Water reuse in Africa: challenges and opportunities

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Abstract

Population and urban growth is one of the major challenges facing Africa. Rapid urbanization poses major infrastructure, economic, environmental and social problems. Total water supply and sanitation coverage is extremely low particularly in sub-Saharan Africa (SSA) and cities are becoming to a large extent informal. Untreated urban wastewater is polluting water sources throughout SSA changing freshwater irrigation into wastewater irrigation in and around most cities. Because of its contribution to urban food supply and poverty alleviation, this informal irrigation sector has positive effects but constitutes at the same time a public health and environmental threat. Different population groups are exposed to serious health risks such as diarrheal diseases. These can be significantly decreased through water and sanitation investments adequately targeted to achieve impact. Traditionally designed sanitation systems have failed because they were inappropriate, ill-planned, -implemented or -managed and did not take into account the whole urban water system including options for reuse and impacts on the receiving environment. The way forward requires a paradigm shift in a) national curricula and the donor community towards appropriate African solutions for wastewater collection, treatment and reuse, b) the decentralization and potential transfer of at least some "treatment" functions to the places of reuse where health risk reduction can be more easily realized according to the particular reuse, and c) the adoption of an approach combining different health protection measures. Designing a range of cost-effective solutions that addresses the technical, institutional, social, behavioural and cultural obstacles for the adoption of such an approach has to be supported. This requires a long-term strategy taking action step-by-step and the creation of new local values and business models. The involvement of practitioners, researchers, policymakers, and local communities in multi-stakeholder platforms may facilitate dialogue, participatory technology development, innovation uptake and social learning and create the effective mechanisms for an integrated urban-rural water management strategy.

Keywords: Africa, integrated urban water management, urban and peri-urban agriculture, upstream-downstream linkages, irrigation, sustainable sanitation systems, wastewater reuse.

Introduction

In Africa, urban and rural water supply and sanitation infrastructures are poor. Populations suffer from inadequate access to drinking water and sanitation services. Population growth, improvement of living standards and socio-economic conditions lead to the generation of increased volumes of wastewater. Effluents are discharged untreated into the receiving environment causing major health and pollution threats to downstream waters. Uncontrolled and direct reuse of wastewater is common place. Often the urban or rural poor rely on this resource for their livelihood and food security needs. This is not without putting at risk their own health, the health of the consumers and the environment as a whole.

In many places, water supply and sanitation have been managed separately and planned and designed for different time-scales. The provision of environmentally sound systems that take into account the whole urban water system - water supply, wastewater, solid waste collection, treatment and reuse - requires a holistic approach involving a variety of stakeholders and overcoming administrative boundaries and rural-urban divide.

Several interlinked key questions need to be first addressed such as: can cities in Africa cope with the infrastructure and capacity requirements needed to simultaneously face the (i) water supply and (ii) sanitation needs of growing urban populations, (iii) to reuse the city effluents in a safe and efficient way, and (iv) to protect the public health and the urban and peri-urban environment? How can we make the management of urban wastewater effective, sanitation affordable and reuse safe for urban dwellers in Africa? How can known technologies be best applied to solve development questions? Does linking sanitation to water reuse help meet the MDG water and sanitation together with food security targets in Africa? Which institutional settings are suitable for sanitation and reuse in these areas? Can sustainable solutions be found through dialogue involving practitioners, researchers, policymakers, and local communities in multi-stakeholder platforms?

This paper tries to give an overview of the water supply, sanitation and wastewater irrigation situation in Africa, of the related development and management issues and of attempts to answer some of the above mentioned questions. Some examples from Ethiopia, Ghana, and Tunisia are used to illustrate different approaches within the continent.

1. Urbanization and food security

Africa is experiencing fast population and urban growth. Rates of urbanization growth in Africa are the highest in the world (5.8% in sub-Saharan Africa (SSA) and up to 10% in some cities) and expected to remain the highest for several decades (UNFPA, 2007). Africa has at the same time, except a few countries, the lowest economic growth. Its urbanization is therefore termed demographic urbanization as it has not been accompanied by infrastructural transformations in the agricultural and industrial sectors (Escallier, 1988). According to Songsore (2004), this is one major reason why the economic, social and health benefits of urbanization have so far failed to materialize.

About 38% of the African population is living today in urban areas; this number is foreseen to increase to 53% by 2030, a percentage already reached in areas like humid West Africa. Indeed, in 2006, there were about 13 countries with at least half of the population being urban. The proportion of urban population is rapidly growing as a consequence of a significant increase in overall population and in rural-urban migration. The projection is that, by 2030, the towns and cities of the developing world will make up 81 per cent of urban humanity (UNFPA, 2007).

By 2020, Africa will have 11 mega-cities with 5 million or more inhabitants and almost 720 cities with population of more than 100,000. This translates in the urgent need for thoughtful urban planning and sound investments in basic services, especially in the emerging mid-size cities to avoid the omissions we face today in many Africa's larger urban centers.

