018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

Deliverable D1.1.2
An overview of conventional and innovative approaches for UWM in Europe and the South: including case studies and the application of Cleaner Production Principles

Due date of deliverable: M18
Actual submission date: M25

Start date of project: 1 February 2006 Duration: 60 months

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Revision [draft]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SWITCH Deliverable Briefing Note Template

SWITCH Document
Deliverable D1.1.2
An overview of conventional and innovative approaches for UWM in Europe and the South: including case studies and the application of Cleaner Production Principles

Audience

The document was prepared for an audience both inside and outside the SWITCH consortium. For consortium members it gives the current draft SWITCH approach to urban water management. Consortium members are invited to take this into account while doing the thematic research, and to give further feedback. The external audience consists of urban water managers that would like to rethink their approach to urban water management.

Purpose

The purpose of the document is to review the current approach to urban water management that is taken in Accra, Belo Horizonte, Birmingham, Cali and Hamburg. Based on this review and a number of case studies, using integrated assessment methods (systems analysis, Life Cycle Analysis and Quantitative Microbial Risk Assessment) the draft SWITCH approach to urban water management is developed.

Background

This document builds on Deliverable 1.1.1 and adds the draft SWITCH approach. The document is a step towards the development of the overall SWITCH approach.

Potential Impact

The document encourages researchers within the consortium to put their own research in the larger context of the urban water system, and, where possible, organize their work such that it contributes to optimization of the entire urban water system, rather than optimization of a sub-element with limited overall effect on the system.

Issues

Not applicable

Recommendations

The document consists of a summary paper and a number of annexes. The annexes include detailed information about the case studies. It is recommended to first read the summary paper to get the context of the various case studies.

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Annexes

1. Introduction and objectives

The challenge of sustainable Urban Water Management is to serve urban dwellers with reliable water services, such as water supply for a variety of uses, hygienic removal of waste and wastewater, prevention of flooding, etcetera, without compromising the integrity of the environmental resources that are sustaining these services. These challenges are clear and therefore the objectives of urban water management are clear. However, the objectives are not reached in many cities, particularly in the developing world.

The institutions that are delivering the services, or managing the urban water system, are basing their actions on a certain ‘approach’. This approach to managing the city or its water system is usually found in mission statements or strategic planning documents. Sometimes the approach is not made explicit, but nevertheless directs the actions of the organisation. In this document the ‘approaches’ that are underlying the management actions of urban water sector organisations are described and analysed based on a number of policy documents and reports from Accra, Belo Horizonte, Cali, Birmingham and Hamburg.

It is believed by many researchers (and indeed one of the assumptions of the SWITCH project) that the underlying approaches should be modified in order to result in more effective and efficient management actions, and ultimately in a sustainable urban water system. In order to develop the new approach case studies were undertaken in Alexandria, Accra and Zaragosa. These case studies were designed to contribute to the testing of the overarching hypothesis of WP 1.1:

‘Design and management of the urban water system based on an analysis and optimisation of the entire urban water system will lead to more sustainable solutions than optimisation of elements of the system’.

The hypothesis will be tested based on the results from research and demonstration activities in the various cities. Not only on the basis of theoretical considerations, but also based on practice in the cities. If the hypothesis is found to be true and of practical value, than it is a strong encouragement to modify the design, planning and management of the urban water system. For example, one should then formulate general sustainability objectives for the entire system, rather than for an element. Equally, one would formulate indicators that measure the state of the entire system, rather than performance indicators that measure the functioning of a subsystem or performance indicators for the organisation that manages a subsystem. Monitoring the value of general sustainability indicators for the entire system will give an indication to policy and decision makers whether the city is moving towards or away from sustainability (economy, environment, society). Based on indicators score the policies and strategies are then adapted.

The objectives of this document are:

1. to review the approaches used in a number of SWITCH cities, by comparing these approaches with the existing paradigm and emerging paradigm previously identified in Deliverable 1.1.1.
2. to describe a new approach to urban water management and to test it in case studies in SWITCH demonstration cities.

2. Existing approaches to urban water management

The Annexes 1, 2 and 3 describe in detail the approach to urban water management taken in Accra, Belo Horizonte and Cali. These approaches are here discussed in short, together with the approach taken in Birmingham (and Hamburg) as reported by Severn Trent (2007) and Hamburg Wasser (2005). In all these five cities the approach that is advocated by the Dublin principles and the European Water Framework directive is recognisable to a large extent in the water sector policies. For instance, the principle of river basin management and stakeholder participation seems to be accepted everywhere. However, the implementation of these policies seems to lag behind, especially in the cities of the developing world. The implementation of river basin management is for instance hampered by the fact that jurisdictive areas are conceived based on political and administrative limits rather than on river basin boundaries (as is the case in Cali for instance).

Some elements of the approach that is advocated by Agenda 21 and the Belagio statement (and also by the draft SWITCH vision; see box 1) are recognisable in the policy documents, but several others are not:

> *'Adoption of a city-wide approach to the management of water resources'*
>
> This approach is not found anywhere explicitly in the documents.
>
> *'The application of infrastructure/technologies/methods that minimise the consumption of energy and materials, or other negative environmental impacts.'*
>
> This approach is not mentioned in Accra, Belo Horizonte and Cali. The need for energy saving is explicitly mentioned in the documents from both Birmingham and Hamburg.
>
> *'The evaluation of effects on investment in wastewater treatment technologies, in comparison to the same effects on water quality that could be achieved in other sectors (agriculture, urban design, pollution prevention etc.)'*
>
> This approach is not found explicitly in the documents.
>
> *'Reuse and recycling of wastewater (or sludge) for appropriate purposes (industry, urban agriculture).'*
>
> None of the documents explicity mentions this approach. Although the WFD stipulates reuse of effluent and sludge wherever possible, neither Birmingham nor Hamburg mention this in their reports. Although these cities are not suffering from water scarcity, one would expect that reuse of municipal effluents for industry would be considered.
>
> *"Individual treatment systems that achieve the same level of environmental protection can be used (decentralized systems), where the establishment of collection systems is not justified because it would generate no environmental benefits or because it would involve excessive costs."*
>
> The issue of centralisation or decentralisation is not addressed in any of the policy documents. Only Birmingham and Hamburg mention the decentralised management of stormwater through SUDS in the documents and also Belo Horizonte is known to apply SUDS. Decentralisation of wastewater management or water supply is not addressed.

