kitchen sink holds about 13 litres at normal washing-up depth, which equates to 208 litres per week. However, for hand washing to be successful, dishes are first rinsed to remove food scraps and grease and finally rinsed to remove soap residues. The additional volume is estimated to be equal to the washing-up water. Thus, hand dishwashing may consume considerably more water than machine washing.

In the laundry, 76% of the houses surveyed used top-loading automatic washing machines averaging 7.3 washes per week, some respondents reporting up to 21 washes per week. Choice (Nov 94) reported that the volume of water used for a normal wash ranged from 139 litres for a Hoover 5 kg load, through 175 litres for a Simpson

6.5 kg wash and up to 200 litres for Fisher & Paykel 7 kg machines. The average use of water through each machine was relatively constant at approximately 28 L $kg^{-1}$.wash. The most popular laundry products were Omo, Amway, Cold Power and Surf. Fifty percent of the respondents used the recommended dose of laundry powder or liquid, the remainder mostly used less than the recommended dose, although some people guessed how much powder to apply and did not measure it. The practice of first dissolving laundry powders in water before adding to the wash was rarely practised.

The toilet is not only used for the disposal of human wastes and toilet paper, but also in 38% of the households received bad food, date-expired medicines, sanitary napkins, condoms and tissues. The sewered households were more likely to use the toilet to dispose of substances which would not fit down the kitchen sink. The purchase of toilet paper was made on the basis of cheapest (35%), septic tank safe (35%) and unbleached (15%). Other products used in the toilet included bleaches, colouring agents and caustic cleaners. Only those households relying upon on-site systems stated that the use of bleaches was minimised because of potential destruction of favourable bacteria in the septic tank.

### 3.2 Supermarket survey

Two major supermarket stores in Armidale provided data on the quantities of laundry and dishwashing detergents sold over a full week. The data shown in Table 1 are from the supermarket which provided the most detailed data. Anecdotal evidence from the manager (*pers.comm*.) suggests that the data reflect an average week. The weights/volumes have been derived from the number of units sold and the unit packaged weight/volume. Popularity has been based upon quantities sold by grouping together products of the same brand name and calculating the percentage of total sales.

Table 1. Results of supermarket survey of laundry products and dishwashing detergents

| PRODUCTS | WEIGHT SOLD | POPULARITY |
|---|---|---|
| Laundry Detergents | | |
| Powder detergents | 548 kg | Surf 23%. Drive 21% |
| Powder concentrates | 435 kg | Radiant XL 16%, Bio-Zet 12%, Hurricane 11% |
| Soap powders | 12 kg | |
| TOTAL POWDERS | 995 kg | |
| Liquid detergents | 435 litres | Surf 11%, Cold Power, Bushland, Dynamo 9% |
| Liquid concentrates | 102 litres | Drive 23% Radiant 22%, Blitz 16%, Surf 14% |
| TOTAL LIQUIDS | 537 litres | |
| Dishwashing detergents | | |
| Machine powders | 125 kg | Finish 75%, Castle 8% |
| Hand liquids normal, | 328 L | Savings 19%, Palmolive 14%, Trix 10% |
| Hand concentrates | 32 L | Savings 49%, Bushland 21%, |

The standard powder detergents contain substances to "enhance manufacturing" that are not included in concentrates. The most common bulking agent is sodium sulphate, a chemical which takes no action in the washing process but may be up to 40% of the product's weight.

### 3.3 Laundry Product Analysis

Laundry products are sold by weight but measured by volume into the washing machine. As the volume of product varies from 125 g (No Frills) to 355 g (Savings) for the standard powder detergents and from 48 g (Amway) to 149 g (Excel Blue) for the concentrates, the task of determining the number of washes in a given pack size is almost impossible for the consumer to calculate while in the supermarket. Liquids ranged from 85 to 250 mL. As a result of both product use and unit price, the price for a standard wash varies from $0.07 (PayLess Liquid) to $0.82 (Cold Power). The median value was $0.52 per wash.