Population increases in rapidly growing urban and peri-urban areas. It is putting enormous pressure on land and water resources and has resulted in serious water stresses, poor waste management and severe diffuse pollution. Urban population growth has led to the spread of poorly-planned settlement areas surrounding many major cities in Africa and to a rapid increase in the number of slums, in unemployment and poverty. According to the UN-Habitat (in UNFPA, 2007), 72% of the urban population in SSA lives under slum conditions. A growing proportion of the urbanization is becoming informal with the proliferation of scattered housing. Construction of spontaneous housing on city outskirts is also leading to annual loss of farm land and causing deterioration in living conditions. Also the use of inappropriate sites, such as flood-prone areas and solid waste landfills neighbourhood, presents major risks, Providing sanitation to the slums and informal settlements requires a different approach given the scale of the problem, the high population density, the complexity of the situation, the difficulty to provide standard services in such conditions (insecure tenure, lack of infrastructure, lack of space, etc.), and the resulting aggravated health, environmental, and other socio-economic problems.

Out of a population of 968 million in Africa, around 50% lives on daily incomes equivalent to less than $1 a day and has therefore little resources to meet basic needs or to pay taxes for infrastructure development. Over 70% works in agriculture, mostly in subsistence agriculture. Agriculture is their major source of food and income. In SSA, 33% of the population is undernourished with a constant low average calorie intake per person about 2000 kcal/day. The urban poor depend heavily on rising agricultural productivity to reduce food prices. Ensuring jobs and food security for the urban poor is a challenge. Urban and peri-urban agriculture is clearly one of the options to address the increasing urban food demand, complement rural supply and for poverty reduction.

Urban and peri-urban agriculture can serve the inherent function of agriculture while recycling urban waste products. Reuse of wastewater in agriculture means making a productive asset out of a waste product, while contributing to natural purification. It is a way of "outsourcing" sanitation services, maximising water use efficiency, as well as closing the water and nutrient loops to sustain or promote agriculture. The agricultural sector can then provide to the urban sector an "environmental function" which can be valued as an "environmental service". Urban and peri-urban agriculture can, at the same time, provide food to the urban areas and act as an "environmental manager" (Thiébaut, 1995). This leads to reconsidering the relationship between urban, peri-urban and rural areas and requires holistic thinking about urban water management.

2. Supply of water and sanitation

With only 64% of the population having access to "improved water supply", the African continent has the lowest total water supply coverage (coverage refers to the number of people receiving adequate levels of water supply and sanitation services (WHO *et al.*, 2000)) of any region in the world. The situation is much worse in rural areas, where drinking water supply coverage is 50% compared to 86% in urban areas (Table 1.1). Sanitation (excreta disposal facilities) coverage in Africa is also poor (60%), with 80% and 48% in urban and rural areas respectively. The situation is even worse in some countries with, for example, Chad, Congo, Ghana and Guinea having less than 30% improved sanitation coverage in urban areas and Chad, Ethiopia, Ghana, Guinea, Mauritania, Niger, Somalia, Sudan and Togo with less than 15% improved sanitation coverage in rural areas (WHO and UNICEF, 2006). Africa houses 30% of the world's population lacking access to improved water supply (335 million persons), and 19% without access to improved sanitation (498 million persons) (WHO and UNICEF, 2006). These figures are respectively 29% (322 million persons, of which 52 million urban and 270 rural) for drinking water and nearly 18% (463 million persons) for sanitation for sub-Saharan Africa. Only 16% of the population in SSA has access to drinking water through household connections.

Table 1.1 Drinking water and sanitation coverage in Africa and sub-Saharan Africa in 2004 (WHO and UNICEF, 2006).

		Africa		SSA	
		People unserved (Million)	Coverage with improved facilities (%)	People unserved (Million)	Coverage with improved facilities (%)
Drinking water	Total	335	64	322	56
	Urban		86		80
	Rural		50		42
Sanitation	Total	498	60	463	37
	Urban		80		53
	Rural		48		28

Figures in Table 1.1 should be considered with caution as "improved" and "coverage" have not been clearly defined. According to WHO *et al*., (2000), "improved drinking water coverage" includes services by either household connections or access within one kilometer to a constructed public water point (standpipe, borehole with handpump, protected wells, protected springs, rainwater collection) where at least 20 liters of safe water per person per day are available. "Improved sanitation coverage" is defined as a household connected to a public sewer or a constructed on-site disposal system (septic tank, pour-flush, ventilated improved pit latrine or pit latrine).

These statistics stress the infrastructure gaps and the dramatic increase in investments needed in Africa in water and wastewater collection, storage, treatment and management to "make" safely usable water out of surface water, groundwater, stormwater, or wastewater, maintain its quality, and reduce possible health risks. They underline the need to develop innovative approaches to meet the 2015 MDG water and sanitation target in Africa. They also show that it will be necessary to increase significantly the speed at which people are provided with safe and affordable drinking water and sanitation … unless the significance of the current definitions of "improved" systems and "coverage" were questioned. There are increasing voices pointing to local definitions of "improved" systems instead of referring to internationally admitted standards.

3. Current practice and problems in wastewater management

The majority of urban dwellers in Africa are served by on-site sanitation systems (over 85% of the population in Ethiopia, Ghana, Mali and Tanzania, for example) and this should grow rapidly. Septic tank sludges regularly pollute the environment in many cities while stormwater gutters also receive and channel greywater and other wastewater to larger drains and inner-city streams (Keraita *et al*., 2003). These appear in many cities as large wastewater drains absorbing in addition all kind of plastics and solid wastes.