When comparing the approaches in the cities with the draft SWITCH Vision, it is clear that statement 1 is adapted in all cities. Especially the European cities and Belo Horizonte stress this element. Statement 2 is not present in any of the documents, maybe because of the theoretical character of it. Showing the practical relevance of this statement is important (see below). Statement 3 is not addressed, none of the cities have a Learning Alliance type of organisation. Although Severn Trent mentions the intention to realise a 'system which encourages innovation' and also intends to improve communication and co-operation between different water sector institutions (between water companies and the regulator in the case of Birmingham). Statement 4 is to some extent reality in Belo Horizonte, since an aggregated indicator (called ISA) is used for decision making concerning investments. ISA is the weighted sum of sub-indicators on water supply, sanitation, solid waste, stormwater, vector control in a particular urban catchment. The ISA can assume values in the interval (0;1); the lower the value the poorer the catchment condition is in terms of environmental sanitation. Therefore, catchments having lower ISA values will be better placed for receiving investments in environmental sanitation infrastructure and service improvements. The other cities seem not to have a system of monitoring the state of the urban water system by using indicators. Obviously performance indicators for the utilities are used in all the cities.

Summarizing, it seems that river basin management is accepted in all cities, although implementation in practice lags behind to a smaller or larger extent. A few elements of the Emerging Paradigm (Bellagio, Agenda 21, draft SWITCH vision) are seen in the European cities (such as the wish to reduce energy consumption reductions), and the use of indicators in Belo Horizonte for decision making. Other elements are still missing, as discussed above.

Box 1. The draft SWITCH General Vision (See Annex 4 for details)

The SWITCH General Vision for Urban Water Management includes the following:

1. *UWM strategies need to be aimed at increasing overall sustainability, which means simultaneously satisfying social, environmental and economic boundary conditions.*
2. *UWM strategies need to aim at increasing the sustainability of the overall urban water system. Optimisation of the entire system will result in more sustainable systems than optimisation of separate elements (sub-systems).*
3. *UWM has the highest chance of success, when based on a learning process in which all water sector institutions are taking part. The City Learning Alliance (LA) is a multi-stakeholder platform that is meant to steer the city towards sustainability. The steps undertaken in this process include a) to agree on a vision for a sustainable urban water system, b) to guide demand-led research to develop innovations that are required to achieve the vision, and c) to upscale successful innovations to the city level.*
4. *The vision for a sustainable urban water system needs to be described in terms of measurable indicators of sustainability. Monitoring (and publication) of the indicators can be used in evaluation of policies, planning and decision making.*
5. *UWM is providing **services to citizens**; it needs to provide equity in terms of equal access to water, sanitation, irrigated green areas and other water related services for each citizen.*

3. New approaches to urban water management

Systems engineering

One of the new approaches advocated in the water sector (Mitchell, 2004; UNESCO, 2007) is 'Integrated Urban Water Management'. There is so far no generally accepted definition of this term. It is proposed here that IUWM can be interpreted as the application of systems analyis and systems engineering to the urban water system. A system is defined as 'a collection of various structural and non-structural (e.g. human) elements which are interconnected and organized in such a way as to achieve some specified objective by the control and distribution of material resources, energy and information' (Smith et al., 1987). For the water system the objective is to create or maintain a safe and clean environment and to deliver water and sanitation services to the urban population. Resources that are used to achieve this objective are construction materials for the various infrastructure components, as well as chemicals, energy and water to run the system.

Systems engineering aims to design systems that are more efficient and effective in reaching the objective as a system, than the individual component would be able to achieve if designed and operated in isolation (Smith et al., 1987). The application of this general statement to the urban water system is the main hypothesis of (WP1.1 of) SWITCH, i.e. that an integrated design and operation of the entire water system is more sustainable than design and operation of the various elements in isolation. This means that the water resource system (rivers, groundwater), the water treatment and distribution network, the stormwater network, the wastewater collection and treatment system, should be designed and operated as one system. Practice in most cities in the world show that this is not generally the case. Analysis of the approach to urban water management in the SWITCH demonstration cities Accra, Belo Horizonte, Birmingham, Cali and Hamburg shows that water management is carried out in a rather fragmented way.

The responsibilities for water supply and sanitation in Accra have recently been separated into two organizations. Water supply is now handled by the Ghana Water Company Ltd. And sanitation by departments of the Accra Metropolitan Assembly. In other cities, the opposite trend is observed. For instance in Hamburg, where the water supply company and the drainage and wastewater company have been positioned within one holding company. One may expect that the latter institutional set-up would make an integrated design and management of the system easier. Although just merging water sector institutions will not achieve this automatically. It is a matter of cooperation, joint design, information exchange, willingness to share and learn.

Institutional boundaries are related to the boundaries of the system that is under analysis. Just like inter or intra-institutional cooperation is important, it is crucial that system boundaries are wide enough, not to externalize important effects, either in space or time. Too narrow system boundaries will result in 'harmful suboptimization' (Hellström et al., 2000).

Systems engineering stresses that both structural and human elements are part of the system. If systems engineering is accepted as an approach in urban planning, it follows naturally that definition of objectives is always a problematic and never an obvious exercise. The human element, in its various organization forms, is an integral element of the system and therefore each stakeholder has its own interest and seeks to achieve different objectives with the urban water system. Whereas shopkeepers in the city center would put budgetary priority at flood prevention measures, environmental groups would prioritize investments towards water quality improvements. And utility customers may primarily be concerned with costs. There is therefore a natural link between systems engineering and Triple Bottom Line assessment (Kenway et al., 2007). The objectives for which the system is designed will always include social, environmental and economic aspects.

Apart from professionals that are needed to design and run the elements of the system, there is also a need for urban water managers that are capable to maintain a 'helicopter view' on the entire system.

The urban water manager is like a system engineer who has to have sufficient knowledge of all elements, so that he or she is able to coordinate detailed investigations. Moreover, the urban water manager needs to evaluate whether the TBL is sufficiently addressed in all planning and decision making.

4. System design, strategy development and strategic urban planning

SWITCH is aimed at the 'city of the future' and therefore can to a certain extent re-design the urban area in order to achieve the sustainability objectives. Designing the elements of the system is addressed in Themes 2 till 5. In Theme 1 the emphasis is on developing strategies for the system as a whole. Its focus is on the development of an overall strategy and the translation of this into 'strategic planning'. A strategy has been defined as "A framework guiding those choices that determine the nature and direction to attain the objective" (Saunier and Meganck, 2004). Strategic planning is therefore the description of the major choices and what these choices mean for the city. And it is fed by data on the urban water system.

The steps in a general process to design a system are (Smith et al., 1987):

- Definition of objectives and identification of design criteria
- Generation of design alternatives
- Testing of feasibility of proposals
- Optimisation and refinement of design to maximize effectiveness.

This general process was translated to planning for the urban water system and adapted to the need of strategic planning. The SWITCH strategic planning methodology was adapted from the EMPOWER project (Moriarty, pc) and Foxon et al. (2002). The different steps in this planning process are indicated in Figure 1. Key elements are:

Visioning and sustainability objectives
A vision is "a concise description of a desired future. Visions provide a picture of how we would like the world (or our water resources and services) to be at some agreed future time" (Moriarty, pc). The next step in the process is that the vision is translated in a set of SMART objectives. We may call these objectives 'sustainability objectives', since the overall aim is to reach a sustainable urban water system. Once the objectives have been agreed by the Learning Alliance, we could formulate one or more sustainability indicator for each sustainability objective.

