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ADB announces its first Water Bond issue

The Asian Development Bank (ADB) and Daiwa Securities Group have announced ADB's planned inaugural Water Bond issue, which will finance its work in the water sector in Asia and the Pacific.

The Water Bond is expected to have two tranches, denominated in Australian dollars and South African rand, and will be issued in April. ADB will provide assistance, in an amount at least equal to the net proceeds of the notes, to water-related projects in Asia and the Pacific.

The bond issue will be arranged by Daiwa Securities Capital Markets, the wholesale securities firm of the Daiwa Securities Group, and will be distributed by Daiwa Securities, the group's retail securities arm, to Japanese retail and institutional investors.

Alongside the announcement, ADB warned that the region must urgently develop better water infrastructure and better policies to manage its water. Around half a billion people in the region have no access to a safe water supply, it noted.

ADB President Haruhiko Kuroda said: 'We have a water crisis on our hands, but we also have choices. What we don't have is too much time. We need to quickly help our developing member countries make the right choices and design the instruments that will make the right reform programme move quickly, facilitating appropriate water infrastructure investments. Asia's water agenda needs to be urgently modified and expanded.'

ADB launched a water financing programme to double investments in the sector between 2006 and 2010 in response to international calls for increased financing for water. A successor programme for 2011 to 2020 is currently being drafted.

The Water Bond will support that programme in achieving a number of targets including higher efficiencies in urban water services, focusing specifically on reducing water losses, improving access and quality, and reducing water's energy footprint.

It will also aim to improve the productivity of irrigated agriculture by using less water and newer technologies and by adapting to locally-appropriate irrigation practices, and to improve water quality through better legal enforcement, widespread wastewater management (including reuse), and expanded investment in clean-up projects.

Other targets include better adaptation to climate change, especially for flood protection, increased investments in water capture and storage, and improved water governance through national water reform and capacity. ●

EIB report unearths significant issues in non-EU water and sanitation projects

The European Investment Bank (EIB) has produced a synthesis report evaluating the financing of water and sanitation projects outside the European Union that concludes that the Bank's own involvement in projects is a vital element in a challenging but vital sector where oversight is essential to counter significant implementation problems.

The evaluation covers 1993 to 2007, during which time the Bank signed 110 water and sanitation investments in 41 partner countries worth a total of €4 billion ($5.8 billion).

The report judged various projects on a number of key criteria. The majority scored badly on the effectiveness criterion, with the report noting 'poor implementation implying cost overruns and delays, and only partial achievement of the specific outputs and outcomes', which has led to negative ratings for most of the projects evaluated.

Most projects rated 'satisfactory' or better for efficiency, with water demand development, tariff policy and operational efficiency all improving.

Environmental and social performance criterion results were found to be positive in most projects, but the overall rating for the sustainability criterion was unsatisfactory or worse for the majority of projects.

Overall, the evaluation criterion results for EIB's own contribution were positive: of 11 projects evaluated, 64% received a rating of significant or high. The Bank's performance in project cycle management was in most cases found to be satisfactory or better (73%).

The Bank's appraisal skills were found to have often improved the overall project quality, and highlighted a number of factors to be overcome for successful project implementation.

The combined results from 22 evaluated projects revealed that almost 60% of these were rated satisfactory or better.

The report concludes: 'The Bank's presence in the sector is strongly required given the socio-economic importance of the sector, but water and sanitation projects demonstrate that regular presence, support and follow-up are essential for project success.

'The EIB plays an important role by way of its financial contribution, but to remedy the difficulties in the sector the Bank has to bring or facilitate a significant non-financial contribution, ideally through technical assistance combined with good donor cooperation and coordination. ●

water asset management
INTERNATIONAL

Water Asset Management International is an international newsletter on asset management in water and wastewater utilities. The focus of the newsletter is on the strategic aspects of this developing field, providing utilities with international perspectives on infrastructure planning and maintenance as they seek to deliver cost-effective services to their customers.

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Association expresses concern about legislation's non-urban focus

The US Association of Metropolitan Water Authorities (AMWA) has issued a statement noting qualified approval of the 'Jobs for Main Street Act' and its recognition of 'the job-creating potential of water infrastructure projects' through its provision of $1 billion for this purpose.

However it adds: 'Unfortunately AMWA is concerned that the legislation will distribute these dollars through a mechanism that limits funding in urban areas.' AMWA notes that as with the American Reinvestment and Recovery Act (ARRA), the current bill would direct states to distribute the funds through states' State Revolving Fund (SRF) programmes.

AMWA warns that 'since the inception of the Drinking Water SRF, urban drinking water systems serving more than 100,000 people have only received 23% of funds distributed through the program. This is despite these large utilities providing drinking water to 46% of the US population and representing 35% of the drinking water sector's total infrastructure needs, according to EPA's (US Environmental Protection Agency's) 2007 Drinking Water Needs Survey.'

Just 16% of ARRA funds have gone to urban water systems, the trade body adds, noting that Congress should direct states to devote a percentage of the new funds to drinking water projects in metropolitan communities. ●

EIB lends funds for Ukraine water and sanitation upgrade

The European Investment Bank (EIB) is lending €15.5 million ($21.3 million) to upgrade water supply and wastewater treatment for the city of Mykolayiv in southern Ukraine. The loan will finance the rehabilitation and modernisation of water supply and wastewater collection and treatment facilities in the city, which has over half a million inhabitants.

The EIB funds will help Mykolayiv to meet national and international standards and provide a higher quality of drinking water and wastewater services than at present.

As the city is also just 65km from the Black Sea, the project will help to fulfil the country's commitments under the Convention on the Protection of the Black Sea against Pollution and also represents an important step towards realising the environmental dimension of the European Union's Black Sea Synergy.

The EIB has so far provided four loans in Ukraine, including the above contract, bringing the total lending in the country to €465.5 million ($640.3 million). ●

EPA criticises plans to move marine force to Guam

The US Environmental Protection Agency (EPA) has criticised plans to move thousands of marines to the island of Guam, on the grounds that the military's failure to plan for infrastructure upgrades would lead to raw sewage spills that would contaminate the water supply, unsatisfactory wastewater discharges and a potable water shortage that would expose people to waterborne diseases.

The agency also said in its response that plans to build a new aircraft carrier at the island's western Apra harbour would create 'unacceptable impacts' to a high-quality coral reef. The criticisms were outlined in a strong six-page letter to the US Navy in response to its draft environmental impact statement (EIS).

The EPA said: 'The impacts are of sufficient magnitude that EPA believes the action should not proceed as proposed and improved analyses are necessary to ensure the information in the EIS is adequate to fully inform decision makers.'

The military's Joint Guam Program Office has said it is evaluating all comments and is committed to working with the EPA and other federal agencies to reach solutions. At its height, the influx of marines is expected to increase the island's population by 45%. ●

World Bank approves loans for China and Senegal water infrastructure

The World Bank has approved a loan of $50 million to China to improve rural wastewater management and township infrastructure in Ningbo municipality.

Ningbo municipality is a major city in the south-eastern coastal zone of China, about 300km south of Shanghai, and has a population of 5.65 million. The Ningbo New Countryside Development project will focus on improving rural wastewater management in about 150 selected villages in Ningbo municipality and enhancing infrastructure development in Chunhu town of Fenghua city by financing construction of an access road, water supply networks, and wastewater collection and treatment facilities. In the meantime, the bank will provide technical assistance to build local capacities.

The World Bank has also approved a $55 million credit to contribute to increased access to sustainable water and sanitation services in selected rural and urban areas of Senegal within the next five years. The Water and Sanitation Millennium Project aims to facilitate access to services through programmes for improving and extending water production and distribution systems and urban sanitation networks, constructing social water and sanitation household connections, public standpipes and on-site sanitation facilities, and consolidating the achievements of the urban water reform, supporting the rural water sub-sector reform and strengthening capacities to deliver and manage water and sanitation services. ●

Water pricing in England and Wales

The 2009 periodic review of prices for English and Welsh water companies by Ofwat, the UK regulator of water and sewerage services, was the fourth since privatisation of the industry in 1989. While the 2004 periodic review allowed an average increase in prices of 4.2% per annum in real terms, Ofwat's final determination for the 2009 review kept charges comparatively stable. Significant capital investment is planned, in order to maintain the existing asset base, and deliver specific ends – such as improving wastewater treatment at some sites, reducing flooding, and balancing supply and demand.

This paper provides: a brief overview of the set-up of the industry for those not familiar with it; and a review of some of the main features of the 2009 periodic review of prices with a particular focus on issues that relate to asset management planning. By Andrew Heather, Bill Hume Smith and Malvika Surendra.

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The UK water industry is in a state of change as the government attempts to increase competition. Consequently there are several types of water utility, with the structure differing between the four main countries of the UK.

There are several types of company in England and Wales. Ten large regulated monopoly 'appointed water and sewerage companies' were privatised from state-owned water authorities in 1989. They have large geographic areas and provide sewage collection services to customers in water-only company areas.

There are currently 12[1] regulated monopoly 'appointed water-only companies', which treat and supply water to customers, which existed before the formation of the original water authorities and cover smaller geographic areas within the water and sewerage company areas. The water only companies also bill customers for sewage services, on behalf of the water and sewerage companies.

Figure 1
Water utilities in England and Wales, (DWI 2009)

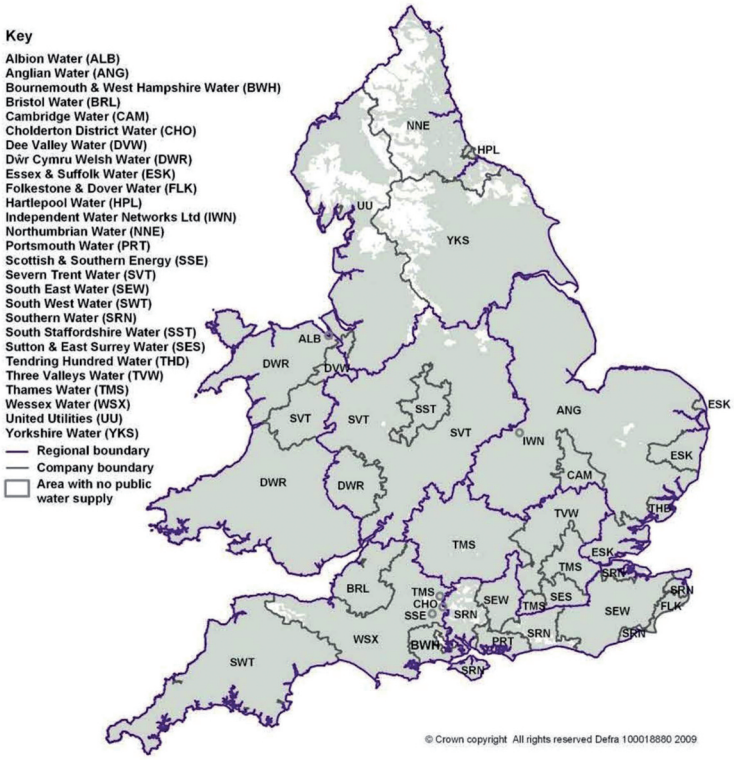


Figure 2 Wastewater (sanitation) utilities in England Wales, Scotland and Northern Ireland (Water UK 2009)

The 22 companies above are all vertically integrated, in that they provide the full service including water resources, treatment process, bulk and local distribution, and billing services, and for the wastewater service, collection, treatment and disposal. The largest water and sewage company, Thames Water, serves a population of 8.6 million, whereas the smallest water only company, Cholderton Water, serves a population of just 2100. The appointed water companies operate under 'instruments of appointment', which can be terminated by the Secretary of State with 25 years[2] notice.

In addition, to date there have been 24 'inset appointments' under which another appointed water company has taken over the functions of an incumbent water company in a defined area. 12 of these inset appointments are to five newly established appointed companies (i.e. in addition to the 22 appointed companies that remain from privatisation).

There are also a number of further companies that have been licensed to provide water services under a licensing regime introduced in 2005 to increase competition in the sector. A 'licensee' can either apply for a 'retail licence' that allows it to purchase water at wholesale prices and retail it to eligible customers, or a licensee can apply for a 'combined license' that allows it to also introduce bulk supplies into the incumbent water company's network. However, these companies are currently limited to serving non-domestic customers consuming over 50 ML per annum. Although there are now a number of licensees, only one customer is understood to have switched under the regime. The framework for competition is currently under review by Ofwat, the regulator of water and sewerage services in England and Wales, and government.

The main companies in Scotland and Northern Ireland are government owned companies. There is non-domestic retail competition in Scotland, but not in Northern Ireland. Water customers pay the utilities directly for the service they receive, except in Northern Ireland, where payment is through local taxation and government funding. Public Private Partnerships are used to fund some capital investment in both Scotland and Northern Ireland.

Figure 1 shows the distribution of the water utilities in England and Wales and illustrates the range of company sizes. Figure 2 shows the wastewater (sewage sanitation) utilities in England, Wales, Scotland and Northern Ireland.

UK water regulators

The UK has pioneered the use of independent regulatory agencies for water utility regulation, setting up separate economic, quality and customer protection regulatory agencies. Table 1 shows the various regulators overseeing the UK water industry.

The remainder of this paper will focus on the 2009 price review in England and Wales. The Water Industry Commissioner for Scotland aligned the Scottish review dates with those of England and Wales, meaning that some comparison between the two countries is possible.

The price setting process in England and Wales

Ofwat sets limits every five years on the prices that the 22 regulated monopoly companies can charge. Companies present business plans justifying all costs that they expect to incur over the following five-year period, together with longer term strategies for 25 years.

Ofwat uses comparative competition techniques to encourage the companies to become more efficient, while service must be either

Table 1 Regulation of water utilities in the four countries of the UK

Country	Economic regulator	Water Quality regulator	Environmental regulator	Customer protection
England and Wales	Ofwat (Water Services Regulation Authority)	Drinking Water Inspectorate	Environment Agency Natural England Countryside Council for Wales	Consumer Council for Water
Northern Ireland	Northern Ireland Authority for Utility Regulation	Drinking Water Inspectorate of Northern Ireland	Northern Ireland Environment Agency	Consumer Council for Northern Ireland
Scotland	Water Industry Commission for Scotland	Drinking Water Quality Regulator for Scotland	Scottish Environmental Protection Agency	Waterwatch Scotland

maintained at existing levels or be improved. Companies are expected to base their plans on forecast risk to service, rather than on simpler indicators such as condition or age of assets.

The outcome of the price review is that Ofwat 'determines' a price limit for each company. The company then chooses whether to accept that price limit offer or refer the determination to the Competition Commission, an independent public body responsible for conducting competition related enquiries, which would review the case and make its own determination. Competition Commission referrals can lead to a price set higher, lower or the same as that proposed by Ofwat, consequently there are risks as well as costs to companies associated with referrals.

Although water and wastewater prices have risen some 45% in real terms since privatisation in 1989, there has been significant investment in improved water and wastewater treatment, and pipe networks, some of the cost of which have been offset by improvement in efficiency.

The price review process applied to the 22 appointed water companies is described below, excluding the new appointed companies that only operate inset appointments and the new licensees.

The 2009 price review

The 2009 price review is the fourth since privatisation of the water industry in 1989, setting prices for the five-year period 1 April 2010 – 31 March 2015. Companies submitted strategic direction statements, covering the next 25 years, in December 2007 followed by draft business plans in August 2008. Ofwat reviewed and challenged the draft business plans, providing feedback to water companies and publishing its view of 'baseline' capital expenditure requirements.

Company final business plans were submitted in April 2009. Following its review of changes between the draft and final plans, Ofwat published its draft determination in July 2009 which forecast an average reduction in price limits of -1% by 2015 together with the outputs and levels of service that companies would be required to deliver. Companies then had an opportunity to provide representations to Ofwat on its draft determination. Ofwat took these into account in its final determination of price limits in November 2009. Companies had until the end of January to decide whether or not to refer the determination to the Competition Commission.

Ofwat's final determination included an average increase in price limits of 2.5% by 2015 in real terms (0.5% per annum). This was substantially less than was sought by companies in their final business plans, as illustrated by Figure 3. Four companies received real annual increases above 1.5%, and three companies received real annual decreases lower than -1%. This represents a substantial challenge to company plans.

In Scotland, the Water Industry Commission announced that prices will rise at 5% below inflation after a freeze in 2010.

