Using Recycled Water for Irrigation

WISE WATERING
Irrigation Management Course

These materials are part of the Wise Watering Irrigation Management Program, developed in part from the NSW Agriculture WaterWise on the farm education program and The Mallee Wells Irrigators manual.

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Introduction

Recycled water includes a range of wastewaters that have been treated in various ways.

Recycled water used for irrigation may require specific management practices to address issues relating to public health and the environment.

This course aims to address the specific management issues that are unique to wastewaters and recycled water.

Technical matters relating to “best practice” irrigation management are covered in other modules of the Irrigation Course.

Additional reading

Environmental Guidelines for the use of Recycled Water in Tasmania, Draft 8, April 2000.
Overview of requirements

A number of State agencies are involved in the assessment of reuse proposals. The following bodies are represented on the Wastewater Reuse Coordinating Group (CG):

- DPIWE; concerned with the assessment, licensing and monitoring of Level 2 sewage treatment plants, including wastewater treatment and disposal, and protection of the environment.
- Dept. of Health & Human Services; protection of public health.
- Mineral Resources Tasmania; groundwater protection.
- Local Government; planning and plumbing issues.

The CG is responsible for the assessment and regulation of Level 2 wastewater reuse proposals involving an irrigation component.

Wastewaters commonly contain dissolved salts, specific chemicals, suspended materials, bacteria and viruses. Specific management practices are required to minimise the risks that might be posed by wastewater when used for irrigation.

This module aims to address the issues and risks associated with irrigation of wastewater.

It is important to appreciate that wastewater reuse is encouraged for two reasons;

- The water is a potentially valuable resource, due to both the water and nutrient content of the “waste”.
- The nutrient and other components of the water are potentially a threat to the environment if discharged or used inappropriately.

There is an important legal requirement in relation to wastewater reuse. There are “severe penalties” under the Environmental Management and Pollution Control Act (EMPCA) 1996 for the misuse of wastewater that results in pollution.

The key environmental objectives of recycling are;

- Reuse that avoids pollution of ground or surface waters.
- Sustainable use of the materials (particularly the nutrients) in the wastewater.
- Management of the wastewater that avoids interference with community health or amenity.
Characteristics of Wastewater

Wastewater may contain a range of pollutants. These pollutants can often be turned into a valuable resource, with careful management, but an appreciation of the risk and hazard potential of the pollutants is necessary.

Toxic components

The most likely toxic substances are;

Heavy metals, eg., mercury and cadmium; are most likely where the wastewater is from industries; unlikely where the wastewater is mainly from residential areas. Most of the heavy metals in the wastewater stream are chemically stabilised during treatment into the sludge. Heavy metals and other toxic substances are therefore generally present in reuse effluents at trace levels.

Pesticides and petroleum products; possible in any area due to careless acts of disposal or use.

Nutrients

Wastewaters commonly contain plant nutrients, particularly nitrogen and phosphorus, that are often applied as artificial fertilizers to irrigated fodders and crops. Use of wastewater can reduce or even replace the need for other fertilisers.

Other nutrients common in wastewater include potassium, sulphur, calcium and magnesium.

The wastewater may supply a surplus of nutrients, ie., more is applied in the irrigation water than is removed from the area in plant and animal products or fixed in the soil (strongly bound to clay particles). If this occurs, then the surplus may become a risk to the environment through leaching into ground or surface waters.

Irrigation with wastewater should be limited to either the water or nutrient needs of the crop. An agronomist will be able to determine whether the application at a particular site will be limited by the capacity of the crop and soil to use the water or the nutrients.

Salinity

Wastewaters commonly contain higher levels of salinity than the original water sources, due to additions from various sources and concentration by evaporation.
The risks related to use of saline wastewater are no different to those associated with other saline water sources, and include:

- The salt can cause burning of the leaves of sensitive plant species.
- Salt can accumulate in the soil (salinisation) and eventually make the soil so saline that plant production is reduced or threatened.