Scenario development
After the vision and the set of sustainability indicators has been agreed, the Learning Alliance's will formulate a number of possible future scenarios. "Scenarios are stories about the way the world might turn out tomorrow. A scenario is a consistent description of a possible future situation as determined by those factors that are both most important and most uncertain" (Moriarty, pc).

Strategy development
Subsequently, the Learning Alliance will work out different strategies that are aimed to reach the vision under the conditions of a certain scenario. The scenarios and strategies that are currently being developed in workshops in the cities are to a large extent qualitative, without a data-based and in depth analysis. This in-depth analysis, using research and demonstration results of the SWITCH project, will be discussed during the workshops 3 and 4. Finally, a City Strategy, based on solid data and in depth analysis will be agreed and adopted on the final workshop on the City Strategy for 2030.

The Visioning workshops will result in city-specific visions. In addition to that a more general SWITCH vision is formulated, as a tool for discussion within the consortium and for disseminating the project result to a wider audience. Based on this general SWITCH vision a set of sustainability objectives and indicators is proposed (see Annex 5).

Although the strategy development is presented here as a linear process, in reality its nature is much more cyclic. After every step in the process the planners need to check previous steps; is the vision still the same and still achievable? Have scenarios changes, for instance due to the availability of new data? Have new strategies emerged, for instance due to the development of new technologies?

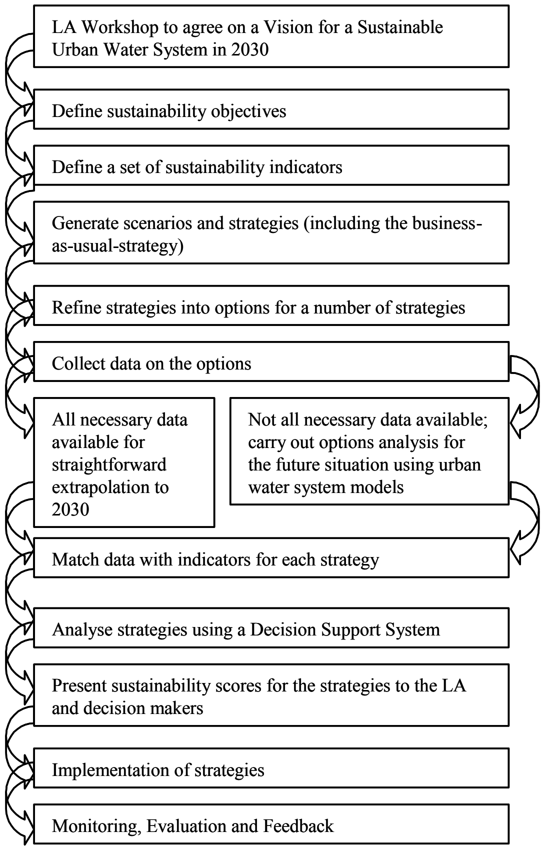


Figure 1. the role of sustainability indicators in the planning process. (Adapted from Foxon et al., 2002)

5. Sustainability indicators

According to Lundin (2003) indicators are pieces of information, which summarize important properties, visualize phenomena of interest, quantify trends and communicate them to relevant target groups. They are useful tools in decision making when additionally a) provide information for spatial comparison, b) provide early warning information and c) anticipate future conditions and trends

A city that is going through a process of re-designing or developing its urban water system for the future, obviously would like to know where it is going. Is it getting nearer to sustainability or not? Firstly, one has to recognize that sustainability cannot be measured in absolute way, such as the pH of a water sample. Sustainability is in fact defined by the stakeholders, that give different weights to different TBL aspects (see Annex 4 for details).

In a strategic planning process, SIs can be used to measure to what extent the sustainability objectives have been achieved. Since the idea is that the sustainability objectives are developed jointly with all stakeholders, one may assume that the set of sustainability indicators are also agreed by the stakeholders. The coordinating institution for urban water management is supposed to coordinate a process by which the data to score the indicators is collected. The result for the different indicators is then used (typically) once per year or once per two years. The score of the indicators is then used to evaluate whether the cities strategies, policies and projects are effective in reaching the objectives. If it is noticed that for some indicators the city is moving away from sustainability, the strategies need to be adjusted. Cities that have a system for indicator data collection and publication in place are Hamburg, Sydney, Tel Aviv and others.

Some indicators are simple to measure, such as the drinking water quality. Other indicators are aggregate indicators and need certain assessment tools to be scored. Such assessment tools include cost-benefit analysis, functional risk analysis, microbial risk analysis, life-cycle assessment, sensitivity analysis, material flow analysis, behaviour/attitude investigations based on interviews and action research (Hellstrom et al., 2007), various financial assessments, embodied energy assessment, ecological footprint and multi criteria assessment (see Kenway et al, 2007 for overview).

6. Case studies

A number of case studies was undertaken in SWITCH demonstration cities to test the hypothesis that design and operation (optimization) of the urban water system in an integrated way results in a more sustainable system than optimization of the individual components would do. The methodology followed was basically a systems analysis approach (Zaragossa), combined with Life Cycle Analysis (Alexandria) or Microbial Risk Assessment (Accra).

Case study Zaragoza (see Annex)

The environmental performance of the urban water system of Zaragoza (Spain) was analyzed by means of systems analysis and a LCA methodology, with a focus on the water withdrawal and use, energy and chemical consumption, CO_2 emissions and emissions of nutrients and heavy metals to the receiving water body and to sewage sludge. The system is shown in Figure 2. The study covered a period of six years between 2000 and 2006. In this period the water supply system of Zaragoza was optimized which resulted in reductions in domestic and industrial water consumption. However, results show that despite a significant reduction of water withdrawal and unaccounted-for-water, resource consumption and final releases to the environment have remained steady.

It shows that assessing the sustainability of the urban water system by only looking at the water consumption can be misleading; although the water consumption in 2001-2006 was reduced by 20%, the energy consumption in both the water supply and wastewater treatment sectors remained constant. This could only partly be explained by the increase in population (and pollution load to the WWTP's) of 7% in the same period. Energy consumption in the pumps and other equipment in use in Zaragosa is apparently relatively independent from flows. Further analysis is needed on how to reduce energy consumption as well as chemical use. The chemical use also remained constant during the 2001-2006 period.

The systems analysis of the urban water system of Zaragosa was also used to develop scenarios and strategies for the future. Since further per capita water consumption is not likely to reduce it was felt that reductions in industrial water consumption (currently 40% of overall water consumption) are most promising. Recycling industrial wastewater would save energy for pumping groundwater, but would mean some extra energy costs for wastewater treatment. A first estimate was made and showed that 30% of industrial wastewater recycling would reduce the overall water consumption by 10% by 2020, and the energy consumption in the water system by 3%. It shows that this type of measures are not sufficient to reach the EU policy goal of a 20% reduction in 2020.