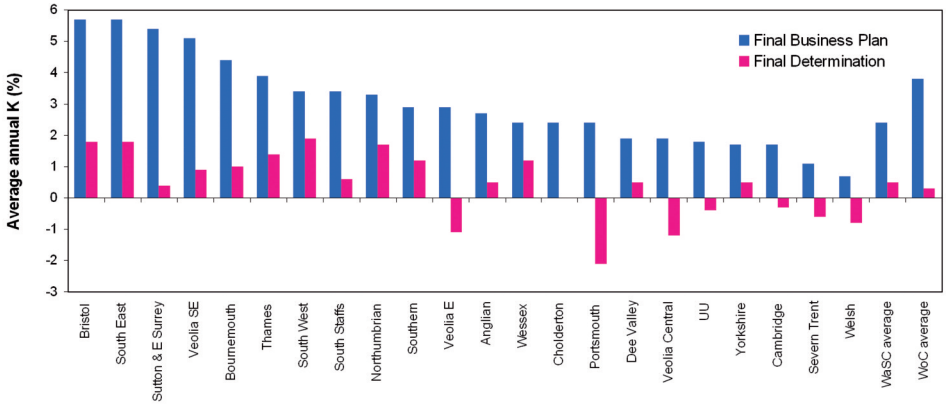


Figure 3 **Comparison between 2009 final business plan and final determination price limits)**

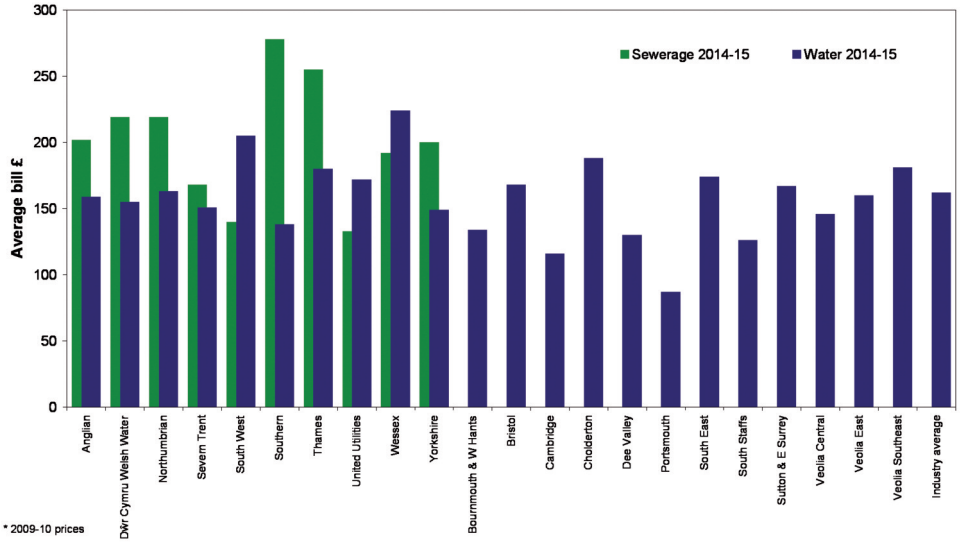
The effect on bills

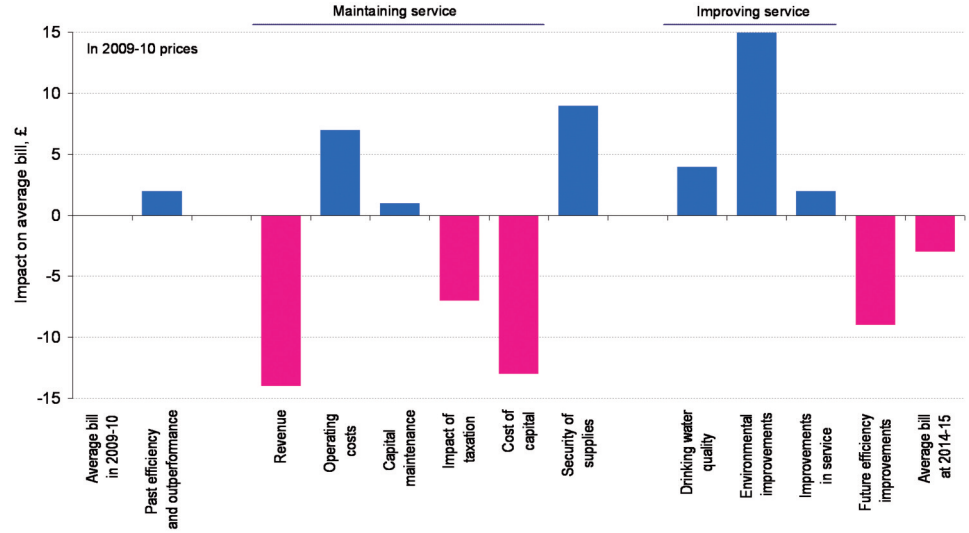
Taking account of future changes in the customer base, Ofwat's final determination forecasts a small reduction in average household water and sewerage bills of £3 ($5) in real terms by 2014/15 to £340 ($548). Figure 4 shows average 2014/15 (the last year of the price setting period) household bills for each company as estimated in Ofwat's final determination. There is significant variation in average household bills in different company areas reflecting geographic, demographic, as well as historical differences between the companies.

Individual household bills are based on price limits, but depend on individual circumstances such as whether the customers have a water meter, or pay a fixed price for unmetered supplies. Looking at Ofwat's forecast typical household bills, unmetered customers in the South West region could face a £935 ($1507) bill by 2014/15 – three times that of the cheapest unmetered water and sewerage company, Severn Trent. Among the water only companies, an unmetered bill in Veolia Southeast (Folkestone and Dover) will reach £253 ($408), compared with Portsmouth's £87 ($140).

The picture is different for metered customers because with a meter, customers only pay for what they use. For average users, metered bills could be less than half the unmetered charge, by Ofwat's estimates. The use of water meters varies across the UK but is more prevalent in the south-east of England where resources are relatively scarce. The differential between metered and unmetered charges will surely encourage customers to adopt metering, and in the south east of

Figure 4 **Average household bills by company in 2014/15 (the last year of the next period)**





Source: Ofwat - Future water and sewerage charges 2010-2015: final determinations

Figure 5
Main changes in average bills 2009-10 – 2014-15)

England compulsory metering is planned, covering about 90% of properties by 2015.

The nature of the challenge facing the industry is further illustrated by Ofwat's analysis of the drivers for change in average household bills, illustrated in Figure 5. Ofwat has assumed that the average bill will rise by +£7 ($11) over the period as a result of increases in operating costs, but that this will be neutralised by a -£7 reduction in taxation. A +£1 ($2) increase in capital maintenance and +£9 ($15) for improving the security of supplies is more than offset by reductions due to changes in revenue and the cost of capital (-£14 ($23) and -£13 ($21) respectively). Water and wastewater quality and other service improvements will cost +£21 ($34) extra, but Ofwat has assumed a -£9 ($14) reduction in costs through improving efficiency.

Capital spending

The 2009 price review considered capital expenditure requirements for:

- Maintaining the asset base such that serviceability is sustained at existing levels;
- Improving drinking water quality or environmental discharge quality (primarily where required by quality regulators);
- Ensuring that water supply and wastewater systems have sufficient capacity to balance future changes in supply and demand;
- Enhancing (improving) the level of service from current levels.

Capital investment assumed in Ofwat's 2009 final determination price limits was a record of £22 billion ($35.5 billion) across England and Wales over the five years (in 2007-08 prices), more than in any previous period. But the picture is quite different across the 21 companies in England and Wales. Figures 6 and 7 show the capital expenditure included in Ofwat's price limits in the 2004 and 2009 final determinations.

When the ten water and sewage authorities were privatised there had been a shortage of capital investment. The regulatory mechanism introduced promoted capital investment and has been successful in attracting about £85bn ($137bn) (in today's prices) over 20 years. But Ofwat became concerned that the incentives might be somewhat biased towards capital investment, making it hard to interpret the reasons underlying company plans, and potentially leading to unnecessary price increases.

For the 2009 price review, Ofwat adopted a 'menu regulation' approach to capital expenditure in the form of its new capital incentive scheme (CIS). Ofwat[3] says that it 'provides strong incentives for companies to put forward challenging and efficient business plans' and to 'strive to beat our price limit assumptions'.

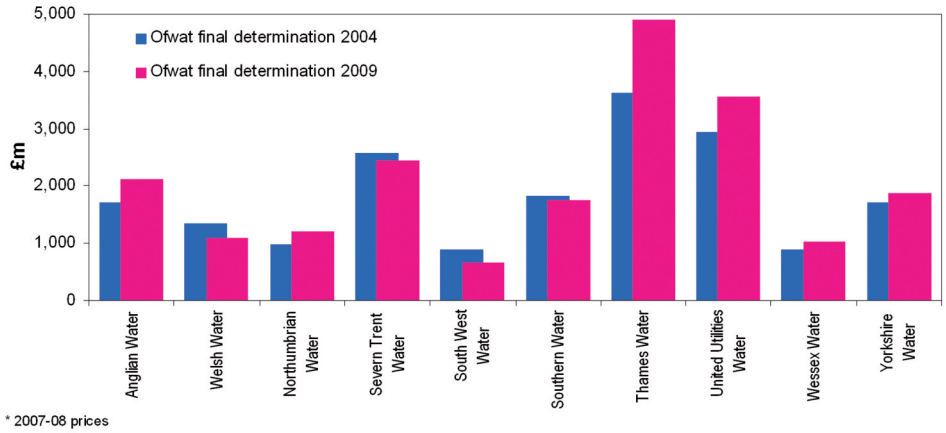
Under the CIS, companies will ultimately be able to get back their actual capital expenditure, plus or minus an incentive allowance that is based on its forecast (in its final business plan) and actual expenditure. The CIS process hinges on the 'CIS ratio'.

Ofwat compares its view of 'baseline' expenditure with company plans. The result is a CIS ratio, greater than 100% if the company wants to spend more than the baseline. The higher the ratio, the harder it will be for a company to earn the full return on capital, which those with low ratios could get. Those companies with high CIS ratios have effectively been challenged to deliver the work they say they need to do, but for much less money. Ofwat published CIS ratios in both the draft and final determinations and these are shown graphically in Figures 8 and 9 for water and sewerage investment respectively.

Ofwat's assessment of the 'baseline' was an important part of its process. To assess company plans for capital maintenance (which comprised over half of the total baseline expenditure) Ofwat developed a qualitative Asset Management Assessment approach, which was derived from UK Water Industry Research's (UKWIR's) Asset Management Planning Assessment Process[4]. It also challenged the efficiency of company's investment proposals using its 'cost base' approach, which benchmarks the costs between companies for delivering a range of standard items of capital works.

As part of the implementation of the CIS, Ofwat revised its approach to recognising capital expenditure in the Regulatory Capital Value (RCV) – the value of the capital base for each company that Ofwat uses to estimate the costs of financing capital that is invested in the company. Previously the approach was asymmetrical with overspends in expenditure not generally added to the RCV. The new approach is, however, symmetrical - correcting over and under spending. Under the new approach companies will still benefit from spending less

Figure 6
Capital expenditure assumed by Ofwat in the 2004 and 2009 price reviews, for the water and sewerage companies



* 2007-08 prices

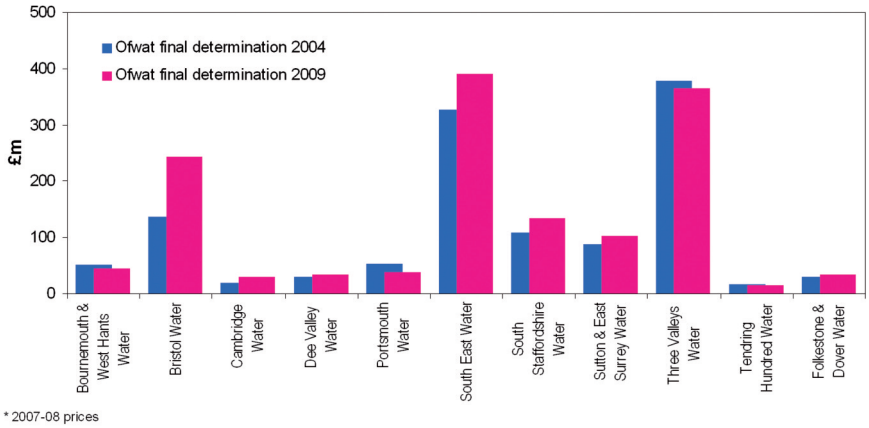


Figure 7
Capital expenditure assumed by Ofwat in the 2004 and 2009 price reviews, for the water only companies.

than forecast, but they won't be hit quite as hard if they spend more. Overall, companies that spend in line with expectations get the best result.

Ofwat's assumptions on the cost of financing the RCV (the 'cost of capital') form an important part of the link between capital investment and profitability of the companies. Historically, a significant proportion of outperformance of regulatory assumptions has been achieved by financial engineering, to reduce the cost of capital below that assumed by Ofwat, thereby increasing the return on capital invested.

Ofwat's final assumptions on the cost of capital are not as challenging as some companies feared after the draft determination. Overall, the weighted average cost of capital – a balance between shares and borrowing – has been set at 4.5%, allowing up to 7.1% for shareholder returns. This is lower – a lot lower – than the 5.1% allowed in the 2004 price review, but then financial markets have changed in that time too. Ofwat says that all companies should be able to get good credit ratings, with most able to get 'A' ratings.

Operating costs

Ofwat bases its assessment of future operating expenditure requirements upon historical operating costs, its assessment of changes to operating costs anticipated in the future, and its assessment of the future operating efficiencies that can be made. Companies highlighted in their business plans the need for additional operating expenditure associated with the operation of new assets and other service enhancements as well as increased pension costs, energy costs and local authority taxes. Ofwat's assumptions on future operating efficiency includes two elements: a 'continuing efficiency' challenge of 0.25% per annum that is applied to all companies; and 'catch-up efficiency factors' that vary between companies (from 0% to 2.9% per year) and are based upon Ofwat's econometric analysis of the efficiency of each company relative to the most efficient 'frontier' company. Ofwat allows companies to retain for a period of five years the benefit of any outperformance relative to its assumptions.

Overall companies sought in their final business plans a 13% increase in operating expenditure over current levels, but Ofwat's final determination reduced this to a 7% increase.

Outputs

At the same time as it determines price limits Ofwat also determines the outputs that companies are required to deliver over the next five years. A number of areas where Ofwat has defined outputs are described below.

Serviceability

To ensure that companies adequately maintain their assets Ofwat requires companies to maintain 'stable serviceability'. 'Serviceability' is a measure of the ability of company assets to maintain service to customers and the environment. It is based on trends in specific asset performance and service indicators, such as the number of sewer collapses or mains bursts, the number of customer supply interruptions or sewer flooding incidents. Being based on outcomes, it is independent of asset age, depreciation or levels of investment. For the next five years Ofwat has determined a set of control limits within which it expects companies to keep each of the serviceability indicators. These will be used to assess whether stable serviceability has been maintained.

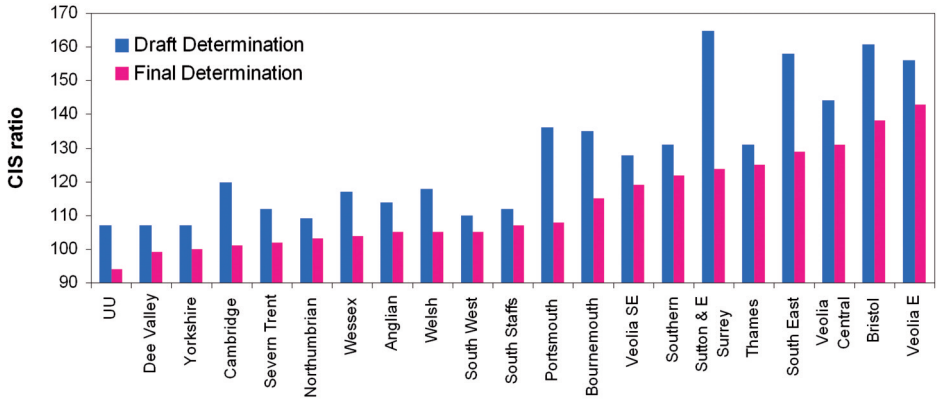
Most companies have achieved stable serviceability over the last five years, but two have been penalised via a 'shortfall adjustment' as a result of missing specific serviceability targets. For the shortfall adjustment, Ofwat assigned a value to the difference in service between the target and actual level – i.e. for service that was 'not delivered' – and deducted it from the settlement. Some other companies rated as delivering 'marginal' serviceability have until 2012 to recover to stable serviceability.

