

Water reuse: a sustainable alternative water supply for industry in the UK?

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Executive Summary

Water is essential to industry for processes such as cooling, heating, cleaning, diluting, transportation and sanitation. Industrial water usage in the UK is metered and therefore businesses have a financial incentive to reduce their water consumption. In recent years abstraction limits have become increasingly stringent and there is growing interest in businesses' environmental performance; hence alongside demand management there is a need to source alternative sustainable water supplies for industry. In parts of the UK recent droughts have exacerbated the situation.

Water reuse - the practice whereby suitably treated wastewater from one process is reused for a different beneficial purpose – is one such alternative water supply. The aim of this report is to investigate whether water reuse is a sustainable alternative water supply for UK industry.

There are a number of policy drivers for industrial water reuse in the UK including the Urban Waste Water Treatment Directive, Water Framework Directive, Integrated Pollution Prevention and Control Directive as well as the more local Catchment Abstraction Management Strategies in England and Wales. Site-specific drivers include the ability to reduce costs associated with water supply and contribution towards an environmental management system (e.g. by reducing natural resource usage). A number of industrial water reuse schemes are already in existence in the UK; examples include Peterborough Power Station and Kronospan's fibreboard production facility in north Wales.

There are clear benefits for a business implementing water reuse – a less drought-sensitive water supply, a 'greener' corporate image, financial savings from the recovery of resources and reduced need for abstraction or mains-supplied water. Society however also benefits from greater environmental flows for freshwater wildlife and water-based recreation, improved environmental water quality and the greater availability of potable water for domestic consumers.

Water reuse has potential to be a sustainable alternative water supply for UK industry, if part of a wider 'twin-track approach' where water demand management is incorporated too. It is not *intrinsically* sustainable *per se* however; various considerations should be taken into account when determining whether a proposed water reuse project is sustainable: What are the energy requirements of treating wastewater and transporting the resultant reclaimed water? How will concentrate from advanced wastewater treatment processes be disposed of? Will the removal of a particular 'stream' of water for reuse negatively affect the quality of the remaining wastewater that has to meet discharge consents?

There are a number of potential barriers that must be overcome if industrial water reuse is to be expanded in the UK; these include the lack of public awareness and support from government and regulators regarding water reuse.

Experience from overseas at both strategic and project level can help inform decisions about the appropriateness of water reuse in the UK. Australia and the USA both have national guidelines for water reuse and government support for large-scale industrial water reuse projects. Good educational programmes for raising public awareness of water reuse are evident in Singapore and the USA.

Water reuse should be an integral part of a suite of demand and supply measures that together can bring about more sustainable water management in the UK. To facilitate the uptake of industrial water reuse in the UK, the following issues will be critical:

1. The need for society to develop a greater appreciation of the anthropogenic influence on the water cycle
2. The need to develop fair pricing for all water resources reflecting their full economic and environmental costs and yet the short-term need for pump-priming financial support from government for sustainable water reuse projects

3. The need for a coherent government policy on water reuse (as CIWEM called for in its 2002 Policy Position Statement) coupled with authoritative reclaimed water quality standards that are realistic and protect public health and the environment
4. The need for existing government programmes such as the Enhanced Capital Allowance Water Technology List and Envirowise business advisory service to be expanded to include water reuse technologies
5. The need for more research and development into low-carbon, economic water reuse solutions

1. Introduction

Industry is one of the largest and fastest-growing users of water. Globally it accounts for around 20 percent of all freshwater withdrawn and in high-income countries it can account for as much as 59 percent (Clarke and King, 2004). Despite the fact that the UK economy is dominated by the service sector, income growth and increasing purchasing aspirations mean that industrial water use has not declined as much as might be expected.

In recent years in the UK, water abstraction limits have become increasingly stringent, coupled with recent droughts (2003 in eastern Scotland; 2006 in southern England) and a growing interest in businesses' environmental performance, there is a need for industries to reduce water use. It is generally agreed that to meet long term demand for water a 'twin-track approach' of water demand management and the development of new water supplies is needed¹.

The aim of this report is to **investigate whether water reuse is a sustainable alternative water supply for UK industry**. Water reuse (also termed water reclamation) is where suitably treated wastewater from one process is reused for a different beneficial purpose². Globally, agricultural irrigation is the biggest use of reclaimed water (predominantly in countries with Mediterranean or semi-arid climates) but in the UK agriculture is a relatively small water user and the total area of irrigated agriculture is declining thus this report focuses on water reuse for industry in the UK rather than irrigation.