A problem tree analysis revealed that mayor drivers of environmental sustainability for Zaragoza water cycle are population increase, Spanish national policies on water and environment and climate change. A scenario analysis showed that industrial recycling would be a good strategy to continue reducing water withdrawal and it will also contribute to reduce energy consumption as well as CO2 emissions, whereas all other analyzed indicators are expected to worsen as long as current societal production and consumption patterns and wastewater treatment technologies remain the same. Comprehensive strategies that involve not just technical solutions are required in order to assure the environmental sustainability of this system.

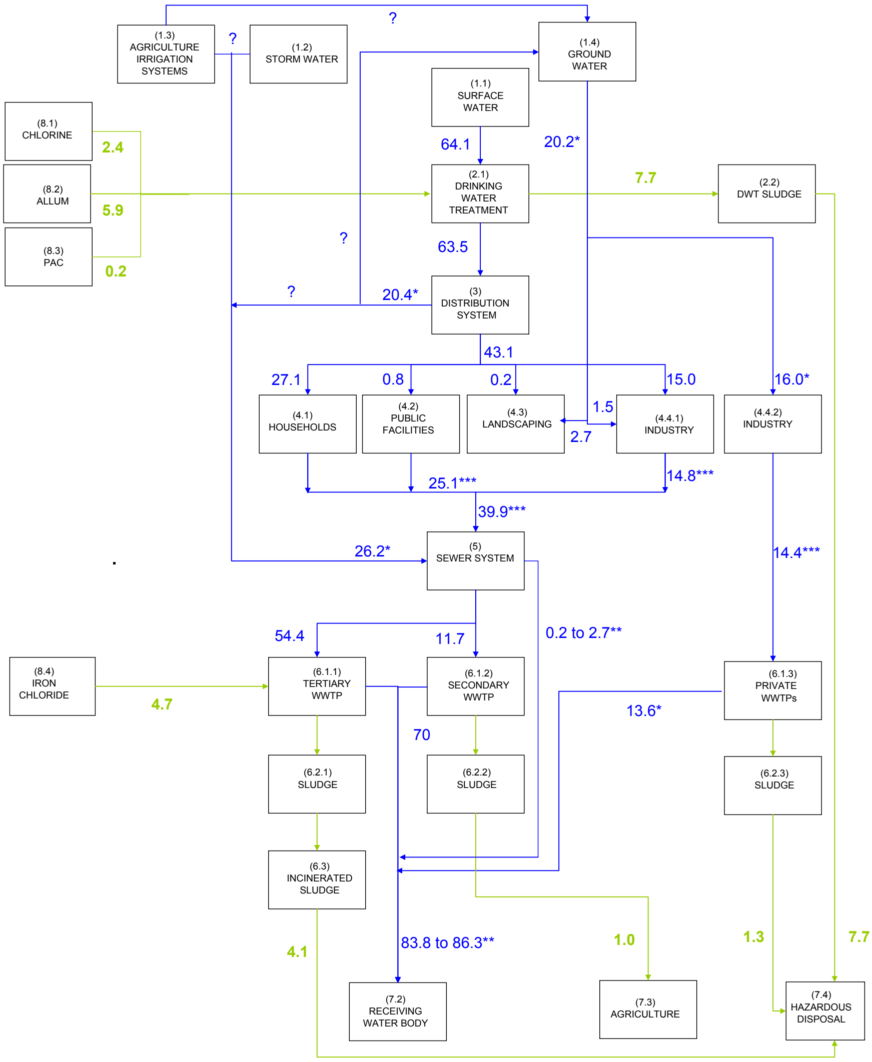


Figure 2. Flow Diagram for Zaragoza UWS. Lines and numbers in blue stand for water flows (units are million m^3 per year). Chemical products as well as sludge flows are represented by lines and numbers in green (units are thousand tons per year). Data used for this diagram are from the year 2006.

* Values that have not been measured but estimated
** Storm water overflows were estimated for the period 2001 – 2006 and are completely different between years. Therefore an average value is not given, but rather a range.
*** 90% of water use is assumed to go to the wastewater system
? Indicates balances that could not be completed due to information gaps
Values that have been actually measured are not given any mark in this figure

Year	Withdrawal (million m^3 per year)	Population (thousand inh)	Average consumption (l $person^{-1}$ day^{-1})
1997	84.7	601.6	139.8
1998	80.2	606.0	132.2
1999	80.4	607.3	132.2
2000	79.3	608.1	129.4
2001	79.7	613.4	128.8
2002	74.5	622.6	124.6
2003	71.7	628.4	122.4
2004	70.8	641.6	123.3
2005	68.2	650.6	118.0
2006	64.1	657.0	110.0

Table 1. Decreasing water consumption in Zaragosa

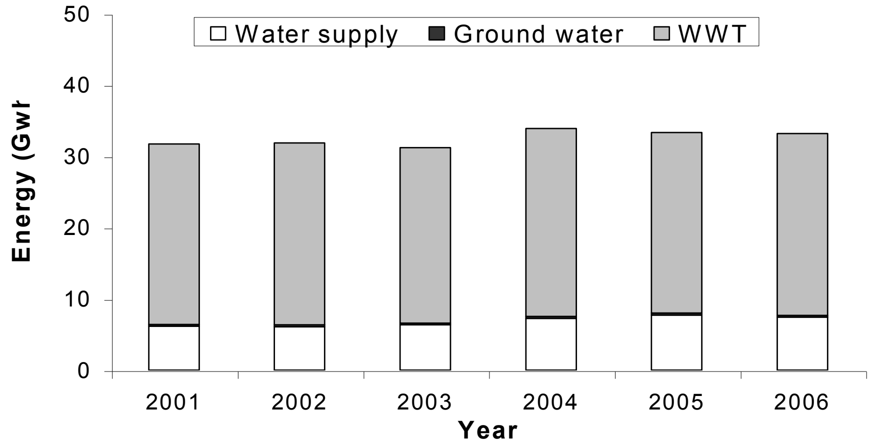
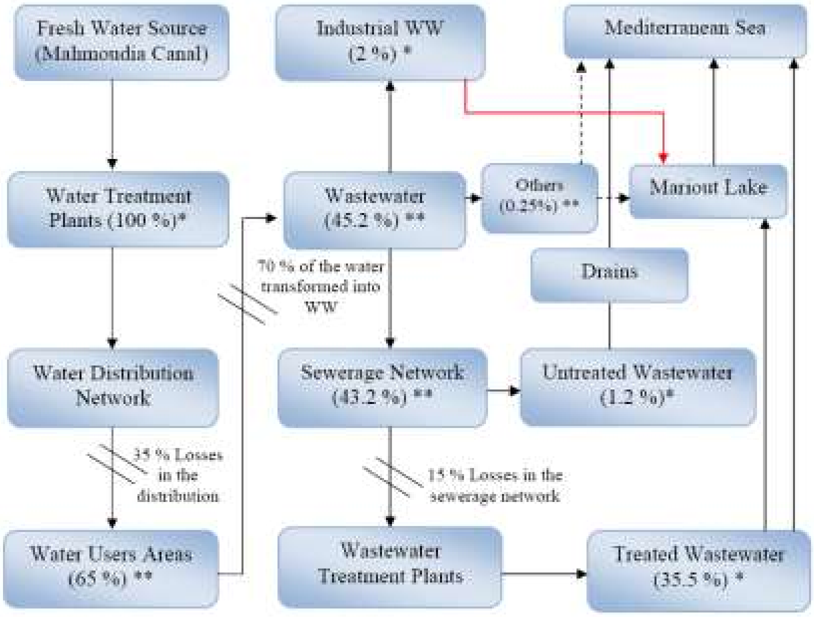