Flooding

Various factors contribute to flooding from sewers. Many urban developments are old and networks have been extended many times since original construction. The increase in connected properties can eventually lead to inadequate capacity and hence flooding, as a result of an imbalance between supply and demand. There has also been an increase in connection of rainwater drains to sewers, which exacerbates the demand increase. Even where separate stormwater and foul water drainage exists, later stormwater drains are often incorrectly connected to the foul sewer, leading to flooding at times of heavy rainfall. Climate change may also be affecting the frequency of flooding, with some regions reporting an increase in long-duration, high-intensity rainfall, compared with historic design assumptions. Sewer flooding is also confused with surface water flooding, which may happen at the same time.

Wastewater utility customers rate sewer flooding as a priority, and consequently there has been a continuous programme of investment to address localised problems. For the next five years, Ofwat has assumed that

Figure 8
CIS ratios for the water service in Ofwat's 2009 draft and final determinations



companies will be able to deal with about 5500 high-risk cases, but after new additions this will be a net reduction of about 1350. Ofwat continues to challenge companies to find cost-beneficial solutions, especially where the unit costs are very high compared with the previous five years. In some cases, 'mitigation' solutions, such as non-return valves, are used instead of full-scale upgrades of the local network.

Leakage

For most companies leakage is already close to the 'sustainable economic level' – where finding new leaks costs as much as the water that's lost – and so leakage is being held broadly stable, with small reductions in some areas totalling about 3% overall. Customer surveys showed that leakage was a priority, but Ofwat says that to reduce it much further would have meant increasing bills. It is possible that customers did not know about this relationship between leakage, maintenance activity, and the price they pay.

Ofwat has included a base service water efficiency target of –one litre per property/day each year, the first time that water companies have had such targets in a determination. Improving water efficiency is seen as an important step to improve drought resilience and enable increasing population to be served while delaying the need to invest in new resources. The new target will increase company involvement in water efficiency programmes, through organisations such as Waterwise[5] and the promotion of water-saving domestic appliances. Ofwat has introduced a new revenue correction mechanism to provide companies with a financial incentive for promoting water efficiency by customers.

Metering

About 37% of household customers have water meters and pay for water and sewage services according to the volume used. The majority of customers therefore pay a fixed price, which varies by region and the 'rateable value' of the house – a historic measure once used for local taxation. Metering is thought to reduce demand and is generally considered a more equitable way of charging than fixed prices, except where families cannot afford to pay for the water they need.

Metering is set to increase and Ofwat has accepted most companies' plans. Overall metering will increase to more than 50% by 2015. In two companies where water is relatively scarce – Southern Water and Veolia Southeast (Folkestone and Dover) – Ofwat expects more than 90% of customers to be metered by the end of 2015. Portsmouth and South Staffordshire will end the period with the least metering, at 24% and 35% respectively. During the five year period, some 2.4m water meters will be installed, at a cost of £470m ($757m) after Ofwat's efficiency assumptions.

Resilience, renewable energy and climate change

Resilience, renewable energy, and climate change are specific issues that were addressed by most company business plans.

Investment to improve resilience is intended to reduce vulnerability of the service to external events (for example, adding duplicate water mains to some isolated towns). Ofwat has accepted some £414m ($667m) proposed to improve resilience of the service. Most of this focuses on water supply systems, adding new pipes to improve companies' ability to move water in an emergency.

Increasing renewable energy generation from hydro-power or sewage gas will help companies to reduce their CO_2 emissions but also spread their energy costs between sources. Ofwat included £57m ($92m) for renewable energy, which will bring a £20m ($32m) annual operating cost saving and generate an extra 300 GWh of renewable energy per year.

Planning for effects of climate change includes detailed assessments of, and adaptation to, the risk to service of rising sea levels and increasing storm intensity. The UKCP09[6] climate change projection was published too late for companies to analyse fully for their business plans. Consequently Ofwat has made climate change adaptation a notified item instead of including expenditure in prices. This means that if, on analysing the projections, companies can demonstrate they need significant expenditure on climate change adaptation before 2015, they can return to Ofwat to ask for it to be included in prices.

Conclusion

Overall Ofwat has softened its stance from its draft determination, which saw a £14 ($23) average reduction in household bills by 2015 compared with the £3 ($5) in the final determination. Capital investment is forecast to continue so that by 2015 more than £100bn ($161bn) will have been invested over 25 years.

CCWater, the consumer representative, said it gave Ofwat 'seven out of ten' for its determination, voicing concerns over prices for customers in some regions. It also claims that Ofwat has 'significantly eased the pressure on companies to be more efficient'.

Nevertheless, the 2009 price review challenges companies to deliver a high level of service for reducing unit costs – maintaining the pressure for ever-improving efficiency. Companies will therefore find the settlement challenging and some might struggle to accept the assumptions in the determination. ●

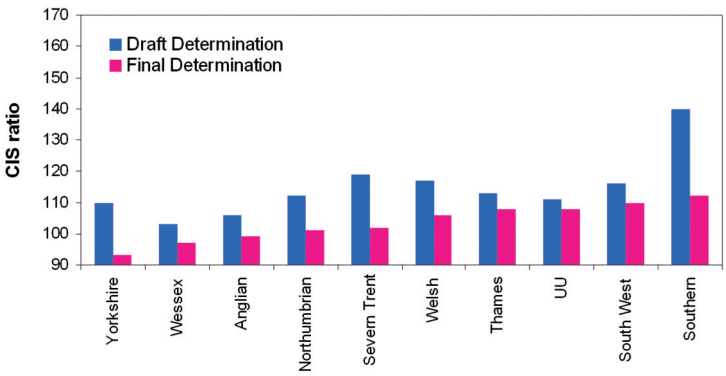


Figure 9
CIS ratios for the sewerage service in Ofwat's 2009 draft and final determinations

Notes

[1] *This number excludes Hartlepool Water and Essex and Suffolk Water that are now part of Northumbrian Water and Anglian Water respectively and have consolidated instruments of appointment, although differences in the level of water bills remain. The number includes Cholderton & District Water Company, which is relatively small. Ofwat's publications on the periodic review provide less information on Cholderton Water than for the larger companies.*

[2] *The notice period is one year for Albion Water.*

[3] *Ofwat 2009: Future water and sewerage charges 2010-2015: Final Determination. www.ofwat.gov.uk/pricereview/pr09phase3/prs_web_pr09fd. Accessed 15 January 2010.*

[4] *UKWIR 2007: Asset Management Planning Assessment Process. www.ukwir.org/ukwirlibrary/91803/*

[5] *www.waterwise.org.uk. Accessed 15 January 2010.*

[6] *http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=163. Accessed 15 January 2010.*

Adequateness and sustainability of wastewater treatment in medium and small communities

Portugal is a small Mediterranean country with a population of ten million inhabitants, but in inland regions the population is widely dispersed. Portuguese levels of service of wastewater treatment were, in 2000 and 2006, 50% and 72% respectively. Despite significant efforts and the allocation of significant human and economic resources after 2006, the lack of appropriate treatment infrastructure is still an issue in some Portuguese rural areas, especially in the northern and central regions. Small wastewater systems ought to provide an optimal combination of maximum protection of public health and the environment, and minimum costs of construction, operation and maintenance. This combination should result in an adequate effluent quality, preferably based on simple and reliable operating processes with a low cost and minimal environmental impact. In this paper we analyze some performance indicators for small wastewater treatment plants in rural areas of Portugal, with special focus on low cost solutions in terms of investment, operation and maintenance. By Helena MM Simão and J Alfeu SÁ Marques.

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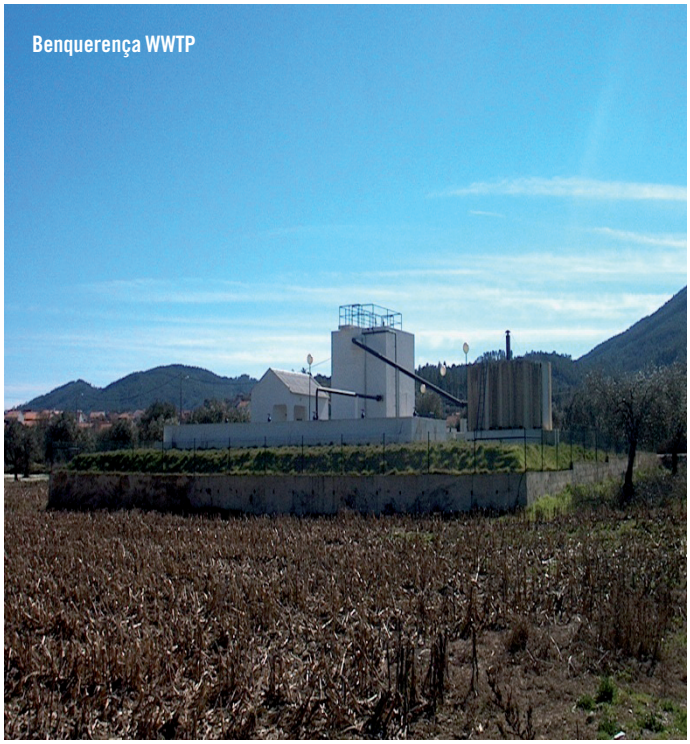

Benquerença WWTP

Increased environmental concerns and continued degradation of water quality have led to the need to implement a new paradigm for water management, expressed in enhanced environmental principles and characterized by the perception that water resources are not unlimited.

An essential goal of the new paradigm for water management is sustainability. Despite their limited financial resources small communities must be supplied with water through the adoption of appropriate technologies that are easy to operate and cheap to maintain.

The decentralization of wastewater treatment plants (WWTPs) could be an approach to sustainability, particularly when applied to small, dispersed rural settlements. Although there may be no consensus on the definition of sustainability, the fact is that it requires effort to protect and preserve the environment and

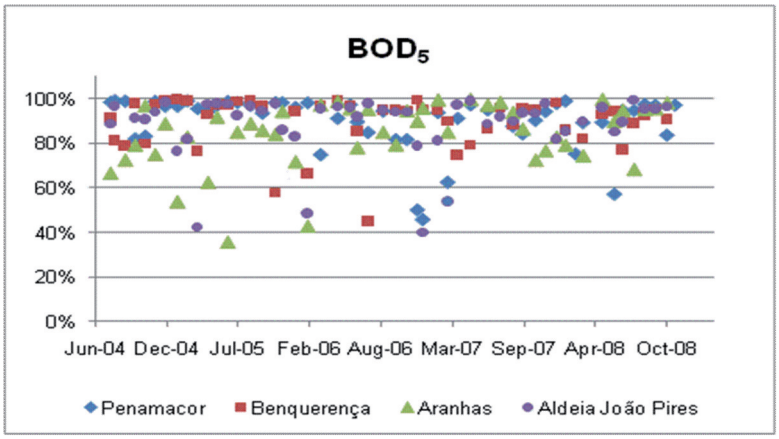


Figure 1
Efficiency of BOD5 removal

natural resources and the socio-economic well-being of the individual. This is the only way to achieve equitable social progress and reduce negative impacts on social conditions, on human health and on the environment.

This work, which is still in its infancy, seeks to assess how the choice of a particular type of treatment affects its overall sustainability. This is because different assessment criteria can be used to evaluate wastewater treatment systems, since the choice of a particular type of treatment should not focus too much on the technical side, but ought to include the environmental and human activities that relate to the community being served.

To assess the sustainability of wastewater treatment, the indicators examined are used to assess efficiency and the environmental and economic impacts, and should take into account the geographical location, culture and population served. In any case, an indicator has to be objective and clear with respect to the targets to be met and has to be measurable in order to evaluate its success or failure.

This study begins to analyze some indicators, starting with the most directly measurable ones, such as those related to efficiency in the treatment of wastewater and the economic costs (construction and operating costs and maintenance).

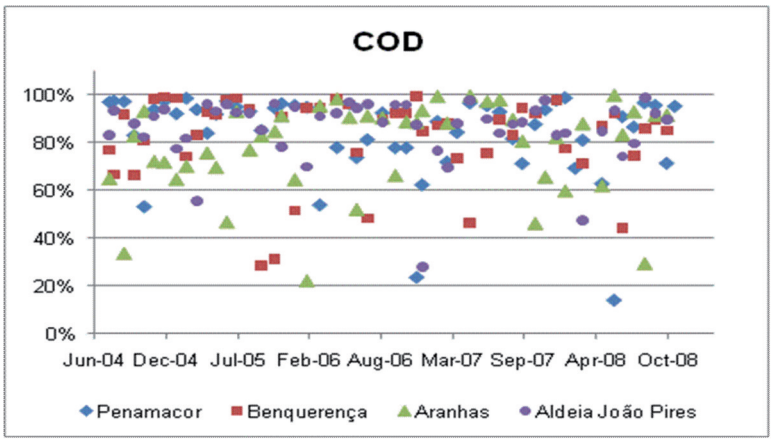


Figure 2
Efficiency of COD removal

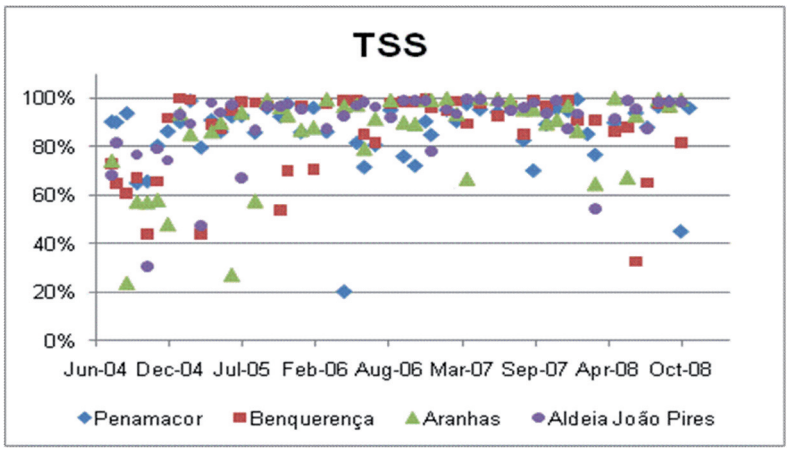


Figure 3
Efficiency of TSS removal

According to INSAAR (2007) less than 80% of the Portuguese population is served by sanitation infrastructure. Despite the enormous effort made in recent years the level of service remains below the European Union average. Figures for wastewater treatment in small villages are even lower; according to the 2001 census (INE, 2002), about 40% of the population in Portugal lives in areas with less than 2000 inhabitants.

Service to these communities must be improved with the lowest possible impact to the quality of natural resources. Issues of sustainability and appropriateness of treatment systems, as reflected in the increasing demands for the good physical-chemical and microbiological quality of water resources, must be involved to ensure that adequate conditions are provided for a balanced ecosystem, but with affordable investment and operating costs.

Wastewater can be treated through preliminary, primary, secondary and tertiary treatments, by means of physical, chemical and biological processes. The use of a septic tank, especially when supplemented by another treatment, is one method. This process is quite appropriate because it is cheap to build, operate and maintain. Its efficiency is not often referred to in the literature and its suitability is qualified, being based on low costs instead of an overall evaluation. The assessment of overall performance is therefore the main objective of this study.

Public health risks from septic tanks such as odour and gas can be mitigated and/or eliminated through the adoption of a process to achieve a higher degree of purification of the effluent from the septic tank. In fact, the septic tank should be seen as a component of a wastewater treatment plant, not only for its efficiency but also because of its mode of operation. If further processing takes place it should be considered an appropriate treatment of wastewater for small populations, in any country with a low population density and mountainous terrain with conditions similar to Portugal.

