Climbing the ladder: a step by step approach to international guidelines for water recycling

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Abstract Given the pressures on the world's freshwater resources, recycled water is a valuable resource. Recycled water can increase the reliability of water supply because it is an independent source of water. Water recycling requires effective measures to protect public health and the environment. In the absence of comprehensive international guidelines, different countries have developed different approaches to managing water recycling depending on the understanding of the health risks, their individual economic circumstances, and affordability. Approaches vary between high technology/high cost/low risk and low technology/low cost/controlled risk. Furthermore, differences occur between countries and within individual countries. Inconsistencies can often be traced to lack of a unified scientific position on health effects. These inconsistencies increase public concerns about health risks and may give rise to conservative controls on responses to water recycling projects that some countries may be unable to afford.

In this paper, an international panel of authors discusses how the different water recycling approaches might be linked together into international water recycling guidelines. These guidelines would incorporate a uniform approach to assessing hazards and risks while providing flexibility for individual countries to vary requirements to suit local circumstances of affordability and risk. The authors propose a framework of guidelines in which individual countries can progressively improve recycled water quality as lower risk levels become more affordable. The authors argue that a uniform international approach will result in a number of benefits including a better focus on risk management, better targeted research and development efforts and greater public confidence in water recycling. The authors invite discussion on the concepts put forward in the paper.

Keywords Guidelines; recycled water; regulations; wastewater; water quality; water recycling; water reuse

Introduction

In the natural water cycle, weather systems circulate the water on Earth through a cycle of evaporation and precipitation. Most of the water on Earth is in the oceans and polar ice caps and the majority of rain falls on the oceans. The rain which falls on land is mostly transpired by the vegetation, but some percolates to groundwaters, and some runs off to the rivers and flows to the oceans, eventually to evaporate and return as rain. The average cycle time is measured in thousands of years. Mankind has significantly altered the natural water cycle by interventions including: diversions from rivers for human uses; mining of groundwaters; and return to streams of inadequately treated or or untreated wastewater.

Rising demands for water for irrigated agriculture, urban consumption, and industry, are creating competition over the allocation of scarce water resources (Croce 1998, Odendaal 1998). Yet the supply of freshwater is finite and threatened by pollution. To avoid a crisis, many countries must conserve water, pollute less, manage supply and demand, and slow population growth (Hinichsen *et al*. 1999).

In these circumstances, recycled water is a valuable resource. Not all uses require water at drinking water standards. Appropriately treated recycled water can be reused to reduce the demand on high quality freshwater sources. Water recycling short circuits the normal circulation of water through the natural water cycle where the average cycle time is over 2,500 years. By increasing the speed of circulation through the water cycle, water recycling increases the available supply of water and enables greater human benefit to be achieved with less fresh water. By reducing the need for fresh water diversions, water recycling for beneficial uses has the potential to make a substantial contribution to meeting human water needs and to lessen mankind's impact on the world's environment.

Water recycling requires effective measures to protect public health and the environment. Such measures must not only be both technically and economically feasible. Individual countries have developed different approaches, which vary between high technology/high cost/low risk and low technology/low cost/controlled risk depending on the local balance between affordability and risk. Because there are many proven treatment technologies available, recycled water systems can be tailored to meet the specific water quality levels for public, commercial and industrial uses.

This paper originates from an international panel session at the "Global Perspectives in Water Recycling" seminar hosted by the WateReuse Association in California in March 1999. In this paper the panel members canvass ways in which the different approaches could be linked to develop the framework for international guidelines for water recycling that would also provide the flexibility to vary tailor the requirements to suit local circumstances of affordability and risk.

Existing water recycling regulations and guidelines: many countries, many approaches

There are many countries in the world and many different approaches have been developed for water recycling regulations and guidelines to provide effective measures to protect against risks to public health and the environment.

Health risks

Health risks include both microbiological risks and chemical risks. Provided industrial discharges are properly controlled, microbiological risks are usually the dominant risk for non-potable applications of recycled water. There are two basic approaches to health risk assessment:

Quantitative Risk Assessment (QRA), the "high technology/high cost/low risk approach". The QRA technique provides a method of quantitatively assessing human health risks associated with exposure to pathogens in recycled water. The framework for quantitative risk assessment involves four steps.