Figure 3. Energy consumption in the water system of Zaragosa

Case study Alexandria (see Annex 7)

A similar systems analysis was carried out in Alexandria, but now extended to include a full LCA analysis, including impact assessment step. The aim was to advice decision makers on the most effective measures to improve the overall sustainability of the system. The first steps in the assessment were a water balance (see Figure 4), a nutrient flow analysis and an inventory of chemical and electricity use. The total water production (100% in Figure 4) is 2.3 Mm3/day. Total nutrient production is 38 tons of nitrogen and 7 tons of phosphorous.

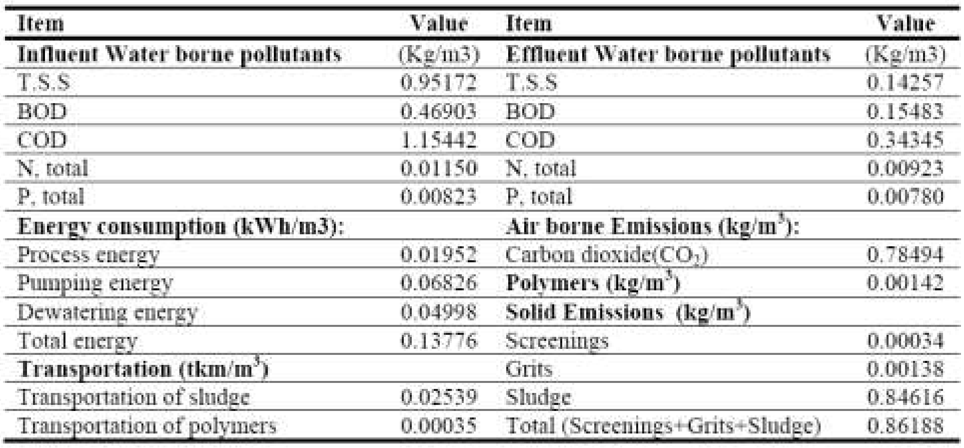
The software SimaPro was used in this research to conduct the LCA for Alexandria's urban water system and its components. SimaPro software (System for Integrated Environmental Assessment of Products) is one of the most widely used software in carrying out LCA studies. It uses the standard ISO methodology to carry out LCA studies.



Note: * refers to collected data, and ** refers to calculated data

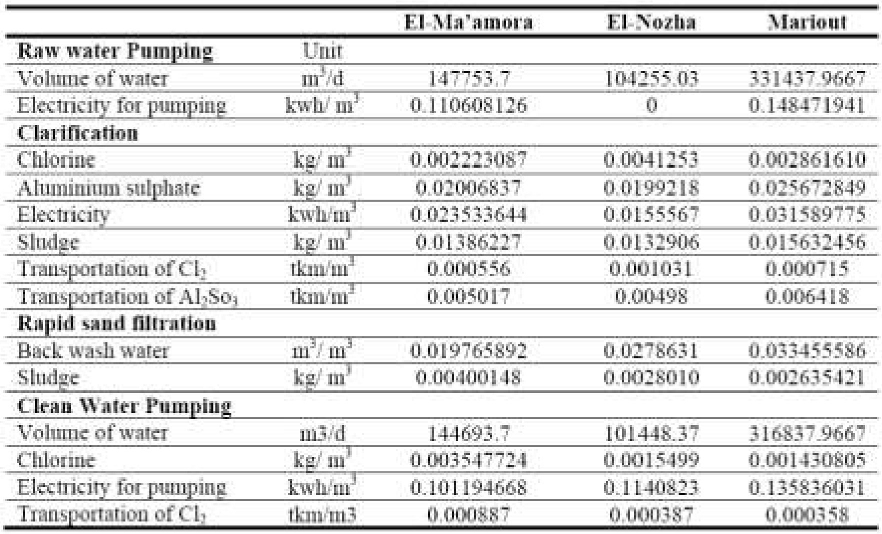
Figure 4. Water balance for Alexandria

Table 2. Data for the West Wastewater Treatment plant used in LCA assessment



Item	**Value**	**Item**	**Value**
Influent Water borne pollutants	(Kg/m3)	**Effluent Water borne pollutants**	(Kg/m3)
T.S.S	0.95172	T.S.S	0.14257
BOD	0.46903	BOD	0.15483
COD	1.15442	COD	0.34345
N, total	0.01150	N, total	0.00923
P, total	0.00823	P, total	0.00780
Energy consumption (kWh/m3):		**Air borne Emissions (kg/m^3):**	
Process energy	0.01952	Carbon dioxide(CO_2)	0.78494
Pumping energy	0.06826	**Polymers (kg/m^3)**	0.00142
Dewatering energy	0.04998	**Solid Emissions (kg/m^3)**	
Total energy	0.13776	Screenings	0.00034
Transportation (tkm/m^3)		Grits	0.00138
Transportation of sludge	0.02539	Sludge	0.84616
Transportation of polymers	0.00035	Total (Screenings+Grits+Sludge)	0.86188

Table 3. Chemical use and electricity consumption in one of the water treatment plants in Alexandria. Data used for LCA.



		El-Ma'amora	El-Nozha	Mariout
Raw water Pumping	Unit			
Volume of water	m^3/d	147753.7	104255.03	331437.9667
Electricity for pumping	kwh/ m^3	0.110608126	0	0.148471941
Clarification				
Chlorine	kg/ m^3	0.002223087	0.0041253	0.002861610
Aluminium sulphate	kg/ m^3	0.02006837	0.0199218	0.025672849
Electricity	kwh/m^3	0.023533644	0.0155567	0.031589775
Sludge	kg/ m^3	0.01386227	0.0132906	0.015632456
Transportation of Cl_2	tkm/m^3	0.000556	0.001031	0.000715
Transportation of Al_2So_3	tkm/m^3	0.005017	0.00498	0.006418
Rapid sand filtration				
Back wash water	m^3/ m^3	0.019765892	0.0278631	0.033455586
Sludge	kg/ m^3	0.00400148	0.0028010	0.002635421
Clean Water Pumping				
Volume of water	m3/d	144693.7	101448.37	316837.9667
Chlorine	kg/ m^3	0.003547724	0.0015499	0.001430805
Electricity for pumping	kwh/m^3	0.101194668	0.1140823	0.135836031
Transportation of Cl_2	tkm/m3	0.000887	0.000387	0.000358

The assessment of Alexandria's urban water system showed that (see Figure 5):

- The WWTPs represented about 68 % of the total impact of the system,
- The water treatment plants represented about 18 % of the total impact of the system,
- The water transportation represented about 4.5 % of the total impact of the system,
- The wastewater transportation represented about 2 % of the total impact of the system, and
- The untreated wastewater represented about 7 % of the total impact of the system.

