THE FUTURE OF WATER USE IN INDUSTRY

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Biographical note
Dr. Ania Grobicki is a chemical engineer and an economist by training, and a policy analyst on water and the environment. She received a PhD in biotechnology from Imperial College, London in 1989. Subsequently, she worked as a consultant for both the public and the private sectors in South Africa and the UK, prior to moving to Geneva in 2003 in order to work with United Nations organisations. Her scientific contribution in the field of industrial water treatment and water reclamation was recognised by the award of a gold medal by the Water Institute of Southern Africa in the year 2000. She has experience of advising at ministerial level both nationally (in South Africa) and internationally. On behalf of UNIDO, Dr. Grobicki was the principal author of the chapter on "Water and Industry" in the latest edition of the World Water Development Report, published by UNESCO. She has consulted to the United Nations Environment Programme and the World Meteorological Organization as well as UNIDO, and is currently employed by the World Health Organization.

Introduction

There is tremendous competition between the water needs of agriculture, industry, and the growing number of people in our world, and there are severe and increasing freshwater shortages in many areas. Indices and maps of water scarcity have been drawn up, there is talk of "the water crisis", and predictions of wars to come over water. Yet our planet is a water planet, with an abundance of water. So why is there so much concern about our future water security?

This question is not so surprising if we consider that of the total amount of water in the world, only 2.5% exists as freshwater, while 97.5% is seawater. It takes a great deal of energy to desalinate seawater, and of course energy is also increasingly constrained. Hence in most places, large-scale desalination is hardly a viable option with current technologies. Of the relatively small proportion of water, which is fresh, about 90% is inaccessible for our use. Two-thirds is locked up in glaciers and ice caps, while most groundwater cannot be sustainably extracted. Fossil aquifers are being tapped in many places - water which is many thousands of years old and not readily renewable. There are many large aquifers, most notably the Ogolalla aquifer in Texas, and the aquifer which underlies the Indo-Gangetic plain, which are seeing dropping water levels, accompanied by rising costs of pumping in order to extract the deeper water. Where groundwater was being pumped from 30 metres depth, it is now necessary to pump from 100 metres or much more, with accompanying increases in energy costs.

Rivers, lakes and wetlands account for less than 0.4% of the world's water (see Figure 1 below). Many of these are remote and not easily accessible. We are now starting to see startling declines in the size of many of the world's lakes and inland seas, notably the Aral Sea, the Dead Sea, and Lake Chad - a freshwater lake shared by 4 African countries which has declined to 10% of the size it was in 1963. The volume of water in the Aral Basin has been reduced by 75% since 1960. The Yellow River, which is one of the largest and longest rivers in the world (over 4000 km long) has ceased to reach the sea for long periods since 2002, due to massive over-extraction for industry, for agriculture, and for the 120 million people who now live in the catchment area of the river basin.

On the other hand, the rainfall, which replenishes our freshwater resources is highly variable in many parts of the world, and much of this freshwater arrives in floods which cannot be usefully harnessed. The frequency of hurricanes, floods and droughts is increasing hand-in-hand with climate change. Much of the surface water and soil moisture is lost to evaporation and evapotranspiration, both of which are also being increased by global warming and higher temperatures. All of these factors affect the outlook for sound and sustainable water management, together with the increasing competition between the needs of various water users and the natural environment. We need to consider the challenges that these changes pose for industry, as well as the opportunities that exist to improve our future water security. In this paper I will be talking about two key opportunities which are available to us today.

1. The challenge for sound water management

By the year 2050, the world population will reach 10 billion, 90% of whom will live in developing regions. We are already well over 6 billion people on earth, and in this year 2007, for the first time in history, over half of humanity is living in cities. It has been well put by Bill McKibben, in his book entitled *The End of Nature :* "We are no longer able to think of ourselves as a species tossed about by larger forces - now we **are** those larger forces."