Moreover, small towns that have managed to solve or reduce wastewater-related problems of sanitation and public health (usually involving the financing of the construction of a plant) are often confronted with economic difficulties

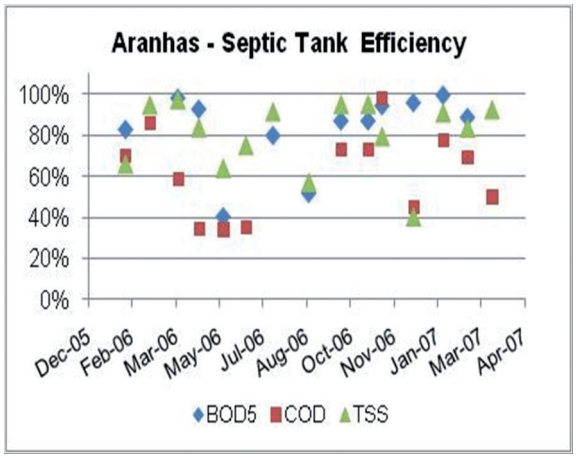


Figure 4
Septic tank efficiency at Aranhas WWTP

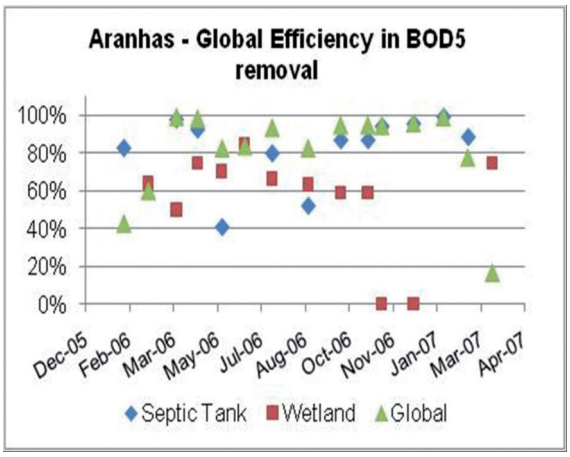


Figure 5
Overall efficiency for BOD5 removal at Aranhas WWTP

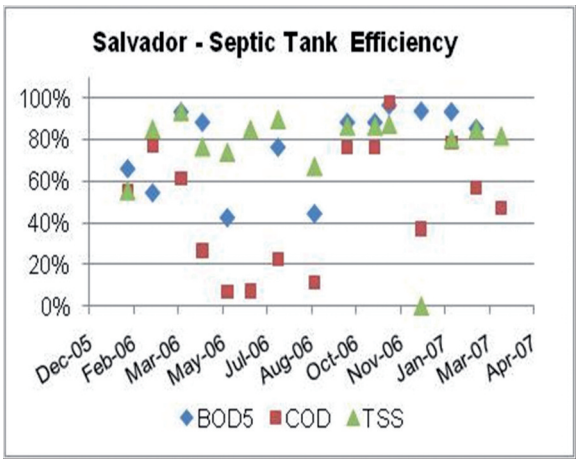


Figure 6
Septic tank Efficiency at Salvador WWTP

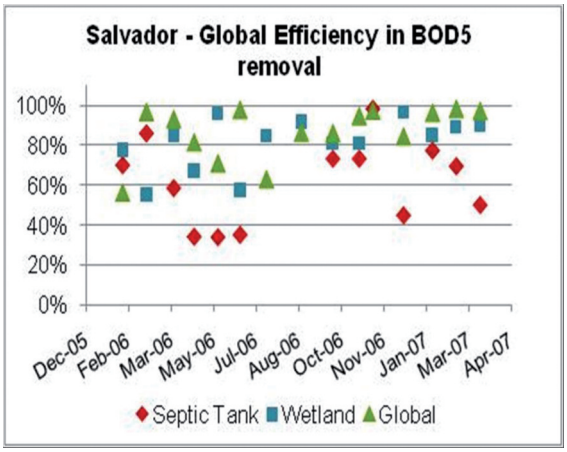


Figure 7
Overall efficiency of BOD5 removal at Salvador WWTP

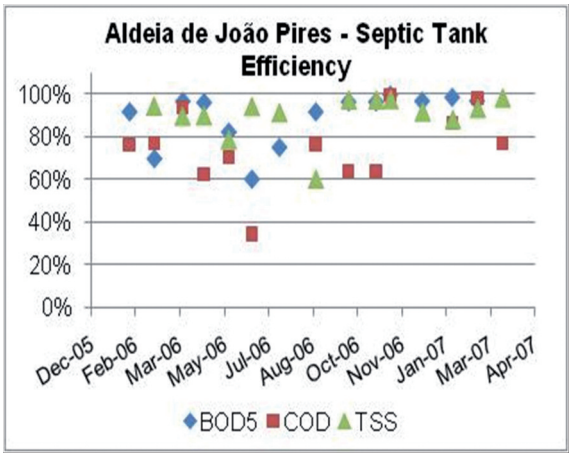


Figure 8
Septic tank efficiency at Aldeia João Pires WWTP

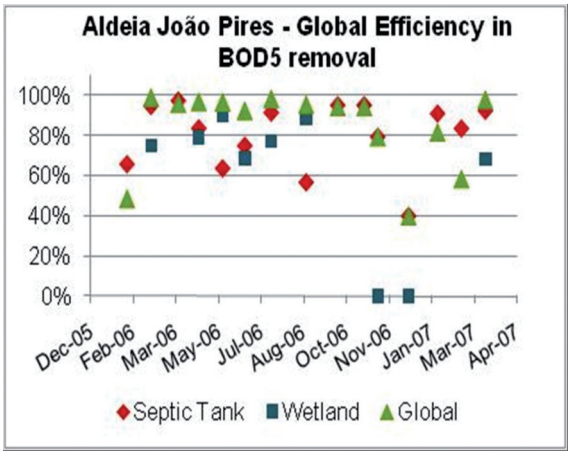


Figure 9
Overall efficiency of BOD5 removal at Aldeia João Pires WWTP

and the need for specialized labour for its operation and maintenance, so low cost systems will be the most appropriate choice.

Methods

According to economic sustainability criteria, the septic tank, especially when supplemented with constructed wetlands, should be considered as a very suitable wastewater treatment solution for isolated populations and small communities, particularly in rural areas. However, focus on these systems is primarily on their low construction, development and maintenance costs, instead of the level of purification or the true yield obtained because of a significant lack of measurement.

A plant should provide an optimal

combination of maximum protection of public health and the environment, with minimum construction, operation and maintenance costs. This combination should result in a quality effluent, preferably produced from simple and reliable operating processes involving low costs and minimal environmental impact.

The water utility Águas do Zêzere e Côa, S.A. (AdZC) provided data from several wastewater treatment systems, mainly composed of constructed wetlands, that process wastewater from medium and small communities. Changes in national legislation and regulations regarding the environment led AdZC to implement low-cost treatment systems in central and northern Portugal where the villages can range in size from a single house to a small settlement. They are often scattered and in areas with unfavourable topography, where local populations are relatively poor (according to INE the average monthly income of families in this region in 2005 was €686 ($925). Other important factors are population aging and deep-rooted local cultural traditions.

The systems studied include any additional treatment by constructed wetlands in which the cleansing by microorganisms appears to help improve the cleansing of the effluent (Dias et al., 2000), especially regarding the removal of five-day biological oxygen demand (BOD5), with values between 70 and 95%, and the total suspended solids (TSS), with values between 60 and 98% (Puigagut et al, 2006).

Also, with respect to other parameters, the literature shows good results such as efficiencies from 82 to 88% for chemical oxygen demand (COD), 24 to 70% for nitrogen compounds and 15 to 68% for phosphorus removal (Relvão, 1999).

The four WWTPs studied were:

- Penamacor, with an activated sludge process, serving a population equivalent (pe) of 3143 and a flow rate of 463 m^3/d;
- Benquerença, with trickling filters, serving 1445 pe and a flow rate of 292 m^3/d;
- Aranhas, with a septic tank, complemented by a wetland, serving 377 pe and a flow rate of 80 m^3/d;
- Aldeia de João Pires, with a septic tank complemented by trickling filters, serving 229 pe and a flow rate of 70 m^3/d.

The results obtained for these WWTPs are shown in Figures 1 to 3 and, as can be seen in the graphs, the results from between July 2004 and October 2008 suggest that the average efficiency of BOD5, COD and TSS removal was quite good (roughly 85%).

In a second phase we considered wastewater systems in which a septic tank is used for primary treatment, and the secondary treatment uses wetlands with tricking filters. The degree of efficiency obtained by the septic tank for BOD5, COD and TSS removal as well as the overall efficiency of treatment in removal of BOD5 were analyzed specifically in the WWTPs of Aranhas, Salvador and Aldeia de João Pires.

Results and discussion

The focus of this study was on the performance of WWTPs for medium and small communities in rural and semi-rural areas of the central inland region of Portugal, which used different treatment processes.

The results showed that, in general, the systems fulfil the legal standards prescribed by the Portuguese authorities for discharge in surface waters (25 mg/L for BOD5, 125 mg/L for COD, 40 mg/L for TSS).

The results in Figures 4, 6 and 8 show that the efficiency for primary treatment with a septic tank is generally quite high, with values above 60% for both TSS and BOD5 removal, while Figures 5, 7 and 9 demonstrate the global efficiency for BOD5 removal.

These results show that, in terms of treatment efficiency, the septic tank with a secondary treatment process may be a very suitable solution for wastewater treatment for small communities with a scattered population.

Figures 10 and 11 present the results of the five treatment plants studied with respect to the removal efficiency of total phosphorus and total nitrogen for 2006. It can be seen that the percentage removal of these parameters does not seem to be very sensitive to different types of treatment.

Since tests results are not available for the septic tank effluent, for these parameters, analysis of the removal efficiency of the septic tank was not possible.

In fact, the Penamacor WWTP, where treatment is carried out by activated sludge, removal efficiency of total phosphorus is about 42% while the removal efficiency of total nitrogen is 57%; two periods (October and November) show very low efficiency (5 and 3% respectively).

In all of the plants analyzed in this study the total nitrogen and total phosphorus removal efficiency figures are similar, and are between 50 and 59% for total nitrogen removal, with the highest being recorded for Benquerença WWTP (trickling filters) and the lowest for the Aranhas WWTP (septic tank and wetlands). Total phosphorus removal ranged from 42 to 50%, with the lowest figure being recorded for the Penamacor WWTP (activated sludge) and the highest for Salvador (septic tank with wetlands).

After analyzing the efficiency of treatment in local conditions (social and environmental criteria), we examined the construction costs and the operating and maintenance costs of some WWTPs in medium and small communities in order to evaluate their economic sustainability.

Tables 1 to 4 give the figures for 60 WWTPs analyzed, 41 serving fewer than 500 inhabitants and 19 serving more than 500.

Construction costs are the first investment and include acquiring the land needed to build the plant, plus the cost of its construction, its electro-mechanical equipment, power supply and monitoring costs. The operating costs include all expenses incurred from operating and maintaining the plant, including electricity charges. The energy costs associated with any pumping stations upstream of the plant are excluded.

In all of the WWTPs analyzed the constructed wetlands correspond to secondary treatment.

Of the 41 facilities for fewer than 500 inhabitants, 40 use a septic tank for primary treatment. In the facilities for more than 500 inhabitants, six are preceded by a septic tank and 13 by Imhoff tanks. These systems, which

	Construction Costs (€)		
	Inhabitants (PE)	treated m^3	per m^2 of wetland
Average=	823.24	4420.88	247.78
Min =	29.54	274.29	9.37
Max =	2376.53	14730.55	1061.67

	Operating Costs (€)		
	Inhabitants (PE)	treated m^3	per m^2 of wetland
Average=	93.54	491.47	19.70
Min =	2.82	26.16	0.89
Max =	157.20	974.36	32.65

Table 1 Construction costs for plants serving fewer than 500 inhabitants

Table 2 Operating costs for plants serving fewer than 500 inhabitants

	Construction Costs (€)		
	Inhabitants (PE)	treated m^3	per m^2 of wetland
Average	579.99	4454.56	143.95
Min.	48.43	403.47	17.29
Max.	3310.32	26624.03	982.92

	Operating Costs (€)		
	Inhabitants (PE)	treated m^3	per m^2 of wetland
Average	12.49	95.55	5.38
Min.	3.28	20.79	0.85
Max.	25.60	201.61	12.31

Table 3 Construction costs for plants serving more than 500 inhabitants

Table 4 Operating costs for plants serving more than 500 inhabitants

are run by Águas do Zêzere Côa, SA in north-central Portugal, are all relatively new.

Of the 60 plants analyzed, 37 entered into service in 2007, 15 in 2008 and four in 2009, so more observation time is still needed before solid conclusions can be drawn.

Conclusions

Many of the systems studied are systems that have been rehabilitated – where previously the only type of treatment was a septic tank, which was then supplemented with a constructed wetland. This is a small investment in economic terms and in most situations it provides an effluent quality that complies with emission standards.

On the other hand, the figures provided by the operator come from samples taken monthly, and they may have been taken on days when the system was under repair, perhaps after very heavy rainfall. All facilities analyzed are horizontal subsurface flow (HSSF) constructed wetland systems, and the overwhelming majority (58/61) of plants are reeds.

It has not been possible to assess the correlation of the removal efficiency of the organic load and the biomass produced with different plant species, with average temperatures, with precipitation and with the physical and mechanical filling material, particularly over time.

Although the efficiency of removal of BOD5, COD, TSS, nitorogen and phosphorus may sometimes vary significantly depending on time of year and the facility, it can be concluded that is between 70 and 90% for BOD5, and 60 and 95% for COD and 70 to 95% and TSS, which are lower than the figures reported in the literature. For the nitrogen compounds and phosphates the values are significantly lower, reaching between 50 and 60% and 42 and 51 % respectively, also according to the literature.

In terms of costs it can be concluded that in villages with fewer than 500 inhabitants the investment figures are around €823/inhabitant ($1109/inhabitant), €4421/m³ ($5961/m³) of treated wastewater and €248/m² ($334/m²) pond area, and the respective operating costs are €94 ($127), €491 ($662) and €20 ($27).

For villages with more than 500 people, the aforementioned costs fall significantly, and amount to €580/inhabitant ($782/inhabitant), €4454/m³ ($6003/m³) of treated wastewater and €144/m² ($194/m²) pond area, with respective operating costs of €13 ($18), €96 ($129) and €5 ($7). ●

Figure 10
Overall efficiency of total nitrogen removal

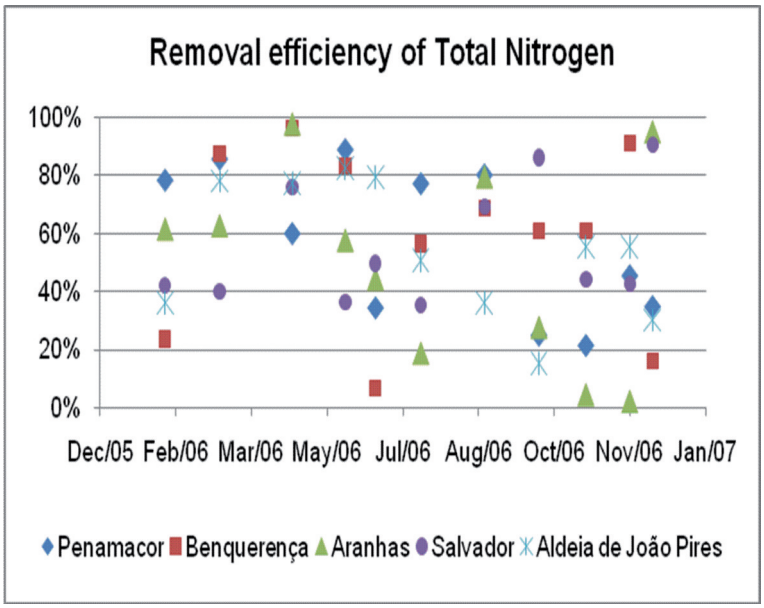
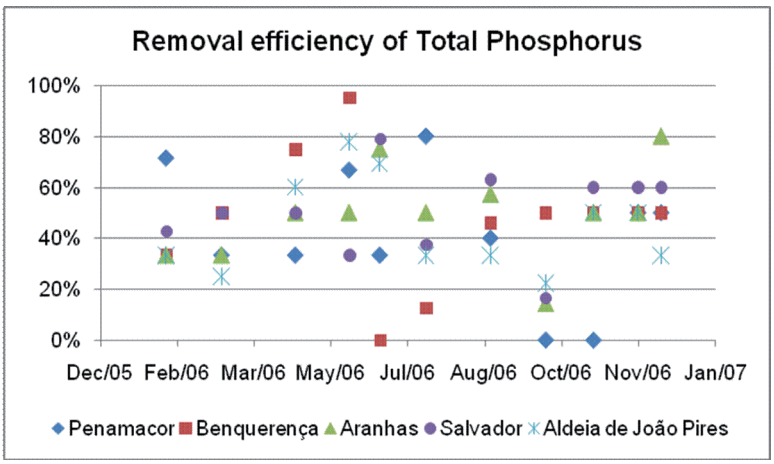


Figure 11
Overall efficiency of total phosphorus removal



Acknowledgements

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Feasibility study on quantitive risk analysis of drinking water networks

Quantitative risk analysis is used by a growing number of water utilities. Various models exist for above ground assets that quantify risks, containing multiple consequences. Quantitative models for water distribution networks are applied as well, however they mostly quantify the risk of failure in relation to service delivery. Nowadays, quantitative risk analysis for water distribution networks is a logical step forward as more (geographical) information becomes available and links can be made with computer models. Research by KWR Watercycle Research Institute executed for the Joint Research Programme of the Dutch drinking water companies made clear that quantitative risk analysis is a feasible method for identifying critical mains sections for multiple consequences in water distribution networks. By Ralph Beuken, Martine van den Boomen, Edwin Blaauwgeers and Kim van Daal.