Background

Around half of all water use in industry is cooling water; other water uses include heating, cleaning, diluting, transport and sanitation. In the UK some industries such as the electricity supply industry chiefly abstract the water they need directly from the environment through the licensing system. Other businesses, using mains-supplied water, are metered for the volume of water they use and the wastewater they dispose of (the latter is based on 95 percent of incoming water being disposed of). Businesses discharging industrial effluent are required to meet discharge consents based on the volume, quality and strength of the effluent.

Before a business can implement water reuse, a comprehensive water audit must be undertaken to quantify the company's water usage and wastewater generated. It is usually most cost-effective for businesses to first implement water efficiency measures including better water management practices (e.g. repairing leaks and not leaving taps dripping) and fitting water-saving products (e.g. aerators, flow controllers and efficient shower-heads/taps/toilets). Some businesses may not find it cost-effective to go beyond this, but those with higher water usage may find that utilising water reuse in addition to implementing water efficiency can bring financial and other benefits. Furthermore as one water company notes "in the industrial sector, reducing demand can be [...] complex..., large-scale water use reductions are difficult to achieve. Other strategies must be employed." (Veolia Water, 2005).

The water quality needed for industrial uses is generally less stringent than water quality for potable consumption. Certain industrial processes such as heating, cooling, quenching and cleaning are particularly suitable for lower quality water use.

¹ Views vary however as to whether these measures should be undertaken in tandem or sequentially

² In contrast the term 'water recycling' refers to where wastewater from a process is used again for *the same purpose*, with or without treatment in between.

2. Benefits and Beneficiaries of water reuse

Water reuse can bring financial, social and environmental benefits. Although the individual business using water reuse will be the primary beneficiary; society as a whole can also benefit through the freeing up of scarce water resources and an improved water environment. The table below highlights some of the main benefits of water reuse.

Table 1: The potential benefits and beneficiaries of implementing water reuse

Benefits	Beneficiaries
A less drought-sensitive water supply. Climate change scenarios suggest that the UK is likely to experience drier, warmer summers with more frequent periods of extended drought (Hulme <i>et al</i> , 2002). Demand for water is also expected to rise (Downing <i>et al</i> , 2003). Reclaimed water is a more drought-resistant water supply and enables better business continuity in the event of restrictions such as drought orders which limit the uses of mains-supplied water.	Industry (Reduced risk and therefore better business security)
Enhanced corporate image. Customers and potential customers look favourably on companies they perceive to care for the environment.	Industry (competitive advantage)
Recovery of resources such as heat, pulp solids (e.g. from MDF manufacture) or paint (e.g. from automobile manufacture) is possible. (after Jefferson <i>et al</i> , 2003)	Industry (financial saving from resource efficiency)
Reduced consumption by industry of potable quality mains-supplied water	Society (more potable quality water available for domestic users) & Industry (financial saving from lower water bills)
Reduced need for abstraction from water bodies	Society (greater environmental flows for aquatic species and water-based recreation) & Industry (financial saving on abstraction licences)
Reduced nutrient content of effluent flow to the sewerage system and water bodies	Society (better environmental water quality) & Industry (financial saving from less stringent discharge consent/reduced trade effluent costs)
Reduced effluent flow loads to the sewerage system and water bodies	Society (better environmental water quality**/ reduced flood risk) & Industry (financial saving from less stringent discharge consent/reduced trade effluent costs)

** Although where treated wastewater forms a significant component of baseline river flow in periods of low rainfall, water reuse can lead to low environmental flows.

Another potential benefit to profit-making UK businesses is the government's 'Enhanced Capital Allowance' scheme whereby businesses purchasing specific water saving technologies can write-off the capital cost of their investment in these technologies against their taxable profits. Although most of the specified technologies on the 'Water Technology List' are water-efficient technologies such as spray taps and flow controllers, a small number of water recycling and reuse technologies are included on the list, such as vehicle wash water reclaim units and efficient membrane filtration systems for wastewater reuse. Using microfiltration, ultrafiltration, nanofiltration or reverse osmosis the membrane filtration systems must enable the recovery and reuse of at least 40 percent of the treated wastewater (Department for Environment, Food and Rural Affairs, 2006a).

3. Learning from experience overseas

In investigating the potential for increasing industrial water reuse in the UK, we can learn from experiences overseas - at both strategic level (policies and regulations) and project level (individual industrial reuse projects).

Australia

All state and territorial governments in Australia have signed up to a National Water Initiative to improve the country's water management. Australia is one of the leading countries in the field of water reuse. In the last five years pressure on mains-supplied water resources has intensified as a result of a lengthy drought – one of the worst on record.

