Sustainable water management in rural and peri-urban areas: what technology do we need to meet the UN Millennium Development Goals?

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Abstract Installation of advanced urban water management systems is one of the most important first steps in the attempt to overcome poverty on earth, outbreak of diseases, crime and even terrorism. Because world wide application of traditional water supply, sewerage and wastewater treatment technology requires financial resources which are basically not available within a reasonable short time frame novel solutions must be found, developed and implemented. The combination of high-tech on-site treatment of the various waste streams generated in households, enterprises and industrial sites, and reuse of the valuable materials obtained from the treatment plants, including the purified water, is one of the options which is investigated by various groups of researchers and technology developers, nowadays. This concept may help meeting the UN Millennium Development Goals, provided people are ready to accept this new way of dealing with household wastes. Education is necessary to build up the foundation which modern water technology can be based upon. In parallel, tailored modifications are to be considered to satisfy the specific demands of local communities. In this context, female participation appears to be extremely important in the decision making process.

Keywords UN Millennium Development Goals; urban water management; flushing sewer concept; source separation; female involvement

Water Science & Technology **Vol 51 No 10 pp 1–6**

Introduction

At the beginning of the new millennium, precisely on September 8, 2000 during the fall session, the representatives of the 191 Member States of the United Nations (UN) at the General Assembly reaffirmed their commitment "to all the world's people, especially the most vulnerable and, in particular, the children of the world, to whom the future belongs". The Assembly formally agreed on a set of 8 goals (Table 1), which became known as the UN Millennium Development Goals (MDG). In particular, it was resolved to halve by the year 2015 the proportion of the world's people who suffer from hunger and who have no access to safe drinking water (www.un.org/millennium/declaration).

The good news is that we now have reasonable and well comprehensible goals worth achieving. Goals like this are certainly a major driving force for innovative developments, and it might be of secondary importance, therefore, whether or not we can meet these ambitious goals by the year 2015 exactly. However, when assessing the chances to meet the goals, one must take into account the large amount of money needed to build up the structural and infrastructural means required to eradicate poverty, extreme hunger and lack of access to safe water and sanitation. According to rough estimations released by the World Bank, up to 180 billion of US$ would have to be spent every year to adjust "the rest of the world" to the standards developed and implemented in the industrialized countries during the past 150 years.

The infra-structural and technological concepts applied in the industrialized world have proven to be very effective. However, they are based, to a large extent, on the scientific knowledge base of the past and can only be modified as new understanding is

Table 1 Summary of the UN Millennium Development Goals, adopted from www.un.org/millenniumgoals

Eradicate extreme poverty and hunger	Reduce by half the proportion of people living on less than a dollar a day Reduce by half the proportion of people who suffer from hunger
Achieve universal primary education	Ensure that all boys and girls complete a full course of primary schooling
Promote gender equality and empower women	Eliminate gender disparity in primary and secondary education, preferably by 2005, and at all levels by 2015
Reduce child mortality	Reduce by two thirds the mortality rate among children under five
Improve material health	Reduce by three quarters the maternal mortality ratio
Combat HIV/AIDS, malaria and other diseases	Halt and begin to reverse the spread of HIV/AIDS Halt and begin to reverse the incidence of malaria and other major diseases
Ensure environmental sustainability	Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources Reduces by half the proportion of people without sustainable access to safe drinking water Achieve significant improvement in lives of at least 100 million slum dwellers, by 2020
Develop a global partnership for development	Develop further and open trading and financial systems that are rule-based, predictable and non-discrimatory In cooperation with the developing countries, develop decent and productive work for youth In cooperation with the private sector make available the benefits of new technologies …and others

obtained. Given the fact that today's knowledge and technical means are available, how would a municipal water/wastewater management system look if we started developing such a system from scratch? Could it be that we come up with a novel technological concept which is comparably effective but costs much less? In this idealistic case, the financial demand would come down from the 180 billion US$ estimate of the World Bank, and the chances to meet the Millennium Development Goals would rise respectively, very much in favour of man on earth and the world's economy.

Flushing sewer: backbone of the current urban sanitation concept

The current concept of urban sanitation is based on the perception that the direct contact of man with his own feces, and the pathogenic organisms potentially contained in feces, is the main reason for the development and spread of diseases such as typhus, cholera, and pest. This perception still holds as the recent SARS (severe acute respiratory syndrome) case demonstrated.

To keep people away from their excreta, flushing toilets were developed and introduced in households, offices, schools and factories throughout the industrializing countries during the second half of the 19^{th} century and thereafter. Closed conduits, called sewers, were laid out in the houses and underneath roads and streets to carry the feces away from the reach of the inhabitants of cities, towns and villages. Soon it was realized that a particulate fraction of the feces settled and accumulated in the sewers, causing clogging and emission of noxious odours as a result of anaerobic processes. To solve this problem, additional water was sent into the sewers to enhance flow and the corresponding tractive forces. The idea was to flush away the particulate matter. The flushing sewer concept was born and has been applied throughout the world, ever since.

