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New perspective of urban water systems: meeting the sustainability challenge

PRATAP RAVAL and TOM DONNELLY
Department of Civil Engineering, University of Newcastle, Newcastle upon Tyne, NE1 7RU, UK.

Abstract
Nineteenth century urban water technology is no longer suitable for 21 St century cities. Increasingly large amounts of water to be imported from catchments located further and further away. Management of water and wastewater in the urban environment has become increasingly complex, and storm water and sewage prove difficult to keep separate and out of the local waterways. The infrastructure investment required to develop and maintain these systems is also high The refurbishment of ageing assets is a multi-billion rupee problem for water industry and the environmental impacts of the operation of these systems are already significant in many cases. A very basic problem of open material flows resulting in accumulation of pollution is not adequately addressed in present practices of water and wastewater resource management. These and other issues such as growing awareness of the environmental implications of current systems clearly demonstrate the need for a fundamental rethink of the way in which urban water services are provided. This paper deals with some of the strategic issues arising from the consideration of the sustainable development of urban water systems. Principles and best practices are discussed, both in general terms and challenges to professionals involved with the co-ordinated planning and management of urban water systems at river catchment levels.

INTRODUCTION

In the new millennium, the effective management of water resources will become a critical issue, especially as the world's population continues to increase. To meet the demand for water, wastewater an undervalued resource, will become a valued source of water. Urban water systems are designed to provide a number of basic functions including, the provision of a safe and reliable water supply, efficient transport of water into the home and waste from the home, safe treatment and disposal of wastewater and management of stormwater including flood protection. The current approach to design has essentially evolved from 19 th century European experience to control water-borne infectious diseases. Due to this, increasingly large amounts of water to be imported from catchments located further and further away. The volumes of wastewater become very large, requiring large and complex sewer systems attached to sewage treatment plants for safe disposal. The infrastructure investment required to develop and maintain these systems is also high. The economic and environmental impacts of severely reducing environmental flow in supply catchments and localised impact of large scale sewage disposal were not taken into account in the environmental impact assessment (EIA) of these programme and projects.

Despite of demand management measures over past few years, population growth in our major urban centres is placing an increased total demand on our water supplies. If we need to exploit new water resources and manage the impacts on these already used, innovative ways of designing the systems will need to be developed. Sustainable development of Urban water systems will involve a closer integration of water and material recycling loop with natural environment and concentrated efforts to minimise waste and primary resource consumption. This paper discusses the concept of sustainability and possibility of alternative approach to design of urban water systems. The approach advocated is not to strive for the unsustainable goal of completely sustainable systems, rather to actively promote " relative sustainable" systems.

Urbanisation and its impact on water cycle

Water protection is a common interest throughout the world. In recent years we have to come to realise that we have made too little use of the opportunities water offers for improving the quality of the built and natural environment, allowing ourselves to be attracted too often by the technically possible. The natural water cycle is dominated by many technical and socio-economic decisions but this is rarely realised. There are strong interaction between the urbanisation process, the discharge of wastewater due to individual, industrial and collective water consumption, the transfer of pollutants in storm water runoff, and their impacts on natural surface and ground waters. Water is continuously being transformed and transported (Fig.1).