Many states and territories have developed their own water reuse policies and guidelines however concerns about inconsistencies between them recently led to the production of *National Guidelines for Water Recycling and Reuse*. The National Guidelines outline best practice and use a risk management and multiple-barrier approach to managing potential health and environmental risks from water reuse. They also provide specific guidance for particular end-uses of reclaimed water, including industrial ones (Environment Protection and Heritage Council, 2006).

The principal use for reclaimed water in Australia is agricultural irrigation although water-intensive heavy manufacturing and energy production facilities also make use of reclaimed water. In 2004-2005 manufacturing industry in Western Australia and Queensland used 9500 megalitres of the reclaimed water supplied by urban water providers, with smaller quantities used in Victoria and New South Wales (Australian Bureau of Statistics, 2006). Most industrial water reuse is based on partnerships between a group of industries in close proximity to each other, and a water supply company providing reclaimed water.

In Australia there is often financial support from governmental bodies, for example the New South Wales Government contributed AUS\$5.18 million (c. £2 million) from their Water Savings Fund towards the Kurnell water reclamation plant due to be commissioned this year (New South Wales Government, 2006). The plant will supply around six million litres of reclaimed water to the nearby Caltex Refinery and Continental Carbon Australia (which produces carbon black used to make rubber). The refinery is one of the largest consumers of water in the region and currently uses around 6.2 megalitres/day of water for heating and as steam to drive pumps and compressors. Switching to reclaimed water will free up 4.5 megalitres/day of potable water (United Utilities Australia, 2006).

USA

The USA is also a leader in water reuse. As in Australia, there are National Guidelines for Water Reuse (revised in 2004) although many states also have their own guidelines or criteria for reclaimed water uses. Projects in the USA are often financially supported by state or local government loans, bonds or grants. Legislation has been approved which allows the Environmental Protection Agency (EPA) to give \$125 million in 'alternative water source grants' to industrial water reuse projects (House Transportation and Infrastructure Committee, 2007).

The American Water Works Association and the WaterReuse Association both sponsor innovative water reuse research and development projects. The WaterReuse Association also encourages federal and state support for reclaimed water and produces educational materials. They have produced a workbook for upper primary school children entitled 'Give water a second chance...re-cycle it!' which explains how water reuse and recycling fit in with the 'natural' water cycle. Another organisation educating the public is the Water Education Foundation which has produced a wide range of videos, games and books including 'A Layperson's Guide to Water Recycling'.

Florida is one state at the forefront of water reuse in the USA. A statement of support for water reuse has been signed by the state's Departments of Environmental Protection and Health, the five Water Management Districts, the United States EPA and others. In the statement the parties "resolve to continue to encourage and promote water reuse, to work together to overcome institutional and regulatory disincentives and funding constraints, to ensure protection of public health and environmental quality, and to promote public acceptance of water reuse in Florida" (Florida Department of Environmental Protection, 2001 p1). In 2003 this was backed up by a comprehensive report which suggested appropriate strategies for encouraging safe and effective water reuse.

Asia

Asian countries which have adopted water reuse technologies are characterised by industrialised economies and a high population density, meaning that water is consequently a scarce resource.

In 2003/2004 the Singaporean government-owned Public Utilities Board brought online four water reuse plants to reduce the country's dependence on imported water from neighbouring Malaysia. Treated municipal wastewater undergoes reverse osmosis and is turned into 'NEWater' which is used primarily by industry but also indirectly reused for drinking water. The industrial users are centralised and therefore a dedicated pipeline is easily used to transport the reclaimed water. The price of NEWater is 23 cents/m³ less than potable water, although the reclaimed water is thought to be subsidised by the government (Department of Trade & Industry, 2007 p14).

The Singaporean government has invested in a widespread public education programme with a showcase NEWater plant/exhibition centre and effective marketing materials to increase public awareness and acceptance of reclaimed water. Amazingly more than sixty percent of the country's 4.5 million residents have visited the NEWater exhibition centre (Department of Trade & Industry, 2007 p5)!

In Japan industrial water reuse has been practiced since 1951 when a wastewater treatment works began supplying a nearby paper mill with reclaimed water (Ogoshi *et al*, 2001). Nowadays Japanese industry is the lowest water-consuming sector of the Japanese economy and water reclamation and recycling is widespread (UNESCO, 2006).

Japan also has a public-funded research and development organisation called the 'Water Re-use Promotion Center' which aims to support and extend the use of water reuse and desalination technologies. The organisation has an industrial water user group as well as self-governing groups in the country's different administrative regions. In some Japanese cities water reuse is mandatory for buildings with a floor space exceeding 3000m². Schemes which re-use municipal wastewater are eligible for financial support covering up to fifty percent of the capital costs (Ogoshi *et al*, 2001).