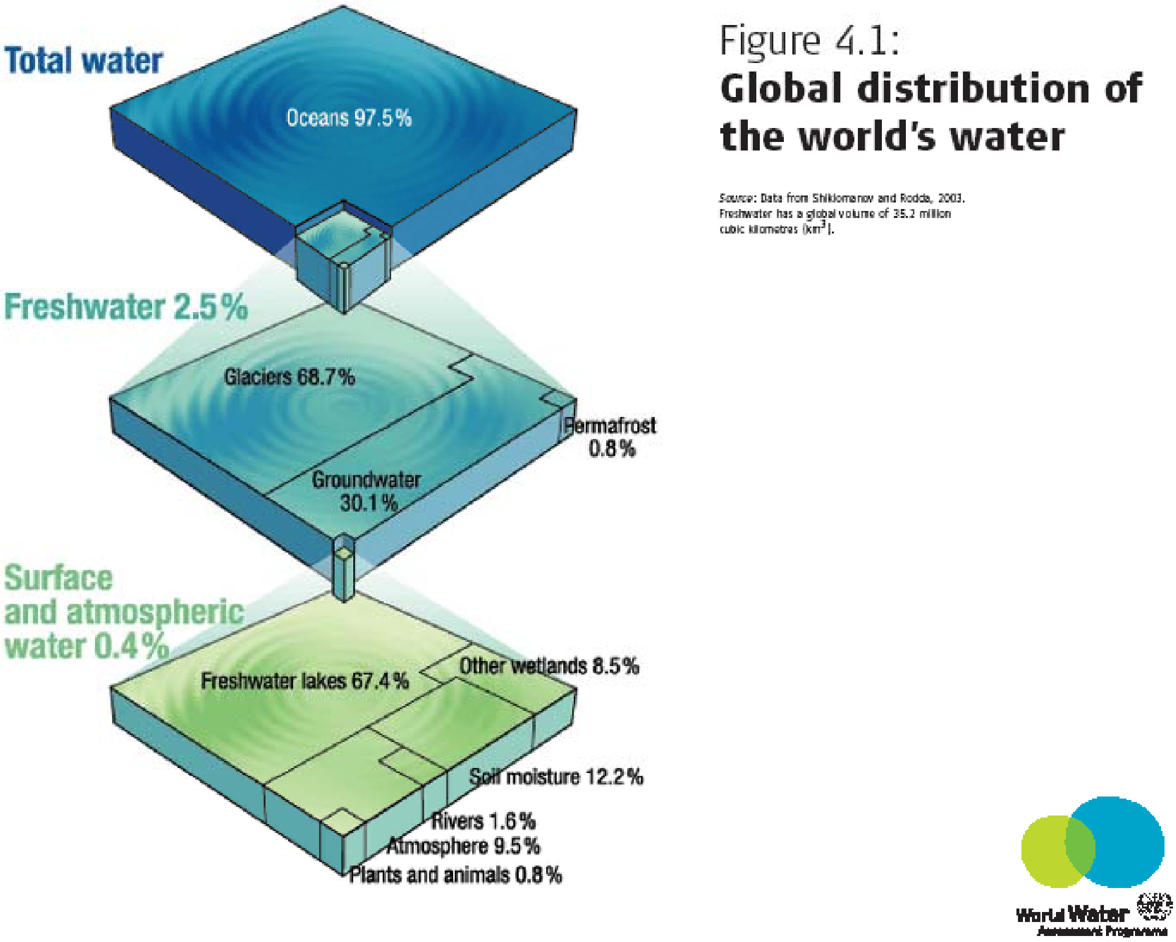


Figure 1. Global distribution of the world's water in 2003 (Source : World Water Development Report)

Cities and industry are both demanding ever greater volumes of water, while at the same time producing wastes and effluent which in many places taint and damage the quality of this precious resource on which all life depends. In agriculture, unsound irrigation practices are creating salinisation problems for both soil and water, and agricultural runoff carries pesticides and fertiliser. While the *quantity* of freshwater available represents one side of the coin of the water crisis, the *quality* issue represents the other. However, in the end, they are both sides of the same coin. Water that is too polluted to be used for a particular purpose, whether for drinking water, for industry, for irrigation, or for sustaining ecosystems, is in effect water that is not available for use. Hence if we are looking to preserve and maximise the *quantity* of this resource, it is essential to ensure at the same time that its *quality* is fit for the use for which it is intended. Technology foresight is the key tool to use to identify the innovations which will enable us to meet this challenge, and to put in place the strategies and the policies which will lead to improved water security and sustainability.

2. Trends in the use of water in industry

Agriculture at present uses the lion's share of water world-wide, with between 70% and 90% of all water in most regions. Interestingly, the East Asia/Pacific region and sub-Saharan Africa are the two exceptions to this, with industrial water use taking a large proportion of water, but for opposite reasons : in East Asia/Pacific, industry has grown extremely rapidly and often unsustainably in recent years. Industry now provides 48% of the total GDP in the region, and this proportion is still increasing. On the other hand, in sub-Saharan Africa, industry takes a large share of total water use not because the industrial sector is especially strong, but because most agriculture is rain-fed and there is relatively little water storage available on the continent.