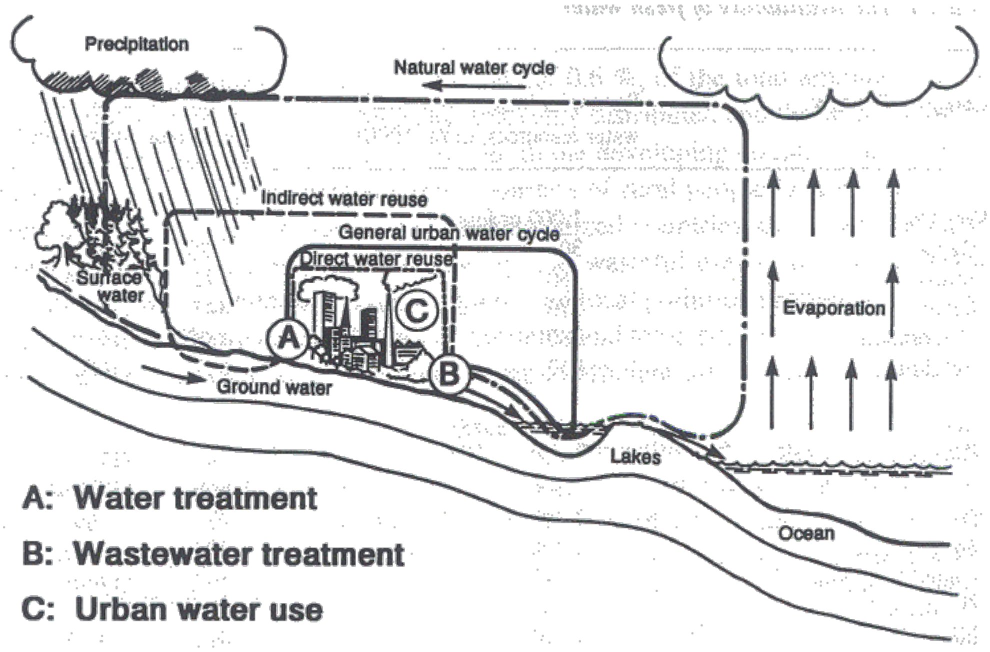

Figure 1. The natural water cycle. The smaller cycles illustrate how increased human use of water shortens the cycles, making a higher efficiency necessary for the wastewater treatment plant in order to cope with a stormwater surge. (Source, MISTRA, 1996).

Urbanisation in the present and prospected form is one of the most drastic global changes that mankind has ever faced. It will touch most humans in coming decades, in developing countries in particular. (Varis and Somlyody, 1997) Historically, the development of reliable water and sewerage systems has been a determinant of the growth of large cities. The growth rate of water and land resource problems is very rapid. Urban wastewater and stormwater pollution is now increasingly recognised for what it is-an accumulative contaminant and, in some cases, even toxic. Environmental messages are continually being observed, with eutrophication of waterways being the most notable example. Currently about 80% of all citizens in the European Union live in cities with more than 10,000 inhabitants and half of them in cities with more than 50,000 inhabitants. (Jan Rotmans et.al, 2000). The picture in Indian context is quite different.

With only 27% of Indian population living in urban areas, it is often proclaimed that Indian lives in its villages. However, in terms of absolute numbers the 217 million urban residents would themselves make up one of the largest countries in the world. With moderate growth of urban population, it is estimated that by 2015 AD over 50% of Indian population will be living in urban areas and there will be over 50 cities with a population of one million and above. Increased consumption of water for various uses has increased the generation of wastewater in Indian cities. Untreated or partially treated wastewater discharged in surface water bodies has contaminated the aquatic resources of the country. In survey conducted by the Central Pollution Control Board in 1988 the total volume of wastewater treated by 212 Class I cities was 22% and of the 241 Class II towns was only 2%. The situation of wastewater treatment is not satisfactory even in metropolitan cities. The 12 metropolitan cities has treated only 30% of total volume of wastewater generated.(Mehta D. et.al, 1994)

An important but often unrecognised dimension of the urban water cycle is the provision of ecosystem services. Town and cities directly and indirectly benefit from ecosystem services such as water supply and waste assimilation. Increased recognition and understanding of the role of the many ecosystem services is required and the value of these services needs to be factored into decision-making.

THE QUEST FOR SUSTAINABLE DEVELOPMENT

There is enough for everyone's need
There is never enough for everyone's greed

Mahatma Gandhi.

In 1987, the World Commission on Environment and Development produced a report commonly known as the Brundland Report, which defined sustainable development as

development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable development is part of the wider concept of sustainability. Sustainable development become the central them of the UN Earth Summit at Rio de Janerio in 1992.The application of sustainable development concept to urban water systems present number of difficulty which may not be solvable. One definition of 'sustainable' revolves around the concept of simply maintaining the capability of providing affordable water services over the long term. Such definition ignores the impact and changes imposed on the external aquatic environment and long term implication of any subtle changes to its ecological balance. A much stricter definition of sustainability demands little to no impact on receiving and source waters. Sustainability lies somewhere between these two opposing views but unfortunately, a detailed definition has not been uniformly accepted. Even though concept of sustainable development has never been formulated very precisely, many working definitions exist, including the one proposed by the American Society of Civil Engineers (1998):"Sustainable water systems are designed and managed to fully contribute to the objectives of society, while maintaining their ecological, environmental and hydrological integrity, and meeting the demands to the system without its degradation, now and in the future".

