HEALTH AND ENVIRONMENTAL ASPECTS OF RECYCLED WATER

J.G. Atherton
Kenmore, Brisbane, Australia

Keywords: Recycled water, health, environment, resource, agriculture, industry, urban, epidemiology, risk assessment, quality, contaminants, microbes, chemicals, toxins, treatment technology, storage, aquifer recharge, regulation, ownership, liability, economics, community involvement.

Contents

Summary

The broad aspects of water recycling are presented as the basis for considering recycling as a means of extending the water resource for use in agriculture, industrial processes, and for urban and environmental enhancement. Health considerations are discussed in terms of risks posed by bacteria, viruses and parasites, and by toxic substances both inorganic and organic, including cyanobacterial toxins. Treatment technology is considered with respect to quality parameters related to reuse practices, and the limitations imposed by health considerations and environmental sustainability. Legal issues, economics and the importance of community involvement in design and implementation of recycling proposals are also mentioned briefly.

1. Introduction

It has been estimated that only three per cent of the world's people have access to water that has not, at least, been "indirectly" recycled. Indirect recycling refers to circumstances where, say, wastewater discharged at one location becomes source water at another. For example, one town abstracting water from a river downstream of another town's discharge point is undertaking indirect recycling. In some areas where there is insufficient treatment of either the water discharged or abstracted, significant health problems are caused. Where such deficiencies do not exist, indirect reuse of water has operated successfully for decades.
Increasingly, however, recycling has become a deliberate goal. Generally speaking, the most extensive schemes exist in areas that face a "water deficit" (a shortage of water to meet requirements) or where the use of recycled water saves money compared to the cost of existing supplies. Options for the use of recycled water implemented internationally include:

- **Direct Potable Reuse**. Where recycled water is provided directly to the consumers from the treatment facility for all purposes including human consumption. (The term "potable" means that the water is of a quality suitable to be consumed by people.)

- **Indirect Potable Reuse**. Where water is made available for potable use after having first been discharged to the environment. For example, treated wastewater is actively injected into aquifers in the United States and in other locations and withdrawn later for human consumption and other purposes.
- **Non–potable Reuse** *(both direct and indirect).* Where recycled water is made available for purposes other than human consumption, such as irrigation of golf courses, dust suppression, various industrial processes, and the like either directly or following discharge to the environment. This category of reuse would include use in agriculture.

Both direct and indirect non-potable reuse are employed extensively in California, Arizona, and Florida, US, principally for agricultural purposes, as is also the case in Israel. In Europe extensive, largely circumstantial, indirect non-potable reuse is practiced for both urban and agricultural supplies.

Growth in recycling overseas has led to the development of various guidelines and regulations to ensure that the schemes are appropriate to the circumstances are properly managed and that health and other requirements are met. California's Title 22 legislation has formed the basis of guidelines implemented at other locations in the US, other countries and to an extent, in Australia. Furthermore, recycled water and the by-products of the wastewater treatment process are increasingly recognized as a resource, rather than as waste products.

In Australia, governments, regulators and operators are exploring reuse opportunities, often driven by communities anxious to end discharge of effluent to land or waterways, or by potential users keen to obtain access to new water sources for various operational and economic reasons. Examples include:

Water is recycled naturally in the environment. The time period over which this occurs may be lengthy in the case of groundwater, or may occur in minutes in the case of rain falling on a hard surface and being evaporated quickly. Humans have intervened in the natural water cycle by damming rivers, extracting water from aquifers, irrigating the landscape, piping water to cities, and removing wastewaters for discharge to rivers, oceans or aquifers. Despite intervention by people, the essential principles of the natural water continue to operate. Most water is conveyed by gravity, albeit some may be piped, and discharge usually occurs at the lowest point (e.g. river, aquifer, or ocean).

Recycling implies a further intervention in the water cycle. Where water is drawn from a river, indirect recycling has been practiced for centuries as one town or farmer draws water previously discharged upstream. Similarly, by-products from wastewater treatment (sludges and bio-solids) and human and animal wastes are recycled through application to land. The impact of direct human intervention in the water cycle through recycling is to make the recycling "loop" smaller.