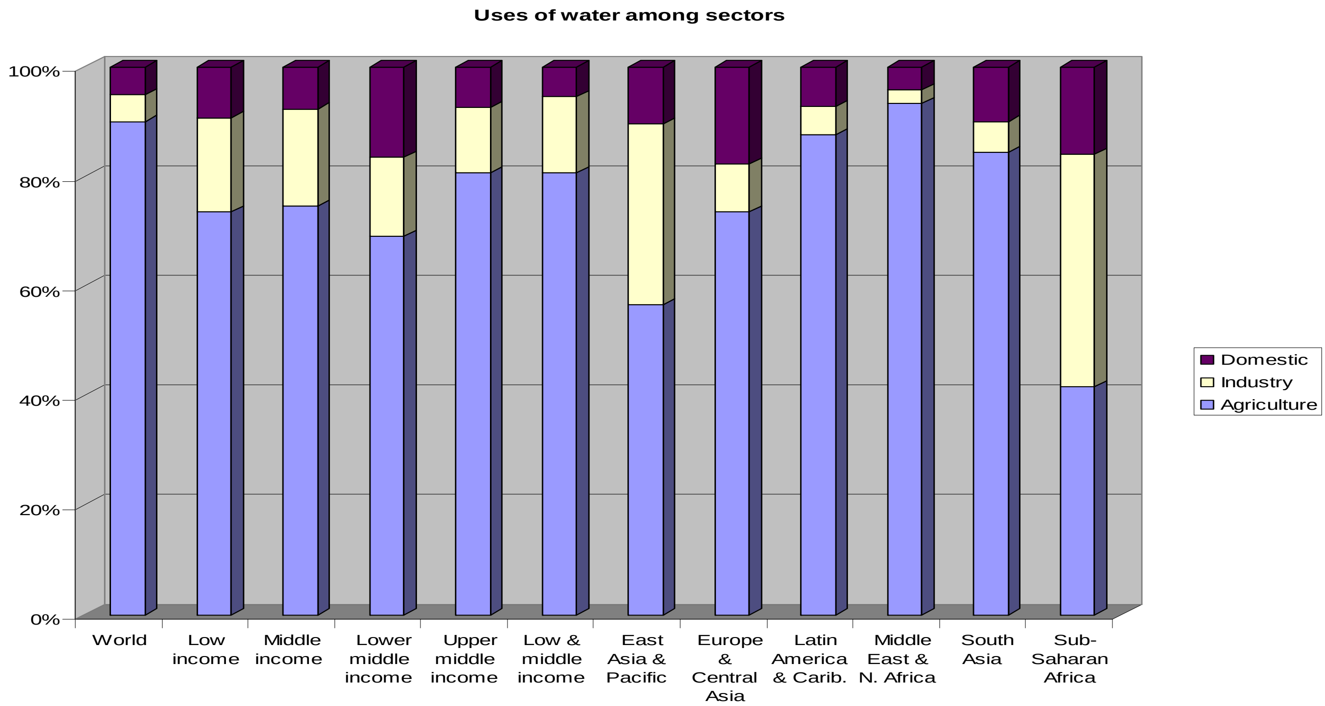


Figure 2. Water use by industry, in various regions of the world (Source: World Bank, 2002)

In the 50 years from 1950 to 2000, world industrial water **withdrawals** climbed from 200 km^3 /year to almost 800 km^3 /year, while industrial water **consumption** has increased from 20 to about 100 km^3 /year. The relationship between industrial water withdrawal and industrial growth is not linear, as technological advances lead to water savings as well as water reuse in industry. Hence industrial water withdrawals in many developed countries have flattened off, while industrial water consumption (which is only a fraction of the total water withdrawal) continues to grow. This can be clearly seen in Figure 3 below, which shows total world industrial water withdrawals and water consumption from 1950 to 2000. However, industrial water use is usually measured in terms of withdrawals. What is the difference?

Water is used by industry in a myriad of ways: for cleaning, heating, or cooling; for generating steam; for carrying dissolved substances or particulates, for instance when pumping slurry; as a raw material; as a solvent; and as a constituent part of the product itself (for example, in the beverage industry). Some of the water evaporates in the process. The water, which is consumed by industry is therefore the water which evaporates, as well as the water which remains in the product, the byproducts or the solid waste generated. The balance of the water is discharged after use as wastewater or effluent. This is why the total withdrawal of water by industry from surface and groundwater is often much more than the water which is actually consumed.

$$\mathbf{Wi = Ci + Ei}$$

where:
Wi = the water withdrawal by industry
Ci = the water consumption by industry
Ei = the industrial effluent discharge

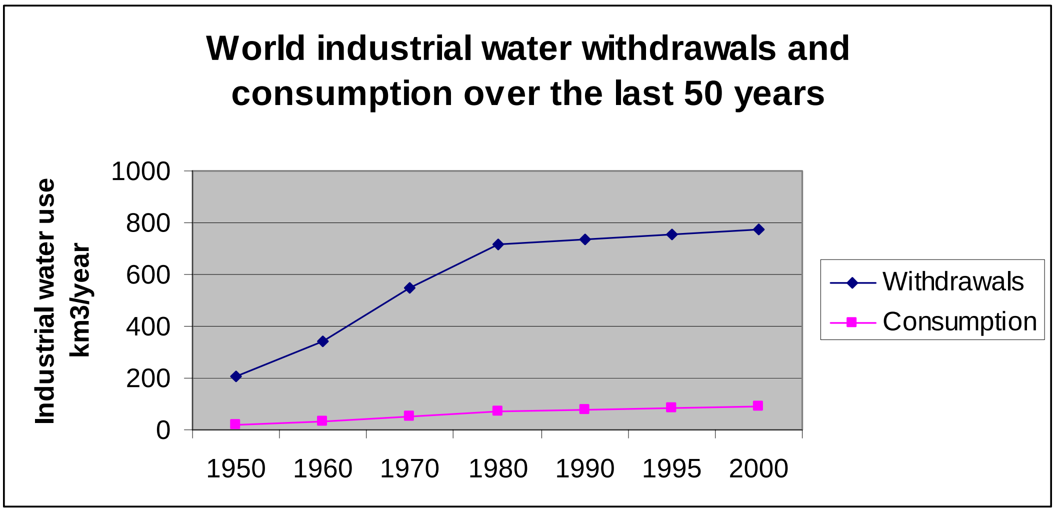
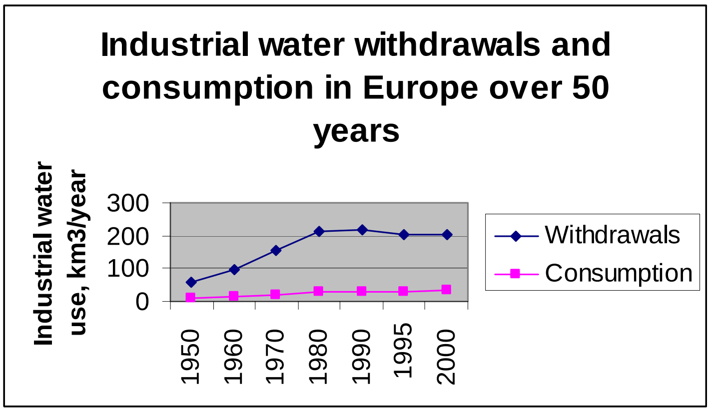