The multidimensionality expressed by definitions of sustainable development emphasises that thinking in terms of economic costs and benefits is no longer sufficient; social, cultural and environmental aspects have to be incorporated into the decision making process, especially with regards to long-term effects. The widely accepted definition of sustainability, from the Brundland Report (WECD, 1997), are rather vague and imprecise. Sustainable development should therefore be viewed as a much broader concept than environmental protection (CEC, 1994), or indeed health and safety protection, and hence sustainable solutions should seek to address the sustainable utilisation of water resources respecting both social and economic as well as environmental interests (Maksimovic, 1996).

DEFINITION OF THE SYSTEM

Urban water systems are the natural, modified and built water systems that exist in town and cities. These two systems are interconnected and interact in both positive and negative ways. Urban water systems consists of all the process and equipment that combine into the fresh water as well as the sewage water systems. The function provided by the built systems of water supply, wastewater and stormwater infrastructure are commonly referred to as water services. Following are the elements of the urban water system,

the water source-e.g. lake water or ground water;
the clean water production;
the clean water distribution system;
the storm water collection system;
distribution and leakage;
the consumers;
drainage and leakage;
the sewer system;
the wastewater treatment;
the receiving waters;
other water users and polluters
(Modified after Aspegren, H.,et.al., 1997)

Numbers of papers (Water Sc. Tech., Vol.35, No.9, 1997) have discussed guidelines for sustainable urban water systems. Urban water system performs number of functions. Larsen and Gujer(1997) defined 5 key elements for an urban water systems. These are,

Maintain urban hygiene and prevent disease transmission by facilitating effective waste disposal
Provide adequate and safe water supply for personal and domestic use
Provide adequate flood prevention and removal of stormwater
Integrate urban agriculture into urban water management
Provide water for aesthetic, pleasure and recreation purposes.
Although it is arguable whether all these functions have equal level of achievements.

The urban water systems of today partially fulfil these basic requirements to certain extends. However, the systems have been criticised from point of sustainability because they lead to increasing water consumption, costly maintenance and renewal of infrastructure, environmental problems due to disposal of contaminated sludge and stormwater run-off.

WHAT DOES "SUSTAINABILITY" IMPLY FOR URBAN WATER SYSTEMS?

The primary objective of urban water systems is to protect and maintain the health and safety of peoples. The second major objective of urban water systems is to protect the natural environment including flora and fauna from adverse effects of contaminants. Today's practices attempts to satisfy these two objectives but in the spirit of current debate it is necessary that there should be a third objective: that the systems should be "sustainable". The question to be answered is" can society sustain such a systems"?

Any change to the system that we make should be informed by a sustainability perspective. This requires that we act in a forward-looking manner, bearing in mind the protection of all resources, instead of merely reacting to existing problems. We should anticipate future problems and challenges to urban water systems and design solution that do not merely shift problems from one domain to another, but that address many aspects we care about. Sustainability has two components, a resource component and environmental component. From the point of view of water, sustainable operations are possible within the current ability of mankind. Sustainability is about maintaining, supporting, enduring and keeping up indefinitely. It is from the Latin root *substenere*, to hold, and closely related to *substenance*, from the same root which means food. But in present context it has become buzzword and its meaning is sometime loosed.

Sustainable measures provide way by which we can quantify relative levels of sustainability. They can be defined numbers of ways. One way is to express relative levels of sustainability as separate or weighted combination of reliability, resilience and vulnerability measures of various criteria of systems. Hellstrom et al. (2000) in their paper proposed set of criteria which have been divided into five main categories: (1) health and hygiene criteria, (2) social-cultural criteria, (3) environmental criteria, (4) economic criteria, and (5) functional and technical criteria. These criteria are developed for comparisons of different water and wastewater systems rather than to the total anthropogenic impact.

Current urban water systems have to deal with unsustainable problem associated with human over-consumption. In realisation of limitation and constrains we have to accept that truly sustainable urban water systems which fully satisfy all criteria is an idealised unattainable goal.

ALTERNATIVE APPROACHES

Any alternative approaches to current systems need to take a holistic view and consider all areas of water catchment, transport, treatment and disposal. It needs to consider methods to save water, recycle water and organic matter, and transport waste either no water or much lover levels of water. An essential aspect in planning, design and management of systems is the anticipation of change: changes in the natural system (e.g. assimilative capacity or self purification capacity), changes in the technical function due to ageing, changes in the demands or desires due to changing society and changing climate conditions. Sustainable Urban water Systems are those which are more adaptive, robust and resilient to these changes. With the current level of investment in existing urban infrastructure, radical modification will not occur and an incremental approach is advocated. (Butler and Parkinson, 1997) It is authors perception that even incremental approach based on technological solution will not give satisfactory results to achieve sustainability goal unless we change our lifestyle and paradigm shift in current management practices. At its core it is challenges the designers to shift their thinking and management focus to a more local orientation. At the design scale this means site responsiveness and use of natural process rather than use of hard engineering solutions, which have often been applied universally with little respect for the local environment.