2. Why Recycle?

Use of recycled water is a means to an end, not an end unto itself. However, recycled water should be considered alongside all other options for improving the sustainability of water use, improving supply security, or increasing the economic efficiency with which water is provided. The following list the range of objectives that might be sought by the community and which may lead to decisions to increase the use of recycled water.

2.1 Economic Advantage

Use of recycled water may be economically advantageous. It may be cheaper than supplies from existing sources providing direct savings to users or operators either immediately or through deferral of new works (such as construction of a new dam). Seen in a regional context, its use may enable growth to occur in areas where water shortages in certain districts exist providing broader but indirect economic benefits. A summary of such benefits would include, but is not necessarily restricted to circumstances where:

- The cost of making water available from a recycled source is cheaper than production from a non-recycled source. This might be the case, for example, where "headworks" costs can be avoided (i.e. the cost of accessing new sources of non-recycled water or the expanding pipeline capacity) or simply in circumstances where recycled water can be produced more cheaply than water from existing supplies.
- A recycled source is available closer to the point of use than a non-recycled source. On average, transportation is 60–70% of the cost of running a water supply network. If transport costs can be reduced because of the proximity of the recycled source to the user, recycling may prove to be cheaper overall, even if the production cost for recycled water is higher.
- The total "lifecycle" cost of an asset can be reduced through the use of recycled water. Lifecycle costs include not just operating and capital costs, but also the cost of energy used in creating an asset, and during the asset's operational life (ie the period of time before it needs to be replaced), the cost of its disposal, and non-economic factors such as the environmental impact of its use and disposal.

Economic benefits are not always available through the use of recycled water. Indeed, the cost of recycling can be prohibitive in many circumstances compared to the cost of using existing supplies at current prices. Where this is not the case, however, economic advantage may drive the expansion of recycling schemes.

2.2 Resource Constraints

It is often said that Australia is the driest inhabited continent. Water shortage has driven the expansion of recycling schemes overseas and this could also be expected to be the case in Australia. It must be stressed, however, that availability of water very much depends on local circumstances. Some areas have ample existing supplies, whereas growth in other areas is limited by water shortages. Still other areas have highly variable rainfall meaning that there is a shortage of water at certain times and a surfeit at others. Water shortage will only be a driver for recycling in some of these conditions.

Of course, rainfall is not necessarily an indicator of water availability. In most cases availability depends on there being a way of storing the water so that it is there when needed. Where storages or aquifers are already fully allocated, increasing the availability of water may require the construction of additional storage facilities. Accessing recycled water may be a more appropriate response in such circumstances. Conversely, it should also be noted that areas with low rainfall may not face shortages of water if storages and aquifers of adequate size to provide water to the population or to the irrigable area are available.

Availability of water changes over time, particularly in response to population increases, increases in irrigated rural lands or other factors such as pollution or salinization of an existing source. Climate change may also affect availability of water in future. Whereas recycling may not have been considered necessary to supplement existing supplies in the past, it may be worthy of consideration alongside other options in the future; such conditions need to be anticipated and planned for if appropriate investment in supplementation of existing supplies is to be made.

2.3 Equality of Access

In many areas, water is abstracted from rivers for use in urban or rural areas and then discharged after use. Users downstream may consequently suffer a degradation in the quality or quantity of water available for their use. Reuse of water may improve the quality and quantity of water available from a river and may reduce abstraction, ensuring equality of access to water supplies by all users.

2.4 Environmental Drivers

Disposal of wastewaters to waterways, aquifers or onto land can cause environmental degradation. Problems of eutrophication (growth of algae through the introduction of nutrients) and salinization of waterways, increased turbidity, presence of pathogens in bathing waters, run-off from land, and build up of nitrates in groundwater are all problems that may be caused by effluent disposal. Increasingly, regulations have been introduced to require sewage treatment authorities, mine operators, and others discharging wastewaters to improve the quality of their effluents prior to discharge. In some areas, no discharge may be permitted due to the sensitivity of the receiving environment. Where such constraints exist it may be environmentally and economically sensible to reuse this water rather than upgrade treatment facilities or move discharge points.