Sodium is a common constituent of salts dissolved in irrigation water, and it can cause the soil to disperse and thereby inhibit drainage and create waterlogging.

**Organic components**

Wastewaters generally contain suspended solids, including organic matter. Breakdown of these components requires oxygen. If the levels of organic compounds are too high, soil oxygen levels can be depleted to such an extent that the soil becomes anaerobic (devoid of oxygen) and unpleasant odours can be produced.

Application rates of sewage wastewater are generally low enough that soils do not become anaerobic, and the organic materials can improve the condition of the soil.

**Living organisms**

Wastewaters may contain viruses, bacteria and other organisms. While these are significantly reduced by the water treatment activities, undesirable organisms will still be present in the wastewater.

Therefore, it is important to exercise care in the use of wastewater.

Normal hygiene practices, such as taking off muddy boots before going inside and washing hands before eating, are an important part of reuse practice.

Farmers should be careful that appropriate signage exists to warn others about the use of recycled water. The standard “Trespassers Prosecuted” and appropriate signage on taps stating “recycled water – not for drinking” is required by the Health Department. The use of purple colored pipe or taping may also be appropriate where supply lines approach the vicinity of potable water lines.
Key Issues for Managers of Wastewater Reuse Sites

Off-site effects

Runoff

One of the important reasons for using wastewater for irrigation is to stop pollutants getting into waterways. Therefore runoff of water that may be contaminated must be avoided.

Prevention requires attention to the amounts of wastewater applied. Applying more water than can be absorbed by the soil will lead to runoff or seepage. Both consequences should be avoided.

As for any irrigation system, management and scheduling should ensure that the amounts applied can be absorbed by the soil. Monitoring of soil moisture can be accomplished conveniently and economically to assist with irrigation management (methods are addressed in the irrigation scheduling module).

Wastewater must not be applied faster that it can infiltrate into the soil. Infiltration rates vary between soil types (higher in sandy soils and lower into clays), and the infiltration rate declines with time; ie., highest when the soil is dry and becoming slower as the soil profile becomes wetter. This is particularly important in clay soils which may have cracks that extend through the profile to the soil surface. As the soil wets, the clay expands and the cracks close, and the rate of infiltration can fall dramatically.

Spray drift

Drift can occur from sprinklers, and is most apparent from high-pressure guns on travelling irrigators. Many people consider this spray drift to be of high nuisance value on roads and even more so onto domestic properties.

Reuse schemes are established after taking account of buffer distances, with minimum distances as follows;

- High pressure spray irrigation, 100 metres to nearest dwelling.
- Centre Pivot irrigators, dependent on sprinkler type.
- Drip irrigation, 20 metres.

In some installations, devices that measure wind speed and direction have been connected to the pump control system so the pump can be automatically turned off when wind speed becomes excessive or comes from an undesirable direction.
Wind effects will obviously be reduced by planted and natural windbreaks, and will be more significant from some directions than others.

**Groundwater contamination**

With any irrigation operation, there is the possibility of leaching of soluble salts (including nutrients) into the groundwater, and this issue needs particular attention when using wastewater. If such leaching occurs, then the quality of the groundwater may be impaired to the extent that it becomes unusable for certain purposes. For example, nitrate leached from the soil into water for human consumption can be toxic to infants.

Groundwaters generally slowly move into surface water sources, so leached nutrients may eventually move into surface waters and stimulate algal blooms.

It is therefore important to avoid the potential for salts and nutrients to be leached into a watertable.

Over irrigation with any water can elevate ground water levels and may bring salt into the rootzone and to the soil surface.

**Prevention.** Reuse sites are generally selected in areas with subsoil layers of clay that restrict seepage, and thus movement of soluble salts, to the groundwater.

Water applications and annual water budgets should be managed so that applications match the capacity of the soil to absorb the water. If this is done, the potential for leaching is reduced (this may result in salts and nutrients accumulating in the root zone, and this is addressed later).

Monitoring of soil moisture levels, particularly deep in the soil profile (say 1.5 to 2.0 metres) provides an effective means of irrigation management to minimise seepage.

