THE POTENTIAL FOR INDUSTRIAL WASTEWATER REUSE

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Abstract

Continuous extraction of water has resulted in depletion of available water sources in and around the industrial areas. In addition, wastewater discharge into natural watercourses has caused surface and groundwater pollution, leaving water unsafe for potable use and impairing industrial use without major and costly treatment. The current low cost end-of-pipe treatment approach will become increasingly expensive as effluent discharge standards become more stringent. Meanwhile, technological advancements now make it possible to treat wastewater for variety of industrial reuse. Most industries in even developing countries are already moving towards wastewater reuse and source separation and treatment of separated effluents is gaining more attention. Wastewater reuse potential in different industries depends on waste volume, concentration and characteristics, best available treatment technologies, operation and maintenance costs, availability of raw water, and effluent standards. Radical changes in industrial wastewater reuse have to take into consideration rapidly depleting resources, environmental degradation, public attitude and health risks to workers and consumers.
This chapter discusses the potential for industrial wastewater recycling and reuse and treatment technologies attaining such a goal, in increasingly competitive market and stringent regulatory environment.

1. Introduction

Since World War II, rapid development has improved the standard of living and quality of life for millions of peoples the world over. This growth has come at the cost of a thirty-fold increase in the use of fossil fuels and a fifty-fold increase in industrial production over the past century. As a result, significant amounts of once freely available natural resources have been consumed by industry, leaving the earth depleted for future generations. Much of the waste produced from these activities is directly discharged into natural water bodies. In developed countries, industry is the biggest consumer of water and accounts for 50 to 80 percent of total demand. This is far more than the 10 to 30 percent in developing countries where agriculture is the largest consumer. However, industrial water use is certain to increase over the next decade. In many countries, the high rates of consumption in the last decade have exceeded capacity to replenish dwindling water sources and put excessive pressure on existing resources driving up the cost of raw water for industrial applications.

Discharge of wastewater into natural water bodies is also increasing costs for industries located downstream and this translates into higher production costs which are inevitably passed on to consumers. This discharge is also exceeding natural purification capacities and depleting dissolved oxygen below levels which can support aquatic life. Meanwhile, industries using groundwater have caused severe damage to aquifers and their recharge capacity resulting in lower ground water levels each year. For countries located in coastal areas, seawater intrusion is also threatening to make ground water unsuitable for direct use.

Public awareness and government application of effluent standards has already forced many industries to implement appropriate treatment technologies. Initially, industries adopted simple physio-chemical treatment systems, but rapid degradation of the environment has forced governments to implement more stringent regulations for wastewater effluent and these standards have led to more advanced biological and membrane technologies. As water for industrial applications becomes less easily accessible, industry is looking for ways to recycle and reuse treated water. Figure 1 shows how raw water for industrial applications can be supplied by recycling and reusing industrial and municipal wastewater.

Figure 1. Wastewater Recycling and Reuse Domain.

Reusing wastewater is an attractive economic alternative and helps conserve an essential commodity for future generations. Economic use also reduces the quantity of waste diverted to treatment facilities and further lowers treatment costs. Companies invest in wastewater treatment and reuse not just to comply with effluent standards but because product recycling and raw material recovery benefit a company’s image as well as the bottom line. In contrast to agriculture, only a small fraction of industrial water is actually consumed. Most is discharged as wastewater.

Industrial wastewater treatment has taken place in a series of development phases (Figure 2) starting from direct discharge to recycling and reuse. This development has been slow considering the growing awareness of environmental degradation, public pressure, implementation of increasingly stringent standards, and industrial interest in waste recycling. The declining supply and higher cost of raw water is also forcing industry to implement recycling technologies. Many industries are now concentrating on methods to abate potable water intake and reduce discharge of polluted effluent. The move toward wastewater reuse is reflected in different Cleaner Production approaches such as internal wastewater recycling, reuse of treated industrial or municipal wastewater, and reuse of treated wastewater for other activities.

Figure 2. Development of industrial wastewater treatment and reuse

The potential for industrial wastewater reuse is dependent on a variety of factors and differs from one industry to another. Industries consuming a large volume of water obviously have greater potential for internal reuse. Similarly, simple physical and chemical treatments may be sufficient for wastewater produced from activities such as washing floors and cooling. Other industrial wastewaters have high concentrations of toxic chemicals, which must be removed, but this is actually an advantage if useable by-products can be recovered.