Water diverted from surface and groundwaters is not available to the environment. Yet, these waters need to be seen as part of an ecosystem, the functioning of which is compromised by lack of flow, or intermittent flow (or even excess flow) resulting from abstraction of water by humans or discharge of wastewater. There has been increasing recognition of the environment's own need for water in recent years and considerable effort has been directed to determining what level of flow should be restored. Recycled water can be used either to provide for "environmental flows" or as a substitute for waters currently abstracted from surface and groundwaters. Maintenance of environmental flows may be another driver for reuse of water.

2.5 Intergenerational Equity

The concept of "intergenerational equity" is one of the key principles of ecological sustainability. It means that the activities of this generation should not compromise the ability of future generations to meet their own reasonable needs. Where, say, degradation of water supplies will reduce our children's ability to meet their own water requirements, the principle of intergenerational equity has been violated. Similarly, if we invest in an activity that allows us to meet only the requirements of this generation but passes a debt burden to future generations, we could not be said to have achieved equity between generations. Maintenance of intergenerational equity may also be a reason for pursuing reuse.

2.6 Recycled Water—a Valuable Resource

It is often suggested that disposal of wastewater represents a waste of a resource. The water disposed of itself, the nutrients it contains, and the by-products (sludge and bio-solids) left over after treatment can all be used again. If, however, the cost of recycling is greater than the value of the water, nutrients, or bio-solids, the value of these resources is negated. Similarly, if there is not a shortage of water or fertilizers, the additional expenditure required to reuse water and its constituents may not be justified. Whether water should be recycled depends very much on the circumstances. Recycling is one of a range of options for supplementing existing supplies and increasing the sustainability of water systems, but it is not the only one. A choice to recycle depends on the conditions that exist in the area in which this option is being reconsidered.

3. Uses of Recycled Water

3.1 Water Quality to Fit the Purpose

With current technology, virtually any quality of water can be produced from any water source, at a cost. Given these costs, it will be important that the right quality of water is provided for particular purposes if recycling is to be economically viable. Water of potable quality may not be needed for reuse as industrial cooling water, for example.

Given the various "grades" of water that can be produced, traditional descriptions of treatment types (e.g. primary, tertiary) have little meaning or value in discussions of recycling. What is important is to describe the quality of water needed against various parameters. These would include level of biological contamination (e.g. pathogens), chemical contamination (e.g. heavy metals), and temperature; that is, the same parameters against which waters from other sources are measured.
Viewed in this way, recycled water becomes one of a range of waters that might be available for use, including natural surface and groundwaters, not as a separate category of water somehow inherently different from water drawn from other sources.

Effluent purification schemes should no longer be looked at in isolation, since effluent reuse is now as much a part of a water supply system as other sources of surface or groundwater.

3.2 Recycling in Agriculture

Agriculture is both a producer of wastewater that might be recycled and a user of recycled water. Frequently, wastewaters are recycled to the same enterprise, but examples also exist of agricultural wastewater being supplied to other enterprises (for example, from a fish farm to a nursery). Categories of water recycling in agriculture include:

- Municipal (i.e. the use of municipal wastewaters for recycling to agriculture)
- Intensive livestock (which is both a producer of wastewater and a user of recycled water, generally within the same enterprise)
- Aquaculture (e.g. fish, prawn farms, etc; both a producer and a consumer)
- Field crops (e.g. cotton; both a producer and consumer, with a tendency to the latter)
- Horticulture (e.g. nurseries, vineyards, etc.; a producer with the potential to be a greater consumer of recycled water)

The quality of water demanded by these industries varies depending on the use to which the produce is to be put (for example, human consumption) and the way in which recycled water is applied (for example, spray irrigated or sub-surface application). That having been said, there are barriers to the increased use of recycled water including:

- Distance of agricultural enterprises from the source of recycled water (elevating transport cost and making recycling uneconomic compared to both other sources and the value of the product produced).
- Lack of information for potential users and operators, and inconsistent application of guidelines for the development of agriculture. Such inconsistency arises among users, who may not be aware of or follow guidelines appropriately, and among regulatory authorities, who either may not apply guidelines consistently or who may not yet have developed appropriate guidelines.

3.3 Recycling in Industry and Commerce

Opportunities for industrial and commercial water recycling fall into one of the following categories:

- Industrial use of treated municipal sewage
- Use of internally generated industrial effluent (that is, reuse of effluent without it first being discharged)
- Industrial use of an external source of industrial effluent (that is, use of effluent previously discharged by another industrial premises).