Changes in pH ranged from -0.9 (Pearsons Liquid) to +3.6 units (No Frills Soap) above the base level of the reticulated water. The low increases in pH were generally from the liquid detergents. Thirty two samples increased the pH above pH 9.0 and were dominated by the powder detergents. Thirteen samples elevated the pH of the water above 10.

Only 12 samples maintained an EC below 1.0 dS $m^{-1}$, the level above which water has a reduced value for irrigation. Most powder detergents elevated the EC above 2.0 dS $m^{-1}$, while the highest was 5.9 dS $m^{-1}$.

Sodium concentrations in the wash water are derived from the use of sodium as the soluble cation in the chemicals because the sodium salts are always soluble and do no precipitate out. The increases in sodium concentration of the wash water varied from 62 mg $L^{-1}$ (Lux Soap) to 332 mg $L^{-1}$ (Castle) for the powders and concentrates and within the range of 2 to 89 mg $L^{-1}$ for the liquids. The contribution of laundry products to sodium in the wastewater stream varied from nil to 113 g sodium chloride equivalent per wash.

Phosphorus was not measured as part of this project. Documented values are available in Cullen *et al.*, (1995) as measured by Albury City Council, although those values have only measured percentage total phosphorus in the raw detergent and not as a concentration in the final wash. It is disputed that 0.05% is low phosphorus, when, for example, one brand requires 335 g per wash, the contribution may amount to 165 mg of phosphorus and so be chosen as a low phosphorus compound compared with another brand in the same category (<0.05%) which requires 125 g powder to produce 63 mg of phosphorus..

### 3.4 Chemicals in General Food Products

As an gauge of the various ratios of chemicals which move through the food chain, Table 2 indicates the mass of protein, fat, calcium, phosphorus and sodium contained in an edible 100 g portion. Protein is a source of nitrogen and sulphur, fat contributes to the total fat in the diet, calcium is beneficial to reduction the sodium adsorption ratio of the effluent brought about by high sodium levels, while phosphorus contributes to pollution generally. Phosphates are common food additives (code numbers 338-343, 442, 450, 1410, 1412, 1413 (NHMRC, 1991).

Table 2. Sources of chemicals in general foodstuffs

| Food | Protein | Fat | Calcium | Phosphorus | Sodium |
|---|---|---|---|---|---|
| | | Per 100 g edible portion | | | |
| | g | g | mg | mg | mg |
| whole milk | 3.4 | 3.9 | 118 | 99 | 58 |
| cheese, cheddar | 26.1 | 33.2 | 860 | 506 | 610 |
| broccoli, boiled | 3..1 | 0.3 | 98 | 61 | 10 |
| potatoes, baked | 2.3 | 10.1 | 11 | 63 | 7 |
| mushrooms, canned | 1.5 | 0.2 | 7 | 110 | 400 |
| peas, green, boiled | 5.4 | 0.4 | 20 | 100 | 1 |
| hamburger with onion | 15.3 | 21.0 | 18 | 141 | 2040 |
| steak, rump, medium | 24.5 | 25.4 | 17 | 240 | 93 |
| corned beef, boiled | 20.9 | 28.4 | 13 | 193 | 1740 |

Source: Thomas and Corden, 1977

### 3.5 Home survey

Personal hygiene in the home produces variable wastewater quality which varies over time and from person to person. Water temperature of shower water was measured in the range 36° to 39°C , bath water 34° to 40°C mostly depending upon personal preferences. The pH and EC changes were dependent upon the use and type of soap, hair shampoos and conditioners and other cosmetics.

The range of products found under the kitchen sink, which over time ends in the wastewater system include strong acid and alkali cleaning agents, abrasive products and strong detergents. Together with solids and greases, the contribution to wastewater quality is highly variable. The wastewater from an automatic dishwasher has a temperature of 60°C, a pH over 10 and an EC around 1.0 dS $m^{-1}$. Hand dishwashing results in larger quantities of solids and greases entering the wastewater.