Figure 3. World industrial water use from 1950 to 2000 (Based upon data from Shiklomanov, 2002)

The gradual increase in water consumption therefore reflects the continuous increase in industrial production. However, as noted above, water withdrawals do not have to increase in proportion, indeed, by cutting back on the volumes of effluent generated, by reusing and recycling water, these two factors can be delinked. What is obvious is that despite the continued expansion in industrial production since 1980, water withdrawals for use by industry world-wide are no longer growing as quickly as pre-1980. This can be seen even more clearly if we disaggregate the water use data by region.

Figure 4. Comparison between industrial water use in Europe (4a) and in Asia (4b) from 1950 to 2000 (Based upon data from Shiklomanov, 2002)



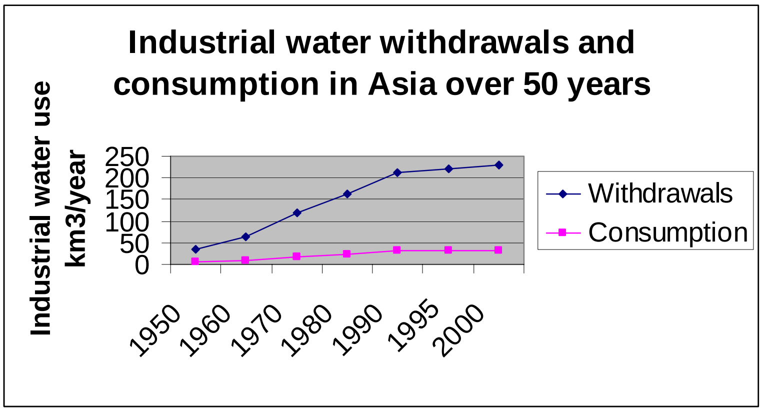


Figure 4a shows that industrial water withdrawals in Europe have actually been dropping since 1980, although industrial output continues to grow. With its strong emphasis on environmental protection, this is evidence that in Europe water re-use and recycling measures are taking effect, allowing industry to grow without putting further strain on water resources. However, as you can see there is still a very large gap between withdrawals and consumption (approximately 160 km^3/year), representing the quantity of effluent that is discharged by industry. Hence there is plenty of scope for improvement and growth. The limit would be reached when the two curves touch - the point at which there would be zero discharge.

In Asia, the growth in industrial water withdrawals was rapid up to the early 1990s, and has since been growing more slowly, as Figure 4b shows, despite the region's continued high growth in manufacturing output. Hence the intensity of water use in industry is increasing both in Europe and in Asia/Pacific - but not as rapidly in the latter. Progress is being made most quickly in those countries where water scarcity is being experienced, and action is being taken both at policy level, at regulatory level and at the level of individual enterprises. As an example, in one Australian brewery, the water used (calculation based upon water withdrawals) dropped from 15 litres per litre of beer produced in 1996, to just 6 litres of water per litre of beer in 2003. This represents an efficiency improvement of 60% in 6 years !

Another way of looking at this improvement at national level is to take the industry value added (in US$ for purposes of comparison) and divide by the industrial water use (measured by withdrawals); this gives the industrial water productivity, measured in US$ per m^3. The figures in Table 1 show that this indicator can different greatly among the largest world economies. If we compare Japan, where water recycling and reuse is a way of life, with the United States, we can see that the industrial water productivity is an order of magnitude higher in Japan. We find that Denmark has the highest industrial water productivity world-wide. One reason may be that most water withdrawals in Denmark are from groundwater, because there is relatively little surface water due to its topography, and hence water has always been viewed as a resource to be conserved. In Canada, on the other hand, which has the highest water availability of any country, we find that despite their sound environmental record their industrial water productivity is relatively low : lower than in the United States.