In Taiwan, water reuse and recycling are one of four core policies that the government's Water Resources Agency is pursuing. The 1963 Water Act gives authorities the power to require the installation of technology to reclaim cooling water for further industrial uses.

Europe

A recent study into water reuse identified over 200 water reuse projects in Europe (Bixio *et al*, 2006). As part of 'Aquarec', a recently-completed European research project, guideline quality standards have been published to help those planning and implementing water reuse schemes in Europe. Many European countries reuse treated wastewater for agricultural irrigation and some have their own quality guidelines for such uses. Industrial water reuse is less common but is practiced in countries including Spain, Belgium, Poland and Italy.

In industrial southern Poland, Krakow University has worked in partnership with the U.S EPA to develop a demonstration wastewater reclamation plant at Plaszow. The plant has a capacity of 1.7 megalitres/day and supplies reclaimed water to power generation and metallurgy industries (Kurbiel *et al*, 1996). The project was conceived because water from the nearby River Vistula had become polluted as a result of coal mining upstream and thus an alternative water supply was needed. The project received funding from the Polish government's scientific research committee.

In Italy water prices are much lower than the European average but the threat of price rises and local water taxes means reclaimed water is being considered by some industries. There are already standards for water reuse in Italy that were established by the environment ministry in 2003.

Examples of industrial water reuse from around the world

USA

In Florida around 2420 megalitres/day of reclaimed water are used for beneficial purposes, of which 14% is used for industrial uses. This includes a combined heat and power plant, an energy-from-waste facility and four Florida power stations which use reclaimed water for cooling purposes.

(Florida Department of Environmental Protection, 2007)

Italy

In Pontedera, Tuscany a pilot industrial water reuse scheme has been set up at Piaggio's scooter factory. The reclaimed water costs €0.55/m³ and is considered to be of a comparable or better quality than the groundwater that was previously used

(Marcucci and Tognotti, 2002)

South Africa

A Public-Private Partnership in Durban set up the country's first water reclamation plant in 2001. The reclaimed water is supplied to a paper mill and a refinery where it is used for fire fighting and cooling purposes.

(Shell, 2007)

Australia

Since 2004 Kwinana Water Reclamation Plant has received secondary treated wastewater from a treatment works near Perth. After microfiltration and reverse osmosis the reclaimed water provides an alternative water source for large industrial facilities in the vicinity requiring steam or cooling water including an oil refinery, iron smelting plant, combined heat and power plant and a fertiliser manufacturer. Water reuse has also caused a reduction in treated wastewater discharges into Cockburn Sound - a sensitive receiving environment.

(Water Corporation, ca. 2004)

Japan

Cities such as Tokyo and Fukuoka have dual-distribution piping which circulates treated wastewater from municipal treatment works to be used for toilet flushing within buildings.

(Rimer et al, 2006)

Jordan

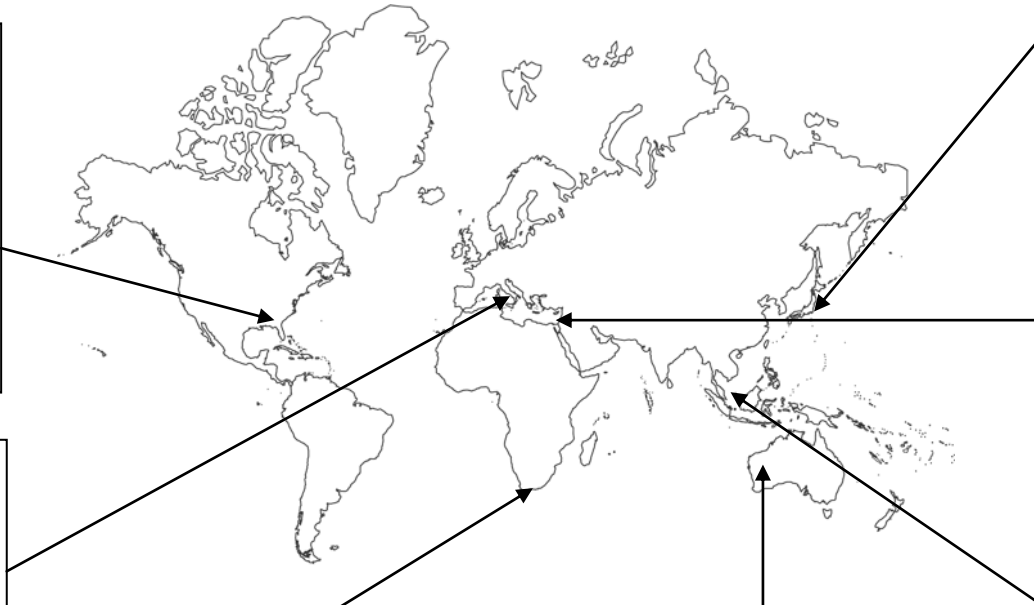
Owing to a zero discharge policy in the Gulf of Aqaba, the Jordanian Government and U.S AID have set up a pilot wastewater reuse scheme whereby tertiary treated wastewater is reused by industry and for landscaping. The focus is on water-intensive processes such as textile bleaching and bottle washing in the soft drinks industry.