Programs for planned industrial recycling and reuse began in the USA in the 1940s when chlorinated domestic wastewater effluent was used for steel processing. In Sweden, a 5 to 6 fold increase in reuse was recorded from 1930-1970. During the last quarter of the century, the benefits of promoting wastewater reuse as a means of supplementing water resources have been recognized by most state legislatures in the United States and the European Union. Interest in reuse is now growing in other parts of the world in response to demand for high quality, dependable water supplies for agriculture, industry, and domestic uses but it has only been in the last quarter of this century that wastewater reuse technologies have been adopted in Asia. Practices implemented in China, for example, have resulted in an average rate of industrial wastewater reuse of 56 percent in 82 major cities in 1989, with a maximum reuse percentage of 93 percent.

2. Water Availability and Consumption

Of the estimated 44,538 cubic kilometers of water available in the world, only 1 percent is fresh water; half of it in rivers, lakes and swamps. Readily accessible water for human use is about 0.007 percent of all the water on the planet. Although the total water available is sufficient to meet estimated demand at present, distribution is not uniform. Table 1 shows total water balance per continent. America, Australia and Oceania have the highest per capita water resources. Asia has far less. Asian countries must therefore think more seriously about conservation because the available per capita water is decreasing every year while consumption has been growing at more than twice the rate of population increase.

Table 1. Water balance per continent

Continent	Annual stream		Water resources per inhabitant (Thousand m^3 per year)		
	Volume (km^3)	Total percentage (%)	1960	1980	2000
Africa	4,570	10	16.5	9.4	5.1
Asia	14,410	32	7.9	5.1	3.3
Australia	348	1	28.4	19.8	15.0
Europe	3,210	7	5.4	4.6	4.1
North and Central of America	8,200	18	30.2	21.3	17.5
Oceania	2,040	5	132.0	92.4	73.5
South of America	11,760	27	80.2	9.7	28.3
World	44,538	100	13.7	9.7	7.1

Food and Agriculture Organization URL: http://www.fao.org/

3. Industrial Wastewater Reuse: Present Status, Trends and Issues

Industrial water use is on the rise. If this trend continues with the same speed without any recycling behavior, there will be drastic and irreparable damage to water resources in the near future. Recycling and reuse practices in most industries in developed countries and a growing number in developing countries are helping reduce the rate of consumption but more needs to be done.

Figure 3. Global water withdrawals by sector (1940-2000)
Kuylenstierna and Najlis (1998)

Although withdrawal is on the rise (Figure 3), the rate of increase is slowing as industrial countries learn to recycling and reuse. In the US for example, there has been a reduction of water intake from 280 m^3 t^{-1} of steel to 14 m^3 t^{-1} and in Germany, a reduction from 700 litres t^{-1} of paper to 7. Although industry uses much less water than agriculture, it is the heaviest source of pollution. The main sources are:

1. Industries consuming high volumes of water for process activities (pulp and paper, power plants etc.).
2. Industries discharging highly toxic effluent to natural bodies of water.
3. Industries producing wastewater with potential for by-product recovery, mainly for economic benefits (photographic processing).
4. Industries with growing demands for water consumption.

The suitability of reclaimed water for industrial processes depends on the particular use. For example, the electroplating industry requires water of almost distilled quality for washing circuit boards and other electronic components. On the other hand, tanneries can use relatively low quality water for washing hides. Recycling and reuse can be categorized, as below, according to the type of industry and the wastewater produced, the treatment technology developed, and its potential for reuse.

3.1 Internal Wastewater Recycling

Process water consumption can be cut 50 to 95 percent by adopting appropriate recycling techniques if, for example, wastewater from processes is treated separately and recycled back into the same process.

3.2 Reuse of Treated Industrial or Municipal Wastewater

Treatment of industrial wastewater using appropriate technology and recycling treated water back to the same or a different process is one solution. Reclaimed wastewater, for example, has been used for years to replace cooling and boiler feed water. Municipal wastewater can be used in industrial applications only after some tertiary treatment depending on the application. In Italy, effluent for industry and agriculture started in the early 1980s. Because there can be problems with reclaimed municipal wastewater such as scaling, corrosion, bacterial slime or fouling and foaming, proper care has to be taken during treatment in the form of disinfection, regular monitoring, and avoiding physical contact with reclaimed water.