Small proportions of the cities in SSA are sewered and only 1% wastewater is treated (WHO and UNICEF, 2000). This is due to low financial, technical and/or managerial capacity. The rapid and unplanned growth of cities makes the management of wastewater more complex. Existing wastewater treatment plants are often not functioning or overloaded and thus discharge into the environment (rivers, lakes, sea, etc.) effluents not suitable for safe reuse. These effluents may contaminate food and downstream water supplies, creating public health risks, environmental damage, and unpleasant living conditions. The perspectives regarding the increase in wastewater treatment capacity in these cities are gloomy. As long as population growth continues to outpace sanitation services, the volumes of untreated wastewater will continuously increase making worse the pollution of water bodies tapped for irrigation.

Industrial pollution from large industries is still limited and restricted to a few cities in Africa, often those with seaports. The bulk of industrial pollution originates from dispersed medium and small-scale industries which are prevalent in Africa's urban centers. Uncontrolled discharge of hazardous contaminants from these industries also results in build-up of toxic constituents in surface water (sediments) and contamination of groundwater.

The management of faecal sludge, wastewater collected from on-site sanitation systems (public toilets, septic tanks and pit latrines), is a major issue. Problems can also be associated with the prevailing use of faecal sludge in agriculture and aquaculture.

Problems related to off-site and on-site sanitation systems are frequently reported in SSA. The IWA Task Force on Sanitation (IWA, 2006) analyzed the different reasons leading to the failure of these sanitation systems. It was found that these systems are either inappropriate to the cities they are meant to serve, badly planned, badly implemented, or poorly managed. Other reasons were the gap which exists between the interests of households and the incentives of utilities/cities, the lack of resources and capacities, lack of focus on long-term operation and no planned provisions for maintenance requirements.

There are major differences in the way countries address these issues. Namibia, Tunisia and South Africa stand apart from the rest of the continent in treating sewage sludge through a range of conventional and non-conventional systems and having national guidelines and regulations. Examples from Ethiopia (Box 1), Ghana (Box 2) and Tunisia (Box 3) are given in the following to illustrate the variety of the situations and the approaches adopted in various contexts.

Box 1: Sanitation in Ethiopia

In Ethiopia, 13% of the population has access to improved sanitation (44% in urban areas and 7% in rural ones) when 81% of urban population and 11% of rural population has access to safe water supply. The population of Addis Ababa by 2005 was estimated at about 3.36 million and the poverty index at 40-50%. Addis Ababa is facing a high rate of urbanization (4.4%) with huge demands for resources (water, food, energy, land, etc.). Surface and underground waters are supplied to 58% of Addis inhabitants. The city has one wastewater treatment plant, the Kaliti waste stabilization ponds (WSP), which is operational since 1985 and treats about 5% of the city effluent of domestic origin mainly. The WSP receives daily 7500 m^3 through the sewage line plus 1000 m^3 sludge extracted from septic tanks and pit latrines, transported by vacuum trucks and discharged in lagoons for drying. A certain proportion of the sludge from on-site systems is co-treated with the wastewater in the WSP.

Suction trucks (with a capacity of 3-12 m^3) from the Addis Water Supply Agency (AWSA), from private companies, the Government and from NGOs are used to suck up the content of pit latrines. AWSA charges the citizens US$7.7 (69 Birr)/truck, others up to US$31.3 (280 Birr). The city is poorly managing the solid waste, industrial and other effluents which pollute the water supply sources and the ecosystem in the tributary rivers, particularly Akaki river and the main Awash itself (Awulachew, 2006).

Box 2: Sanitation in Ghana

In Ghana, urban sanitation infrastructure is poor, less than 5% of the population has sewerage connections and only a small share of the wastewater is treated (Keraita and Drechsel, 2004). 20% of households do not have access to any form of toilet facility; about 31% relies on public toilets, while 22% has access to pit latrines. About 7% of households uses KVIPs (Kumasi ventilated improved pit) latrines and 9% has access to water closets. Access to water in rural and urban areas has generally improved gradually resulting in increased generation of faecal sewage and wastewater with increasing waterlogging and stagnant pools of water in many towns and cities because of lack of drains. Inadequate water and sanitation has a significant impact on public health and contributes to 70% of the diseases in Ghana (WaterAid, 2001).

In Accra, 46% of the population has access to water in irregular intervals. About 10% of the Accra metropolis (an estimated population of 1.66 million in an area of 240 km^2) is connected to a piped waterborne sewerage network ending in one of the 44 Ghana's treatment plants. More than half of all plants are in the Greater Accra Region, but only about 20% are functional, and this usually below design standards. The largest sewerage is covering Accra's ministerial center leading to a UASB plant which became dysfunctional shortly after its commission. Waste stabilization ponds and trickling filters are other common systems serving e.g. the local university, military camp, hotels, etc. (Obuobie et al., 2006). Most common are however on-site sanitation systems, in the form of septic tank and pit latrines, usually without adequate drain fields. Very little extension of the sewerage network has taken place since its construction in the early 1970. Faecal sludge treatment plants fed by trucks receive wastes from public toilets, pit latrines and septic tanks. Due to the limited number of sludge treatment sites and their poor accessibility and/or status, more than 60% of all collected excreta are dumped into the ocean.