In some cases creeks flowing through a settlement were used for flushing sewers. Mostly, however, drinking water delivered to and used by customers for various purposes serves as flushing water. In households we use water for cooking, cleaning, washing and showering. In the course of its usage the water picks up a wide variety of particulate and dissolved matter which is subsequently sent to the sewer, often together with storm water runoff from roofs, drive ways and roads. This way, a complex and highly dilute mixture of organic and inorganic substances is generated (Figure 1).

At the beginning of the development of modern urban sanitation, and in many cases today, this mixture of substances was and is sent directly to rivers, lakes or to the open sea. In the heavily populated areas of Europe and the United States, it was soon understood that discharge of fecal matter and other wastewater constituents into surface waters still allows contact of people with pathogenic organisms and the outbreak of diseases. Gradually, it was understood that pollution of surface water with the other wastewater constituents leads to a variety of negative economical and ecological impacts. Wastewater treatment technology was developed, and systematically further developed with the aim to remove pollutants from the wastewater or to convert pollutants into less problematic substances prior to discharge to any surface water body.

Critical review of the current urban sanitation concept

Development, implementation, operation and control of sewer systems and wastewater treatment plants has given "bread and butter" to generations of environmental engineers since the advent of this technology at the end of the 19th century. Nevertheless, this system requires critical review.

Wastewater contains, besides noxious and hazardous matter such as pathogenic organisms, a variety of substances which are directly or indirectly valuable. The purified water itself exhibits value, in particular in locations where water is scarce, be it because of climatic conditions or because of overpopulation of the metropolitan area. Other valuable substances include nutrients (N, P, K, etc.) for fertilization of agricultural land (Table 2; Figure 2), fatty acids as raw material in industrial chemistry, and organic matter as energy source. Our current sanitation concepts hardly make use of the inherent value of wastewater. Only in relatively rare cases, purified wastewater is used for groundwater recharge, or for irrigation of gardens and of agricultural land (Hermanowicz and Asano, 1999).

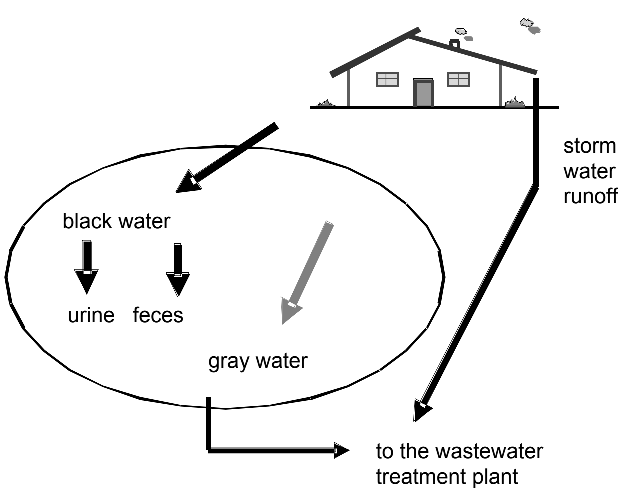

Figure 1 The various categories of waste streams generated in houses

In some cases, sludge from wastewater treatment plants is anaerobically treated for biogas production, and the treated sludge, after dewatering, is used as a soil conditioner and as a substitute of fertilizer on farm land. The latter use, however, is heavily questioned nowadays because of the hygienic hazards associated with sludge use, and because sludge may contain problematic substances such as heavy metals, pharmaceuticals and endocrine disruptors.

The biggest problem of treating wastewater results from the fact that potentially valuable substances are present in extreme dilution and mixed with all sorts of other substances. In general, one can say that biodegradation, the destruction of organic substances down to the mineral end products, is the only way of dealing with the organic fraction of wastewater constituents. However, it is an expensive solution from the economical and ecological point of view.

The dilution effects and the heterogeneous mixture of substances in wastewater are to be understood as a direct result of the flushing sewer concept currently applied for urban sanitation (Wilderer, 2004). This concept implies four other very serious economical and ecological consequences:

1. High demand of drinking water, most of it to be used only for flushing.
2. Interference with the natural water cycle in the vicinity of the urban area, as a result of the high water demand.
3. High costs to treat the extra amount of the raw and the waste water used for flushing.
4. High costs to build and maintain the sewer system.

About 80% of the total costs of the overall water supply and wastewater treatment system are attributed to sewer system installation and repair. If the urban water management system could be changed so that sewers would not be needed anymore, it would be much easier to satisfy the demand of financial resources to meet the UN Millennium Development Goals.

Despite of this, we must admit that the urban water management system which has developed over the past decades – irrespective of its merits with respect to convenience and public heath – does not meet major sustainability criteria, either economically or ecologically.

Basic considerations concerning sustainable urban water management

During the past years, various proposals have been made to design and implement alternative methods of water supply and sanitation (Larsen and Gujer, 1996; Otterpohl *et al.*, 1997; Venhuizen, 1997; Wilderer and Schreff, 2000; Zeeman *et al.*, 2000). The spectrum ranges from primitive to high-tech solutions. The following guidelines describe the minimum requirements of sustainable urban water management.