(Stedman, 2006)

Singapore

The Panasonic semiconductor factory in Singapore uses 'NEWater' (reclaimed municipal wastewater). In the 2006-07 financial year NEWater accounted for 87% of process water used in the factory.

(Matsushita Group, 2007)



4. Policy drivers for water reuse in the UK

In the UK water reuse is still relatively rare although awareness of it is growing. The House of Lords Science and Technology committee, in their recent Water Management report, stated that "there is scope for greater industrial use of wastewater that has been treated to a sub-potable standard" and that the Government needs to investigate how this can be encouraged (Authority of the House of Lords, 2006 p69). The main policy drivers that affect the implementation of water reuse include:

- *Urban Waste Water Treatment Directive*: This European legislation aims to protect the environment from the adverse effects of urban wastewater discharges. It requires that municipal and certain industrial wastewater deriving from areas with a population equivalent of more than 15,000 must receive secondary and tertiary treatment (Council of the European Communities, 1991). Wastewater from smaller settlements must also receive some form of treatment and sensitive waters must be properly protected. The Directive also asserts that sewerage undertakers must ensure treated wastewater is reused 'whenever appropriate'. Although this assertion is somewhat vague, as a minimum it suggests that the potential for water reuse must be considered, to determine whether it is 'appropriate' given the circumstances.
- *Water Framework Directive*: This European Directive requires inland, estuarine and coastal waters to reach "good status" by 2015. The water environment must be managed in an integrated manner on the basis of river basin districts. To achieve good status, agriculture, water companies and industry will be required to be more stringent in preventing the discharge of pollutants into receiving waters. Only sustainable levels of abstraction from rivers will be allowed because certain minimum flows are required to support the algae, plants, fish and macro-invertebrates whose presence confers good ecological status on a water body. Reduced abstraction and more stringent discharge consents are likely to lead to more businesses considering water reuse.
- *Integrated Pollution Prevention and Control Directive*: The IPPC Directive requires potentially highly-polluting industry to obtain a permit from a competent authority (the environment agencies of the UK administrations). Permits are only issued if certain environmental criteria are met and information is provided about how the company will reduce and prevent various kinds of pollution including wastewater discharges.
- *Catchment Abstraction Management Strategies*: The aim of these locally-developed documents is to help balance the demands of water abstracters and the aquatic environment and ensure that decisions are made equitably and publicly. To ensure abstraction is sustainable, those wishing to abstract significant quantities of water require a licence. This licence has certain conditions such as a maximum quantity that can be abstracted and a minimum flow requirement before any abstraction can take place. Businesses which cannot obtain sufficient licences to meet their requirements must find an alternative water supply. Catchment Abstraction Management Strategies have been developed by the Environment Agency and as such cover only England and Wales. Whilst there aren't directly comparable strategies in Scotland or Northern Ireland, both now have an abstraction licensing system.

5. Current practice in the UK

Despite the absence of guidelines for water reuse in the UK, a number of businesses have adopted water reuse in an effort to reduce costs, as part of an environmental management system or to have a more drought-proof water supply. Some water and sewerage providers such as Wessex Water and Anglian Water have also sought out industrial customers which can reuse highly-treated municipal wastewater as an alternative to mains-supplied potable water. Below are three case studies which demonstrate the breadth of water reuse schemes already taking place in the UK.

Case Study: J & A (International) Ltd

J & A International Ltd is a specialist printer based in Lincolnshire that produces printed heatseal transfers, embroidered badges and helmet stickers for work clothing. The company are implementing water reuse as part of their environmental management system and ISO14001 accreditation. They were shortlisted for the 2001 Water Efficiency Awards.

They have reduced their consumption of mains-supplied potable water by 69 percent by using treated greywater for washing screens on the stencil developer. Now only one run of mains-supplied water per cycle is used and wastewater costs have been reduced by 93 percent (Water UK and Environment Agency, 2001). Two reed beds were installed to filter the remaining effluent however these were found to be ineffective and have been taken off-line whilst alternative treatment methods are being trialled (J & A (International) Limited, 2006).