Studies have been carried out to improve sewerage, effluent disposal and sanitation through off-site and on-site sanitation facilities. The Accra Sewerage Improvement Project will provide two new sewage treatment plants, based on waste stabilization ponds, with outfalls discharging into the sea and into watercourses, etc. (ADB, 2005). Transfer of sanitation and sewerage functions from central Government agencies to the Assemblies is considered in the National Environmental Sanitation Policy, which is however not automatically combined with a corresponding transfer of capacities and operational funds.

Box 3: Sanitation in Tunisia

In Tunisia, most residents of large urban centres have access to various adequate sanitation systems and wastewater treatment facilities. The sanitation coverage is 85% for all the population versus 96% in the urban areas and 65% in the rural areas. Industries have to comply with the Tunisian standards (INNORPI, 1989) prior to discharge their wastewater into the sewerage system; they are given subsidies to equip their industrial units with pre-treatment processes. Of the 240 Mm^3 of wastewater collected annually, 187 Mm^3 (78%) are treated in 61 treatment plants of which around 41 have a daily capacity less than 3500 m^3 and 10 above 10 000 m^3, the largest with 120 000 m^3/d. Five treatment plants are located in the Tunis area, producing about 62 Mm^3/yr, or 54% of the country's treated effluent. Several treatment plants are located along the shoreline to protect coastal resorts and prevent sea pollution. Most municipal wastewater is from domestic sources (88%) and receives secondary biological treatment, mainly in oxidation ditches and stabilization ponds. Sanitation master plans have been designed for several towns.

4. Wastewater irrigation

Wastewater irrigation is a common established practice in urban and peri-urban areas in Africa. Practices range from the use of polluted surface water, to raw wastewater to the piped distribution of secondary or tertiary treated wastewater to irrigate different kinds of crops and trees. This illustrates the challenge of estimating the extent of "wastewater" irrigation with global figures ranging from 4 to 20 million ha (IWMI, 2006). There are only a few countries in Africa such as South Africa, Tunisia or Namibia with experience in planned reuse and a record of wastewater treatment plants producing a safe effluent. In most of the other countries, urban wastewater is widely used very partially treated or untreated to irrigate vegetables, rice and fodder for livestock. Due to lack of cool transport, 70-90% of the most perishable vegetables consumed in many African cities such as Dakar, Bamako, Ouagadougou, Accra, Addis Ababa or Nairobi are also grown within the city boundary, and this implies usually with highly polluted water sources, mostly of domestic origin (Drechsel et al., 2006).

Wastewater irrigation can be both, a major health risk for farmers and consumers and a major economic contribution in terms of jobs and food supply. Among the health risks are of particular concern endemic and epidemic diseases (cholera, typhoid, etc.) (WHO, 2006). Wastewater irrigation raises also issues related to environment protection as its nutrient, salt and other contaminants contents can be high.

However, it is usually not a choice for farmers to use "wastewater" or not, as it is often difficult to find clean water sources in and around most cities. Wastewater has many advantages for farmers as it can contain – depending on the degree of dilution - significant amounts of nutrients for food crop production that reduce the need for chemical fertilizers. Wastewater content in organic matter, nitrogen, phosphorus, and potassium may improve soil fertility, enhance plant development and increase agricultural productivity. More important, however, it is a reliable water supply, usually free-of-charge, and continuously available in urban market vicinity. Wastewater reuse supports the livelihood of many farmers and traders and plays a significant role in poverty alleviation. It also provides a niche for urban food supply complementing rural production (Drechsel *et al.*, 2006, 2007).

From the IWRM perspective, reuse is desirable as it conserves freshwater and contributes to reduce unplanned wastewater discharge and pollution of water bodies and the environment in general. Integration of urban and peri-urban agriculture into urban sustainable sanitation planning is therefore critical in African cities, and should be considered as a contribution to sanitation services if the lack of full urban wastewater treatment can be compensated for by treatment options for health risk reduction at the farm level as outlined by WHO (2006). Salient aspects of wastewater irrigation in three African countries, Ethiopia, Ghana and Tunisia, are highlighted in the following. Wastewater reuse in Addis Ababa (Box 4) illustrates upstream-downstream linkages and the impacts of upstream producers of wastewater on downstream users.

Box 4: Wastewater reuse in Addis Ababa (Ethiopia)

About 35.5 million m^3 of wastewater is annually generated in the city of Addis Ababa. Wastewater is mainly of domestic origin with 13.4% industrial. Most of this greywater is disposed into the rivers and streams flowing through the city, like the Akaki river. Farmers have been producing vegetables using Akaki river for the last 50 years and 1240 ha of land are being irrigated, mostly by gravity using furrow or flood irrigation. Rural areas are supplying Addis with almost all crops, livestock, horticulture and fruits, while urban agriculture is providing 61% of the vegetables consumed in Addis (lettuce, Swiss chard, cabbage, spring onion, potato, beat root, etc.). The main concerns are pollution of the water sources, the health hazard related to the use of untreated water for irrigation, the environmental degradation and allocation of agricultural land to other purposes. A survey carried out by Bayrau et al. (2008) on a sample of 1258 farmers on the health incidence of wastewater irrigation the producers showed that (i) prevalence of reported intestinal illness is higher in the downstream wastewater irrigation district as compared to the upstream one; (ii) this prevalence of illness increases in parallel with the river pollution increase; and (iii) prevalence of illness is also higher in those who work in wastewater farms compared to those working in freshwater farms after consideration of all compounding factors[1]. The marginal health cost of working with wastewater for a representative wastewater household was estimated to be about Birr 50 per year, which is about 1.6% of its annual net farm income (Bayrau et al., 2008). The analysis also showed that awareness and protective clothing have a significant impact on farmers' health.