Of the other products found under the kitchen sink, the majority came without statement of the ingredients, most using terms such as “keep out of reach of children”, “may be fatal if inhaled”, “caution: phosphoric acid”, “wear gloves”, “see medical advice”. The consumer may be unaware that the substances are highly corrosive, reactive or in combination carcinogenic.

The volume of water used for flushing the toilet varies from household to household, older dwellings using 11 litres per flush and recent installations having a dual flush of 3 and 6 litres. Many toilet cleanser are available which fall within the range of strong alkali or strong bleach. The toilet contributes a significant solid load to the sewer, however, that is the main purpose of the sewer and is unlikely to be reduced.

### 3.6 Trade Waste Disposal

Armidale has a liquid trade waste policy which requires all mechanical workshop operators to have an oil separator installed and working. Four tests are required over two months and the discharge must satisfy the criteria. Tests conducted by the author for the operators of regulated premises show that the guidelines are being met after minor adjustments to the equipment. The criteria most commonly specified are detailed in Table 3. All restaurants and food preparation premises must have an adequate grease trap installed and maintained but no monitoring of sewer discharges is required. It is assumed that the grease trap will function to arrest the range of cooking oils in common use such as canola, sunflower, olive and grape.

Table 3 Criteria for trade waste disposal to Armidale sewer

| Parameter | Limit | Parameter | Limit |
|---|---|---|---|
| Temperature | < 38°C | suspended solids | <300 mg/l |
| Oil and Grease | < 100 mg/l | Total dissolved solids | < 4000 mg/l |
| pH | 7.0 to 9.0 | detergents | biodegradable |

Source: Armidale City Council (1996)

## 4 DISCUSSION

### 4.1 Removal of Solids

An initial operation of the STW is to remove solids and greases from the liquor. The prevention of solids entering the sewer at the household is relatively easy to achieve. Garbage grinders in the first instance should be banned from all premises. The practice of disposing of tea leaves and vegetable peelings down the sink can be a greatly reduced though the use of sink colanders, small mesh baskets through which only very small particles and liquids pass. The author successfully achieved a trade waste clearance when such a device ($1.49) was installed at a local veterinary laboratory.

The use of the toilet as a depository for articles which will not fit down the kitchen sink can be addressed as an education item. The disposal of date-expired medicines may require a central collection point, perhaps the local pharmacy. The role of composting within each household, while removing larger organic residues from the solid waste stream, has overlooked the need to prevent smaller materials entering the sewer.

That cooking oils are disposed of down the sink indicates that either the householder is unconcerned about impact upon sewage treatment or that there is no easy remedy for disposing of the oils. The oils in use today, together with the high detergent quality, cause the oils to pass through the primary treatment process and foul the secondary processes. The use of additional chemicals at the STW does not address the problem. Grease traps on individual homes are not the answer as they do not collect the non-solidifying oils, they will invariably be poorly maintained and become a localised health hazard The additional problem then becomes one of collection and disposal of grease trap waste from urban dwellings. The removal of grease from dishwashing can be addressed by scraping, rather than hot water rinsing plates and utensils, the scaping going to compost or with solid waste.

### 4.2 Removal of Chemicals

An audit of the urban home would produce data consistent with that for a hazardous site, except that labelling, storage, handling, treatment of spills, safety and disposal of containers would fail first assessment. While commercial premises have a plethora of regulations to consider, the household is immune from similar requirements even when the cumulative effect of a suburban area is compared. The restrictions upon use and disposal of household chemicals is one which can be used to reduce the impact of household chemical upon the sewage treatment systems.