Scaling reduces heat transfer in cooling towers due to deposits of impurities such as calcium, magnesium, sodium chloride and silica. Lime softening is one way to reduce scaling and treatment of reclaimed water with ion exchange and reverse osmosis also reduces scale formation in boilers. Corrosion is associated with the presence of excessive ammonia in reclaimed municipal wastewater. High nutrient content causes bacterial slime formation resulting in resistance to heat transfer but dispersion agents can be used to avoid fouling. Foaming, the result of biodegradable detergents, can be overcome by anti-foaming chemicals.

Ozone treatment of corrosion and scaling problems in reclaimed wastewater used for cooling is an effective method if a residual concentration of 0.06 to 0.19 mg L^{-1} is maintained. Public health is also a concern, particularly regarding aerosol, transmission of organics and pathogens in cooling water and pathogens in various process waters.

Effluent from municipal wastewater treatment plants can be used for boiler feed water after advanced treatment with membrane technology resulting in economic benefits for power plants and municipalities. A saving of A$1 million per year was reported by using 4000 m^3 d^{-1} reclaimed water in the Earing power station near Newcastle, Australia. There was an additional cost savings by eliminating the need to pump wastewater 15 km from the treatment plant to the disposal site. Sappi Pulp and Paper Group's Enstra mill in South Africa is fulfilling 50 percent of its water demand from municipal wastewater treatment plant effluent thereby reducing the burden on fresh water resources. Reports on area-wide use of reclaimed water in Japan indicate the second highest volume is in the industrial sector with a utilization rate of reclaimed water of 15 million m^3 d^{-1} and a total reclamation of 85.5 million m^3 d^{-1}. Reuse of treated industrial wastewater for miscellaneous activities such as fire protection, irrigation and dual system water supplies is also reported in various literatures depending on the types of treatment implemented. A dairy farm in the UAE is using 900 m^3 d^{-1} of wastewater for irrigation. Wastewater from the food industry in Germany has been proposed as a potable water supply after pretreatment-skimming, cartridge filtration, UV; two-pass NF; UV and chlorination disinfection.

In general, industrial wastewater reuse can be classified as cooling, boiler feed, and process water. Cooling water accounts for 90 percent of the total consumption. Recycling cooling water is the backbone of any savings practice. Simple engineering design modifications, changes in nozzles to reduce flow rates, a shift from continuous to intermittent systems, sequential reuse, and monitoring for leaks are some of the basic techniques. Impurities such as suspended solids can be treated relatively easily and reused in the same process. Reclaimed municipal wastewater can be used for cooling with some minor treatment. Two examples are a drop of 96 percent in water demand between 1989-1992 in a sporting goods factory in Boston, and a drop of 50 percent in cooling water intake in one year at Epton Industries, a Canadian plastics and rubber manufacturer. Water for boiler feed should be cleaner than cooling water but needs only minor treatment for reuse and has been used in a power station near Newcastle, Australia.

Although relatively small in volume, process water characteristics vary from industry to industry. Similarly, the required quality differs for water used in different processes. Some needs only simple physical treatment and some higher quality treatment by membrane or activated carbon systems. A pilot plant study with wastewater from a kimchi factory (a pickled fermented food item) in Korea illustrated the potential for reuse by separating brining water after treating it with chemical and membrane processes.

A range of economic instruments can be used for industrial pollution control and promote wastewater reuse. Abstraction charges could be used for cost recovery, revenue, incentives, and tax replacement whereas the effluent charges can be applied for economic or financial efficiency, to reduce environmental impact, practicability, and acceptability. A concept of zero pollution could conserve resources for other uses and help increase production. Various economic and environmental benefits could be achieved through water loop closure as shown in Figure 4.

Figure 4. Interrelationships of economic and environmental parameters relevant to water loop closure
RIZA (1999)

Different industries have different degrees of potential for treatment and reuse. In the same industry, different processing units produce waste with different characteristics and volumes. Segregation of different volumes and concentrations is one of the most important factors to consider in designing reuse technology. A good solution for such industries is recycling waste from one processing unit after some level of treatment, and disposal from another processing unit, again after some treatment, to meet required effluent standards. It is essential to decide on the type of waste to be recycled and disposed of after an effective waste inventory. A high volume of wastewater with a low pollutant concentration has obvious potential for recycling but it is more difficult to recycle low volumes of water with high concentrations of pollutants. Recycling is governed by factors such as availability of raw water, possibilities of expansion in the processing units, effluent standards and recovery of products from waste treatment. Based on some of these governing factors, wastewater reuse potential is summarized in Table 2.