Case Study: Peterborough Power Station

Peterborough Power Station originally used 1200m³/day of demineralised mains-supplied water to produce steam to drive the combined cycle gas turbine plant (Murrer and Macbeth, 2006). In the late 1990s the power station owners were approached by Anglian Water who saw the power station as a potential customer for the large volumes of high quality wastewater generated by their Flag Fen wastewater treatment plant. A contract was signed and in 2000 the new plant at Flag Fen was opened. The wastewater undergoes pre-screening, microfiltration and reverse osmosis to remove between 80 and 90 percent of dissolved ions. 1.6 megalitres/day of tertiary treated wastewater is converted into steam (*ibid.*).

During commissioning it was found that the reverse osmosis membranes were being fouled. The foulant was identified as calcium phosphate and the problem was solved by chemically adjusting the wastewater feed. Another more on-going challenge is that the quality of the wastewater feed varies seasonally due to contaminants such as salt from road gritting in winter (*ibid.*).

Despite these difficulties there have been clear benefits from using reclaimed water. The reclaimed water has a very low total dissolved solids content compared to the mains-supplied potable water. A low total dissolved solids content is essential to prevent scaling and fouling in the power station – something which had been happening before. Also using the reclaimed water means the operators have reduced the use of chemicals that were previously needed to demineralise the mains-supplied water so as to protect the power stations boilers and steam turbine (Centrica, 2006). The power station has an ISO14001 certified environmental management system and these chemical and water savings have contributed to meeting targets set as part of this process.

Case study: Kronospan

Kronospan Ltd based in Chirk, Wales manufactures wood-based products such as medium density fibreboard (MDF). Chipped wood fibres are washed and softened and excess water is removed prior to heating. The fibres are then mixed with resin, compressed into shape and the resultant fibreboard is cooled. The manufacturing process results in the production of nearly 48 megalitres/year of effluent. The high suspended solids content and high chemical oxygen demand meant that historically it has had to be tankered away - at a minimum cost of £9.80 per tonne - rather than being discharged to the sewer system. This high cost and the fact that timely production was dependent on the regular removal of the effluent led the company to investigate options for water reuse.

In 1995 a reverse osmosis plant was installed at the factory to treat the effluent to enable water reuse and material recovery. The plant is operated by the technology supplier. The effluent from the manufacturing process firstly undergoes coagulation/flocculation and filtration to remove solids greater than 5 µm in diameter; the collected material contains pulp solids that can be reclaimed and fed into the production process again. The remaining effluent undergoes reverse osmosis to remove dissolved organics and remaining suspended solids. Finally the effluent passes across a carbon polishing filter and the resultant treated wastewater is reclaimed as boiler feed water. The net cost savings from undertaking water reuse have been over £250,000 per year at 1998 prices (because the wastewater no longer needs to be transported off-site), potable water consumption has fallen and virgin wood fibres have been replaced with reclaimed ones.

Reference: (Envirowise, 2000)

6. Considerations

Water reuse is not *intrinsically* sustainable *per se*; there are various considerations that should be taken into account when determining whether a proposed water reuse scheme will be sustainable:

1. Energy requirements

The two major energy costs in producing reclaimed water are treating the wastewater and distributing the resultant reclaimed water.

Swinton (cited in Dimitriadis, 2005) explains that the energy needed to produce 1000 litres of *potable* water from treated wastewater is double that needed for conventional water treatment (but still considerably less than the energy required to produce potable water through desalination of seawater). Not all industrial uses however require potable-quality reclaimed water and therefore need to undergo energy-intensive advanced treatment processes.

A lot of energy is required to pump water through a pipeline network due to the heavy weight of water. Distributing reclaimed water long distances is therefore not financially viable in most cases because the increased energy costs are likely to offset lower water costs or not having to pay for consents to discharge wastewater to the sewer. Where industrial water reuse does take place there are usually several

water-intensive industries grouped together so that these water users can be served by the same pipeline.

This should also be set in the context of rising global energy prices meaning that energy costs are an important variable for many industries. Statistics published by the UK Government show that industrial electricity and gas prices were both over 75 percent higher in 2006 than in 2001 (Department for Business, Enterprise and Regulatory Reform, 2007).

2. Disposing of the concentrate

Another important consideration is what to do with the concentrate from advanced wastewater treatment processes. Whilst water reuse will decrease the volume of treated effluent discharged to the environment, the load of impurities will not be reduced as substantially. It is therefore important to determine a viable disposal method. The options for disposing of the concentrate are either to return it to the sewers, treat it separately (although this has energy and financial implications), dispose of it untreated into the environment via long sea outfalls (this could have environmental and public perception implications) or find an alternative beneficial use for the concentrate.