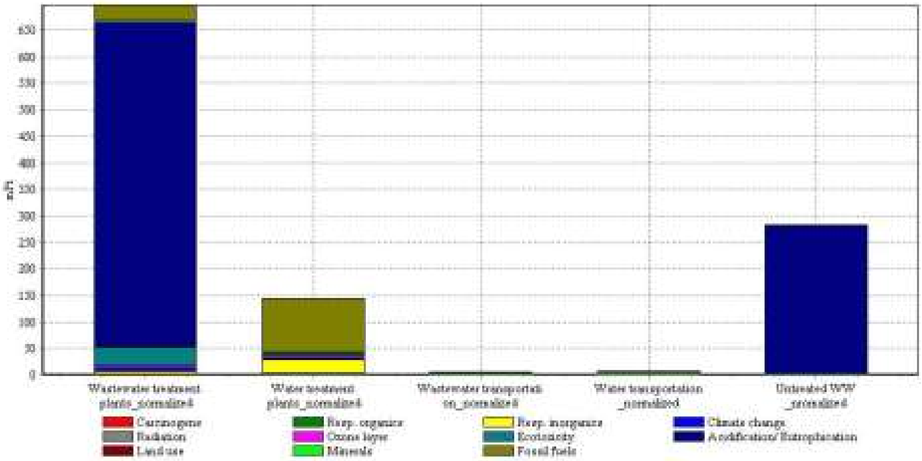


Figure 5. Total environmental impact (in mili Ecopoints) of the various elements of the urban water system.

After the current system was assesses, the following strategies for improvement were proposed:

1. Technical Interventions:

a. Scenario No.1: Upgrade the primary treatment plants to secondary treatment with nitrogen and phosphorous removal units by the use of activated sludge technology. The sludge treatment will remain as it is in the current situation. The treated effluent will be used in irrigation, therefore the secondary effluent will be polished in a sand filter and chlorination unit.

b. Scenario No.2: The use of green energy in pumping of water and wastewater by the use of solar energy driven pumps.

2. Improved Management:

a. Scenario No.3: This scenario will depend on decreasing the losses in the drinking water distribution network to be 10 % instead of the current 35 %. In addition, demand management will decrease the demand for water with about 15 %.

b. Scenario No.4: Extending the sewerage network to collect the wastewater that is currently not collected. This wastewater will then be treated by the current treatment plants (the capacity of the wastewater treatment plants can handle this amount). The amount of additional wastewater is about 81,000 cubic meters per day.

3. Paradigm shift:

a. Scenario No.5: A decentralized wastewater treatment system proposed by Tillman et al. (1998) was analysed. The system is based on the separation of different kinds of waste to be treated separately. The system separates the urine, the faeces and the grey water. The urine will be used in agriculture directly. The faeces will be dried using drying beds and then transported to be used for land application. The grey water will be pre-treated to separate the sludge which will be dried and reused for land application and then the effluent of the pre-treatment will be send to sand filter beds to be treated and reused in irrigation. The system will be used only for the domestic wastewater. The industrial wastewater and the storm water will be handled in the same way as in the current situation.

b. Scenario No.6: In this scenario the same system used in the previous scenario will be used for the treatment of the domestic wastewater. In addition the industrial wastewater and the storm water will be treated in an activated sludge plant with nutrients removal unit in the same way as in the first scenario.

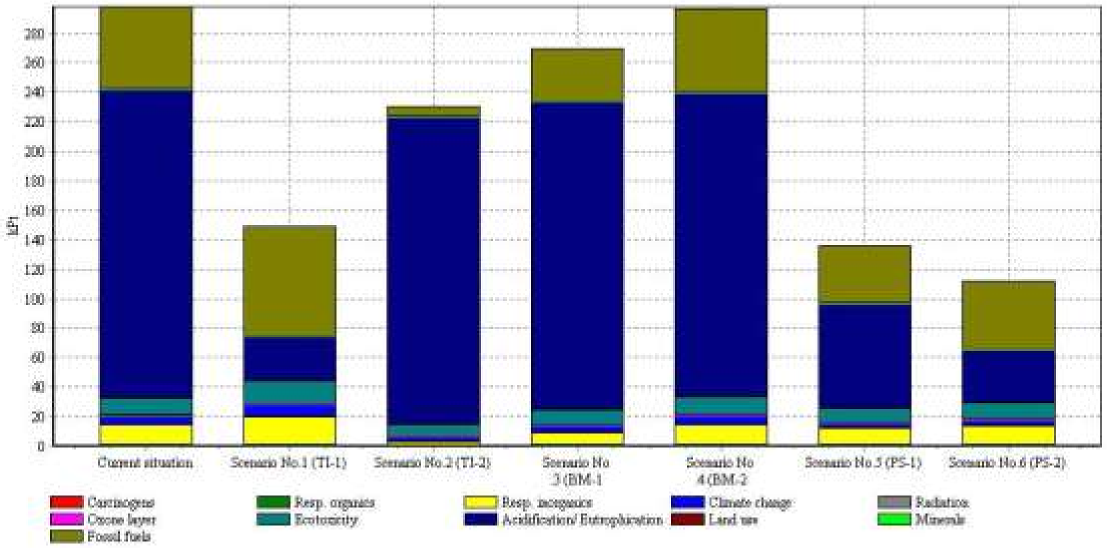


Figure 6. Total impact for different scenarios

Figure 6 shows that providing activated sludge with nutrient removal (scenario 1) gives good results, although the percentage reduction in total environmental impact is much smaller than the treatment efficiency for BOD and nutrients of the treatment plant. This is caused by the increase in use of fossil fuels in scenario 1. Scenario 2,3 and 4 give limited improvements, mainly because the nutrients from the wastewater continue to cause eutrophication of Lake Mariout and the Mediterranean. Striking is that scenario 4 (extending the sewer system to collect all wastewater) does not improve the overall environmental impact at all. Scenario 5 and 6 (paradigm shift) give similar results as scenario 1. These scenarios however would require enormous changes in the way the urban water system is managed. Both in terms of infrastructure provision (from centralized to decentralized) and in terms of utility management.