Table 2. Wastewater reuse potential for industries

High Potential	Medium Potential	Low Potential
• Pulp and Paper • Cotton Textile • Pulp and Paper • Glass and Steel	• Slaughterhouse • Dairy • Canning and Food Processing • Distillery • Wool Textile • Photographic Processing • Chemical • Fertilizer • Oil refining • Petroleum • Electroplating • Meat Processing	• Tanneries and leather finishing • Pesticide • Rubber • Aluminum • Explosives manufacturing • Paint manufacturing

4. Available Treatment Technologies

The degree of treatment required varies according to the specific reuse application and associated water quality requirements. The simplest treatments involve solid/liquid separation such as sedimentation, aerobic biological treatment, oxidation ponds, biological nutrient removal, and disinfection. More complex treatment systems involve combinations of physical, chemical, and biological processes employing multiple barrier treatment approaches for contaminant removal such as activated carbon, air striping, ion exchange, chemical coagulation and precipitation. More advanced technologies include microfiltration, nanofiltration, ultrafiltration and reverse osmosis. Use of membrane technology has been successful in removing most contaminants from wastewater thereby increasing the potential for even greater reuse. The advantages of membrane technologies are the small space requirement compared to other systems, better process control, and potential for intermittent operation. Successful removal of dye concentrations from 6-9 gm/L to 0.01 mg/L in an acrylic fiber plant in Istanbul used a two stage RO process and bioreactors combined with aerated membranes can be used in pulp and paper and textile wastewater treatment and reuse. Membrane technology provides an attractive alternative to extend the range of wastewater applications. Examples of potential reuse in some major industries are described below.

4.1 Pulp and Paper Industries

This industry has traditionally been a heavy water user. The quantity and quality of raw water used differs from one process to another (Table 3).

Table 3. Water consumption in pulp and paper industries

Processes	Water consumption $m^3\ t^{-1}$
Mechanical pulping	5
CTMP pulping	5
Chemical Pulping Unbleached Bleached	 15 45
Recycled Fiber Pulping Brown papers Deinking	 2 10
Paper Making	15

UNEP/IE (1996)

A large volume of process water becomes contaminated from contact with raw materials, byproducts and residues. The basic wastewater sources from various processes is given in Table 4.

Table 4. Wastewater sources in pulp and paper industries

Fundamental process	Wastewater source
Wood preparation	Evaporator condensate, bleach plant pulp washer filtrate
Kraft pulping	Condensate from recovery evaporators and heat exchangers, smelt dissolving underflow from turpentine separator
Paper machine operations	White water from paper machine

Carmichael and Strzepek (1987)

Membrane treatment systems are effective in removing pollutants. For example, 60 percent recycling of process wastewater has been reported in a corrugated board plant in Turkey by using a two-stage UF and RO system and dissolved air flotation (DAF) is attracting more attention, mainly from the paper industry. Treatment with DAF has the advantage of recovering pulp while recycling treated water back into the process.

The Mondi Paper Mill at Piet Retief in South Africa successfully reused 1700 m^3 d^{-1} of black liquor after treatment with tubular UF, ion exchange and RO. A significant reduction in wastewater discharged into streams has been reported by the Norwegian pulp and paper industry. Figure 5 shows the effluent reduction from 1985 to 1998 at Norske Skog Skogn, an integrated TMP (thermomechanical pulp) and newsprint mill, and illustrates the potential for wastewater internal recycling practices.

Figure 5. Effluent reduction at Norske Skog Skogn, an integrated TMP and newsprint mill Andersen et al. (1999)

4.2 Power Plants

Power plant utilities are large volume consumers mostly for cooling in electricity generation. Average water consumption per megawatt is 700 gallons (2650 L). Evaporation in a cooling tower requires a large amount of make-up water for boiler feed but water can be recycled with some treatment. The major pollutants from power plants are summarized in Table 5.