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Many different definitions exist on risk. The definition applied in this article is that risks are uncertain events that lead to unwanted consequences once they occur. A risk therefore consists of a probability of an event occurring and the potential consequences of that event. In recent years, a large number of theories and methods have been developed to minimize the effects of unwanted events, generally referred to as risk management. A commonly used definition of risk management (IEC, 1995) is 'a systematic application of management policies, procedures and practices to the tasks of analyzing, evaluating and controlling risk'. Analyzing risks is the 'systematic use of available information to identify hazards and to estimate the risk to individuals or populations, properties or

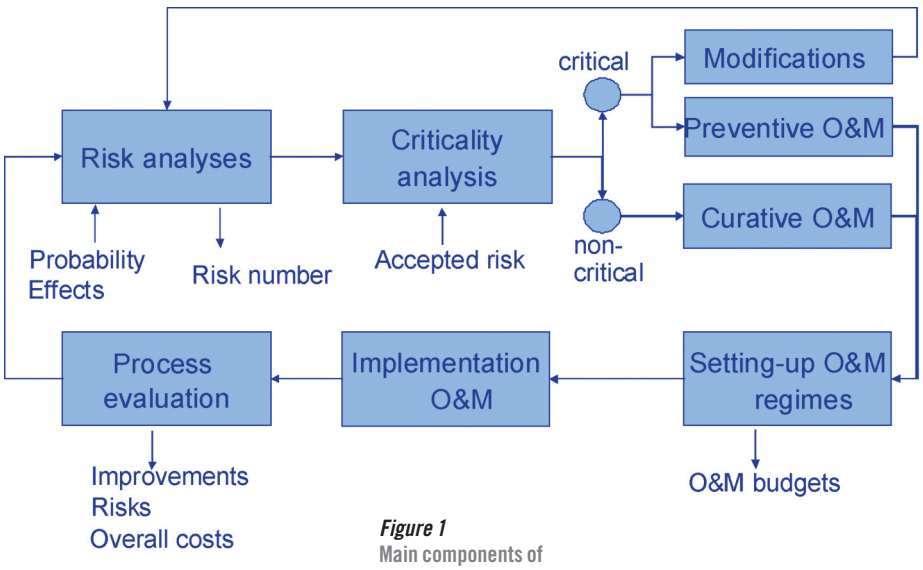

Figure 1
Main components of Reliability Centred Maintenance

the environment' (IEC, 1995). Qualitative risk analysis is based on assigning probabilities and consequences in predefined descriptions (e.g. very likely, likely, unlikely, very unlikely). This method is well suited for an initial screening of risks, if there is insufficient data or if the level of risk does not justify the time and resources needed for a numerical analysis. Quantitative risk assessment is based on the calculation of the risk components' probability and consequence.

Drinking water companies apply risk analysis methods, most commonly for water treatment and pumping installations. A commonly used method is Reliability Centred Maintenance (RCM), a method for improving maintenance schedules based on asset reliability risk analysis. RCM originates from the aviation industry. RCM is defined as a process to define the requirements for maintenance of an asset in a specified environment, with the aim to assure its assigned function. The main components of RCM are shown in Figure 1. Analyzing risks within RCM is normally done by assessing the condition of assets with help of visual inspections, measurements or recordings of performance and maintenance evaluations.

Existing methods for risk analysis of assets for water treatment and pumping are believed not to be suitable for water distribution assets, as the latter:

- Are positioned underground and easy inspection is not possible;
- Are scattered over a large area and are subject to many different influences from the environment, so no uniform relations exist between the attributes of an asset and its condition;
- Have limited options for preventive maintenance; the most common option is replacement.

Qualitative risk ranking is a simple and relative quick method for identifying the most critical parts of a system. The most common approach is the use of an assessment matrix, in which values of consequence are measured against likelihood, see amongst others UKWIR (2008) and WEF (2007). This risk ranking approach is rather difficult to apply to larger scale water distribution networks, due to the large number of components, the subjective use and the complex network structure. Burn (2007) notes that ideally the analysis of asset-related risk will consider the asset location, material, soil condition, traffic loading etc., to give a quantitative measure of risk that incorporates both the likelihood and consequence of failure, including whole-life costing factors. Burn (2007) also states that externalities, such as environmental damage and social costs should be taken into account.

The central questions in the presented research were: 'Is it possible to perform various types of quantitative risk analysis of a water distribution network into one risk prioritization matrix and does this provide useful results for water companies?'. In the execution of this research, five risk evaluation matrices were set up and applied in a case study. The risk scores within these matrices were computed by applying various methods for quantitative analysis.

Consequence							Probability: Burst rate				
	1. Interruption		2. Subst. pressure	3. Subst. quality	4. Image	5. Costs	Category				
Cat.	period of interruption or	number of customers or	number of customers	Score	Interruption of sensitive customers	In vicinity of	1	2	3	4	5
							<0,2 /yr	0,2 - 0,5 /yr	0,5 - 1,0 /yr	1,0 - 2,0 /yr	>2,0 /yr
1	< 2 h	< 50	< 50	3 or 4	housing	-	Non-critical				
2	2 - 4 h	50 - 100	50 - 100	5 or 6	industry	main urban roads					
3	4 - 8 h	101 - 1000	101 - 1000	7	risky industry	historical centre					
4	8 - 24 h	1001 - 2000	1001 - 2000	8	schools, r.care homes	provincial road			Critical		
5	> 24 h	> 2000	> 2000	9	hospitals	dyke, monument					

Table 1 Risk matrices for five types of consequence of a pipe burst

Methodology

In a work group with representatives from water companies, five risk matrices were developed. These five matrices have a 5*5 grid showing the probability of an asset failure on the horizontal axis and the consequence of a failure on the vertical axis. In the work group extensive discussions were held about the nature of failures, the definition of the consequence of a failure and the ranges of the categories with respect to water distribution assets. The matrices contain two risk classes: critical and non-critical. The failure to be studied is a spontaneous pipe burst. The defined types of consequences are: interruption of supply, substandard pressure, substandard water quality, image and costs. In Table 1 a combined 5*5 risk matrix is presented that is composed of five types of consequence and one type of probability. The risk classes are represented by the red and green blocks. The distribution of these red and green blocks can and will differ per consequence type depending on the companies' objectives on what is critical and what not. Only for the sake of presentation in this paper, the five matrices have been combined into one. The line between critical and non-critical in this paper is arbitrary. In this perspective, critical assets are the ones where specific measures are to be taken. This could be main replacement, but it could as well mean more intensive proactive maintenance on valves, more intense condition assessment of mains or an improved network configuration.

Horizontal axis: probability of failure

The probability of failure is determined by applying statistical data on spontaneous pipe bursts. Attention has to be given whether the data set is representative for the area of analysis and to the level of discrimination (only pipe material, or also diameter class, age class, soil type, etc). The probability of a pipe failure is expressed as the number of bursts per valve section per year, independent of the length of the section.

Vertical axis: consequence of failure

In most cases a pipe burst will not directly result in an interruption of supply, this will take place during repair

Table 2 Method for rating the consequence of a pipe burst on the water quality

Component sections	Subcategory	Ranking	Score	Valve
Customer complaints	low	< 10 per /1000 connections per year	1	266
	moderate	10 to 20 per 1000 connections per year	2	15
	high	≥ 20 per 1000 connections per year	3	16
Flow velocity	low	vmin < 0.05 and vmax < 0.10 m/s	1	31
	moderate	vmin < 0.10 or vmax < 0.25 m/s	2	52
	high	vmin ≥ 0.10 and vmax ≥ 0.25 m/s	3	214
Flow	low	Q < 25 m^3/h	1	283
	moderate	Q ≥ 25 m^3/h and < 50 m3/h	2	4
	high	Q ≥ 50 m^3/h	3	10
	Sum	Consequence category		
	3 or 4	1		63
	5 or 6	2		225
	7	3		9
	8	4		0
	9	5		0

activities. KWR Watercycle Research Institute developed the tool CAVLAR (Criticality Analysis for Valve Location And Reliability). With help of this tool the period of interruption and the number of affected connections are calculated. Inputs for CAVLAR are the duration of an interruption, the number of connections per valve section, the valve reliability for closing and the network configuration. More information on CAVLAR is found in Trietsch, 2006.

Substandard pressure caused by a pipe burst appears in two situations: during the burst as a direct consequence of the discharge of the leak and after the burst due to the closing of the mains section for repair. With the help of hydraulic modelling of both, the number of affected connections is calculated. Calculation of pressure effects due to the discharge is done by simulating an additional water demand. Calculation of pressure effects due to the closing of a valve section is done by performing an analysis where mains are closed one by one and pressure effects are evaluated.

At this moment in time, models are not capable of predicting the water quality effects of a pipe burst such as discoloration or contamination in terms of severity and spreading. Substandard water quality is therefore derived from three factors, notably:

- Customer complaints: in mains with a higher number of complaints more negative effects are to be expected due to hydraulic disturbances caused by a burst;
- Flow velocity: in mains with a low flow velocity an accumulation of sediment is more likely to occur;
- Flow: in mains with a relative high flow, closing the main for reparation will result in more irregular flows in the neighbouring mains causing more negative water quality effects.

For all factors a ranking was made. The sum of the three factors is used for quantifying the water quality consequence of a pipe burst (see also Table 2).

Water companies regard public image as an important factor in risk analysis. Image is however an awkward factor, as it is not independent and anterior quantification is usually not possible. In this study image is linked to the interruption of supply to more sensitive customers, such as schools, industry and residential care homes and hospitals. Information on sensitive customers is made available from geographical databases. This type of consequence is additional to the consequence 'interruption of supply', that only refers to the number of affected connections.

The consequence of a pipe burst on direct costs is determined by identifying objects in the vicinity of mains and by estimating the potential costs for repair of the main and the object. In this analysis direct costs for repair are assessed. Not assessed are indirect costs such as negative impact on public image or lost revenue for the water company. Cost estimates are made for different objects, like roads, dykes and historical buildings. The location of these objects relative to mains is defined by performing a geographical analysis.

Cons. cat.	Indication of potential costs	Specific object in case study	Zone of influence
1	low (< € 5.000)	standard	not relevant
2	moderate (€ 5.000 - € 10.000)	main urban roads	7 m from axis
3	high (€ 10.000 - € 25.000)	historical zones	within zone
4	very high (€ 25.000 - € 100.00)	provincial roads	10 m from axis
5	extreme (> € 100.000)	monuments	20 m from centre
		dykes	10 m from axis

Table 3 **Consequence categories for potential costs caused by a pipe burst and the applied zone of influence**

The risk analysis was carried out on the distribution network of Montfoort. Montfoort is a small town in the centre of the Netherlands. The distribution network in Montfoort is operated by Vitens, the largest water company of the Netherlands. For this analysis a detailed network model including information on burst rates and customers complaints was provided. The network of Montfoort consists of 47 km of mains, supplying 3424 customers. Materials applied are: asbestos cement (20%), cast iron (12%), polyethylene (11%), PVC (53%) and concrete (4%). With respect to the diameters of the mains: 72% is smaller than 150 mm, 17% is between 150 mm and 300 mm and 12% is bigger than 300 mm. The network of Montfoort contains of 391 valves, divided between 297 valve sections.

At the start of the risk analysis, the level of analysis was chosen. Possible levels are main section level, street level and valve section level. In this study, the level of analysis chosen is valve section level. Valve sections are the units that are isolated in case of repairing a burst and correspond most to the operations of water companies.

Results of the analysis

In the period February 1993 to November 2005, 57 pipe bursts had been recorded. Of these bursts, five relate to mains that have already been replaced, two relate to bursts caused by external circumstances and one to the failure of a fire hydrant. The remainder of 49 spontaneous bursts results in an average burst rate of 0.10 bursts/km/year. The number of reported bursts is too low to present representative figures of the pipe bursts per pipe material. For obtaining improved results, data sets of two comparable regions were applied, containing respectively 295 and 249 bursts. Based on an analysis of the burst of Montfoort and the additional data sets, a burst rate for different pipe material was obtained for this case study.

Analysis of the burst rates shows that from the 297 valve sections, 294 are within the first probability category, meaning that the number of burst is lower than 0.2 bursts per year per valve section. Of the remainder of valve sections, two are in the second probability category (0.5-1 bursts per year) and one in the fourth (one to two bursts per year).

The consequence on the interruption of supply caused by pipe bursts is calculated with help of CAVLAR. This analysis shows that for this case study the calculated period of interruption is very low and therefore not a criterion for this consequence category. Only ten valve sections have a calculated period of interruption of more than five minutes per year and the maximum period of interruption is calculated as seven minutes per year. As the number of repairs is less than once a year, these periods are much shorter than the regular shut-off period for repairing a main.

Analysing the number of connections affected by a pipe burst, results in 272 sections in the first consequence category (<50 connections), 15 in the second (50-100 connections) and nine in the

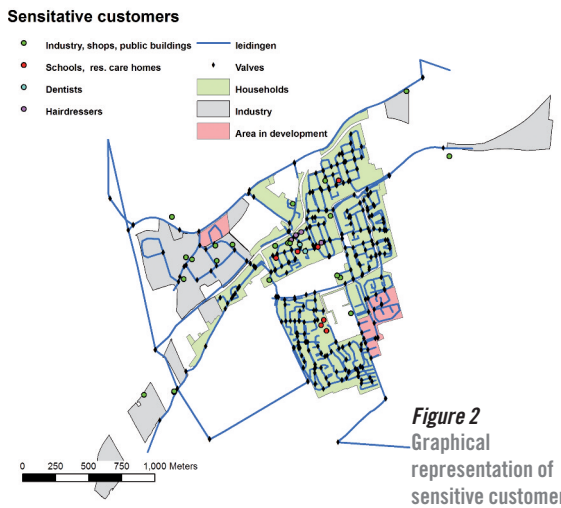

Figure 2 **Graphical representation of sensitive customers**

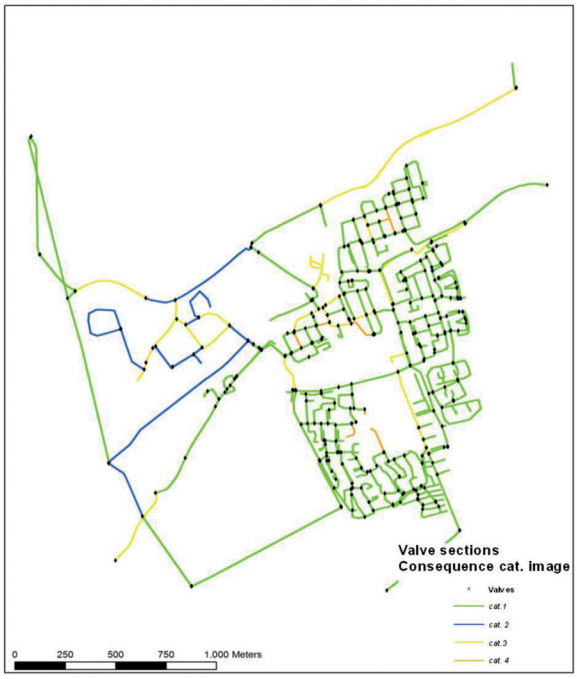

Figure 3
Valve sections divided into consequence categories on public image

third (100-1000 connections). One connection appears to be in the fifth category. In reality this is not the case, this has to be regarded as an inaccuracy of the input model of CAVLAR.

The consequence on substandard pressure caused by pipe bursts is calculated by simulating a pipe burst as a supplementary demand and by counting the number connections with a pressure lower than the required standard, for this case defined as 200 kPa. The number of valve sections where in case of a pipe burst less than 50 connections (first consequence category) suffer from a substandard pressure is 272 out of 297. In one section 50-100 connections are affected (second consequence category), in one section 100-1000 connections (third consequence category), and in one section 1000-2000 connections (fourth consequence category). For eight sections, however, the number of connections with a substandard pressure is higher than 2000 (fifth consequence category), these sections are part of the trunk main feeding the pilot area.

For estimating the consequences of a pipe burst on the substandard quality of water supplied to customers an analysis is made of the number of customer complaints, the flow velocity and the flow.

In the period 1993 to mid 2005, 351 customer complaints related to water quality were registered. This corresponds to 8.3 complaints per 1000 connections per year. These complaints were registered per address and were assigned to valve sections. Flow velocities are based on the minimum and maximum velocities on an average day and were calculated with a hydraulic model. For every section average velocities were defined and with a hydraulic model the largest flow was calculated per section on an average day.