Table 1. Industrial water productivity by country, 2000/2001

Country	Industry, value added (IVA)(billions constant 1995 US$)	Industrial water use (km3/year)	Population (million)	Industrial water productivity
	Year : 2001 (some 2000) Source : World Bank 2001	Year : 2000 Source : AQUASTAT 2003	Year : 2000 Source : AQUASTAT 2003	($ IVA/m3)
Armenia	1.19	0.13	3.79	9.18
Austria	82.15	1.35	8.08	60.85
Azerbaijan	1.02	4.77	8.04	0.21
Belarus	5.76	1.30	10.19	4.44
Bulgaria	3.48	8.21	7.95	0.42
Canada	**205.98**	**31.57**	30.76	**6.52**
Czech Republic	20.97	1.47	10.27	14.31
Denmark	**44.90**	**0.32**	5.32	**138.59**
Estonia	1.72	0.06	1.39	26.80
Finland	53.22	2.07	5.17	25.66
France	430.02	29.76	59.24	14.45
Germany	748.18	31.93	82.02	23.43
Greece	28.18	0.25	10.61	114.44
Hungary	17.26	4.48	9.97	3.85
Italy	332.94	16.29	57.53	20.44
Japan	**1889.94**	**15.80**	127.10	**119.62**
Kazakhstan	8.39	5.78	16.17	1.45
Kyrgyz Republic	0.36	0.31	4.92	1.17
Latvia	1.88	0.10	2.42	19.60
Lithuania	2.48	0.04	3.70	60.34
Moldova	0.78	1.33	4.30	0.59
Netherlands	119.90	4.76	15.86	25.17
Norway	49.05	1.46	4.47	33.56
Poland	50.65	12.75	38.61	3.97
Portugal	36.71	1.37	10.02	26.87
Romania	12.32	7.97	22.44	1.55
Russian Federation	139.79	48.66	145.49	2.87
Spain	208.17	6.60	39.91	31.54
Sweden	81.68	1.61	8.84	50.67
Tajikistan	0.70	0.56	6.09	1.25
Turkmenistan	3.46	0.19	4.74	18.34
Ukraine	21.62	13.28	49.57	1.63
United Kingdom	340.03	7.19	59.63	47.28
United States	**2147.80**	**220.69**	283.23	**9.73**
Uzbekistan	2.79	1.20	24.88	2.33

Source : World Water Development Report 2, UNESCO, 2006.

3. Opportunities for the future

In this paper I wish to present two opportunities, which exist to look at water use in industry in a different way: strategies for more socially and environmentally responsible use of water; strategies which I believe will take us a long way down the line to addressing the problems and threats to both the quantity and the quality of water available for use. Because security of water supply is essential for stable industrial development, these opportunities must be worth taking.

The first opportunity relates to increasing industrial water productivity, which as shown in the last section can be assessed and monitored over time. This can prove to be an incentive for improvement. The second opportunity is a longer-term, more visionary effort - achieving zero discharge. There are a number of intermediate strategies, which can take us closer to this end point. While it may take time to achieve everywhere, and is without a doubt easier to achieve on an individual enterprise level or on a small district level, zero discharge is a worthwhile goal.

3.1. Opportunity #1 : increasing industrial water productivity

The higher the water productivity, the greater is the value, which is intrinsically being placed upon water. In water-scarce regions, where there is competition for water among various users, water is likely to be allocated to the more highly productive uses. Various strategies are available to improve industrial water productivity, such as:

- Water auditing
- Matching water quality to use requirements
- Water recycling and reuse on site
- Using reclaimed water
- The concept of the virtual water trade in manufactured products
- Policy instruments and economic incentives

Water auditing

Carrying out a water audit over an industrial plant or manufacturing facility shows clearly where the water, which is supplied to the plant is used, how much is used in each process, and where it ultimately ends up. Rainwater, which falls on the site, as well as the natural evaporation which occurs, should also be included in the audit. Hence the topography of the site can also be important. Once a water audit has been done, it is possible to draw a flow chart and show the water balance over the plant, or over individual units of the process. This is the first step in finding innovative ways to save water on an industrial site.

Water can be saved either by cutting down on water input, where it is being unnecessarily wasted, or by identifying water recycling and reuse opportunities, which are discussed in more detail below. Rainwater harvesting on site may also be considered, since this is preferable to allowing rainwater (which be contaminated) simply to run off into the stormwater system. There are some generic lessons that can be learned for a given production sector, but in the end each factory site needs to be audited and analysed individually.

Matching water quality to use requirements

In many instances, the water used in industry is of an unnecessarily high quality for the use to which it is put. The analogy in domestic water use is, for instance, using water of drinking quality in order to flush toilets, or to water the garden. Similarly, in industrial processes there are many applications where lower water quality could be used. This offers recycling opportunities. Often 50 % or more of the water intake to an industrial plant may be used for the purpose of process cooling alone, a need that can often be met with lesser quality water. On the other hand, some industries (such as the pharmaceutical industry) require water of exceptionally high quality. In such processes, additional water treatment is carried out on the water, which is received from the local water utility, or withdrawn from groundwater or surface waters, in order to further improve the water quality before it is used.

There are cases in industry where water is used inappropriately, where a completely different approach could be taken to save water in water-scarce areas. An example of this would be switching to using pneumatic or mechanical systems for transportation, instead of using water, as is often done in the poultry and other food industries.

Water recycling on site

Water recycling is the primary means of saving water in an industrial application : taking wastewater which would otherwise be discharged, and using it in a lower quality application (often after treatment). Each cubic meter of water which is recycled on site represents one cubic meter which is not withdrawn from a water source. Water can be used many times over. In such cases, where for instance a given cubic meter of water is used 10 times over in the process (a “recycle ratio” of 10 to 1), this represents nine cubic meters which are not withdrawn from a water source. Increased water savings can be made by raising the recycle ratio. The industrial water productivity of the product (in terms of industrial value added per cubic meter of water used) is also greatly increased thereby, as far less water is used to produce the same quantity of product.