Wastewater reuse in Ghana (Box 5) demonstrates the potential health risks as well as the socio-economic benefits to the farmers and the overall benefit to the city.

Box 5: Wastewater reuse in Ghana

In Ghana, urban and peri-urban agriculture is developing wherever land is available close to streams and drains (Obuobie *et al*., 2006). Around Kumasi, informal irrigation, which often uses polluted stream water, is estimated to cover 11,500 ha, which is twice the total area reported under formal irrigation in the whole country (Keraita and Drechsel, 2004). Typical concentration in faecal coliforms of irrigation water ranges from 10^4 to 10^8 CFU/100 ml (Keraita *et al*., 2003). Watering cans are the most common irrigation method used in the country. Buckets, motorized pumps with hosepipe and surface irrigation are also used to fetch, pump and water crops. In Accra, 800-1000 farmers irrigate more than 15 kinds of vegetables (lettuce, cabbage, spring onions, cauliflower, cucumber, tomatoes, okra, eggplants, and hot pepper). Urban plot sizes vary between 0.02-0.3 ha per farmer. All-year-round irrigated vegetable farming can achieve annual income levels of US$400-800 per actual farm size. The annual value of the production, a significant part of which is irrigated with wastewater, has been estimated by HR Wallingford for dry-season farming as US$5.7 million around Kumasi (Keraita and Drechsel, 2004) and for year-round production as US$ 14 million in case 'wastewater' irrigation gets banned in Accra and the same crops have to be imported from neighbouring countries with safer water sources (Drechsel *et al*., 2006).

Every day, about 200,000 urban dwellers from all classes of the capital Accra benefit from this production when consuming raw salads as part of urban fast food. But the same number is also at risk due to vegetable contamination. Irrigated vegetables sold in the markets showed faecal coliforms and helminth eggs (> 10^3 FC/g fresh weight and up to 3 helminth eggs per gram of vegetables) (Keraita *et al*., 2003). Both municipal food supply and safety are therefore significantly affected by the urban sanitation situation. This is a major concern of the authorities who tried to ban the use of polluted water for irrigation purposes, with the same success as to stop water pollution. Alternative interim health risk reduction strategies are currently explored as proper wastewater collection and treatment infrastructure is not yet available and the existing one not functional.

Tunisia (Box 6) offers an example of water reuse operations integrated in the planning and design of sanitation projects. A phased approach was taken to set up a planned water reuse strategy.

Box 6: Integrated wastewater treatment and reuse in Tunisia

About 30-43% of the treated wastewater is used for agricultural and landscape irrigation in Tunisia. Reusing wastewater for irrigation is viewed as a way to increase water resources, provide supplemental nutrients, and protect coastal areas, water resources and sensitive receiving bodies. Reclaimed water is used on 8,000 ha to irrigate industrial and fodder crops, cereals, vineyards, citrus and other fruit trees. Regulations allow the use of secondary-treated effluent on all crops except vegetables, whether eaten raw or cooked. Regional agricultural departments supervise the water reuse decree enforcement and collect charges (about \$0.01 m^{-3}). Golf courses are also irrigated with treated effluent, while industrial use and groundwater recharge opportunities are being investigated.

Tunisia launched its national water reuse program in the early 1980s. Most existing reuse programs were integrated into the scheme of already existing treatment plants. However, for new plants, treatment and reuse needs are combined and considered at the planning stage. Although some pilot projects have been launched or are under study for groundwater recharge, irrigation of

[1] Indeed, those farmers who still have clean water sources available live far outside the city in much poorer conditions. The prevalence of intestinal illness due to hookworm or Ascaris infection was in total 3 times higher in freshwater areas than in wastewater areas. Similarly, the prevalence of diarrhea was 7 times higher among freshwater farmers (Bayrau et al., 2008).

forests and highways and wetlands development, the wastewater reuse policy launched at the beginning of the 1980s favours planned water reuse for agricultural and landscape irrigation (Bahri, 2000). About 35 Mm^3 of reclaimed water annually is allocated for irrigation. In some areas, irrigation with reclaimed water is well established and most of the volume allocated is being used, while in new areas, where irrigation is just beginning, the reuse rate is slowly increasing. The annual volume of reclaimed water is expected to reach 290 Mm^3 in the year 2020. At that point, the expected amount of reclaimed water will then be approximately equal to 18% of the available groundwater resources and could be used where excessive groundwater mining is causing seawater intrusion in coastal aquifers.