Such industrial reuse is extensive around the world. Generally, industrial and commercial reuse occurs where there is otherwise a shortage of water, or where it is economically viable to do so, either because recycling is cheaper than the cost of existing potable supplies or because the cost of developing new potable supplies is prohibitive.

There are limitations to the use of recycled water in certain applications. Water used in some industrial boilers (for example, those employed at power plants) must be particularly pure (better than the potable supply) to prevent scale build-up, algae growth and other problems. Manufacturers of food products have also been reluctant to use other than existing potable supplies (which in many cases receives further treatment on site, prior to use). Significant opportunities exist, however, including use as cooling water, in tanning, hide curing, textile manufacturing, metal manufacturing, mineral processing, brick making and concrete batching. Examples of recycling in the industrial sector include recycling of municipal effluent at a sugar mill, a tannery, and planned use by a power generator.

The viability of industrial and commercial recycling is dependent on a number of factors. These include:

- Proximity of the source of recycled water to the application
- Water quality
- Volume available and consistency of supply
- Costs comparative to alternative water sources
- Pre-treatment requirements
- Health risk

Given the large volumes of water used by particular industries, however, the potential for industrial recycling to contribute to sustainable management of water resources must be considered to be high.

-
-
-

Bibliography

Asano T. (ed.) (1998). Water Reclamation Reuse. *Water Quality Management Library*, Vol. 10, 638pp. . Pennsylvania: Technomic Publishing Company Incorporated. [This presents a comprehensive discussion of all aspects of water reclamation, recycling and reuse.]

Ashbolt N.J. (1995). Public health water microbiology for the 21st century. *Recent Advances in Microbiology* **3**, 173–214. [A recent review of public health aspects of infectious agents in water]

Beavers P.D. and Gibson, H.E. (1999). *Queensland water recycling strategy*.380pp. Brisbane: Queensland Government Department of Natural Resources. [A series of thirteen background studies concerned with the development of a water recycling strategy.]

Ford T.E. and Colwell, R.R. (1996). *A Global Decline In Microbiological Safety Of Water. A Call For Action*. Washington: American Academy for Microbiology. [A discussion of modern aspects of water microbiology.]

Haas C.N., Rose, J.B. and Gerba, C.P. (ed.) (1998). *Quantitative Microbial Risk Assessment*. 482pp. New

York N.Y.: John Wiley and Sons. [Health risk based assessment of water quality.]

National Guidelines for Water Recycling, Managing Health and Environmental Risks, Oct 2005 [A detailed discussion of health risks from recycled water, prepared by leading scientists] www.ephc.gov.au/ephc/water

National Water Quality Management Strategy, Australian Drinking Water Guidelines [A comprehensive discussion with recommendations for all aspects of drinking water quality] www.nhmrc.gov.au/publications/-files/awg2.pdf

Membrane Bioreactors for Municipal Wastewater Treatment, Van der Roest, Lawrence and van Bentem, I.W.A. Portland Press [Comprehensive information on the application of membrane bioreactors in wastewater]

Toze,S. PCR and the Detection of Microbial Pathogens in Water and Wastewater,.Water Research, Vol.33, No.17. pp3545-3556, 1999 [A comprehensive review of nucleic acid-based techniques applicable to detection and identification of infectious agents in water]

Wastewater Microbiology, 3rd ed. Gabriel Bitton, Wiley [A comprehensive text dealing with all aspects of wastewater microbiology]

Wastewater Microbiology, (plus CD) American Water Works [A review of wastewater microbiology]

World Health Organisation (1989). *Guidelines for the Study of Dietary Intake of Chemical Contaminants*. WHO Offset Publications No. 87. Geneva: World Health Organisation. [Comprehensive article on chemical contaminants relative to wastewater reuse for horticulture.]

Biographical Sketch

John G. Atherton B.Sc.App.(Med.Sci), Ph.D., Member Australian Society for Microbiology (MASM), now retired from the Microbiology Department at the University of Queensland has been involved in water microbiology for over 30 years, and has authored several publications and official reports prepared for government and semigovernment instrumentalities. Recently his involvement has been in engineering consultancies and chairmanship of a Technical Advisory Group in the development of a Water Recycling Strategy for the Government of Queensland, Australia.