In Table 2 the method for rating the consequence of a pipe burst on the water quality is given.

Quantifying the negative impact on public image due to a pipe burst was done by assessing more sensitive customers in the pilot area. Sensitive users are identified by applying publicly available geographical information on land use, risky objects and on the domicile of specific users (in this case-study limited to dentists and hairdressers). For a graphical representation of these sensitive customers, see Figure 2. Based on the land use (www.cbs.nl), valve sections were assigned to households (consequence category 1) and industry (consequence category 2). The layer on land use originates from 2000 and lacks some building areas that have been developed since 2000. Valve sections in these areas were assigned manually.

All risk objects in The Netherlands are presented on a publicly available risk map (www.risicokaart.nl). In the pilot area 38 objects are indicated on the risk map of which 30 are assigned as risky industry (consequence category 3) and eight as schools and residential care homes (consequence category 4). The pilot area has no hospital (consequence category 5). The domicile of dentist and hair-dressers (consequence category 3) was defined by using the Golden Pages (www.goudengids.nl). These addresses were assigned manually to valve sections. In Figure 3 the valve sections are divided into consequence categories.

The potential impact of a pipe burst on costs was assessed by identifying certain objects in the vicinity of mains. In Table 3 an overview is given of these objects in the pilot area.

By applying geographical information, the locations of objects in the proximity of mains are made explicit. A zone of influence was determined to identify whether a pipe burst can potentially cause harm to a certain object. It has to be taken into account that this is an oversimplification of reality as:

- Information is only available of the axis or centre of objects and not of its periphery;
- No information is available of the erosion crater caused by a pipe burst, which is influenced by the hydraulic capacity, the pipe material, the soil type and the possibility of drainage of water;
- No information is available on the actual costs to objects, depending on e.g. the type of construction of roads and buildings, the foundation or the presence of other underground infrastructure.

Geographical information on historical zones and monuments was obtained from a publicly available database containing all historical objects in The Netherlands (www.kich.nl). Dutch Water Boards manage the geographical data concerning dykes and roads.

The number of valve sections where in case of a pipe burst the potential costs are estimated as low (first consequence category) is 161 out of 297. In 63 sections the costs are estimated as moderate (second consequence category), in 32 sections the costs are estimated as high (third consequence category), in six sections as very high (fourth consequence category) and in 32 as extreme (fifth consequence category).

All valve sections in the pilot area were assigned to five categories representing the probability and consequence of a pipe burst. An overview is given in Table 4.

After having defined the five risk matrices for every valve section, the five different matrices have to be consolidated into one. Also the probability and consequence categories have to be combined into one risk category. Various methods for consolidation are possible, such as:

- The number of times critical: count for every valve section the number of times it is critical (in the red area);
- The average risk score: define for every valve section the average position of the five matrices;

Table 4
Valve sections assigned to categories for probability and type of consequence of a pipe burst

Cons. cat.	Interruption					Pressure					Quality					Image					Cost				
Prob. Cat.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	270	14	9	0	1	283	1	1	1	8	63	222	9	0	0	257	13	18	6	0	161	63	32	6	32
2	2	0	0	0	0	2	0	0	0	0	0	2	0	0	0	1	0	0	1	0	0	1	1	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- The maximum score: define for every valve section the maximum position of the five matrices;
- Weighted average score: define for every valve section the average position, where each matrix is given a specific weight.

For the three lowest consolidation methods, the risk category can be computed by dividing the consolidated risk matrix into a number of zones, where the zone with the lowest risk is located in the upper-left corner (low probability – low consequences) and the zone with the highest risk is located in the lower-right corner (high probability – high consequences). In Figure 4 a consolidation is shown of the number of times valve sections are counted critical.

Information for quantitive analyses

During this study it was found that a gap exists between the desired and the available information. A quantitative judgement depends on the existence and quality of information and in some cases this has to be done with derived information, e.g. quantifying the consequences of a pipe burst on image is done by ranking more sensitive customers. Based on this research the following criteria are drawn up to evaluate if the available information fits to the desired information:

- Is the desired information directly available (e.g. burst rates for probability of failure) or has to be made use of derived information (e.g. sensitive users for image)?
- Especially in the case of derived information, to which extent is this information appropriate and which assumptions are made?
- Is the available information complete and is the time frame sufficient?
- Is the available information reliable and up-to-date?
- Is the available information of sufficient detail and in an appropriate format?

Conclusions

This research explores the possibility of making a quantitative risk assessment of a water distribution network. Risk matrices have been established for this purpose and have been applied on an existing network. Based on this the following conclusions are drawn.

- This case study on quantitative risk assessment of water distribution networks shows that in the case of Montfoort (the Netherlands) 39 valve sections out of 297 are considered to be critical on one of the five consequence criteria. From these 39 critical valve sections, one section is two times critical and one four times. It is emphasized that this case study focuses on the possibility of making a quantitative risk assessment of a water distribution network with the aim to identify critical valve sections. The red and green markings in the risk assessment matrices used in this case study are therefore purely hypothetical. In practice, it is the water company's policy that determines the position of the borderline of critical and non-critical valve sections.
- The case study proves that it is possible to make a quantitative risk assessment of a water distribution network, by using information available from various sources such as hydraulic models, CAVLAR, geographical information and databases on burst rates.
- The execution of this quantitative risk analysis is time-intensive. This is mainly due to the numerous manual data conversions. This research focused on the feasibility of making a quantitative risk assessment of a water distribution network. It is to be expected that if this kind of assessment will be implemented, manual conversions will be automated, resulting in a more efficient assessment.

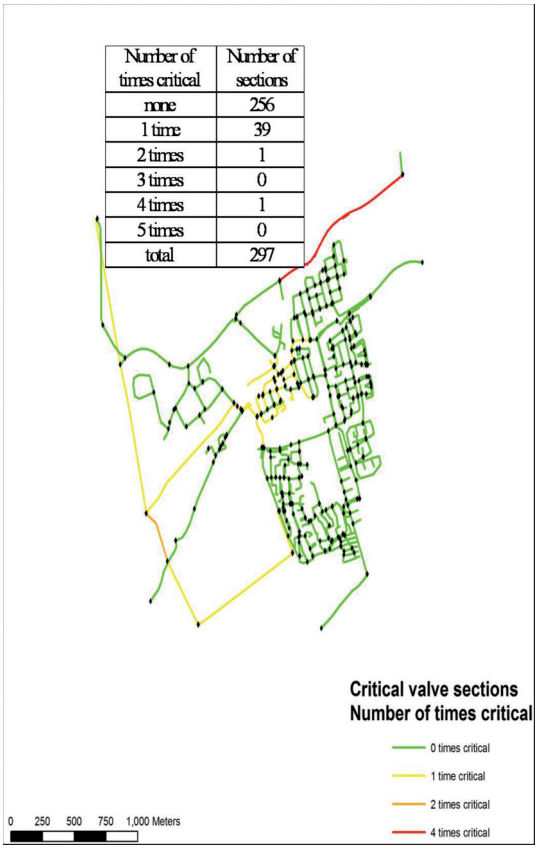

Figure 4
Critical valve sections consolidated as number of times critical

Risk analysis of the reliability of assets is meant to develop the most appropriate intervention for assets in order to manage risks. Risk assessment for distribution assets is hindered by their underground location and the difficulties in predicting their condition. Also maintenance strategies for distribution assets are less extensive than for production installations. As distribution assets represent two third of the capital of water companies in the Netherlands, being able to identify the most critical sections can be of great help to developing the most appropriate and effective maintenance and replacement strategies. The economic value involved in replacing water mains and the direct consequences of failures for customers justify thorough further research on risk assessment of water distribution networks.

This economic driver for risk assessment of water distribution networks coincides with technological developments, like new and better simulation models, the availability of geographical information and open standards enhancing the exchange of information. ●

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Reuse of treated wastewater for irrigation purposes in Greece: Investigation of economic, social and environmental factors

The objective of this study is to investigate how economic, social and environmental factors could be examined in an integrated way in order to evaluate the treated municipal wastewater reuse procedure for irrigation purposes in Greece. Such factors could be used as essential data, which will serve in the construction of an evaluation model. The purpose of such a model operation is to determine whether recycled water could be exploited as an alternative water resource in a Greek region, according to specific economic, social and environmental aspects. This model could be based on a decision making methodology whose goal is the selection of a best alternative wastewater reuse scenario or scenarios. The operation of such an integrated model could therefore be useful in promoting wastewater reuse as one of the valid solutions to water stress problems observed in many Greek regions in recent years. By Sophia Bakopoulou and Athanassios Kungolos.

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Water scarcity and deterioration in the quality of water resources in many countries has led to the recognition that integrated water resource management, where all pertinent factors are considered in the decision making process, should be adopted. Such a holistic approach requires, among others, incorporation of alternative water resources in water resource management (Bower, 2000). Desalination of seawater as well as reclamation and reuse of municipal wastewater are the main strategies that have been proposed for investigation and application in many countries all over the world (Brenner et al., 2000). Public involvement is also extremely important and should be taken in mind when looking to implement integrated water management.

Treated municipal wastewater could be reused for specific purposes, such as irrigation, industrial uses and aquifer recharge purposes. However, the most common reuse application is agricultural irrigation. On this occasion, wastewater can serve as a source of both water and nutrients, thus reducing fertilization costs. On the other hand, landscape irrigation and other non-potable urban uses have been gaining interest in recent years (Metcalf and Eddy, 2003). In the Mediterranean area, a lot of drainage problems have occurred in recent years, especially in countries like Greece and Portugal. In these countries, the main problem may not be scarcity of water in terms of average per capita quantity, but the high cost of making water available at the right place and at the right time, of the required quality, especially because of temporal and regional variations of precipitation, increased water demand during summer months, and difficulty of transporting water (Angelakis et al., 1999). So, in such countries an integrated approach for water resources management, including wastewater reclamation and reuse, is required.

Taking in mind the above information, this paper aims to present the main problems related to wastewater reuse practices in Greece, thus enabling us to develop an evaluation model which could be used as a basis for determining whether it is worthwhile for municipal recycled water to be exploited as an alternative water resource in a Greek region. The model evaluates in an integrated way the most important pertinent factors, such as economic, social and environmental. In Greece, there have been a number of studies aimed at investigating the feasibility of wastewater reuse projects, taking in mind either economic or social factors (Angelakis et al., 2000; Soupilas and Papastergiou, 2003). However, it is still essential that all pertinent factors are evaluated by the same model, so accurate decisions are made.

The status of wastewater reuse worldwide and in Greece

In the Mediterranean basin, Israel has been a pioneer in the development of wastewater reuse projects. It is estimated that by the year 2040, treated sewage effluent will become the main source of water for irrigation in Israel and the Palestinian autonomous regions, supplying 70% of the total irrigating water used in the country (Haruvy et al., 1999). The Israel 'example' was followed by Cyprus, Jordan, Tunisia, Italy and France. In these countries, fully fledged national regulations set the basic conditions for the safe reuse of wastewater. In the remaining Mediterranean countries a lack of national regulations has resulted in relatively few efforts regarding the development of new projects in the wastewater reuse sector. Spain is an exception, since the existence of regional regulations has had a positive effect regarding the implementation of wastewater reuse projects in the country (Angelakis et al., 1999).

Other countries which have developed national or regional regulations regarding municipal wastewater reuse include the USA, Japan and South Africa. The USA, specifically states like California, Florida and Arizona, are pioneers in using modern technology in sewage wastewater recycling. Canada and China have supported in recent years a significant number of research projects regarding treatment and reuse of municipal wastewater for non-potable uses (Chu et al., 2004; Exall, 2004).

In Greece, the most significant problems regarding distribution and availability of water resources are in the Aegean islands, as well as in most of the eastern Greek regions. In these areas rainfall is relatively low compared to those of the western regions of Greece (Angekakis et al., 1999). Nevertheless, reuse of municipal wastewater has not been a common management practice in the country, while direct disposal of treated effluents in rivers, lakes or the sea is usual. The main effect of this situation is that a lot of alternative water sources in Greece are not exploited, while a large volume of high quality water is used in non-potable uses like irrigation.

In Greece, no guidelines or criteria regarding wastewater reclamation and reuse have yet been adopted, despite the fact that many research projects

and studies have been carried out aimed at determining such guidelines (Anglekakis et al., 2000; Andreadakis et al., 2003). The goal of such research projects and studies relates to specific criteria determination regarding the quality of wastewater that will be used for different purposes. Such purposes include agricultural irrigation, landscape irrigation, aquifer recharge, etc. The above studies set the basis for the legal solution of the problem. Furthermore, a lot of studies regarding effects of wastewater irrigation on specific crops have taken place in recent years (Tsantilas and Samaras, 1996; Paranychianakis et al., 2002; Vakalis and Tsantilas, 2002). However, a crucial point is the problem of whether it is worthwhile for municipal recycled water to be exploited as an alternative water resource in a Greek region and how this project could be implemented in a sustainable way. The sustainability of such projects depends mainly on crucial factors such as economics, society and the environment. For example, in Greece many municipalities are not keen on constructing advanced wastewater treatment systems which will make the secondary effluent suitable for reuse purposes because of high costs involved. As well as this, some Greek farmers are not willing to use recycled water because of the lack of information regarding wastewater quality as well as relative health and safety issues. It seems that extra information on the advantages of recycled water use has a significant impact on farmers' willingness to use it (Tsagarakis and Georgantzis, 2003; Katsavou et al., 2008). In an effort to solve these problems, we propose the development of an evaluation model which should incorporate the relative economic, social and environmental aspects regarding wastewater reuse and determine how it is or how it could be sustainable for municipal recycled water to be incorporated into water management plans of a Greek region.

Description of the model structure

The economic aspects incorporated into the model can be expressed in quantitative terms directly while the social and environmental aspects could be expressed either in quantitative terms indirectly using specific techniques or in qualitative terms. A literature review has shown that decision making methodologies have been used worldwide for solving complex environmental problems. Cost-benefit analysis (CBA), as well as multi-criteria analysis (MCA), are the most popular decision making methodologies used in environmental planning (Haruvy, 1997; Jaber and Mohsen, 2001; Ganoulis, 2003; Tsagarakis, 2006).

CBA is an example of a rational choice-based technique which emphasizes maximising an objective function subject to constraints. CBA is based on real or simulated markets where people are defined as 'consumers'. Their willingness to pay for buying a good is used for placing monetary values on non market goods (Refsgaard, 2006), thus CBA can be used only for evaluation of quantitative variables where the gains of any criterion can be traded off against the losses of other criteria. However, the complexity in environmental processes makes trade-off risky, since important criteria may not be evaluated at all. On the other hand, the 'consumer' definition during the CBA decision making procedure is also risky, since, in environmental planning, which is a participative procedure, the decision maker should act more like a citizen than a consumer. When discussing environmental planning decision problems, the decision makers and the stakeholders should try to value goods from a wider perspective, taking into account not only their own ethical values, but also other people's interests and values.

Alternatively, MCA is a tool helping decision makers to effectively handle complex decision situations characterized by conflicts. MCA does not provide a solution, like CBA does, but it can lead to a variety of solutions suitable to the problem. This fact makes MCA better for use in environmental planning problems since in such participative procedures not only one solution but a variety of solutions exist (Diakoulaki and Mavrotas, 2004). In most MCA methods, preferences between alternatives are established through a set of criteria identified and set in a process between decision makers and other stakeholders. The criteria used for assessing the extent to which the alternatives have been achieved may be quantitative or qualitative. In general, MCA enables people to think about their values and preferences from several points of view through communication about problem definition, the setup of alternatives, and criteria (Refsgaard, 2006). This fact, among others, makes MCA a convenient method to be used for evaluation of environmental problems like wastewater reuse procedure in a region. The most important disadvantage of MCA methods is the fact that they are characterized as subjective methods while CBA methods are generally objective methods (Dodgson et al., 2001). This subjectivity stems from the emphasis of MCA on the judgement of the decision making team in establishing objectives and criteria, estimating relative importance of criteria weights and, to some extent, in judging the contribution of each alternative to each performance criterion. This subjectivity, however, can be important, since MCA can bring a degree of structure, analysis and openness to classes of decisions that lie beyond the practical reach of CBA.

In general, every multi-criteria decision making problem can be evaluated by a model which includes: a set of alternative activities or scenarios A ($a_1, a_2, a3, \ldots, a_{10}$), a consequent family of criteria F ($f_1, f_2, f_3, \ldots, f_{10}$) as well as the table of multi-criteria evaluation. In our case, all pertinent factors regarding wastewater reuse procedure (economic, social and environmental) could be incorporated as criteria f. All criteria will be evaluated by a decision maker or makers on the basis of how they can promote sustainability of the project (incorporation of recycled water in water management plans in a Greek region). Afterwards, the decision maker or makers will fix the alternative scenarios of water and recycled water management a that will be compared. The set of alternatives A is evaluated on basis of the score of all criteria in each scenario, thus an optimal or a set of optimal alternatives (solutions) arise.