Monitoring of groundwater depth and chemical composition provides the ultimate test of efforts to ensure groundwater quality is not affected.

**On-site effects**

A number of potential on-site effects must be considered and managed;

- Nutrient accumulation in the rootzone.
- Nutrient accumulation on stock fodders.
- Salt scalding of plants.
- Salt accumulation in the rootzone.
- Sodicity.
- Rising watertables.
- Contamination of marketable produce.
- Contamination of fodders.
Nutrient accumulation in the rootzone

Wastewaters commonly contain significant amounts of phosphorus and nitrogen, and these may be in excess of plant requirements. Nutrients are taken up by the plants and may be subsequently removed from the paddock. Therefore, crops that are removed from the paddock will remove much larger amounts of nutrients than fodder crops consumed by stock grazing in the irrigated paddock.

Nutrient applications in the wastewater need to be considered when determining the amounts of artificial fertilisers that might be required. For example, the wastewater may not contain sufficient potassium for optimal production, so normal bagged fertiliser may be needed to supply particular nutrients.

An example of a phosphorus balance follows:

Irrigated lucerne.
Water applied, 4 megalitres/hectare (400 mm depth).
Phosphorus concentration in the wastewater, 10 parts per million.

The amount of phosphorus applied is $4 \times 10 = 40$ kg/ha/year.
(The water contains 10 kg of P per million kg of water, and we are applying 4 million kg of water.)

If the lucerne is cut for hay or silage that is removed from the paddock, then the P removed is calculated as follows:

Say 12 t/ha of lucerne is removed, at a phosphorus concentration of 0.25%; this removes approximately 30 kg of P.

If this is removed from the paddock, the annual surplus of phosphorus is 10 kg. While this is very likely to become "locked up" by binding to the clay in the soil, the capacity for the clay to attract the phosphorus may be reduced after a long period. If this happens, then the excess phosphorus becomes mobile and may pollute groundwater.

If the lucerne is grazed, then very little nutrient is removed in animal products. Losses of P in meat and wool, and by binding to the soil, is estimated at about 0.5 kg per dry sheep equivalent. Where fodders are irrigated with wastewater and grazed there is generally a considerable surplus of phosphorus that will lead to increasing levels of P in the soil.

Monitoring of soil nutrient levels is important to provide forewarning of accumulating nutrients and thus the potential for losses to the environment.

Nutrient accumulation in fodders

High nutrient applications in the wastewater could create high levels in fodders. An example is the accumulation of nitrates in some brassica crops (eg., forage rape). Stock eating such fodders can be poisoned.
Introduce stock to new feeds gradually to ensure they have time to adjust to the new feed.

**Salt scalding of plants**

Some wastewaters contain such high levels of soluble salts that the leaves of sensitive species (for example green beans) can be burned. Most wastewaters from domestic sources contain around 200-300 ppm Total Dissolved Salts, which does not require any special management. Where the salinity of the wastewater exceeds 1,500 ppm TDS, salt management needs to be a feature of the irrigation management plan.

Plants vary in their sensitivity to salts, for example peas and beans are amongst the most sensitive (although these are unlikely to be irrigated with wastewater). The effects are more severe if irrigation is conducted during hot windy days, as the salts are concentrated by evaporation.

The salinity of water is easily measured with a conductivity meter (~ $100), so if the salt level in water is marginal use a conductivity meter to check it regularly.

Where high levels of salinity are known to exist, irrigation schemes may require the dilution of the wastewater with lower-salinity water from other sources.

**Salt accumulation in the rootzone**

If the wastewater has high salt levels, salts are likely to accumulate in the rootzone over the irrigation season. While these salts may be reduced by the leaching effect of winter rainfall, a gradual buildup in salinity may occur. This is most likely to become apparent in drainage lines which receive the discharge from sub-surface movement of saline groundwaters.

This effect is most likely to be observed when the salt concentration of the water supply is high, or where the irrigation is applied to areas which already have a saline watertable close to the surface.