The urban water systems-both constructed and natural-provides that interface between human settlements and local and regional ecosystems. Modern perceptions of this interface give us opportunity to look for more holistic approaches to management of the urban water cycle. The provision of urban water services is a complex task requiring the management of resources and the protection of ecosystems. One concept that has not been explored greatly in the development of urban water systems is the relationship between urban and rural areas. There are strong opinions that material cycles should be closed by linking agriculture to congested urban areas.

The strategies fundamental to the promotion of more sustainable urban water systems are proposed:

- separate storm runoff from flows of polluted wastewater by soft engineering techniques
- rainwater recycling and greywater reuse at lowest possible level of human settlement
- avoid mixing of industrial wastewater with domestic sewage
- reduce the reliance on water as transport medium for waste
- integration of urban agriculture into water management

IMPORTANCE OF STORMWATER: ECOLOGICAL THINKING

Combined urban wastewater is current common practice of urban drainage adopted by engineers. The separation of storm runoff from sewage is not a new idea. One of the advantages is to reduce overflow discharge of combined sewer. The sewage flow is reasonably constant, but the rainfall run-off fluctuates, and when CSOs fail to cope with increasingly torrential downpours, the water backs up and raw sewage overflow causing environmental damage. In order to cope with a stormwater surge, big sewage treatment work needs pumping which increases electricity consumption. Sustainable strategy for storm water involving all kinds of imaginative ways of holding back the flood is the possible answer to prevent so much of stormwater reaching the inadequate combined sewer overflows (CSOs). Sustainable urban drainage systems involve measures right from where the rain first hits the ground and not just at the point where flooding occurs. Water should be allowed to percolate into the soil rather than wash into the nearest stream or storm drainage. Runoff can be held in the ponds and wetlands to allow natural processes to act on pollutants and to avoid overloading local watercourses.

In the urban landscape we could start to reinvent the porous city, with soakaways in housing areas; marshes, ponds lakes in open spaces; porous surfaces for car-parks to slow down the rate at which rainfall hits the ground. Soft engineering techniques can allow concrete and steel to be replaced with natural processes and material. In the denser urban environments, road carriageways may be utilised as a drain to convey large stormwater flows (Kolesky et.al., 1996)

RECYCLING AND RE-USE

Reuse is a viable option when limitations are placed on a wastewater treatment facility's ability to dispose of sewage effluent. It is clear that, in order to alleviate the problems of water supply, it is necessary to develop methods for multiple and/or quality-dependent water use in households and to introduce more efficient economical incentives to save or reuse water. Water conservation has been an element of water management for some time it is fair to say that it is only just beginning to receive some attention of policy maker and designers. Water conservation, which also includes using of water of lower quality for toilet flushing, irrigation and other industrial uses. Water re-use covers a wide range of practices. There is rainwater collection, grey water recycling (water from the bathrooms, including showers and baths), black water recycling (all water going to sewer), treated water effluent reuse and even aquifer recharge. Reuse can take place in an individual home, over a whole development, on an industrial site or be discharged to farm or recreational land. In other words water re-use initiatives are primarily site specific both in design and in applying standards.

The project at Millennium Dome in London is one few impressive example which demonstrate water conservation and water reuse at the site level. The rainwater tally on the roof of the dome combined with greywater from hand basins is used for toilet flushing. It will save the equivalent of 30 million toilet flushes over the year. This project show that there are convincing models at both the low-tech and the high-tech ends of the spectrum.

Water re-use is applied on large scale in Israel and in southern states of America which often faces perennial shortage of water.

Recycling water is not a new concept by any means. It is nature's own method to ensure that the limited supply of water on Earth is made available over and over again. Over-population, intensive agriculture and industry pose a threat to the stability of natural cycle and only by creating smaller reuse cycles within Nature's bigger water cycle can we to some extent reduce our devastating effect on the natural environment.