- Step 1: Hazard Identification involves identifying the specific pathogens likely to be of concern.
- Step 2: Exposure Assessment entails measuring the number of organisms present in the recycled water and the number transmitted to a person by a particular exposure or activity.
- Step 3: Dose-Response Assessment uses data on dose-response relationships for a particular organism to determine the probability of infection from the dose received.
- Step 4: Risk Characterisation involves calculation of the theoretical risk based on the exposure and dose-response assumptions.

While hazard hazard is a function of recycled water quality, exposure and dose are also functions of application methods and hygiene measures. In controlled access situations, risks can be reduced considerably by simple measures such as a withholding period between application of recycled water and access to the irrigated area. Response to an exposure is a function of health and immunity, both of which can vary considerably in exposed populations. QRA allows a theoretical calculation of extremely small risks to which the community is exposed by particular practices. QRA is capable of providing estimates of extremely low risks, typically two or more orders of magnitude less than those derived from epidemiological studies. Such risks are so small that they will never be statistically demonstrable in a community where recycling occurs. The design determination as to what is an acceptable risk of disease, relative to other normal lifetime risks and compared to the benefits of recycling, then becomes a political and economic decision. Microbiological risk assessment is a useful tool in assessing relative health risks associated with water reuse. It is likely to play a role in future development of regulations/guidelines as models are improved.

Real or Attributable Risk (AR), "Low technology/low cost/controlled risk". Attributable Risk takes into account the epidemiological chain. This may include physical and social factors such as acquired immunity and ratio of susceptible to immune members of the population which affect the probability of contracting disease as a result of exposure to recycled water. Practices and guidelines are then based on the principle of incurring no incremental risk to the population through recycling practices, or reducing the risk from existing practices such that the benefits of water recycling outweigh the risks. AR cannot be as sensitive as QRA in the estimation of risks, as epidemiological studies are, by their nature, limited in size and in the availability of controls. There are significant difficulties in conducting effective epidemiological studies for reuse sites.

Environmental risks

While guidelines for the use of recycled water have traditionally focused on health protection measures, in the past 20 years there is increasing recognition of the need also to ensure that the impact of recycled water applications on soils and groundwaters are environmentally sustainable for the long term. There is little value in pursuing reuse of recycled water if the outcome is to render land or groundwater unfit for any further use within a small number of years. Factors to be considered in guidelines include salt and chemical content, as well as hydraulic and nutrient loading rates. These are not just a function of recycled water quality but also local environmental circumstances and how the recycled water is applied. For each water recycling scheme, an irrigation management plan should be prepared to suit the local environmental circumstances.

Many countries, many approaches

Different countries have developed different approaches to protecting public health and the environment. Clearly economics is a key factor in the choice of philosophy. The developed countries have tended to adopt an QRA approach which leads to conservative high technology/high cost/low risk guidelines or regulations of which California's water recycling regulations are the best known example. Some countries have endeavored to follow this regulatory approach to guidelines, but have not always achieved low risk in practice because of insufficient money, experience or regulatory controls. Limits of affordability have led some developing countries to follow the low technology/low cost/controlled risk path of the attributable risk approach that is embodied in the World Health Organisation Guidelines. The WHO approach aims to provide guidance that can be adapted to national conditions and constraints, and allows the introduction of threshold criteria devised from balancing risk and affordability.

In the absence of international guidelines, there are inconsistencies between countries in the guidelines that have between adopted. Even when the approaches are broadly similar, there is wide variation in the details. There is also inconsistency within individual nations as evidenced by the variations in the guidelines adopted by the different state jurisdictions in federations such as the USA and Australia. The absence of a unified scientific position increases community concerns about risk and can lead to unnecessarily conservative responses to proposed water recycling projects. For example, excessive concern about infection from parasites can lead to prohibitively expensive treatment requirements, or costly operating limitations that preclude the use of normal agricultural methods. Development of a common international framework will improve public confidence in water recycling, improve risk management and lower costs.

Climbing the ladder step by step: an international framework with national decision making

"Only one world"

We live in one world. In the face of economic globalization, small and developing countries will find it increasingly difficult to sustain separate guidelines in national and provincial jurisdictions. There would be global benefits in developing an international guideline framework that can be tailored to suit local circumstances.