The information generated by the LCA gives decision makers a more holistic picture of the cities urban water system. And it allows the evaluation of the total environmental impact of various scenarios. It shows that some scenarios have hardly any overall effect, although they may be rather costly (like extending the sewer system). A serious limitation of the LCA methodology is that it does not include a social and economic evaluation of the different scenarios.

Case study Accra (see Annex 8)

In Accra a different methodology was used to test the same hypothesis, namely that optimal design of the urban water system and its management is best done taking an integrated approach. Quantitative Microbial Risk Assessment was used to quantify the health risks for citizens originating from the urban water system. The procedure for quantitative microbial risk assessment outlined in Haas et al., (1999), was followed. The steps are as outlined below:

1. Hazard identification

A hazard was defined as the pathogen that causes waterborne diseases. Literature review was done in order to identify waterborne pathogens that were detected in sewage in Ghana. Four reference pathogens, were chosen to represent bacteria, viruses, protozoa and helminths. These were *Campylobacter,* rotaviruses*,* *Cryptosporidium* and *Ascaris* respectively.

2. Exposure assessment

A comprehensive field survey was done (between November 2006 and January 2007) in order to determine the possible exposure points and population. This was complemented with interviews from water/wastewater experts. Exposure volumes for the sanitation pathway were estimated from literature, while exposure doses were determined from data obtained at the water treatment plants (water supply) as well as literature (sanitation). The exposed population was determined by field surveys and by interviews with people with knowledge on the particular exposure point. The 2000 national population census was used to determine the population exposed to flooding of the Odaw drain, open drainage channels and contaminated water supply.

Table 4 outlines exposure assessment in the sanitation pathway. These were then grouped into 5 major pathways: Recreational swimming (exposure 1), flooding of the Odaw drain (exposures 2-4), UASB treatment plant (exposures 5-7), faecal septage disposal point (exposures 8-10) and Open drains (exposure 11).

Table 4: Points of exposure from the sanitation pathway with assumptions on ingestion volumes, frequency and number of exposed population

Type of exposure	Volume ingested (ml)	Frequency (per year)	Exposed population
1. Recreational swimming	100	7	29,878
2. Unintentional ingestion of flood water	1	1	111,790
3. Unintentional immersion at lagoon	30	1	10
4. Children playing in flood water	1	1	23,699
5. Workers desludging the UASB treatment plant	5	12	10
6. Workers removing debris from the UASB inlet works daily during the rainy season	1	90	10
7. Workers taking samples from the UASB inlet works for laboratory analysis	0.1	1	3
8. Workers handling septage at the faecal septage disposal place	1	317	100
9. Children playing with contaminated sand at the faecal septage disposal place	5	2	8037
10. Fishermen ingesting contaminated water at the shore next to the faecal septage disposal point	1	1	10
11. Children playing near open drainage channels	5	4	81,272

Table 5: Points of exposure from the water supply pathway with assumptions on ingestion volumes, frequency and number of exposed population

Type of exposure [a]	Volume ingested (litres)	Frequency (per year)	Exposed population
1. Power outage at Weija treatment plant	2.9	3.6	646,986 [b]
2. Filtration error at Weija treatment plant	2.9	1	646,986 [b]
3.Disinfection error at Kpong treatment plant	2.9	365	348,378 [c]
4.Coagulation error at Kpong treatment plant	2.9	365	348,378 [c]
5.Filtration error at Kpong treatment plant	2.9	1	348,378 [c]
6. Contaminated distribution system	2.9	146 [d]	944,678 [e]
7. Pollution entering part of system without pressure (108 hours per week) [f]	2.9	234	298,609
8. Pollution entering part of system without pressure (120 hours per week) [g]	2.9	260	348,378

[a] Exposures 1, 2, and 5 were based on incidents while 3 and 4 were based on normal operations at Kpong treatment plant ; [b] 65% of AMA population; [c] 35% of AMA population; [d] 40% of the year, estimated from a previous research findings (Cobbina, 2004)

[e] Population of Odaw catchment without the population of Accra New Town (50,685) as it is without water supply; [f] 30% of the population receive water 12 hours a day, five days a week (Wateraid, 2006); [g] 35% of the population receives water twice a week (Wateraid, 2006).

3. Dose- response assessment

The dose response relationships used were adopted from Haas et al., 1999 (*Campylobacter* and rotaviruses) and Teunis *et al*. (1996) (*Cryptosporidium* and *Giardia*). For *Ascaris,* the dose response model for *Giardia* was adopted as they were assumed to have the same infective dose (Bitton, 2005). The formulas for annual infections and symptomatic cases were adopted from Haas *et al*. (1999).

4. Risk characterizations

The results were expressed as annual probability of infections per person per exposure; annual number of infections and annual symptomatic cases per exposure route. Number of symptomatic cases per pathogen from all exposure routes was then summed up in order to be compared with the endemic waterborne disease incidence in Accra, which was estimated from reported cases, and adjusted for underreporting. A ranking was then performed according to suggested definitions of severity of consequences in Westrell et al., (2004).

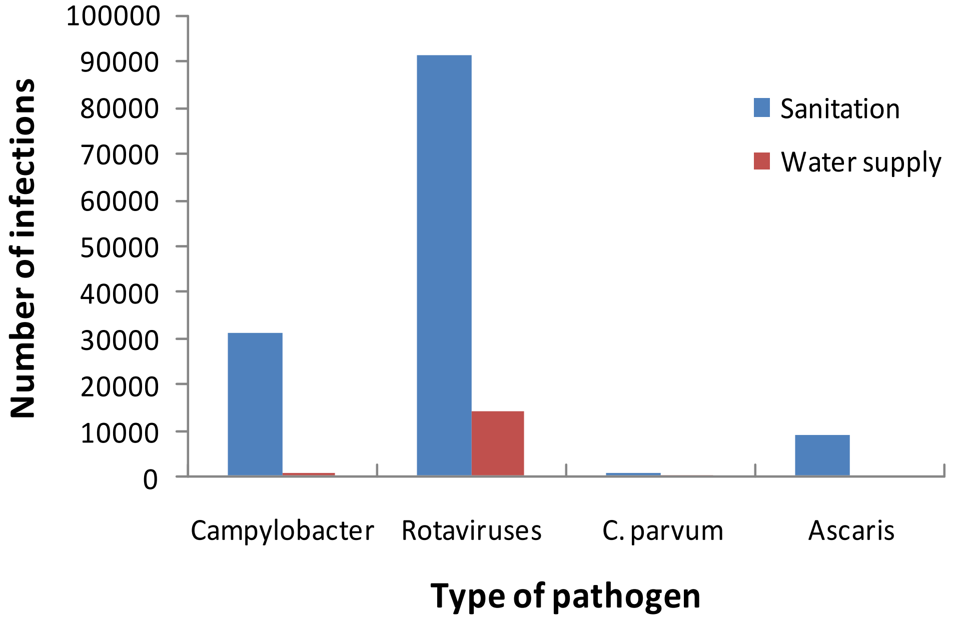


Figure 7. Predicted number of infections based on QMRA for the Odaw Catchment in Accra, caused by the sanitation and water supply pathways.