CONTROL INDUSTRIAL INPUTS

Initially, sewerage systems were constructed to remove the organic waste i.e. domestic wastewater. Over the time, however, the system has been used to transport non-organic industrial wastewater resulting in the loss of resources and the creation of water pollution problem. Toxic substances, heavy metals and synthetic organic chemicals present in waste accumulate in the environment causing problems to ecosystems. Source control of such substances, through cleaner production and technology backed by regulation rather than their transportation and diffusion in the environment, is a potential solution to this problem. This is a task to arrange by the industries themselves. It is possible to use novel treatment technology to treat such highly contaminated waste in any industrial facility. Even though complete isolation of an industrial waste stream is impractical, pre-treatment at source level to reduce concentration of undesirable wastes is necessary prior to discharge into the sewer. It increases the potential for treatment facilities to be localised and recycled effluent can be utilised as a reusable resource.

WATER AS TRANSPORT MEDIA

Current urban water systems are extremely inefficient in utilisation of water. It is estimated that 35%-40% of water supplied to house is used for non-potable use such as toilet flushing, cloth washing, bathing and gardening. In the UK, approximately 33% of total household consumption are squandered on this non-potable application (Butler et. Al., 1995). All delivered water becomes wastewater due to unnecessary mixing and dilution of waste, requiring treatment before it can be released to the environment. Costly end of pipe technology is then needed to remove solid waste component from the liquid waste component of the waste flow. It is understood that present paradigm of water-borne sanitation creates not-easily-reversible, long-term obligation. Researcher and practitioners will have to accept future challenges and need for change in terms of promoting innovative concept of sanitation. Dry sanitation systems or vacuum sewerage and urine separating toilets used in Sweden are some the examples of non-flow to minimum flow technologies should be investigated as feasible technical options for the future.

The wording of the conclusions from the Stockholm Water Symposium 1999, Workshop 8, on long-term water and sanitation systems also stated that: "future sanitation systems should be developed so that they do not use water as transportation media. It is particular important in arid and semi-arid regions" and "new solutions are explored in a multidimensional fashion, including water and nutrient cycles as well as energy saving as a natural component."

URBAN AGRICULTURE

There are strong opinions that material cycles should be closed by linking agriculture to congested urban areas. This requires close consideration of flows within the urban system in relation to the environments in which they are located. An approach that seeks to re-establish links in material (including water flows) would potentially prevents the degradation of aquatic environments and of potential productive lands. The retention or re-establishment of agriculture in urban areas will help the separation and concentration of nutrient rich materials (particularly faeces and urine) facilitating their re-use. The development of human habitats should be designed from broad perspective and fragmented and strictly sectorial approaches to planning avoided.

FUTURE PERSPECTIVE

The form of urban water systems is shaped by several critical characteristics of urbanisation. The provision of urban water services is a complex task requiring the management of resources and the protection of ecosystems. Society really only has a number of limited options for handling water and wastewater disposal. It can eliminate or minimise use, recycle and reuse, convert to another inert form, immobilise or contain or, as final resort, disperse into the background environment. However, a tension exists between development and employment of traditional approaches that are embedded in institutions and general practice and the ver increasing global water businesses versus a shift towards alternatives. Evolution as opposed to revolution seems to us to be the most likely development scenario in which elements of both the "high-tech" and the "low-tech" approach will play complementary roles in tacking the problems associated with the sustainable urban drainage. (Butler and Parkinson, 1997). A good approach to design and management of future urban water systems such that it will minimise the increase in entropy (a measure of disorder or inefficiency) at each step. However, local conditions will always lead to different local solution.

CONCLUSION

Urban water systems reflect characteristics of urban area. They are linear in form and in moving to close systems, water and wastewater services must be placed in their environmental context and viewed holistically. It is becoming increasingly apparent that old technical paradigm of water and wastewater management is culturally, economically and ecologically inappropriate. New and emerging perspectives suggest that innovative approaches to urban water systems will require technologies that are responsive to their biophysical and cultural environment.

The need for sustainable urban water management is both urgent and achievable, and it can be met with little need for new resources. But there are approaches that need to be adopted to bring it about:

any alternative approach to current systems needs to take a holistic view and consider all areas of water catchment, transport and disposal

it needs to consider methods to save water, recycle water and organic matter, transport wastes with either no water or much less levels of water

choosing appropriate technology containing both high-tech and low-tech solutions

integrated land and water management to support sustainable development

Sustainable urban water should enhance the public health and wellbeing of our communities in an affordable, equitable, efficient, effective and environmentally sound way. To achieve these objectives we require changes not only in applied technology but also in education systems, social habitats, policies, structure and management of societies.

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