The area currently irrigated with reclaimed water is about 8,000 ha, 80% of which is located around Tunis and a few other locations near Hammamet, Sousse, Monastir, Sfax, and Kairouan. The Medjerda catchment area sanitation program has equipped the 11 largest towns of that area with sewerage networks, treatment plants, and reclaimed water irrigation schemes in order to protect natural resources, and particularly the Sidi Salem dam (550 Mm^3), from contamination by raw wastewater. One new large water reuse project is planned for Tunis West area. The new wastewater treatment plant for the City of Tunis West will have a design capacity of 224,700 m^3/d (82 Mm^3/yr) by the year 2016, which will enable the irrigation of about 6,000 ha. By 2020, the area irrigated with reclaimed water is planned to expand up to 20,000-30,000 ha, i.e. 7-10% of the overall irrigated area, from which 14,500 ha will be located around the Great Tunis. Reclaimed water is used mainly during spring and summer, either exclusively or as a complement to groundwater. The most common irrigation methods are sprinklers (57% of the equipped area) and surface irrigation (43%).

Water reuse in agriculture is regulated by the 1975 Water Law and by the JORT Decree No. 89-1047 (1989). The Water Law prohibits use of raw wastewater in agriculture and irrigation with reclaimed water of any vegetable to be eaten raw. The 1989 decree specifically regulates reuse of wastewater in agriculture. As an enforcement of these regulations, using secondary treated effluents is allowed for growing all types of crops except vegetables, whether eaten raw or cooked. The main crops irrigated with treated wastewater are fruit trees (citrus, grapes, olives, peaches, pears, apples, and grenades), fodder (alfalfa, sorghum, and berseem), sugarbeet, and cereals. Specifications regarding the terms and general conditions of reclaimed water reuse (and the precautions that must be taken in order to prevent any contamination to workers, residential areas, and consumers) have also been established.

The National Sewerage and Sanitation Agency is responsible for the construction and operation of all sewerage and treatment infrastructure in the larger cities of Tunisia. When effluent is to be used for agricultural irrigation, the Ministry of Agriculture, Water Resources and Fisheries is responsible for implementation of the projects, which includes the construction and operation of all facilities for pumping, storing and distributing the reclaimed water. Regional Commissariats for Agricultural Developments (CRDAs) are in charge of the enforcement of the regulations related to agricultural reuse and collection of charges, about \$0.01/m^3. Water users' associations are in charge of the management of the water distribution system, fees collection and enforcement of the regulations related to agricultural reuse for small perimeters. A water reuse strategy aimed at developing water reuse and considering reclaimed water as a water resource has been drafted. Forthcoming projects aimed at meeting a real water demand -in quantity and quality- should allow a higher utilization of reclaimed water. Water reuse primarily for agricultural purposes and secondarily in other sectors, will continue to develop in Tunisia. By upgrading the water quality and with more widespread information, reclaimed water reuse should gain wider acceptance in the future.

Inter-departmental coordination and follow-up commissions with representatives from the different ministries and their respective departments or agencies, the municipalities and representatives of the users (Water users' associations) have been set up at national and regional levels so as to bridge the gaps between the needs of different parties, ensure the achievement of development objects, and preserve the human and natural environment. Within the CRDAs, a multi-disciplinary unit is in charge of planning, design, implementation, follow-up and assessment of schemes irrigated with reclaimed water.

5. The impacts of inadequate supply of water and sanitation and of wastewater irrigation

Health risks related to wastewater irrigation should be targeted in the general context of poor water supply and sanitation, and not in isolation. What is generally known is that lack of clean, adequate, safe and affordable water and of safe sanitation facilities affects people's life, health, growth and development. It affects more particularly women and children in charge of water collection and raises issues of personal safety and dignity (Norström, 2007). It jeopardizes children's education and gender equity (WHO and UNICEF, 2006). It has a huge impact on human suffering and productivity. It is a barrier to economic development through (1) the labor hours lost due to disease and time spent fetching water (overall average for Africa is about half an hour) and (2) the human capital lost when sick children miss school. It may deepen the inequities between the urban rich and the urban poor who pay more for water provision, and are usually the last to be extended water and sanitation services.

Lack of water access and sanitation and reuse of polluted water increase the emergence of diseases and illnesses. At any given time, one-half of the African population is suffering from one or more diseases associated with inadequate provision of water and sanitation services and wastewater irrigation (diarrhea, intestinal worms, schistosomiasis, cholera and trachoma). Africa has the worst statistics for cholera and child diarrhea (Warner, 2000). "In Africa, 155 children die every hour of everyday from sanitation, hygiene and water related diseases. The number of cholera cases reported from Africa is increasing every year. A total of 187,545 cholera cases and 8,051 deaths were officially reported in 1999 in the African Region" (WHO, 2000). Recently, several cholera outbreaks were reported in different African countries: Zimbabwe, Tanzania, Rwanda, Kenya, Angola, Republic of Congo and Ghana due to contaminated drinking water or poor sanitation. In SSA, the annual global burden of water-related diseases is estimated at 82 million Disability Adjusted Life Years (DALYs). Diarrheal diseases form the bulk of the health risk and kill more Africans every year than HIV/AIDS. There are an estimated 1.2 billion cases of diarrhea in sub-Saharan Africa every year (25 million DALYs) that lead to the deaths of 770,000 children under 5. This places an average health burden on every African of 21.7 years of ill health (Rijsberman, 2006).