3. Reclaimed water quality and wastewater discharge quality

Businesses considering implementing water reuse also need to consider whether there are appropriate sources of wastewater to recycle and the implications that recycling may have on the quality of the remaining wastewater. In many industrial processes several streams of wastewater of different qualities converge into one discharge, leading to temporal variations in water quality (Jefferson *et al*, 2003). This can make water recycling more difficult because a consistent water quality is important for users of reclaimed water. Furthermore if one stream of water is removed from the discharge for recycling purposes, this may affect the quality of the remaining discharge water such that it leads to exceedance of discharge concentration limits (American Institute of Chemical Engineers, 1995). This is because streams suitable for recycling such as cooling water often have a diluting effect because they are comparatively pure.

7. The potential to expand water reuse in the UK

Miller (2006) has highlighted barriers experienced in attempting to implement water reuse projects. Although he doesn't focus specifically on industrial uses or the UK in particular, many of the barriers are applicable in the context of industrial water reuse in the UK, namely: the need for public education, better documentation of the benefits of water reuse, support from government and regulators and the lack of funding.

1. Public Education

It is hard to envisage industry, the public or trade unions supporting water reuse unless there is education about why water reuse is needed and what is done to manage the potential health risks from it, particularly where the end use potentially involves human contact with the reclaimed water.

Whilst the scale and success of the 'NEWater' publicity campaign in Singapore would be hard to replicate in the UK because of differences in population size, culture and

the structure of the water industry, a useful starting point would be for school curricula in the UK to place a greater emphasis on the anthropogenic influences on the water cycle. Does the public realise that indirect potable water reuse is already normal practice in parts of the UK? Age-appropriate learning resources relating to reclaimed water such as those produced by the U.S WaterReuse Association would also be extremely valuable in the UK.

2. Developing confidence in the technologies and documenting the benefits of water reuse

Businesses considering water reuse need to be able to access information on the possible opportunities, constraints, advantages and disadvantages of water reuse to determine whether it is appropriate for their water needs. This information needs to be easily accessible, authoritative and independent. The government-funded organisation 'Envirowise' already provides independent environmental information and guidance to UK businesses and is well placed to provide this help.

Businesses also need to have confidence that the technology will work effectively and reliably, is easy to maintain and produces the savings expected (both financial, water and any other). Problems experienced can include scaling of membranes and corrosion of pipework. Concerns about process reliability and costs are deemed to have limited the uptake of water reuse (Jefferson *et al*, 2003). Technology-specific and industry-specific workshops would enable interested businesses to get specialised advice.

3. Support from regulators and politicians

The House of Lords Science and Technology Committee in their Water Management report suggested that there is greater scope for industry to make use of sub-potable quality reclaimed water and that the Government should investigate ways this could be encouraged (Authority of the House of Lords, 2006).

Quality standards for reclaimed water generate confidence that the alternative water supply is safe, clean and suitable for the intended use. The committee recommended that the Government should "consider, as a priority, the feasibility of introducing a universal statutory standard for subpotable water intended for re-use" (*ibid.* p111). In their recent follow-up report they criticised the government for failing to respond to this recommendation (Authority of the House of Lords, 2007).

The government's Market Transformation Programme is currently reviewing alternative water sources with the aim of determining actions required over the next 20 years to ensure alternative water supply technologies become a routine part of construction projects (Market Transformation Programme, 2007). Although the focus of the Market Transformation Programme (MTP) is greywater reuse and rainwater harvesting in residential developments rather than municipal and industrial wastewater reuse, the work still has some relevance to encouraging industrial water reuse in the UK. For example through the MTP the Government seems to acknowledge that it should support and encourage water companies that are promoting alternative water sources (*ibid.*). The MTP itself is also reviewing water quality standards and whether it should make recommendations for rainwater and greywater reuse quality standards in the UK.

A general aversion to risk and investment for the long-term and a concentration on short-term profit means that the current inertia within industry regarding alternative water sources will only be overcome if there is pro-active, strategic political and

financial support from government, the environment agencies³ and Ofwat – to compel water and sewerage providers and industrial water users into considering water reuse.

4. Funding and fair pricing for all water resources

To use water resources sustainably society must value them properly and therefore pay a fair price that reflects the full economic and environmental costs. To date, few, if any, municipal water reuse schemes have tested consumers' willingness to pay because the reclaimed water has been sold at a subsidised price and has not always been metered. The price has been set artificially low because of the perceived need to incentivise potential domestic and industrial customers by pricing below the cost of mains-supplied water (Costello, 2006). To achieve these below-cost prices most schemes have received external financial support from quasi-governmental bodies. Whilst the ultimate aim should be for all water sources to be priced at their full environmental and economic costs, as long as mains-supplied water is underpriced, some kind of similar financial incentive is likely to be required to drive forward water reuse projects in the UK and persuade industrial customers to switch to reclaimed water.