Relative literature review among MCA methods that have been used in water and waste management planning (Bellehumeur et al., 1997; Karagiannidis and Moussiopoulos, 1997; Raju and Kumar, 1999; Ganoulis, 2003; Vassiloglou et al., 2005; Linkov et al., 2006) has shown that the use of outranking methods is the most popular method for evaluation of such environmental problems. Preferences in outranking methods are modelled by using binary outranking relations, S. Four possible preference situations may occur: a' is better or presumed better than a; a is better or presumed better than a'; a' is indifferent to a; and a' is incomparable to a.

Incomparability is a preference situation used only in outranking methods. Such a preference situation is important because in complex environmental problems the decision maker may not be able to compare two alternative scenarios. Another advantage of outranking methods is that they function well by using a low number of criteria and/or alternatives. On the other hand, the criteria trade-off, observed in the CBA method, is not being developed in outranking methods. In general, the construction of an outranking relation is based in two major concepts: the concordance

concept, and the discordance one. According to the concordance concept, for an outranking preference situation to be validated, a sufficient majority of criteria *f* should be in favour of the corresponding assertion. On the other hand, the discordance concept relates to the possibility a criterion *f* discards the assertion that an alternative *a* is better than the alternative *a'*. Thus, outranking methods make use of discrimination thresholds, such as preference, indifference and discordance ones (Figueira et al., 2005). So, a decision maker when using an outranking method should fix, besides the criteria and the evaluating alternatives, threshold values such as preference, indifference and discordance ones, thus making a complex problem easier to be solved. Criteria that could be evaluated in our model include:

- Economic: Includes investment cost of advanced wastewater treatment technologies, as well as the corresponding operation and maintenance costs. Construction and operation costs of a water distribution network, as well as construction costs of water storage tanks should be taken in mind.
- Social: The most important social criterion is public acceptance of recycled water use. Surveys aimed at investigating this criterion could be designed for various target groups such as farmers, consumers of agricultural products, or the total population living in a region.
- Environmental: The most important environmental criterion is water saving. Other criteria include suitability of recycled water for irrigation purposes, and the environmental and health risks arising from recycled water use in such purposes, etc.

The above criteria should be evaluated (through weighting their significance) by the decision maker or makers in the context of how they promote the economic, social and environmental sustainability of recycled water use in the region examined. Afterwards, the fixed alternative scenarios will be compared on basis of score of all criteria in each scenario, taking in mind values such as the discrimination thresholds as well. The final result will be one or several of the preference situations, letting us draw a variety of conclusions.

Conclusions

In this study, the possibility of evaluating treated wastewater reuse procedure in an integrated way was examined for the case of Greece. Furthermore, the current status regarding reuse of municipal wastewater for irrigation purposes in the country was analyzed. Our main conclusion relates to the fact that there has been an increasing interest in the above sector of waste management in recent years in Greece. Projects that are being carried out in this sector can contribute positively to the general strategy of sustainable management of water resources and protection of natural resources from pollution. By evaluating economic and social aspects in relation to the necessary environmental ones, one can solve significant problems regarding wastewater reuse procedure in Greece. In the present study we described the main criteria that could be evaluated by a multi-criteria model. On the other hand, there are many more criteria (technological, territorial) that could affect the decision in such model. However, we strongly believe that the criteria described in this study are the most important in our preliminary effort to construct an evaluation model regarding wastewater reuse procedure in Greece.

In conclusion we could say that informing and educating local authorities, workers in wastewater treatment plants and farmers of the real significance of wastewater recycling is necessary. The media should also contribute to this effort by informing the local society on how important such water management could be for the protection of natural resources and the environment. ●

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Evaluation of wastewater systems in rural areas of the Balkan region with focus on ecological and socio-economic aspects

Wastewater is usually generated from the kitchens and toilets of residential households, the effluent from small and large industries, residues and diluted pharmaceutical drugs from hospitals, and generally from public institutions in rural and urban settlements. Over the last two decades, the treatment, reuse and methods of emission of wastewater into surrounding ecosystems have become a topic for scientific research and technological development with regards to environmental protection and sustainability. Hence the operation and maintenance (O&M) of waste-water treatment plants (WWTPs) should be economically viable (affordable), socially acceptable, technically and institutionally appropriate, manageable and adaptable, with an aim to protecting the environment and all the natural resources therein (SuSanA, 2008). This paper puts forward the outcomes of a development cooperation project which aimed to evaluate WWTPs in rural areas in the Former Yugoslav Republic of Macedonia (FYROM).

FYROM has one of the lowest per capita gross domestic products (GDPs) in the whole of Europe, and the country is highly dependent on external financial loans and grants for development. The rural areas of FYROM are generally characterized by low income populations engaged mainly in the cultivation of fruit and vegetables and processing of diary products for local and regional markets, generating 11-12% of the country's GDP. Geographically, FYROM is a landlocked country characterized with dispersed and condensed cities, towns and villages with hilly/mountainous topography. The types and quality of residential units vary considerably from modern architectural styles in major urban cities to traditional architecture in rural areas.

The main goal of the project initiated by the Austrian Development Agency was to develop an approach for implementing appropriate wastewater technologies in rural areas of FYROM, as a pilot project for the Balkan region, based on the performance rating of existing systems (WWTPs). Analysis by Prandtstetten (2009) showed that problems associated with a lack of sufficient financial capital for the O&M of WWTPs in FYROM is similar to other developing countries like Albania and Romania, considering for example the percentages of rural houses that are connected to a sewer system and the ratio between wastewater disposal tariffs and average net income of rural population (Table 1).

This project focused on the ecological and socio-economical aspects of wastewater systems in FYROM with regards to affordability, investment costs and operational costs. The evaluation of the four treatment plants selected focused on the tariff structure (billing and methods of payments) as well as on the efficiency of the WWTPs.

The study was based on predefined objectives according to the European Standard for drainage and sewer systems outside buildings (EN 752, 2008). The four overall objectives of EN 752 are: Public health and safety; Occupational health and safety; Environmental protection; and Sustainable development.

Methods

The project team was made up of academic staff and lecturers from two partnering Universities[1] that included

This paper puts forward the outcomes of a development cooperation project that aimed to evaluate wastewater systems (treatment plants) in rural areas of the Former Yugoslav Republic of Macedonia (FYROM). Focusing on the lessons learned could be essential for the planning and operation of wastewater treatment plants (WWTPs) in developing countries with similar socio-economic and political characteristics to FYROM, for example Albania and Romania in the Balkan region. Four types of treatment plants were evaluated in four rural communities, each having sufficient treatment potential according to the European Union (EU) Urban Waste Water Directive (UWWD, 1991) in terms of chemical oxygen demand (COD), biological oxygen demand (BOD), and nitrogen and phosphorus removal. The outcomes of the survey showed that insufficient financial capital led to problems of operation and maintenance (O&M) (e.g. costs of repair and replacement of worn-out parts, and biological and chemical analyses). Due to the economic situation of residents in rural areas of FYROM, the wastewater tariff should be as low as possible. This low tariff structure is a fundamental selection criterion for choosing the most appropriate technology. Owing to this fact, the investment costs, the O&M costs as well as the energy consumption of the WWTPs selected for this evaluation should be as low as possible, but also have to be included in the tariff calculation. Beside the limited financial capacity of local residents, generating revenues from wastewater disposal tariffs poses a financial challenge to municipal authorities as only around 20% pay their disposal tariffs, thus the total operational costs of treatment plants cannot be covered. Municipal authorities need effective tools to improve tariff collection. Public acceptance and awareness of environmental and health issues have to be taken into account when considering the design and planning of WWTPs. The participation of stakeholders from the public and private sectors is of vital importance to the design and planning processes of WWTPs as the stakeholders' role would lead to the formulation of policies backed by good action plans and implementation strategies of wastewater management in FYROM and in other developing countries in the Balkan region. Water pollution control measures should also be planned particularly with regards to nutrient aspects. In rural areas alternative sanitation systems with nutrient recovery may be considered. In FYROM, there is lack of information on the environmental impact of wastewater management. The monitoring of surface and groundwater quality is strongly needed to fulfil the requirements of the FYROM National Water Act of July 2008, within which the principles of the EU Water Framework Directive have been implemented. By Thomas Ertl, Michael Wippel, Christoph Prandtstetten, Stefan Kuvendzijev, Helmut Jung, Norbert Weissenbacher, Florian Kretschmer and Todor Anovski.

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supervisors and master students, and one external supervisor. The project was begun in July 2008 after a two-day seminar at the University of Skopje. The project started with a research review regarding sustainable wastewater management (Ujang and Henze, 2006) and a baseline study on the socio-economic conditions of people living in rural areas of FYROM, in relation to wastewater generation, disposal and treatment. To achieve its objectives the survey employed face-to-face interviews as a technique to acquire relevant qualitative data. Ordinary face-to-face interviews were carried with local residents and their community heads, while expert face-to-face interviews (Rietbergen-McCracken and Narayan, 1998) were conducted with major political stakeholders, directors and operating personnel in four rural areas with WWTPs. Site monitoring and control of the four WWTPs was also carried out to gather technical/quantitative data needed for performance benchmarking.

A planning method was employed to strategically evaluate and identify the strengths, weaknesses, opportunities and threats (SWOT) of wastewater management in FYROM. Using the planning method (SWOT), analyses were carried out by all major participating stakeholders during a one-day workshop organized in Skopje, FYROM in August 2008. The outcomes of the workshop added value to the final analyses of acquired data and also to the final report writing. Four WWTPs consisting of two intensive (activated sludge and trickling filter systems) and two extensive (constructed wetlands

and aerated lagoons) processes of wastewater treatment financed by the Austrian Development Agency (ADA, 2008a and 2008b) were selected for monitoring, control and evaluation of the overall performance of the treatment plants.

These WWTPs are located in four rural areas[2] of FYROM and they include:

- Makedonski Brod – has an activated sludge system of wastewater treatment with 5000 PE (population equivalent). The treatment plant has been in operation since 2001.
- Krivogastani – has aerated lagoons with 4000 PE and has been in operation since summer of 2007.
- Cucer Sandevo – has a trickling filter system with 3000 PE and has been in operation since summer of 2009.
- Jasenovo – has a constructed wetland with 250 PE and has been in operation since autumn of 2006. Due to its geographical location the Jasenovo constructed wetland was specifically designed and constructed for the Jasenovo specialist hospital, which produces wastewater constituents of diluted pharmaceutical drugs used for the treatment of patients with lung infections and other cancerous illnesses.

Beside the collection of relevant quantitative and quantitative data, the sampling and analyses of inflow and outflow from each of the WWTPs was carried out under the supervision of the Vodovod i Kanalisazija laboratory[3] and the Austrian University laboratory. For the purpose of establishing a standard evaluation of all the WWTPs with regards to their adjoining rural population, a socio-economic/environmental assessment of the settlements in the entire catchment area was carried out. The final analyses of all quantitative and qualitative data gathered, employed the IWA's performance indicator/evaluation system used for wastewater services (MATOS et al., 2003).

Results and discussion

Economics

The evaluation of the economical situation of FYROM showed that the average income of the total population is €258 ($351) per month (State Statistical Office, 2008). Due to a lack of statistical data it was difficult to obtain specific information concerning the economic situation of all the rural areas in FYROM. However, during the face-to-face interview phase conducted with local residents, it was gathered that the average income level of rural inhabitants is significantly lower (approximately €150 ($204)/month) than the income level of major urban cities. The average unemployment rate in FYROM is 34.8% (State Statistical Office, 2008). The unemployment rate in FYROM is one of the highest in the Balkan region and is expected to increase due to the global financial crisis, with the majority of unemployed people living in rural areas where agriculture is predominant (World Bank, 2010).

Country	Water	Wastewater	Tariff / average net income
Albania	20%	5%	-
FYROM	27%	10%	3.4%
Romania	17%	10%	2.6%
Austria	88%	83%	1.2%

Table 1 **Connection rates in rural areas and tariff ratio (Prandstetten, 2009)**

Operation and monitoring

As a criterion under the European Water Framework Directive (WFD), the management and operation should be such that treatment plants are financially capable of covering all operational costs with regards to replacements of broken/failed parts and population increase and settlement expansion. However, the outcomes of monitoring and control of the Makedonski Brod, Krivigastani and Cucer Sandevo WWTPs, excluding Jasenovo, showed that the standards of operations and maintenance of each of these plants fell short, for example not carrying out regular chemical analysis of the in- and outflow.

As put forward by UNEP (United Nations Environment Programme) (1997, cited by Muga and Mihelcic, 2007) the operational costs of conventional WWTPs (activated sludge and trickling filters systems) are on average much higher than the operational cost of the alternative WWTPs (constructed wetlands and aerated lagoons). The operational cost, total re-investment cost, running costs and energy costs of the four evaluated plants are summarized in Table 2.

Makedonski Brod's activated sludge treatment plant was designed to achieve maximum rate of efficiency in treating wastewater hence, its total operational cost was quite low when compared with the operational cost of Krivogastani's aerated lagoons used for treating wastewater.

The total operational cost of Jasenovo's constructed wetlands is almost zero as all other cost is included in the budgeted operational cost of the Jasenovo specialist hospital. The almost zero operational cost, of which most constructed wetlands offer, would tend to suggest that constructed wetlands have the lowest operational cost when compared with other types of WWTPs. Many years of worldwide experience with constructed wetlands have demonstrated that constructed wetlands used for wastewater treatment is a good option for settlements with less than 500 PE (e.g. Haberl et al., 2003; Cooper, 2009; Vymazal and Kropfelova, 2009). The high operational cost excluding total re-investment cost of Cucer Sandevo (trickling filter) is mainly due to the high cost of chemicals used for phosphorus removal.

Tariff collection

Due to the economic situation in rural areas in FYROM it was important to take the economic and financial capacities of the evaluated rural communities into consideration. The system and structure of wastewater disposal tariff showed that 80% of the local residents (except Jasenovo) connected via sewer system to the WWTPs are not paying the fees for the disposal and treatment of their generated wastewater ('bad payments'). Knowing the exact income earned by local residents was a difficult task to achieve, thus it was impossible for the survey to distinguish low income earner from high income earner. This lack of knowledge posed a limitation to predicting the willingness of local residents to pay for the tariffs for disposal of their generated wastewater.

Not knowing the income earnings of local residents and their willingness to pay for wastewater disposal poses a big issue for authorities to implement a legislative framework that allows appropriate measures to reduce 'bad payments'. At the time this survey was carried out, the reinvestment costs (amortization) were not fully included in the tariff system, which may pose huge financial and operational problems in the future. Should the operating parts or sensitive components which make up a WWTP fail to function at the expected standard, there exists the possibility that municipal authorities with a non-effective tariff system would lack the sufficient financial capital for O&M of their treatment plants (reinvestment cost). When municipal authorities lack the funds, there is the tendency to seek financial support from external donors, thus suggesting that the municipalities lack the ability to manage the operation of

the treatment plants on their own.

In situations when the O&M are not timely backed up by sufficient financial capital, delayed reinvestments might become very high due to inflation, which in turn would increase the tariff for wastewater disposal. When municipal authorities are faced with high costs to sustain the O&M of the treatment plants, there exists the possibility that municipal authorities will invest in the cheapest available technologies (bad investments), rather than investing on the best available technologies (BATs) that could stand the test of time and cope with increasing populations.

Wastewater treatment performance and environmental impact

The activated sludge system in Makedonski Brod, the aerated lagoons of Krivogastani and the constructed wetlands of Jasenovo fulfil the quality standards regarding treatment efficiency in water sensitive areas, i.e. 70-80% of nutrient removal or outflow concentrations of phosphorus (< 2mg/l) and of nitrogen (<15 mg/l) (EU UWWD, 1991). At the time of data collection the trickling filter of Cucer Sandevo was in the incubation phase. However, the WWTP was confirmed to be working properly by the plant operators. The performance evaluations showed that the wastewater treatment systems of Makedonski Brod, Krivogastani and Jasenovo are performing well. Although problems in financing new technical parts or components and chemicals for the laboratory analyses were evident, the O&M of the treatment plants were carried out in an adequate way. This was mainly because of the enthusiasm of the operators and improvisation when problems arose. Other factors which contributed to the performance rate of the treatment plants were the standard training and translated manuals given to the operating personnel before the plants began operation, and continuous supervision by Austrian sanitary engineers after treatment began.