The risks which arise from a particular use of a particular quality recycled water are the same no matter where we live. So it should be possible to create one international recycled water framework (thinking globally) with a series of steps progressing from low quality/high risk to high quality/low risk. The resulting risks depend on exposure, dose and response, which are a function of the application method and local conditions. Tolerable risk levels are conditioned by local economic circumstances, public acceptability, and affordability. Therefore, choosing a step on the quality/risk ladder should be based on national or provincial circumstances (acting locally). It follows that international guidelines should specify what recycled water quality gives low risk for a particular application, and also provide guidance on how to assess and manage risk to achieve acceptable risk matching local circumstances.

Matching recycled water quality to applications

It is possible to tailor recycled water quality to meet health and environmental requirements of particular applications; i.e. to specify it in terms of fitness-for-purpose. In doing so it is possible to define a series of recycled water grades or "products" which are linked to specific applications. It follows from the previous discussion on risk assessment that fitness-for-purpose can be linked to assessed risk which is not just a function of recycled water quality, but also the method of application, the local health and environmental circumstances and local economic circumstances.

In Australia, the federal and state governments have combined to develop a national water quality management strategy. The strategy includes draft national guidelines for use of recycled water (NHMRC 1997). The draft guidelines nominate four grades of recycled water in terms of microbiological quality expressed in median faaecal coliform (FC) levels, measured in terms of colony forming units.

High Contact	FC <	10/100mL
Medium Contact	FC <	100/100mL
Low Contact	FC <	1000/100mL
Restricted Access	FC <	10000/100mL

Table 1 Possible recycled water grades and treatment: an Australian suggestion

Grade	Description	FC/100mL	Treatment
5 star	Potable		Advanced multi-barrier treatment processes effective against microbiological and chemical pollutants.
A+ 4 star	Open Access	<1	Secondary + membrane filtration + disinfection Secondary + coagulation + filtration +disinfection
A $3^{1/2}$ star	High Contact	<10	Secondary + filtration + disinfection
B 3 star	Medium Contact	<100	Secondary + disinfection
C 2 star	Low Contact	<1000	Secondary + disinfection Advanced Primary + filtration + disinfection (Jimenez 1998) Upflow anaerobic sludge blanket + disinfection (El Gohary 1998)
D 1 star	Restricted Access	<10000	Secondary + maturation ponds Oxidation pond systems

The draft national guidelines leave room for the states to vary approval, monitoring and risk management measures to suit local conditions.

Separately in 1993, the state of New South Wales (NSW) established a fifth “unrestricted access” urban and residential grade similar to California’s tertiary filtered and disinfected grade:

NSW Urban & Residential FC < 1/100mL

Simpson (1998) has proposed a simple star grading system for recycled water that makes a clear distinction between a) appropriately treated recycled waters which are suitable for beneficial reuse, and b) untreated or partially treated effluents which do not meet basic requirements for beneficial reuse.

These ideas can be combined to produce a scale of recycled water grades of increasing quality which require increasing levels of treatment as shown in Table 1. Moving up the scale of increasing quality/treatment to achieve lower levels of risk can be viewed as something akin to climbing up the rungs of a ladder.

Applications such as agricultural irrigation may also have requirements for limitations on salinity and chemical contents as well as microbiological requirements. These might be combined with basic microbiological quality grades to identify a set of recycled water products designated Agricultural Grade A, B, C and D. For high contact non-potable applications, microbiological criteria may include virus and parasite limits. For applications where recycled water may supplement or impinge on drinking water quality, it may also be necessary to set additional requirements for total organic carbon and other chemical contaminants.

Table 2 shows how an individual nation might use this approach to set guidelines for reuse applications using the draft Australian national guidelines as an example. Other countries might choose to set higher or lower quality requirements for a given application depending on their assessment of affordable levels of risk.

Discussion

Balancing risk and affordability

The risk–affordability balance is a function of the local economy. As with pollution control, the benefit to cost ratios for water recycling are governed by laws of diminishing returns. Removing 99% of the pollutant load or risk may cost twice as much as removing

Table 2 Linking recycled water applications and grades. Example based on draft Australian water recycling guidelines