Monitoring of the soil salinity, and the groundwater depth and salinity, is cheap and effective, and is recommended on most reuse sites.

**Sodicity**

Sodicity is a measure of the sodium content of the soil, relative to calcium and magnesium.

Irrigation with water that contains high levels of sodium can lead to displacement and leaching of calcium and magnesium, and their replacement on the clay particles with sodium. This causes the clay particles to be more expansive, and they may move so far apart that they become dispersive when wet.
The dispersion reduces the permeability of the soil and can lead to waterlogging.

This effect of sodium can be anticipated from an analysis of the wastewater and the soil. It is most likely to be a problem in the following circumstances:

- When the irrigation water contains a high level of sodium relative to calcium and magnesium (calculated from an analysis of the water and calculation of the Sodium Absorption Ratio).
- When the soil contains a high level of sodium relative to calcium and magnesium (determined from soil analysis, Exchangeable Sodium Percentage).
- When the total salinity of the water is low. Water with a high salinity reduces dispersion (that is why dispersion tests are conducted with distilled water).
- When the surface soil contains a high level of clay. Dispersion of surface soils leads to crusting and reduced permeability.

The potential for sodicity problems should be assessed during the initial planning and monitored by soil analyses. The problem can be reduced by applying gypsum, which replaces sodium in the clay with calcium. Application rates are commonly in the region of 1 tonne per hectare, but should be calculated on the basis of soil tests from the paddock in question.

**Rising watertables**

Irrigation is often accompanied by rising watertables, which can create waterlogging (on the irrigation area and nearby. This occurs when irrigation is applied in excess of the capacity of the soil to absorb it or the plants to use it.

Rising watertables are also more likely from rainfall that falls either during the irrigation season or in the autumn, when the soil profile is already wet from irrigation.

Rising groundwater is difficult to avoid, and it even happens in dryland paddocks. The main issues are to ensure that the rise is minimized by good irrigation management (through the use of irrigation scheduling and soil moisture monitoring) and to monitor groundwater levels.

The most serious result of rising watertables occurs when a saline watertable exists before irrigation is introduced, and irrigation brings the saline groundwater closer to the soil surface (and possibly to the rootzone of crops and pastures). For this reason, areas with shallow saline watertables should not be irrigated.

Trees planted around the irrigation area may help to lower watertables, to intercept water moving over the top of subsoil clay, and also reduce the effects of wind on spray drift.
Contamination of marketable produce

Wastewaters often contain undesirable bacteria and other organisms. The current environmental guidelines for the use of recycled water manage health risk caused by these organisms by categorising the wastewater into three classes.

- Class A – advanced treatment; unrestricted use (includes salad crops).
- Class B secondary lagoons and polishing ponds; requires withholding for fodders, accepted for irrigation of crops subject to further processing. Most wastewaters in Tasmania are treated to a secondary level, and with disinfection are classified as Class B Reclaimed Water.
- Class C secondary lagoons, requires withholding for fodders, acceptable for non-human food-chain crops only.

Market requirements are important. While potatoes will be cooked before consumption, Simplot has indicated they will not process potatoes irrigated with municipal wastewater.

Within a farmer’s quality assurance (QA) system, crops from wastewater irrigated systems must be tracked by the appropriate paper work to make sure that crops for further processing are not consumed raw. The Agriculture Division in Department of Primary Industries, Water and Environment is working on an advanced food safety system that could incorporate this certification system.

Contamination of fodders

As most wastewaters contain bacteria and other potentially harmful organisms, fodder consumption by livestock should not occur until a suitable withholding period has elapsed. The duration of the withholding period depends on the treatment the wastewater has received, and the type of livestock. Pigs should not be grazed on any land irrigated with recycled water.

For Class A wastewater no withholding period is required.

For Class B wastewater a withholding period of 5 days is required for grazing animals (sheep, cattle, goats and horses).