The documentation of plant operations regarding chemical and microbiological analyses for self-monitoring of the WWTPs is normally carried out by the plant operators (internal supervision). In general, the results over the last few years showed that the WWTPs Makedonski Brod, Krivogastani and Cucer Sandevo have been working properly since they have been in operation. There was no data available for Jasenovo as no wastewater analyses have been carried out since the start of its operation in autumn of 2006.

Under the context of cost-benefit analysis the environmental costs on land, plants/animals, surface and groundwater resources of discharging domestic and industrial wastewater directly into the adjoining ecosystems, and the benefits of WWTPs to the rural communities have not been evaluated at the time of this survey. Hence, the importance of water quality was not taken into consideration during the design/planning phase of the WWTPs.

The principles of the European Union Urban Wastewater Directive (EU UWWD, 1991) and the WFD (2000) had been already implemented into the National Water Act, in July 2008. For the technical implementation of wastewater management strategies/procedures, Zessner et al. (2004) (see also daNUbs, 2005) put forward the following outcomes of a study regarding nutrient removal and recovery by WWTPs for the Danube River Basin. The study outcomes can be summarized in the following context. The management and treatment of wastewater by treatment plants have to conform strictly to the EU UWWD standards regarding the treatment and removal of nutrients (nitrogen and phosphorus). When these standards are not fully met by these conventional methods (intensive) due to other technical/financial reasons, alternative (extensive) methods of wastewater treatment have to be employed to deal with nutrient recovery. In the eastern Danubian countries only 50% of the population (residential houses and small/large scale industries) are connected to sewer systems, which suggests that nutrient management and its resulting impact on society and the environment have been given a low priority, therefore not conforming to environmental sustainability principles and the protection of natural resources.

When focusing on the appropriateness of wastewater treatment by plants in rural areas of FYROM, the water quality of the receiving rivers, lakes and streams must be of high priority and thus it must be taken into consideration. This requires the implementation of an adequate monitoring system. As mentioned before there is a lack of environmental data. Nevertheless data is needed to define the ecological status of rivers and lakes. A monitoring system allows the investigation of point sources of pollution, which would provide a good scientific basis for the implementation of integrated nutrient management for river basins. Allan et al. (2006a) presented reasonable and functional ideas for strategic river basin monitoring in regards to the WFD. A 'toolbox' for biological and chemical monitoring requirements was reviewed by Allan et al. (2006b). Halasza et al. (2006) described the establishment of a surveillance monitoring system for small water catchment areas, and Borja et al. (2005) has provided a methodological approach to assess the risk of failing to achieve good ecological status according to the EU WFD.

SWOT and stakeholder analysis

The SWOT stakeholder analyses that were carried out at the workshops in Skopje showed that the major stakeholders were aware of strengths, opportunities, weaknesses and threats with regard to wastewater management. The outcomes of the SWOT analyses put forward that the threats and weakness which the treatment plants may face could include insufficient financial capital to sustain the operations of the treatment plants, hence it would require a transparent tariff system coupled with raising the awareness level of local residents. The aforementioned criteria are necessary because local residents' participation and their willingness to pay tariffs are essential to the sustainability of treatment plants through revenue generation (re-investment financial capitals) in cases where the re-investment financial capital is given by external donors. The

Table 2
Comparison of the operational costs (inclusive and exclusive the re-investment costs), the total re-investment, running and energy costs per population equivalent

	Makedonski Brod activated sludge	Krivogastani lagoons	Cucer Sandevo trickling filter [1]
Total operational costs incl. re-investment per PE	€18.20 ($25)/(PE.a)	€24.90 ($33.70) /(PE.a)	€11.70 ($15.80)/(PE.a)
Total operational costs excl. re-investment per PE (PE.a)	€4.40 ($6)/(PE.a)	€5.40 ($7.30)/(PE.a)	€8.40 ($11.40)/(PE.a)
Total re-investment costs per PE	€13.90 (18.80)/(PE.a)	€19.50 ($26.40)/(PE.a)	€3.20 ($4.30)/(PE.a)
Total running costs per PE	€1.20 ($1.60) /(PE.a)	€3.20 ($4.30)/(PE.a)	€6.90 ($9.30)/(PE.a)
Energy costs per PE	€1.00 ($1.35)/(PE.a)	€2.90 ($3.90)/(PE.a)	€2.90 ($3.90)/(PE.a)

[1] Calculated with 0.5% of the investment costs (construction works of WWTP & sewage system) per year (with 4% for the WWTP and 2% for the sewage system in Mak. Brod & Krivogastani)

lack of local residents' participation (bottom-up strategy) in the treatment of wastewater could mean that the O&M of treatment plants are destined to fail (SuSanA, 2008).

Analyzing the opportunities and strengths using the SWOT method, the major stakeholders could identify opportunities since it was (then) a new technological/environmental approach to managing wastewater in FYROM. With this new approach jobs could be created for individuals who may have acquired training/education; the end-products (dewatered/treated sludge) could be packaged by municipal authorities and then sold to rural farmers for application on land, thus serving two purposes: generating revenue for the management of the treatment plants and meeting the economic goals of both the rural farmers and municipal authorities.

In the same vein, highlighting the strengths while using the SWOT method, stakeholders could identify possibilities where municipal authorities involved in wastewater management could learn from past mistakes by capitalizing on the knowledge of how projects (of this magnitude) failed in the past, and how they could utilize the expertise of external development partners through knowledge and information sharing. Using this strategic method to approach planning and operations by municipal authorities in FYROM the whole process could lead to establishing a more sustainable partnership and trust between FYROM as a country and its development partners.

Some key opportunities highlighted by the stakeholders while using the SWOT method that that the management of WWTPs in conjunction with development partners would lead to were:

- Improvement of water quality of receiving rivers and lakes.
- Knowledge transfer, information sharing and network establishment based on trust and mutual working relationships.
- Technical implementation of river basin management/strategies.
- Satisfying the objectives of EN 752 by achieving public and occupational health and safety, environmental protection and sustainable development.
- Creation of new jobs, which would lead to economic growth and development and improvement of the economy.
- Stimulate public participation in environmental protection issues and thus raise the awareness level of local residents.
- Operators of treatment plants attaining high competences and expertise would set standards of wastewater management for other countries in the Balkan region.

Furthermore, the stakeholders could also use the SWOT planning method in highlighting threats which must be treated with high priority. They included the following:

- The national rate of poverty (high) and rural income earnings (low) coupled with little or no environ mental protection awareness could lead to the non-participation of local residents in the wastewater management process.
- Local residents' unwillingness to pay wastewater disposal tariffs may pose difficulties in generating revenue needed to cover the operational costs of treatment plants, hence hindering their performance.
- Lack of information and technical knowledge may pose a challenge for treatment plants aiming to achieve high rates of performance/efficiency.

Conclusions

This study revealed the following key aspects that need to be considered for sustainable management and development of WWTPs in rural areas of FYROM. The strategies developed and implemented, the challenges faced and resolved, and the whole project management cycle could be used as a model for similar projects in developing countries in the Balkan region, and elsewhere in the world with similar socio-economic and environmental realities.

Economic situation and public participation/acceptance

According to the economic situation of most people living in rural areas of FYROM the wastewater disposal tariff should be as low as possible. However at their current levels this cannot cover all O&M costs. Therefore, the options left for the generation of revenues to cover the investment and O&M costs are either pegging the wastewater disposal tariffs (exponential discounting) or seeking grants/loans from external donors. Alternative wastewater treatment systems such as constructed wetlands have low O&M costs and low or zero energy consumption, so may therefore be considered as appropriate alternatives.

Another challenge which the economic situation poses to the effective management of WWTPs in FYROM is the willingness of local residence to pay wastewater disposal tariffs. Only 20% of the total population connected to the treatment plants in the Makedonski Brod, Krivogastani and Cucer Sandevo communities pay their disposal tariffs. This therefore suggests that the lack of willingness to pay by local residents displays a low level of environmental awareness and motivation and the resulting consequences. What is therefore needed by the municipal authorities is an effective method of tariff collection backed by enforcing laws and policies. Thus, in the design/planning process of wastewater treatment systems, local residents' participation should be given high priority to create the acceptance needed to generate revenues to cover operational costs.

Education and training

Training programmes for potential operators are essential for the proper O&M of the wastewater treatment systems and the survey showed that most operators reported sufficient training on O&M. Nevertheless, there is need for further development of plant operator knowledge, expertise, commitment and capacity, which are necessary for high performance and good outputs of treatment plants. These are fundamental to sustainable management of WWTPs in the long term. Furthermore, external control of system performance should be institutionalized as this survey showed that there exists a lack of continuous independent monitoring of the evaluated treatment plants.

Treatment performance and environmental impact

The evaluation showed that all treatment technologies fulfil the EU UWWD standard for sensitive areas, which includes nutrient removal. As cost is a crucial factor for consideration, there are cheaper technologies without nutrient removal that would fulfil the basic requirements for non-sensitive areas. To define the ecological status of water bodies according to the EU WFD (2000), quality monitoring is strongly needed since there is a lack of information on environmental conditions and the impact of wastewater management in FYROM. Impact assessment on receiving rivers/lakes should therefore be integrated into regional and local planning procedures. It is imperative to know at the design/planning phase which appropriate wastewater system would suit the municipal/rural economic realities, considering the operational costs. Furthermore, the objectives of wastewater treatment systems should clearly stated on whether the goal is to improve public/occupational health, environmental protection/

development, or both.

Organizational aspects
The lessons learnt in development cooperation in south-eastern European countries in the concerning wastewater management as put forward by Prandtstetten (2008) can be summarized into two categories:

Donor coordination and cooperation (harmonization) and alignment with national partners
As stated above, the EU WFD approach of river basin management has been implemented into the FYROM National Water Law. For this large scale approach it is necessary to cooperate with other donors aligned with national institutional and legal settings so as to obtain the necessary financial capital needed for interventions at this level. Because Austria through its department for international development and co-operation (ADC) has been working on development issues such as this in the Balkan region for a long time, there is wealth of experience gathered which was utilized in their interaction with administrative authorities in the region. These actions led to Austria attaining a coordinating and mandatory role as an 'honest arbitrator' to which other development donors are being invited and integrated into the processes.

Capacity building, institutional strengthening (on different levels)
The cooperation between the University of Natural Resources and Applied Life Sciences, Austria and the University St. Kyril and Methodius (UKMS), FYROM was the basis for this project and reveals the role of universities in sustainable infrastructure development. Universities can play an important role in the education of engineers for training of sewer personnel, research in construction, O&M and rehabilitation. The Austrian Development Corporation (ADC) aspires to boost scientific cooperation and knowledge transfers between the region and Austrian academic institutions in the long term. ●

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Notes
[1] University of Natural Resources and Applied Life Sciences (BOKU) Vienna and University St. Kyril and Methodius (UKMS) Skopje.

[2] There are various definition of 'rural areas', in the context of this work settlements up to 5000 inhabitants with predominant agricultural economy are considered as rural

[3] The Vodovod I Kanalisazija laboratory is part of the Skopje Public Water Utility, equipped with 'state of the art' drinking water and wastewater analyzing equipment.

Decision Analysis and Implementation Guidance in Strategic Asset Management

WERF Report SAM1R06c
Author: Duncan Rose

Track 3 of WERF's Strategic Asset Management Project was developed to 'provide guidance on implementing SAM…and develop analytic tools for SAM implementation' – the decision support tools and implementation guidance goal.
In Track 3, the decision support tools and implementation guidance goal was organized around two major elements:

- Analytic/decision support tools – Develop staged, user-friendly analytic and decision support tools (gap analysis, cost benefit analysis, risk management, life cycle costing, condition assessment selection tool, etc.) for SAM implementation and continuous improvement.
- Implementation tool – Provide practical, accessible guidance for an implementation tool to undertake SAM in incremental stages leading to a well-planned, structured, and progressive implementation to suit the needs of a diverse range of utilities' communication practices.

Task Order 2 provided for, amongst others, the following deliverables:

- Set up practitioner tool-review working group and establish framework
- Catalogue available 'commercial off-the-shelf' SAM tools
- Identify and prioritize core set of tools

Asset management can be defined as a way of management thinking and a set of best practices built around a structured framework that assist asset managers in making the most cost effective investment decisions in existing and new assets to sustain long term performance of the assets in an environment of limited resources where these decisions represent an integration of operations, maintenance, and capital intervention strategies. At the heart of the framework is the concept of business risk – a metric that measures the interaction of the probability of failure, the consequence of failure, and risk mitigation strategies. This research:

- Facilitates the adoption of best practice in asset management in the public water utility industry.
- Provides an asset management knowledge base that is a structured repository of a broad range and deeply substantive collection of materials oriented toward the practicing asset manager.
- Addresses the why and how of asset management at levels for novice, intermediate, and advanced practitioners.

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Development of Protocols and Methods for Predicting the Remaining Economic Life of Wastewater Pipe Infrastructure Assets: Phase 1 (Development of Standard Data Structure to Support Wastewater Pipe Condition and Performance Prediction)

WERF Report SAM3R06
Author: Sunil K Sinha

Accurate prediction of wastewater pipe structural and functional deterioration plays an essential role in the utility asset management process and capital investment planning. The key to implementing an asset management strategy is a comprehensive understanding and prediction of asset condition and performance. The primary objective of this research is therefore to develop protocols and methods for predicting the remaining economic life of wastewater pipe assets. This report presentes the short-term phase-1 which has been completed with results from intensive literature reviews, various interviews with utilities, and pipe associations.
In this phase, the research team investigated the life cycle of wastewater pipeline and identified the causes of pipe failure in different phases including design, manufacture, construction, operation and maintenance, and repair/rehabilitation/replacement. The research team has prepared various modes and mechanisms of pipe failure in wastewater infrastructure system as well as identified environmental and societal consequences of the failure. After reviewing all relevant reports and utility databases, the research team has developed a set of standard pipe parameter list (data structure) and pipe data collection methodology. The data structure has been classified into Gold, Silver, Bronze and Wood standard.

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Remaining Asset Life: A State of the Art Review

WERF Report SAM1R06d
Author: Anthony Urquhar

This report is an output of the fourth research track (Track 4) of WERF's strategic asset management research programme 'Asset Management Communication and Implementation' (SAM1R06). Track 4 addressed 'remaining asset life', and had the overall objective of contributing to the development of techniques, tools and methods for estimating residual life of wastewater assets. Track 4 research was planned to be undertaken in a staged manner, so as to provide a stepwise development of concepts and protocols.
To this end, the research team has produced a synthesis of knowledge in relation to 'end of life' and 'remaining asset life', which is the subject of this report.

Drawing on the literature and the knowledge-base of the research team and industry partners, information is presented on the range of factors that influence the life of the different asset classes involved in the provision of wastewater services. A taxonomy of asset life is also given, along with a critical review of the conceptual linkages between risk, asset management and remaining asset life. A review of techniques used to assess remaining asset life is also included, as well as a detailed 'state of the art' review of modelling tools and approaches.

One of the key questions to be addressed in this initial stage of the research was the state of knowledge with respect to the estimation and prediction of remaining asset life, and if there is the capacity to translate between condition and performance data and the residual life of an asset. In this regard, this report builds on previous work undertaken by the research team into protocols for condition and performance assessments, as detailed in WERF (2007).

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Assessing Infiltration and Exfiltration on the Performance of Urban Sewer Systems

APUSS
Authors: Bryan Ellis and Jean-Luc Bertrand-Krajewski

Sewer systems constitute a very significant heritage in European cities. Their structural quality and functional efficiency are key parameters to guarantee the transfer of domestic and industrial wastewater to treatment plants without infiltration nor exfiltration. Infiltration of groundwater is particularly detrimental to treatment plant efficiency, while exfiltration of wastewater can lead to groundwater contamination.

The European research project APUSS (Assessing infiltration and exfiltration on the Performance of Urban Sewer Systems) was devoted to sewer infiltration and exfiltration questions. It was structured in three main work areas dealing respectively with; the development of new measurement methods based on tracer experiments and accounting for detailed uncertainty analyses; the implementation of models and software tools to integrate structural and experimental data and to facilitate data display, operational management and decision-making processes; and the integration of economic and operational questions by means of cost estimation, economic evaluation, performance indicators and multi-criteria methods applied to investment/rehabilitation strategies.

This final report describes the objectives, methods and main results for each work area. References to detailed methods, protocols, reports and tools are given in this final report which will be an invaluable source of information for all those concerned with the performance of urban sewer systems.

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