The impact of providing clean water and sanitation and the use of safe water for irrigation is huge as it can increase economic well being at the household level, mainly through saving large amounts of people's time and energy. SSA overall economic cost of reduced access to water and sanitation is estimated to be $23.5 billion, or 5% of GDP. Health benefits are significant and the largest share of the economic benefits may arise in SSA from meeting the water and sanitation MDG target (Evans, 2005). According to Fewtrell *et al.* (2005), diarrheal morbidity can be greatly reduced through water and sanitation investments: up to 45% reduction from improved hygiene, up to 39% reduction from household water treatment, up to 32% reduction from improved sanitation, and between 6 and 25% reduction from improved drinking water. Reaching the MDG goals to halve hunger, poverty, and people with no access to safe water and basic sanitation by 2015 is therefore especially a challenge in Africa.

6. Sustainable approach to water supply, sanitation and reuse

Water and nutrient recycling has so far not been considered as an objective sufficiently important to modify the general approach to sanitation. When conventional technology is adopted for treating wastewater, treatment plants are designed with no concern for reuse and independently of reuse requirements. The key elements of sustainable sanitation in Africa therefore require a paradigm shift in three regards: a) national curricula and the donor community have to aim towards appropriate African solutions for wastewater collection, treatment and reuse, b) the decentralization of wastewater treatment closer to the places and demands of reuse and c) the adoption of an approach combining different health protection measures. The reuse potential of different waste products as a function of crops, soil and climate conditions, including health, socio-cultural, economic, and reuse policy aspects has to form an integral part of future sustainable sanitation strategies (Rijsberman, 2006).

For social equity and environmental concerns, there is a need to consider in Africa all options available for collection, treatment and reuse systems from pit latrines to water borne sewered system - from the safe collection, storage, and disposal/re-use of human excreta to the treatment and disposal, re-use and recycling of sewage effluents. A combination of different technology solutions, depending on local conditions and available resources and capacities, may help solving the problem in a sustainable and environmentally sound manner. There are opportunities for the design of sanitation systems using local materials, technology, and know-how. Systems based on conventional practices or combining natural and conventional systems may be used when land is not available or in the case of topographical or others constraints. Financial savings both in terms of investment and O&M costs may be achieved in addition to ecological advantages and landscape fit-in. Land application of sludge may also be practised after proper treatment (composting, digestion, etc.). In order to overcome the financial constraints faced in providing wastewater services, these services may be developed in a phased manner moving gradually along the "sanitation ladder" (4WWF, 2006).

A complementary approach is combining treatment and non-treatment measures for health risk reduction (WHO, 2006). Such a multiple barrier approach can combine source control, and farm-level and post-harvest measures to minimize risks and protect agricultural workers and consumers (Lazarova and Bahri, 2005; WHO, 2006; Qadir *et al*., 2007). Risk reducing alternatives are for example currently tested in Ghana to explore their potential impact (Drechsel, *et al*., 2007). This approach is directly addressing the common lack of sustainable or comprehensive wastewater treatment by outsourcing its functions according to the needs and potential of the stakeholders involved in wastewater reuse. It comprises small wastewater sedimentation ponds on farm as well as safer irrigation techniques and appropriate washing of crops to be eaten raw. Where possible, these should be combined with wastewater treatment.

In view of the current freshwater shortages in most African cities, planners are increasingly skeptic about extending the coverage of flushing toilets and sewer systems. Adopting dry toilets where possible combined with a closed-loop systems appears to be an appropriate way forward. Related technologies are today widely available and installed e.g. around Durban, South Africa, at a rate of 1500 toilets per month, reaching so far 60,000 units.

For optimized water collection, distribution, sewerage and reuse systems, the challenge consists in the development of a decentralized approach to infrastructure planning and design to address the needs of urban and rural settings. Decentralized systems such as water harvesting for domestic and agricultural purposes or satellite wastewater treatment plants may better protect watersheds and water resources and avoid transfers over long distances. Senegal which is increasing its urban sanitation coverage with on-site sanitation systems as its main focus is treating (ONAS in collaboration with Sandec) the increasing volumes of faecal sludge in decentralized treatment plants. The design of simple and multiple facilities with locally-capable O&M instead of sophisticated and large facilities would leave a needed resource close at hand and facilitate reuse at local scale (Kreissl, 1997). Local recycling and reuse may reduce the total water withdrawal. Smaller amounts of wastewater flows will be generated and more easily controlled; less energy might be consumed and less sludge produced (Harremöes, 1997).

The development and implementation of strategies and options to cope in particular with solid waste, faecal sludge and urine adapted to the conditions prevailing in Africa is still under-researched with only a few organizations having the expertise, such as CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût based in Ouagadougou (Burkina Faso)), WASTE in The Netherlands, EAWAG-SANDEC (Swiss Federal Institute of Aquatic Science and Technology – Water and Sanitation in Developing Countries), and e.g. the Water Research Commission in South Africa. A major challenge in view of urine reuse from urine diverting toilets is its transport and storage from urban areas to farms. To faciliate this, SANDEC is working on a low-cost transformation of liquid to solid urine.