Class C treated water (wastewater with no disinfection after treatment) can not be used on pastures or fodders for grazing with cattle. It can be used for silage or hay production.

No withholding period is specified before fodders can be cut for hay or silage. However, management practices would dictate that the fodder should be dry before mowing, so a reasonable withholding period will result anyway.

Make sure livestock can not drink pools of water contaminated with wastewater, or drink from wastewater storage dams.
Soil Monitoring

Monitoring of the soil and groundwater is usually a requirement of a reuse scheme licence. This involves taking samples according to a defined procedure, and having these samples analysed by standard and consistent methods. These procedures are likely to be specified in the development application and documentation. The following suggestions are indicative of the general nature of monitoring required at wastewater reuse sites.

Soil sampling

Timing of sampling

Before wastewater is applied. Background or baseline samples must be taken within the irrigation area before there is any irrigation with wastewater. The results from this sampling will help determine fertiliser practices for the ensuing cropping or fodder program.

Subsequent monitoring. The licence for the area will probably stipulate the frequency of soil sampling to monitor the level of salts and nutrients. Annual sampling is commonly required, at least until the sustainability of the system is demonstrated. It is important to remember that the potential for adverse effects is greatest where the rates of effluent application are highest and continue for the longest periods. An example is lucerne, where relatively high application rates of effluent will probably occur for a number of years. Where annual crops are grown in rotation with dryland pastures, less frequent sampling is indicated.

Sampling areas

The area to be sampled must be defined. It will normally be a paddock that is treated uniformly; ie, grows one crop and is irrigated uniformly. Paddocks with different crops or different irrigation management need to be sampled separately.

Taking samples

Same time of the year. Samples should be taken in the same month, because seasonal effects (such as soil temperature and rainfall) will effect the levels of some constituents. Sampling is best conducted when soils are moist and soft, so avoid sampling during the summer (as some areas may be un-irrigated when the next sampling is due). Spring (say October) and autumn (say May) are generally good times to sample, as the soil will be moist. Sampling of land that is to be used for annual cash crops should be done several months before sowing so that requirements for fertiliser applications can be determined.

Sampling procedure. The best approach is to take a number of samples from specific sites within a given paddock. These should be combined for the required sampling depths to create a composite sample for each depth.
It is not possible to permanently peg sampling sites, so some other means is required. One way would be to use a GPS (Global Positioning System) to locate sites, although the accuracy of the equipment needs to be within at least 5 metres.

An alternative is to peg the starting and end points of a straight line traverse across an area (with the pegs on fence lines and therefore out of the way). Sampling points would then be at set distances along the traverse (say 50 metre distances).

There should be a minimum of 12 sampling points across the area (the number of points can be used to establish the distance between points). Record the sampling procedure on a diagram.
**Sampling depths.** Depths must be consistent; it is usual to sample the top 100 mm.

A subsoil sample is required to detect whether there are changes in the subsoil. The depth of this sample depends on the characteristics of the soil profile. Nutrients and salts leached from the surface are likely to be absorbed in subsoil clay layers. The subsoil sample should therefore be taken from the surface of the subsoil clay in Duplex soils (i.e., soil profiles with a marked texture contrast). This will probably mean that the sample is taken from different depths for each hole, but it is appropriate to standardize on sampling the upper 100 mm of the subsoil clay.

Where the soil profile is Uniform or Gradational (in soil texture) it is appropriate to take the subsoil sample at a set depth, say 50-60 cm.

**Composite samples.** Combine all the soil from the same depth, mix thoroughly, and take a sub-sample of about 2-cups in volume (say 500 ml).

**Sampling equipment**

Surface soil samples are most readily taken with a tube sampler, designed to sample to a set depth and with a consistent diameter of the sample core.

Sampling the subsoil can be accomplished with a hand auger (e.g., Jarrett 50 mm) or with a sampling tube that takes a core (30-50 mm diameter). In either case, care is required to ensure the sampling depth is correct and consistent.