Restricted D (1 star) FC<10000	Low contact C (2 star) FC<1000	Medium contact B (3star) FC<100	High contact A ($3\frac{1}{2}$ star) FC<10	Open access A+ (4 star) FC<1	GRADES APPLICATIONS
					Surface Waters and Impoundments
Not Allowed	Not Allowed	Water quality met post mixing	Allowed	Allowed	Surface Water – Protected Water Supply Primary Contact Recreation
Not Allowed	Water quality met post mixing	Allowed	Allowed	Allowed	Surface Water – Primary Water Supply
Water quality met post mixing	Allowed	Allowed	Allowed	Allowed	Surface Water – Secondary Water Supply Secondary Contact Recreation
Allowed	Allowed	Allowed	Allowed	Allowed	Surface Water – Restricted Access Ornamental Water Bodies
					Groundwater
Not Allowed	Not Allowed	Not Allowed	Water quality met post mixing	Allowed	Groundwater Potable Aquifer Direct Injection Retention >12months
Not Allowed	Water quality met post mixing	Allowed	Allowed	Allowed	Groundwater Potable Aquifer Percolation >3m & Retention>12months
					Non Food Crops
Allowed Withhold 4hrs	Allowed	Allowed	Allowed	Allowed	Silviculture, Turf Farms Fodder, Fibre and Seed Crops
					Pasture Animals and Fodder
Not Allowed	Not Allowed	Allowed except pigs	Allowed	Allowed	Stock Water
Not Allowed	Allowed Withhold 5days	Allowed	Allowed	Allowed	Pasture and Fodder for Dairy Cattle and Pigs
Not Allowed	Allowed	Allowed	Allowed	Allowed	Pasture and Fodder for Beef Cattle, Sheep, Dairy wash down water
					Food Crops
Not Allowed	Not Allowed	Not Allowed	Allowed	Allowed	Foods eaten raw incl. salad vegetables and root crops, RW contacts edible portion
Not Allowed	Allowed	Allowed	Allowed	Allowed	Foods cooked, processed, before eating
Not Allowed	Allowed	Allowed	Allowed	Allowed	Orchards, Vineyards, No RW contact with edible portion
					Urban and Residential
Not Allowed	Not Allowed	Not Allowed	Allowed	Allowed	Residential Gardens, Car washing, Pavement Washing
Not Allowed	Not Allowed	Not Allowed	Allowed	Allowed	Toilet Flushing Indoor Fire Protection Systems
Not Allowed	Allowed Withhold 4hrs	Allowed	Allowed	Allowed	Sporting Fields, Golf Courses, Parklands, Open Space, Landscaping,
Not Allowed	Allowed Withhold 4hrs	Allowed	Allowed	Allowed	Highway Landscaping, Lawn Cemeteries Outdoor Fire Protection
					Commercial & Industrial
Not Allowed	Allowed	Allowed	Allowed	Allowed	Open Systems Minimal Aerosols
Not Allowed	Allowed Withhold 4hrs	Allowed	Allowed	Allowed	Road Making, Soil Compaction Concrete Mixing
Not Allowed	Allowed Withhold 4hrs	Allowed	Allowed	Allowed	Mining, Dust Suppression Coal Washery Make Up
Allowed	Allowed	Allowed	Allowed	Allowed	STP Process Water & Sewer Flushing

90% of the pollutant load or risk. In terms of achieving maximum benefit from the investment of scarce capital funds, it is then better to achieve 90% removal of risk in two projects than to achieve 99% removal of risk in one project. While doing nothing has high health and environmental costs, requirements intended to assure a very low risk might be too expensive. A controlled risk approach may be a better alternative in such circumstances.

An advantage of establishing flexible international guidelines with a series of steps is that an individual country can climb the ladder of progressive investment over time in upgrading recycled water quality, as lower risk levels become more affordable commensurate with the capability of that country's national economy.

Benefits of international collaboration

Developing a single framework for international water recycling guidelines will confer a number of benefits:

- national and local authorities will be able to change their focus from standard setting to risk management;
- with a single framework, international research and development efforts can be better targeted;
- a common international framework will improve public understanding and confidence in water recycling.

The benefits of project certainty

Onerous regulation and complex project assessment, approval and monitoring processes delay projects and make them more costly. There are a number of benefits which flow from simplifying water recycling guidelines and project approval processes:

- establishing the rules allows project proponents to get on with the job;
- simplifying approvals transfers money from regulation to implementation;
- projects become more affordable, which then encourages more investment in water recycling;
- increasing affordability/investment allows greater investment in higher recycled water quality resulting in lower risks.

Guidelines versus standards and regulations

There is a debate in some jurisdictions about whether water recycling should be controlled through regulations or guidelines. There are arguments for and against each approach. Regulations can be set to ensure adequate health and environmental protection particularly when risks are perceived to be high. In some circumstances regulations may also protect project proponents from vicarious interpretations by local officials. In other cases "one-size-fits-all" regulations may impose unnecessary extra costs. Guidelines can provide flexibility to suit local circumstances, avoid unnecessary costs and provide incentives to improve and innovate. Guidelines are more workable when risks are assessed to be low and there is confidence in institutional arrangements and risk management measures.