Development of wastewater treatment systems that make the water biologically and chemically safe, but keep the nutrients that replace fertilizer for farmers, is also still a challenge. It is urgently needed to design a range of cost-effective solutions that addresses the technical, institutional, social, behavioural and cultural obstacles that constrain making a full complement of sanitation alternatives available to communities. A well articulated portfolio of sanitation alternatives would help both communities and planners to choose viable sanitation options (IWA, 2006).

Low implementation costs, proven technology, ease of operation and flexibility of upgrade in subsequent stages are all desired features of appropriate wastewater collection and treatment technology. Where land is available, natural systems such as waste stabilisation ponds or constructed wetlands may be used. Land treatment techniques could also be implemented, such as rapid infiltration, overland flow, slow rate or subsurface infiltration. Chemically enhanced primary treatment and upflow anaerobic sludge blanket reactors are other examples of applicable and affordable technologies. The choice should depend on local capacities and downstream uses. Adaptation and standardisation of some unconventional processes and combinations of treatment and non-treatment measures still need to be tested. An important partner to be explored and supported is the private sector in view of business models for low cost toilets, urine marketing, etc. which can tailor sanitation services for different users.

7. Stakeholder participation

Conventional sanitation planning does not empower end-users to "add" their knowledge and perception of progress to the process. There is therefore a need for platforms through which appropriate blending of knowledge systems and requirements can occur. The use of participatory approaches will allow community participation, personal involvement in decision-making processes, appropriation of sustainable sanitation and adequate operation and maintenance, and facilitate greater consensus between key municipal, state, and national stakeholders. This can also ensure participatory technique development to gain acceptance.

In order to enable the community of stakeholders to participate to the decision-making process, optimize the management process and the output, two approaches are being investigated: The "Household Centred Environmental Sanitation" (HCES) approach (SANDEC/WSSCC, 1999) and the "learning alliance" stakeholder approach (LA). The HCES puts people and their quality of life at the centre of any environmental sanitation system (rather than trying to change people's behavior to accommodate technology). The learning alliance stakeholder approach seeks to facilitate dialogue and breaks down barriers to information sharing at multiple levels. It is designed to speed up identification, development and uptake of innovation and the scaling up of research outputs through their alliances of practitioners, researchers, policymakers, activists and local communities. The SWITCH (http://www.switchurbanwater.eu) and Cities Farming for the Future (RUAF) are two examples of projects implementing the LA or similar multi-stakeholder approaches.

The SWITCH project is carried out in a number of cities across the globe. Its key proposition is that sustainable urban water management is only possible if the entire urban water cycle is managed in a holistic manner adopting IWRM principles. A large number of partners including IWMI are responsible for different components of the only SWITCH pilot project in SSA, which is based in Accra. The RUAF project aims at integrating agriculture in urban planning, with pilot cities worldwide including the western, eastern and southern Africa regions. The main objective of this programme is to contribute to urban food security, urban poverty reduction, environmental management, empowerment of urban farmers and participatory city governance through capacity development of stakeholders in urban agriculture and participatory multi-stakeholder policy formulation and action planning.

Conclusion

With a few major exceptions, most countries in Africa are characterized by inadequate water supply, poor environmental sanitation services and food insecurity. The approaches followed over the past 40 years have not succeeded in achieving sustainable water supply and sanitation services. New concepts and directions that fit African capacities, needs and possibilities are required (Warner, 2000).

The growing water demand and the discharge of mostly untreated wastewater pose a huge challenge for managing Africa's water resources in an integrated manner. Direct reuse of wastewater as well as the use of freshwater resources polluted by wastewater in farming are very common throughout urban and peri-urban SSA. Despite a positive impact on local economies with large socio-economic benefits from the irrigated areas, public health risks are undeniable.

The key question coming from both preceding observations is how to maintain sanitation services in the future especially the treatment of domestic wastewater in a situation where most conventional approaches fail and polluted stream water and raw wastewater are already used by ten-thousands of farmers?

The answer is a paradigm shift where water reuse defines the required degree of treatment, where technical solutions have to match African capacities, where urban source treatment will be partially "outsourced" along a multiple barriers approach combining different health protection measures.

The challenge is to integrate agriculture into urban sanitation concepts with the additional advantage of water and nutrient recycling as two of the major ways of closing the water and nutrients loops in the urban- rural interface addressing the MDG targets on sanitation and hunger simultaneously.

Alternative wastewater treatment methods based on the principles of closing cycles exist and several unconventional and low-cost wastewater technologies can be implemented for individual and collective sanitation systems. Designing a range of cost-effective solutions that addresses the technical, institutional, social, behavioural and cultural obstacles for the adoption of such an approach remain probably smaller challenge than convincing the major donors to support 'African concepts' of sanitation. A long-term strategy taking action step-by-step and the creation of new local business models are needed. But most of all, local capacities have to be built which value realistic standards and African solutions more than any imported sanitation curricula.

One of the major challenges for the continent will be our capacity to design a more sustainable urban and rural development that will limit rural-urban migration and put an end to informal settlement. Lessons can be drawn from experiences within the continent that can lead to more effective programs at the national and community levels. A key need is to ensure that proposals for technological solutions are based on holistic scientific, economic and social overviews of the entire urban water system where e.g. limitations in water supply are fully considered in setting sanitation targets, and where local communities can express their needs and suggestions in open multi-stakeholder platforms.

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