It will generally be most convenient to use the same implement for the surface and subsoil sampling. A Jarrett auger is slow but reliable in all soil types, convenient and not subject to breakdown.

**Sample preparation and storage.**

Samples should be sealed in airtight plastic bags and sent to the laboratory as soon as possible. Include a label indicating the site and depth.

**Soil analyses**

Methods of analysis for particular components vary, so always confirm the method of analysis with the laboratory. As a precaution, refer to previous analysis results from the site and confirm the method.

For example, soil pH can be determined on a 1:5 soil:water suspension, or a 1:% soil:calcium Chloride solution. The results differ by on average 0.7 of a pH unit. Therefore, when reporting results and requesting analyses always record the method of analysis.
Groundwater depth and chemical composition is most conveniently monitored in test wells (also called piezometers).

Test wells should be drilled into the watertable, and are generally 50-100 mm in diameter with a PVC pipe to the base. The PVC pipe should be slotted or perforated in at least the lower metre.

Fine gravel should surround the PVC in the lower metre. Above this, clay or topsoil should be back-filled so that surface water can not flow into the hole. Finish the PVC a set height above ground level (say 100 or 200 mm) so this height can be subtracted from the tape measure used to measure the water depth.

Figure 2. A test well installation.

The depth to ground water should be measured monthly and recorded (preferably graphed).

Water samples should be taken by bailing the water out of the hole (use a bailer made from a short length of PVC pipe, sealed and weighted with lead shot at the closed end), then allow the water level to be restored and then take a sample. If it is not possible to bail out all the water before taking a sample bail for a
minimum of 10 minutes, then take the sample. Fill a 1.25 litre bottle with water and cap it with no air in the top. Dispatch for analysis as quickly as possible, otherwise refrigerate.

A second smaller sample for bacteriological analysis (at least 250 ml) should be taken and stored in a sterile container, with an air gap of say 20% of the capacity of the container. This sample should be conveyed to the laboratory within 24 hours of sampling, and stored in cool conditions (refrigerator) if there are delays. Samples should be taken and dispatched early in the week so they can be at the laboratory for analysis before the weekend.

Figure 2 illustrates a “perched” or un-confined watertable. There may be sites where the groundwater is trapped or confined between two layers of low permeability. For example, the water may be trapped in a gravelly layer between two clay layers. This water may be under pressure, and be artesian (where water flows out of the top of the test well) or semi-artesian (the water level rises up the pipe but not to the surface).

In these circumstances the space between the PVC pipe and the hole in the soil must be sealed above the gravel layer so that water can not move upward on the outside of the PVC pipe and escape into higher soil layers. This is achieved by back-filling the space above the slotted part of the pipe with a powered clay (bentonite) that expands when wet to seal around the pipe.

Care in installing these test wells is very important to obtain reliable results.

Changes in watertable levels and composition are likely to be slow, so monitoring over a long period is required (minimum 5 years).

As salt, nitrogen and phosphorus are the constituents most likely to be of concern, samples should be analysed for the following;

- Electrical Conductivity (EC, a measure of salinity).
- pH (easily measured).
- Calcium, Magnesium, Sodium and Potassium
- Nitrogen as nitrate, nitrite and ammonia.
- Phosphorus as phosphate.
- Faecal coliform bacteria.

Label samples with the name of the collector, site and date. Store in the dark and refrigerate.
Safety issues

Areas of wastewater irrigation must be appropriately identified with signs to advise people entering the land.

Pipe outlets, pipes and fittings must be identified and installed in such a way as to reduce the chances of someone drinking the water. A practical matter is that there should be no above-ground outlets from the irrigation system (so it is very difficult to drink from the reticulation system).

Employees responsible for irrigating must be warned to avoid exposure to the water and practice normal hygiene such as washing their hands, removal of boots etc after contact.

Make sure pumps etc are secure from un-authorised access.

Crops grown with Class B effluent that require further processing such as canning or pasteurisation before final consumption must be tracked for the purposes of product QA. Tasmanian Quality Assurance can give guidance on how to establish effective QA systems.