Expanding the UK Government's Enhanced Capital Allowance Water Technology List to include further water reuse technologies would enable businesses purchasing one of these technologies to benefit from the tax break. There are still only a very small number of water reuse technologies on the list; this needs to increase if the ECA tax breaks are going to be considered a real financial incentive for implementing sustainable water solutions.

5. Presence of suitable end-users for reclaimed water

Another potential barrier to water reuse in the UK could be the lack of suitable end-users for reclaimed water. There needs to be water-intensive industrial customers that can use non-potable water in proximity to the wastewater treatment works producing the reclaimed water. Thames Water came across this problem when looking at options for water reuse in its London supply region; the only water-intensive industry near to their treatment works was a packaging company that unable to use sub-potable water because of their food packaging business (Rachwal, pers. comm.). If water reuse is to become more widespread in the UK, individual water and sewerage providers will need to supply groups of co-located industrial water users, as is the case in most Australian examples of industrial water reuse. UK growth areas such as the Thames Gateway where 160,000 new homes, industry and public infrastructure will be developed could be an ideal opportunity for the supply of reclaimed water to groups of industries to be planned into developments (rather than needing expensive retro-fitting). Development of the growth areas in south-east England is likely to exacerbate the region's water stress so water reuse could be of particular benefit to this part of the country.

6. Research and Development

In the UK more research and development is needed with regards water reuse to identify suitable associations between water & sewerage providers and industries and to assess the economics of water reuse. Another area for research is the factors that influence a company's choices regarding water (Renzetti, 2002). If reclaimed water is

³ Respectively the Environment Agency in England & Wales, SEPA in Scotland and the Environment and Heritage Service in Northern Ireland

to be marketed effectively as an alternative water supply, information about the motivations of customers and potential customers is critical.

Perhaps one of the most pertinent issues for research however is how to improve the energy efficiency of water reuse technologies. This is significant because reducing carbon footprints and improving energy efficiency are policy goals for water & sewerage providers and many industrial firms.

Already the Australian research institute CSIRO (in collaboration with US and South Korean academics) has developed durable new energy-saving membranes that could potentially be used in reverse osmosis (CSIRO, 2007). The hourglass-shaped pores in the polymer membrane can readily separate water from other small molecules (*ibid.*) and the researchers are currently investigating commercialisation of this technology. In the UK researchers at Loughborough University are trialling the incorporation of renewable energy generation into advanced membrane technologies (in particular photovoltaic-powered reverse osmosis). Further research and development into these methods for reducing the (fossil fuel) energy consumption of water reuse technologies is vital.

With regards how research should be funded and conducted, Rachwal (2007b) has suggested that Ofwat should allocate ring-fenced budgets for research & development that the water industry as a whole could then pool together (potentially through UKWIR) to undertake research and develop five-year water reuse demonstration plants.

8. Conclusions

Water reuse should be an important part of a suite of demand and supply measures that together can bring about more sustainable water management in the UK.

This report has considered the scope within the UK for industrial water reuse to play a more significant part in dealing with growing water-scarcity and enabling more sustainable water management. Despite some economic, social and environmental differences the experience of the countries investigated in this report will be helpful to the UK government, regulators and the UK water industry in considering how best to enable the development of water reuse in the UK. In particular the UK can learn lessons firstly about the need to communicate water reuse to the public and secondly the benefit of national guidelines for water reuse.

The following issues can be highlighted as critical to facilitating sustainable water reuse by industry in the UK:

- 1. The need for society to develop a greater appreciation of the anthropogenic influence on the water cycle**
- 2. The need to develop fair pricing for all water resources reflecting their full economic and environmental costs and yet the short-term need for pump-priming financial support from government for sustainable water reuse projects**
- 3. The need for a coherent government policy on water reuse (as CIWEM called for in it's 2002 Policy Position Statement) coupled with authoritative reclaimed water quality standards that are realistic and protect public health and the environment**

- 4. The need for existing government programmes such as the Enhanced Capital Allowance Water Technology List and Envirowise business advisory service to be expanded to include water reuse technologies**
- 5. The need for more research and development into low-carbon, economic water reuse solutions**

Addressing these issues will greatly assist the expansion of water reuse in the UK, although as Miller (2006) points out the best friend of water reuse is paradoxically further droughts.

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