The way in which water recycling is done on site must be governed by the principle of matching water quality to use requirements, as mentioned above. This is dependent on the nature of the manufacturing process, as well as on the degree of wastewater treatment which is carried out on the site. Processes such as heating, cooling and quenching are the most common applications for lower quality water. It can also be used as washdown water, and for site irrigation.

A second consideration in recycling industrial water is the cost of treating the wastewater to the level required, and the cost of the new pipes and pumps required to be laid, compared to the cost of “raw” water supplies (freshwater). Where the quality of freshwater locally is declining, or where freshwater supplies become unreliable due to water scarcity in the region, droughts or declining groundwater levels, industrial water recycling on site becomes an increasingly attractive option. Water recycling on site can be regarded as a component of industrial risk management, since it contributes to reducing the risk related to unreliability of freshwater supplies.

As one example, the micro-chip manufacturer Intel established the Corporate Industrial Water Management Group to improve water-use efficiency at its major manufacturing sites, which use large amounts of highly treated water for chip cleaning. The group includes representatives from fabrication sites, corporate technology development experts, and regulatory compliance staff. Intel set an initial goal to offset by 2003 at least 25 % of its total incoming fresh water supply needs with recycled water and more efficient systems. In 2002, the company exceeded this goal by achieving 35 % water savings through recycling water and efficiency gains.

Using reclaimed water

Water recycling occurs on one industrial site, but water reclamation refers to reusing wastewater that was produced elsewhere (with a treatment step in between, if necessary). Again, the principle of matching water quality to use requirements must be followed. The availability of the wastewater at the times when it is needed, and its variability in terms of quality, also need to be considered. For instance, an industrial plant could use wastewater from a nearby municipal sewage treatment plant. This reclaimed water is sold to industry by municipalities in many countries, including Australia and the USA. The most common uses are for industrial cooling and power generation, followed by boiler feed and quenching. The use of reclaimed water by industry eases the pressure on scarce water resources in the region.

In the Durban metropolitan region of South Africa, an innovative public-private partnership has been supplying reclaimed water to industries since 1999. The Southern Sewage Works of the Durban Metro Water Services treats over 100 Ml/day of domestic and industrial effluent (through primary treatment only), prior to discharging it to sea through a long sea outfall. Projections showed that the capacity of the sea outfall would soon be reached, due to the growing population and industrial water discharges in the area. A secondary treatment plant with a capacity of 48 Ml/day was built which was allowed to discharge water into a canal, flowing over the beach into the sea. A nearby paper mill then contracted to take 9 Ml/day of the treated water. However, it was found that tertiary treatment would be required to sell reclaimed water to other industries in the area, who need higher quality water. Since it was not economically feasible for the municipal water utility to construct and operate such a high-tech plant, the tertiary treatment works (which currently treats and sells up to 30 Ml/day of reclaimed water to local industries) was built through a public-private partnership.

Agricultural irrigation and urban irrigation (of parks, sports fields and golf courses) are also major applications for reclaimed water, which is important since irrigation is usually the largest water user in any region. Israel currently reuses 84% of its treated sewage effluent in agricultural irrigation. The World Health Organisation has laid down guidelines for the use of reclaimed water in irrigation, as there may be health implications where reclaimed water is sprayed in the open. Reclaimed water is also used for aquifer recharge, for instance to avoid saline water intrusion into the aquifer, or simply to augment the groundwater supply. In the Adelaide region of Australia, it has been found that half of the city’s water demand can be met through reclaiming water by aquifer storage and recovery.

In construction applications, reclaimed water can be used for dust control, soil settling and compaction, aggregate washing and concrete making. Domestic applications for reclaimed water include fire fighting, car washing, toilet flushing and garden watering. Supplying non-potable water in urban areas requires two sets of piping, one for potable and the other for reclaimed water – termed "dual reticulation". The laying of dual reticulation is usually done in new housing developments, as laying it retrospectively may be prohibitively expensive. The Tokyo Metropolitan Government in Japan has long encouraged the fitting of new office blocks and apartments in Tokyo with dual reticulation. There are even a few cities in arid regions, such as Windhoek in Namibia, where reclaimed water is treated to a very high standard and then reused directly to augment the potable (drinking) water supply.

The virtual water trade in industry and manufacturing

The concept of the virtual water trade applies both to trade in crops and food products, as well as to manufactured products. A particular product embodies the volume of water which is used to produce it. This can be calculated as m3 per tonne of product, or as m3 per $ of added value. By looking at the imports and exports of each type of product, it is possible to calculate the virtual water flows into and out of the region that this trade represents. In water-scarce regions, it makes sense to focus upon the manufacture of products which use little water in the manufacturing process, and hence only to export products with a high water productivity. This minimises the amount of virtual water which is exported. On the other hand, water-intensive products and products with low water productivity, such as aluminium and beer, should be imported into water-scarce regions, as this represents a way of indirectly importing water.