Table 5. Origin and characteristics of liquid waste in power plant wastes

Industries producing wastes	Origin of major wastes	Major characteristics
Steam power	Cooling water, boiler blow-down, coal drainage	Hot, high volume, high inorganic and dissolved solids
Nuclear power and radioactive materials	Processing ores, laundering contaminated clothes, research lab wastes, processing fuel, power plant cooling waters.	Radioactive elements can be very acid and “hot”.

Because the water quality for a cooling tower is not high, it is possible to recycle cooling wastewater, reclaimed water from municipal wastewater treatment plants and the effluent from other industries. This practice saves water charges for the plant and effluent discharge costs for treatment authorities. Examples from Istanbul indicate that most reclaimed water from sewage treatment plants is used for boiler feed water. The Palo Verde Nuclear Generating Station is the nuclear facility using treated effluent in its operation. In 1995, in Ponhandle and the South Plains of Texas, almost 5.48 billion gallons (20.74 billion liters) of water was conserved by reusing wastewater for power plant cooling and treating water with lime softening methods to control scaling.

4.3 Textile Industries

Finishing raw fabrics is a basic textile industry operation. Water use varies with the type of fibre being produced and can range from 50 to 600 m^3t^{-1}. Water use in weaving mills also depends on the fibre. Synthetic fiber mills use more water than cotton and wool and range from 1000 to 2000 m^3t^{-1} or more. Here also, cooling water is quite high compared to other processes.

Table 6. Distribution of water use in the textile industry (cotton processing)

Processes	Wastewater per ton of product

	m^3
Yarn Sizing	4.2
Desizing	22
Kiering	100
Bleaching	100
Mercerizing	35
Dyeing	50
Printing	14

Economopoulos (1993)

A high volume of wastewater is produced from kiering and bleaching (Table 6) which could be treated separately. Some waste streams can be directly reused with little or no treatment. Final rinse water after mercerizing, bleaching, and dyeing are only slightly contaminated and can be recycled for further rinsing. Combining water reuse with recovery further improves the economics. A textile plant in Istanbul using 2500 to 3000 m^3 d^{-1} recycled one third of its wastewater successfully with a minimum cost of \$0.3 per m^3 compared to \$6 per m^3 for raw water. A dyeing plant in Italy is recycling wastewater using clariflooculation, multiple filtration coupled with a RO system and 40 percent of the wastewater recycling in a textile finishing factory in Germany is treated with an aerobic biological process followed by precipitation, flocculation and adsorption. All wastewater generated in the textile industry could be recycled through a sequence of anaerobic digestion and aerobic treatment followed by granular or activated carbon (GAC) or membrane treatment. Ozonation prior to GAC or nanofiltration can reduce color and surfactants from wastewater. Quartz filtration followed by UV sterilization of biologically treated wastewater from printing, matrix washing and dyestuff leakage in silk and lycra printing in Italy produced good quality water for reuse as wash water reducing by 30 to 40 percent of the wastewater produced.

4.4 Food Processing Industries

Basic production steps in any agro-industry include washing raw materials, removing inedible portions, preparing foodstuffs and packaging. The main characteristic is the large consumptive use, mainly from process water. In canning or juice making, water is incorporated into the product itself. Wastewater is water that comes into contact with spoiled raw materials or finished products, rinsing or washing, transport, process water, cooling, spills, and water used for cleaning equipment. General characteristics are shown in Table 7.

Table7. Pollutants and their origin in agro-industries

Industries producing wastes	Origin of major wastes	Major characteristics
Canned goods	Trimming, culling, juicing and blanching fruits and vegetables	High in SS, colloidal and dissolved organic matter
Dairy products	Dilutions of whole milk, separated milk, butter milk, and whey	High in dissolved organic matter, mainly protein, fat and lactose
Brewed and distilled beverages	Steeping and pressing grain, residue from distillation of alcohol, condensate from stillage evaporation	High in dissolved organic solids, containing nitrogen and fermented starches or their products
Meat and poultry	Stockyards, slaughtering animals,	High in dissolved and

products	rendering bones and fats, residues in condensates, grease and wash water, picking of chickens	suspended organic matter, blood, and other proteins and fats
Animal feedlots	Animal excreta	High in organic suspended solids and BOD
Beet sugar	Transfer, screening, and juicing water, drainings from lime sludge, condensates after evaporator, juice and extracted sugar	High in dissolved and suspended organic matter, containing sugar and protein
Soft drinks	Bottle washing, floor and equipment cleaning, syrup storage-tank drains	High pH, suspended solids, and BOD