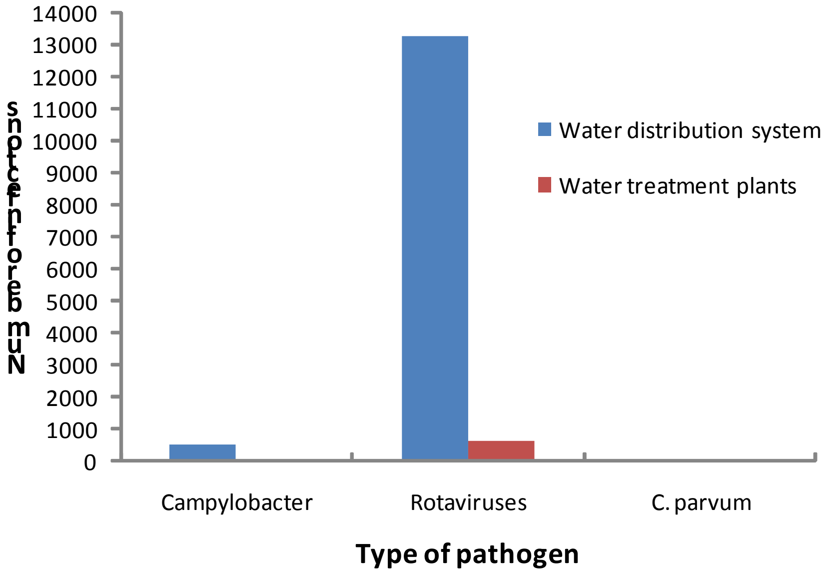


Figure 8. Annual number of infections caused by failures of the water treatment plants and the distributions system.

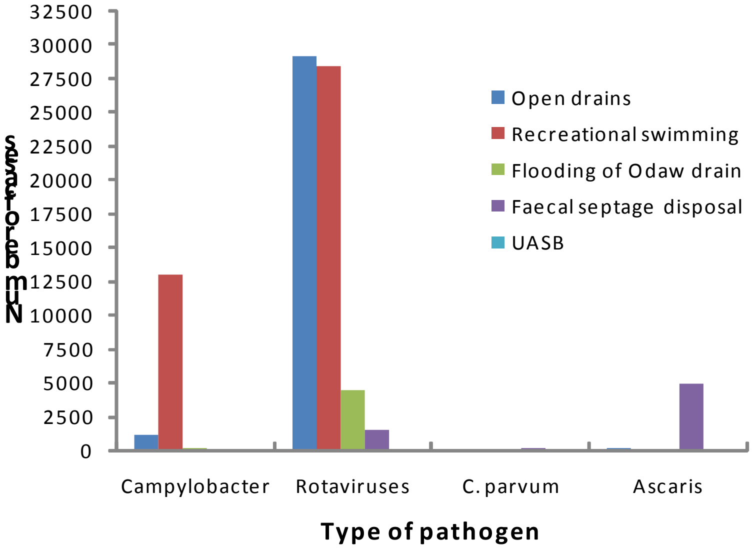


Figure 9. Annual number of infections from the various pathways of the sanitation system

The MRA shows that the risk originating in the sanitation system is significantly larger than in the water supply system (Figure 7). It also shows the relative importance of the water treatment versus water distribution systems (Figure 8). Figure 9 shows the number of infections caused by the various pathways of the sanitation system. The next step in this research line is to assess the costs and effects of various interventions, in order to calculate the efficiency of interventions in (risk reduction)/(Euros invested). This information can be used by decision makers to evaluate different plans. It shows again that effective management of the urban water systems needs this kind of integrated assessment. Decision makers could decide, for instance, not to put priority with investments in further improvements of drinking water quality, while most infections result from the sanitation system.

7. Evaluation of integrated assessment methods

Data requirements and uncertainties

The three case studies have shown that a lot of data is required for a proper integrated assessment and that in none of the city all required data is readily available. Therefore assumptions had to be made hat introduce large uncertainty in the analysis. Within the SWITCH project there is some capacity to fill the data gaps by new research projects (MSc, PhD) in the coming years. But in fact cities need to invest more in collection, archiving and making accessible this kind of datasets. The lack of data and the dispersion of data over many institutions is not only the case in developing countries but also in Europe. On-going work in Hamburg has shown that data required for an integrated assessment in one of the most advanced cities in Europe is also spread and fragmented over many (municipal) institutions. In fact this is not surprising, since this type of integrated assessment is cross-cutting, and cuts through traditional system and institutional boundaries.

The lack of data and the need for assumptions introduced uncertainty. On-going work on risk assessment and decision making (PhD Krishna Khatri) will give more insight whether this uncertainty will or will not prevent this approach to be used for strategic decision making.

Complexity

The integrated assessment methods (especially the LCA and QMRA) require specialist knowledge to be fully understood. Although the general principles could be communicated to decision makers, ultimately they need to rely on interpretations by specialists. LCA and QMRA results still need to be translated in a small set of key indicators, that summarise the results and provide the necessary information to decision makers. An on-going study in Zaragosa addresses this challenge.

Tool for strategic planning

Because of the complexity of systems analyis, LCA and QMRA they are not directly suitable to be used in strategic planning. It is suggested that these methods are used to score indicators, that urban planners feel comfortable with. The link between these methods and the indicators strengthen the scientific basis under the use of indicators. In that sense this suggestion is an improvement to the current situation, in some cities, where indicators are selected rather haphazard and without scientific basis.

Conclusions

The approach to urban water management in Accra, Birmingham, Belo Horizonte, Cali and Hamburg have incorporated the ideas of Integrated Water Resources Mangement, such as a river basin approach and the involvement of stakeholders. Implementation in practice of these ideas lags behind to a smaller or larger extent. A few elements of the Emerging Paradigm (Bellagio statment, Agenda 21, draft SWITCH vision) are seen in the European cities (such as the wish to reduce energy consumption reductions), and the use of indicators in Belo Horizonte for decision making. However, most elements of the Emerging Paradigm play only a marginal role. There is, so far, no city that has made a real switch towards full implementation of all (or most) elements of the emerging paradigm.

The studies on the application of systems analyis, systems engineering, Life Cycle Analysis and Quantitative Microbial Risk Assessment in the demonstration cities have shown that an integrated analysis and design of the urban water system is possible. The tools for analysis are available and within a relatively short period, a general picture of the urban water system can be created and the effect of different strategies can be evaluated.

However, two major challenges remain. Firstly, to overcome the lack of sufficient data (availability and accessibility) to do more detailed integrated assessments. Secondly, the results of the assessments can only be used for decision making and strategic planning after the results have been translated into a limited number of relatively simple indicators.

Further research will focuss on the translation of the results from integrated assessment methods into sustainability indicators that are feasible for use in strategic planning.

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