Policy instruments and economic incentives

Industrial water management strategies with the intention to minimize water consumption and minimize wastewater generation, and to improve water productivity, can be either internal or external. Internal strategies are those measures that are required to be taken at a factory level in order that water consumption and wastewater generation are controlled. These measures as described above can be taken more or less independently of external strategies.

External strategies are measures that are required at the industry level, or are taken in the context of local, regional or national water management in industries. Generally, the factory management does not control these strategies, although in most cases some measures are required at factory level in response. The nature and number of a particular type of industry present in a locality or a region can significantly influence these strategies. Some of these strategies are summarized as follows:

1. Grouping of industries in a particular site (industrial parks) and having combined treatment methods and reuse policies.
2. Rationing or target-setting for water use within industry, so that each process uses a defined quantity of water.
3. Applying economic instruments such as penalties, water charges, subventions, credits and grants.

National water conservation policy, also called water demand management, is the key factor in water recycling and reuse in industries. It forms an important component of national water efficiency plans. In some developing countries, industry is not charged for water nor for wastewater services; in other words, both industrial water withdrawals and wastewater discharges are still free and unregulated. Both regulation and the imposition of stepped water tariffs according to the volume of water used are key instruments for governments to use in these situations. Compliance with stringent effluent requirements can force industries to implement new technologies to reduce effluent discharges. Fines for non-compliance and the threat of closure for repetition of non-compliance can also significantly achieve higher recycling and reuse. Higher charges for raw water can be applied to industries using large volumes of water. An example can be seen in Singapore, which levies a 15 % water conservation tax on operations using more than a specified amount, and new factories needing more than 500 m^3 of water per month must apply for approval from the City Council during the planning phase. A fertiliser plant in Goa, India cut water demand by 50% over a 6-year period in response to higher water prices. Dairy, pharmaceutical, and food processing industries in Sao Paulo, Brazil reduced water use per unit output by 62%, 49% and 42% respectively[i].

Given proper incentives, it is generally found that industry can cut its water demand by 40 to 90 % even with existing techniques and practices (Asano and Visvanathan, 2001)[ii]. However, water conservation policies need to be fair, achievable, and enforceable. Economic incentives should be given to industry to comply with standards and policy and to reduce raw water intake. Furthermore, such incentives could include:

- subsidies for industries implementing innovative environmental technologies, and
- financial and advisory support for industries funding new research.

Both regulatory policies and economic incentives can dramatically increase industrial water productivity. They often go hand-in-hand with policies for reducing wastewater discharge and industrial water pollution, which leads us to the second major opportunity for industrial water use : zero discharge.

3.2. Opportunity #2 : closing the loop with zero discharge

Zero discharge is a key target both for reducing water withdrawals by industry, and for reducing pollution to the environment. All the effluent that would normally be discharged is treated, recycled or sold to other users. Without going into detail, I wish to note that there are a range of techniques which can be used to facilitate moving in this direction, including :

- stream separation
- raw material recovery from waste
- energy recovery from waste
- reuse of waste (in a different form)

Reducing the volume of effluent discharged back into the water environment by industry is essential to closing the gap that exists between water withdrawals and actual water consumption, as we noted earlier. Once no more water is discharged from an industrial installation, its overall water consumption will equal its water withdrawal from source. In practice, this means that water withdrawals by industry will gradually decline, as levels of water recycling increase, down to the point where withdrawals equal consumption. This process has already begun in Europe, as we saw in Figure 4a, which showed by the declining water withdrawals by industry over the past 25 years. Moving towards zero discharge can be done at the level of the individual enterprise; at the local level (say by a group of companies operating in an industrial park); or at a district or municipality level.

The city of St Petersburg in Florida, USA, is the first municipality in the world to have achieved zero effluent discharge to its surrounding surface waters. Situated on a bay, which is a major tourist attraction, the city has laid an extensive dual-reticulation system. All the domestic and industrial wastewater generated is treated to a high standard. The reclaimed water is then reused for irrigation and industrial cooling applications by thousands of customers, accounting for nearly half of the city's water needs of 190 Ml/day. By substituting reclaimed water for potable water in many applications, the city has eliminated the need for expansion of its potable water supply system until the year 2030. Equally importantly, there is no pollution of the beaches and marine ecosystems by municipal wastewater, and no unsightly sea outfalls.

It should be noted in this context that irrigating city parks or agricultural land counts as reuse of water, as these are applications where more freshwater would have been taken out of the natural cycle, had the wastewater not been available for use. It is not counted as discharge. However, strictly speaking, some of this water might seep through into groundwater and run off into streams and drains. On balance, irrigation of land with wastewater is a technology, which purifies wastewater and can be regarded as an additional and sustainable treatment step.

Materials recovery and waste reuse

There is a growing understanding worldwide that we need to find ways to make our industrialised society more cyclical in its use of materials and resources. At present the uses of materials and other inputs to industrial processes (such as energy and water) are primarily linear. Resources are mined, products are manufactured, wastes are generated and then disposed of at the end of the process. The products themselves sooner or later end up as waste to be thrown away. At present much environmental protection is still based upon "cradle to grave" thinking. By contrast, the "cradle to cradle" concept is a vision of cyclical flows of materials. The materials, which go into making up products could be reused over and over again, if products are designed in such a way as to facilitate materials recovery. This approach seeks to eliminate the whole idea of waste, and hence it is much closer to the way things are done in nature.