The waste from agro-food plants contains mostly high organic compounds and bacteriological contamination (Table 7). The recycling rate is low because organic and bacteriological pollution can affect public health. Since the quality of water required is high, recycling may be less economical but there is always potential for recycling cooling water. An experimental study in The Netherlands reported treatment by anaerobic and aerobic reactors combined with a secondary clarifier followed by a crossflow filtration membrane process. In a poultry slaughterhouse, chilled floor washing water is recycled for rinsing. Segregation of highly polluted water from less polluted wastewater would be even more effective. In New Zealand, a pilot plant study on wastewater from the dairy industry used completely mixed activated sludge followed by filtration. The effluent was of sufficient quality to be reused in the process.

4.5 Other Industries

Wastewater reuse technology has been adopted in many other industries in order to overcome the difficulties associated with the rapid depletion of raw water quality, governmental policies and public attitudes. For example, water savings between 27 to 90 percent have been reported in 15 factories in San Jose, California with an investment return period of less than 12 months. IBM was able to achieve an astonishing saving of 90 percent.

5. Policy and Institutional Aspects

Government water conservation policy is the key factor in wastewater reclamation and reuse. Policy can be related to incentives for industry to promote internal recycling, implementation of economic instruments and discouraging effluent discharge through stringent standards. However, in developing countries industry is neither charged for water or wastewater services nor are pollution control regulations adequately enforced. The Polluters Pay Principle is a good starting point. Compliance with stringent effluent standards can force industries to implement new technologies to reduce effluent discharge. Higher charges for raw water could be applied to industries using large volumes of water and/or water with certain pollutants. Banning priority pollutants with significant health hazards also needs careful consideration. Examples can be seen in Singapore which levies a 15 percent water conservation tax on operations using more than a specified amount, and new factories needing more than 500 m^3 per month must apply for approval from City Council during the planning phase.

Given proper incentives, industry has shown it can cut water demand by 40 to 90 percent with existing techniques and practices. Economic incentives should be given to industry to comply with standards and policy and to reduce raw water intake and wastewater discharge. Incentives might consist of fines for non-compliance, closure for repetition of non-compliance, incentives to management for higher recycling and reuse, subsidies and incentives for industries implementing new and innovative technologies, and financial and advisory support for industries funding new research. Policies need to be acceptable to industry and must protect the environment to specified levels. For example, a fertiliser plant in Goa, India cut water demand in half over a six year period in response to high water prices and government pressure to reduce effluent discharge into the sea, and dairy, pharmaceutical, and food processing industries in Sao Paulo, Brazil reduced water use per unit output by 62, 49 and 42 percentages respectively. Within the industrialised countries, California has been a pioneer in systematic approaches to wastewater reuse.

The concept of a central effluent treatment plant within an industrial complex should be encouraged. It is better to accommodate different types of industries requiring different water qualities in one complex. Similarly, permits should be given to wastewater plant owners to supply effluent of required quality to industries located nearby. Proper care has to be taken in reclaiming municipal wastewater for industrial applications, especially with regard to microbiological quality. Water quality criteria required for some industries may not require stringent microbial standards but health is an important consideration and basic minimum criteria for microbial content should be reflected in standards for reclaimed water. Monitoring systems with high level detection and sensitivity should be developed to control wastewater recycle and reuse.

6. Conclusions

The increase in living standards through uncontrolled industrial development has resulted in the depletion and pollution of water resources. Increasingly stringent regulations have forced industries to implement reduction in water consumption and waste disposal. Higher water prices are only one factor putting pressure on industries using conventional production processes. Advanced technologies can now treat wastewater that can be recycled in the same process or different processes and locations. Segregation of waste and multiple reuse after simple treatments is practiced in industries which require less pure water. Identification of industries with high potential for wastewater reuse is the main concern for the industrial sector. Industries demanding a high volume of water for cooling and boiler feed should be the first priority. Industrial estates can play an important role in treatment and reuse. Another option that can help reduce the water shortage problem is reclamation of municipal water. Advanced technologies such as membrane processes, ion exchange, and adsorption are capable of producing water of any required quality. Policy devised by government and regulatory bodies can include implementation of various economic instruments and provide incentives to environmentally friendly industries. Finally, the health of workers handling reclaimed and recycled water is an important consideration when planning recycling activities.

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