Conclusions

Water recycling requires effective measures to protect public health and the environment. For solutions to be physically implemented they must be technically feasible and economically affordable. Different nations have developed different approaches to managing risk through water recycling regulations and guidelines. The approaches vary between high technology/high cost/low risk, and low technology/low cost/considered risk depending on the local balance between affordability and risk. These inconsistencies in approach, and the absence of a unified scientific approach, increase public concerns about risks, and sometimes give rise to unnecessarily conservative responses to water recycling projects.

The risks which arise from the particular use of a given quality of recycled water are the same no matter where we live. So it is possible to create a single international framework of recycled water guidelines (thinking globally) with a series of quality steps progressing from low quality/high risk to high quality/low risk. The resulting risks depend on exposure, dose and response, which are a function of the application, the method of application and local conditions. And tolerable risk levels are conditioned by local circumstances and cost structures. Therefore, choosing a step on the quality/risk ladder should be based on national or provincial circumstances (acting locally). It follows that international guidelines must not only specify which recycled water quality gives low risk for a particular application, but must also provide guidance on how to assess and manage risk to achieve acceptable risk matching local circumstances.

While doing nothing has high health and environmental costs, a low risk approach may be expensive, so that a controlled approach which balances risks and costs and keeps water recycling affordable, may be a better choice in some cases. An advantage of establishing flexible international guidelines with a series of steps is that an individual country can climb a ladder of progressive investment to upgrade recycled water quality as progress in the national economy makes lower risk levels more affordable. At any point in time, an individual country can maximise the benefits obtained from water recycling and its investment of scarce capital funds.

Developing a single framework for international water recycling guidelines will confer a number of benefits.

- National and local authorities will be able to change their focus from standard setting to risk management.
- With a single framework, international research and development efforts can be better targeted.
- A common international framework will improve public understanding of, and confidence in, water recycling.

The authors recognise that the international guideline concept which that is presented in this paper requires further development to create working document. The authors invite discussion and suggestions for further development of the concept.

References

Croce, F. (1998). *Policy Formulation for Sustainable Reuse of Wastewater: The Egypt Case Study*, Proc. AWT 98 Advanced Wastewater Treatment, Recycling and Reuse, Milan Sept 1998, 781–788.

El Gohary, F.A., Nasr, F.A. and Wahaab, R.A. (1998). *Integrated Low Cost Wastewater Treatment for Reuse in Irrigation*, Proc. AWT 98 Advanced Wastewater Treatment, Recycling and Reuse, Milan Sept 1998, 757–763.

Hinichsen, D., Robey, B. and Upadhyay, U.D. (1999). *Solutions for a Water-Short World*, Population Report, Series M, No.14, John Hopkins University School of Public Health, Population Information Program, February 1999.

Jimenez, B., Capella, A. and Landa, H. (1998). *Advanced Primary Treatment: A New Technology*, AWWA-WEF Water Reuse 98, Orlando Florida, February 1998, 269–279.

NHMRC (1998). *Guidelines for Sewerage Schemes: Use of Reclaimed Water (Draft)*, National Health & Medical research Council Australia & Australia and New Zealand Environment Conservation Council, National Water Quality Management Strategy Vol 16, April 1997.

NSWRWCC (1993). *Guidelines for Urban and Residential Use of Reclaimed Water*, Recycled Water Coordination Committee, State of New South Wales, Australia, May 1993

Oddness, P.E, van der Westhuizen, J.L.J. and Grobler, G.J. (1998). Wastewater Reuse in South Africa, *Wastewater Reclamation and Reuse*, T. Asano Ed., Water Quality Management Library Vol. 10, Chapter 25, Technomics Publishing 1998.

Simpson, J.M. (1998). *Star System Terminology for Recycled Water*, personal communication.

State of California (1978). *Wastewater Reclamation Criteria*, California Administrative Code Title 22, Division 4, California Department of Health Services.

State of California (1997). *Water Recycling Regulations (Draft)*, California Department of Health Services.

World Health Organisation (1989). *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture*, Report of a WHO Scientific Group, Technical Report Series 778, World Health Organisation, Geneva.