The "cradle to cradle" type of thinking is developed through initiatives such as chemical leasing, whose business model is based upon providing a service rather than selling a product. The chemicals remain the responsibility of the chemicals leasing firm, while the customer, the industrial enterprise, purchases services such as cleaning, coating, colouring and greasing. This business model aligns the incentives for both the customer and the supplier to reduce the amount of the chemical used. The implication for industrial water management is that much more attention is paid to ensuring that the chemical in question does not enter the process water streams in the first place, or is efficiently stripped out again if it does.

In order to recycle or reuse materials effectively from waste streams the various material flows to be kept as distinct as possible, according to the principle of stream separation mentioned earlier. This may require *process* re-design or modification. Developing products and markets from waste streams can also require innovative *product* design. The clear benefits here for water management are through reducing the effluent load. A case study of cheese production in El Salvador provided by UNIDO demonstrates this very effectively.

A typical dairy company in El Salvador was using 10 litres of milk (and about 80 litres of water in the process) in order to produce one kilogram of cheese. Nearly 9 litres of whey were produced as a byproduct, and were simply discharged into the wastewater. Whey is a highly concentrated organic liquid, containing proteins and lactose. Large dairy companies use ultra-filtration plants to produce pure lactose, additives for ice cream and other food products from this byproduct. However, this technology is not affordable for small and medium-sized companies.

The solution proposed by the National Cleaner Production Centre in El Salvador was to process the whey in order to produce a marketable whey-fruit drink. Such drinks are available on the European market and are popular with consumers. No additional investment was required by the company in order to process the whey. The estimated benefits were found to be as follows :

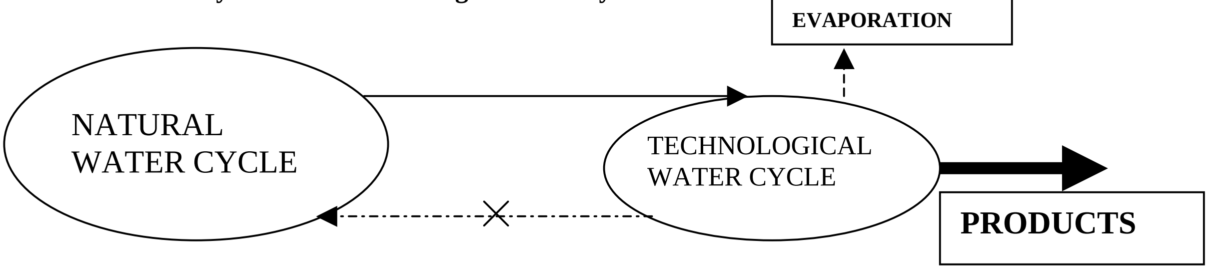
- 11.5 % reduction in the volume of wastewater
- 40,000 mg/l reduction in BOD level in wastewater
- 60,000 mg/l reduction in COD level in wastewater
- US$ 60,000 per year saving in wastewater treatment costs

Other dairy companies in El Salvador are starting to produce this product, and similar programmes are being developed in Guatemala and Mexico. This case study shows that there are substantial financial benefits to be found in waste recovery, hand-in-hand with the goals of reducing pollutant loading and wastewater discharge.

Towards zero discharge

Implementing zero discharge to the water environment ensures that water once used by industry must stay within the technological cycle, except for that fraction which evaporates and is thereby returned to the natural water cycle, free of contaminants. Through zero discharge, abstraction of water from the natural water cycle is kept to a minimum. The water, which is abstracted is reused over and over, or consumed in various ways. There should be no residual effluent or wastewater, which needs to be disposed of to a river, to a stream, or to a marine outfall. In this way we are protecting the environment, ensuring our future water security, and maximising industrial water productivity at the same time.

Figure 5. The natural water cycle and the technological water cycle



Going "all the way" to zero discharge places great emphasis on water recycling and water reuse within the factory or enterprise. The cleaner the wastewater stream, the simpler and cheaper are the treatment methods that need to be applied in order to reuse it. However, often there are simply not the resources, nor the applications within one single enterprise, or within a group of enterprises, where lower-grade water can be treated and reused. Also, economies of scale can be achieved by treating larger volumes of wastewater. In these situations, achieving zero discharge on a local or district level requires the building of partnerships and linkages between industries and local government, and also may necessitate some innovative financing mechanisms.

4. Conclusion

Of course there are many intermediate steps to be taken to reach the ultimate goal of zero discharge, just as there are varied mechanisms, which will improve and increase industrial water productivity over time. Many policies and regulatory strategies need to be worked out in order to implement the vision; much research and development, innovation, and technology transfer needs to take place; and partnerships aiming to achieve these ends need to be built and strengthened, locally, nationally and regionally. These will be the subject of other papers and workshops during the course of this conference. However, I trust that this paper will have set out some of the fundamental challenges for the technology foresight process and the decision-making: how precious our freshwater is; how industry has a major responsibility and a major role to play in protecting and conserving this resource; and finally, how close at hand are the opportunities that we have to ensure our future water security and the sustainability of water use in industry.

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