- The novel solutions should provide as high a comfort as the classical methods of water supply and sanitation do.
- The costs for implementation of the novel solutions should not be higher but lower than those for the classical overall system, including water treatment and distribution, sewer installation and maintenance, wastewater and sludge treatment and discharge.
- Operation and maintenance of the alternative methods should be accomplished by specifically trained service men or women, not by the individual users.

Table 2 Composition of urine, faces and gray water in comparison with municipal wastewater (adopted from Lange and Otterpohl, 1997)

	Household wastewater		Gray water	Urine	Feces
N	4–5 kg/(capity a)	100%	3%	87%	10%
P	0.7 kg/(capita a)	100%	10%	50%	40%
K	1.8 kg/(capit a)	100%	34%	54%	12%
COD	30 kg/(capita a)	100%	41%	12%	47%

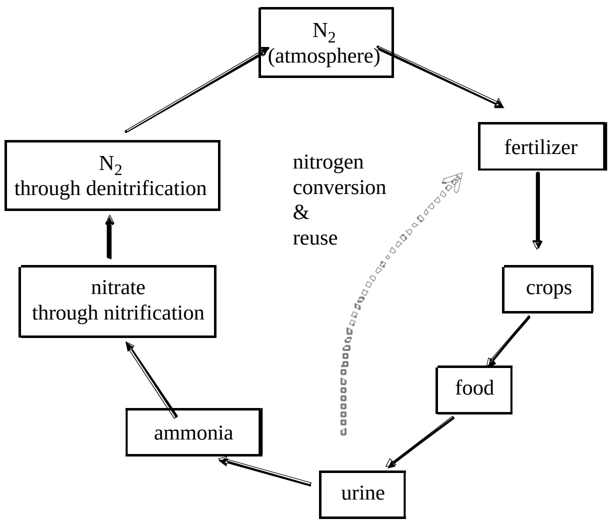

Figure 2 Short cutting the nitrogen cycle by urine separation and direct conversion into fertilizer

- The distance from the source of wastewater to the wastewater treatment plant should be as short as possible to minimize the costs for sewer installation and maintenance.
- The amount of fresh water applied for transportation of waste substances should be as low as possible to minimize the overall water consumption.
- Particulate materials should be kept from settling in the sewer to avoid development of hygienic problems, development of bad odour, and corrosion.
- Recovery of valuable materials (including water for further use) should be favoured.
- It should be confirmed that the recovered materials are hygienically safe, and free of toxic substances.

Taking these points into consideration, it becomes clear that a holistic approach must be taken to enter into a sustainable and financially affordable method of water management. It is not enough to consider bits and pieces only. There won't be a universal solution but every local situation has to be analyzed, including the financial bearing capacity of the region, the educational status of the people, climatic conditions, traditions, and even religious concerns.

The end-users of water technology, especially women, should participate in the process of identifying the type of technology which fits best into the every day life of families. The role of women is especially important because in many cultures the way water is used in households as well as sanitation practices are a female concern. Education and continuing information is needed to bring the local population to the level needed to evaluate alternatives and make proper decisions. Only technology acceptable by the local people should get selected and implemented.

The question of whether high or low tech solutions are best should be discussed free of ideological prepossessions. Unfortunately, representatives of international aid organisations and environmentalists do not always act in conformity with this general rule. Perhaps primitive methods, self-made devices, and community involving actions (i.e., digging a well, installing a pit latrine) are important steps to overcome obvious and dangerous hygienic problems in rural areas or slums. However, in the long run, all people deserve the same right to have financially affordable access to safe drinking water, reliable protection against waterborne diseases, and comfort. A "pit latrine" – to put it straight – has not the capacity to lead human communities into prosperity.

With respect to financial affordability, people, both in developed and in developing countries, must learn that water is a common good, but conversion of raw water into safe drinking water and distribution of drinking water cannot be provided for free. People who are ready to pay for fancy brands of mineral water can also pay for safe tap water! And people who can afford a mobile phone can be expected to pay a fair price for drinking water!

Conclusions

The UN Millennium Development Goals provide a significant driving force in urban sanitation with particular emphasis on the development of new concepts of urban water management.

The traditional system of water supply – wastewater collection and treatment – as it has developed over the past 150 years has its merits, but it does not meet the common sustainability criteria to be rated as perfect.

Tremendously high costs would have to be covered if the traditional system would need to be installed all over the world, in order to meet the Millennium Development Goals. Because sewer installation generates the major portion of the costs, development of a technology which does not rely on flushing sewers is worth considering.

Source separation of the various categories of wastewater generated in homes, enterprises and industry, treatment of the individual wastewater fractions, and reuse of the valuable product (including the purified water) appear to be a reasonable approach to sustainable urban water managements.

Various concepts of source separation, treatment and reuse have already been proposed. It should be realized, however, that the solution, which satisfies the demands and requirements of the actual local community, requires a different set of technological concepts.

Women should play a key role in the process of selecting and implementing the technology which best fits into the local traditions and habits.

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