The laundry product survey indicates that almost one tonne of powder detergents and 500 litres of liquid laundry detergents are sold from one supermarket in Armidale in an average week. Given that there are three major supermarkets, an estimate of three tonne of powder and 1500 L liquid per week, totalling 4.5 tonnes of detergent is not unreasonable. Armidale has approximately 6500 dwellings for a population of 23 000 persons. For an average of 7 washes per week per household, using an average of 150 g per wash equates to 1.05 kg per household per week, or 6.8 tonnes per week. While the two calculations do not agree, it is suggested that a value over 4.5 tonnes per week is acceptable. That 4.5 tonnes of detergent ends in the wastewater. As shown by the detergent analysis, up to 30% of the powder may be sodium salts from fillers and “manufacturing agents”, then the reduction of up to 1.5 tonnes of salt per week is achievable through selective use of detergents, that is, low sodium formulations. There is an opportunity for inducing the product manufacturers to replace sodium based chemicals with potassium salts which in turn may benefit many re-use options, particularly bananas.

It is unlikely that the chemicals in food, particularly the sodium and phosphorus will be reduced by education. The impact of food scraps and uneaten portions being washed down the sink can be reduced through community education. At the present there is no indication that any education occurs.

The imposition of load based licences on STW operators will require that the total load of pollutants such as nitrogen, phosphorus and metals will have to be addressed where 100% land application is not practised While salt is not scheduled, the effects upon the soil are significant and amelioration with lime or gypsum is only a short term solution. Rather than develop new methods for dealing with current chemical concentrations or continually moving re-use projects because of salt accumulation, reduction of those chemicals from the wastewater is the more positive option, achievable through better practices in the home.

At government level there needs to be a rational approach to the availability of chemicals for use in the house, not the “free for all” that exists at present. Consumer awareness could be improved by accurate labelling and identification of ingredients as for food products.

### 4.3 Application of Consistent Rules

The requirements for trade waste disposal to meet national guidelines has changed the management practices of the operations affected. Motor repair workshops have installed oil separators, truck wash points have removed oil and soil from their wash points. Restaurants and cafes are installing grease traps while some are considering their options for reviewing their kitchen procedures. Unfortunately, the majority of connections to the sewer have no such impositions and cumulatively the private dwellings have a greater ability to overload the STW than the commercial operations. The wastewater from a domestic dish washing machine is an unacceptable trade waste because of high temperature and above range pH. Consistency is needed across all sewer connections and fair and equitable monitoring of those requirements.

### 4.4 Education

The community's increasing awareness of effluent re-use as beneficial use of a limited resource may provide the opportunity to involve them, as residents to minimise the solids, oils and chemicals which as caste to the wastewater system. That the STW operators invest money in education for the improvement in wastewater quality may create greater potential for re-use of the effluent and further reduce costs imposed by load based licensing.

### 4.5 Collection Point

The recycling of glass, paper, green waste, aluminium can and PET plastics shows that the community will invest the time in removing products from a waste stream and delivering, or have collected, those products to a centralised point. In a similar manner, cooking oil recycling, date-expired medicines, other household chemicals could be collected or a collection point nominated. The cost of the collection could be charged against the sewerage fund as the benefits will accrue to the fund through reduced load based licence fees, a more attractive effluent for re-use and reduced treatment costs.

## 5 CONCLUSIONS AND RECOMMENDATIONS

There is an inconsistent approach to wastewater generation across the community and an unreasonable expectation that the sewage treatment systems will cope with the irregular and random chemical quality. Further, with load based licensing, there are additional expectations that re-use of the effluent is a means of reducing licensing costs or face additional state government charges. The beneficiary of any cost saving is the community, yet to date the residents have uncontrolled use of the sewer as a repository for a range of chemicals which, in many instances, are hazardous substances and they can use the sewer to dispose of oils and solids at will. The commercial sector does not have the same latitude and a bound by a set of operating criteria.

While there is a need for regulation of the chemicals available for uncontrolled use in the home, there is a pressing need for the community to become aware of the need for their cooperation in the operation of the sewerage scheme. Through education and establishment of collection points the residents can be made aware of the "sewer safe" products which will lead to sustainable re-use options at reduced licensing costs.

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