Wastewater Use for Urban and Peri-urban Agriculture[1]

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Introduction

Agriculture is often associated with rural areas, even though it has been practiced in urban and peri-urban areas since ancient times in backyards, on roof tops and road sides, in vacant plots and un-constructed areas, on river and lake beds and in other such small land lots. Urban and peri-urban agriculture (UA) provides nutrition and income, improves the urban environment by using the organic solid and liquid wastes of the city, provides aesthetic value to these areas and helps to achieve optimum land utilisation. However, city planners often ignore this important economic activity and do not include it in their planning. Agricultural finance institutions do not provide loans to urban farmers due partly to the fact that most of them do not have land titles and because the activity itself is considered insignificant. In addition to these factors that can hinder the success of UA, urban and peri-urban farmers often do not have access to a safe and reliable water supply. Issues related to this essential resource for agriculture are discussed in this paper.

Increasing volumes of freshwater are being converted into domestic, hospital and industrial wastewater in rapidly growing towns and cities around the world. By 2015, the world will have one billion more people than it does now and 88% of this growth will be in cities, mainly in developing countries (UNDP 1998). This population growth will have a dual effect: 1) a substantial increase in the volume of urban wastewater produced, since greater volumes of surface and groundwater will be diverted to supply these burgeoning cities; and 2) an increase in urban demand for food. The increasing volume of wastewater will therefore be utilised by farmers on an even greater scale than at present. Particularly in the case of urban areas in semi-arid, drought-prone areas, the lucrative and large market for fresh produce and the urban water demand will make freshwater even more scarce. The use of wastewater for agriculture in and around cities across the world is a current and future reality that cannot be denied. In some countries, such as Mexico and China, it has been practised for centuries (Shuval *et al* 1986). Since conventional treatment is very costly, most wastewater is allowed to be dumped, untreated, into water bodies or onto the land. Untreated wastewater use for urban and peri-urban agriculture is often either ignored or actively condemned by the public and by government officials.

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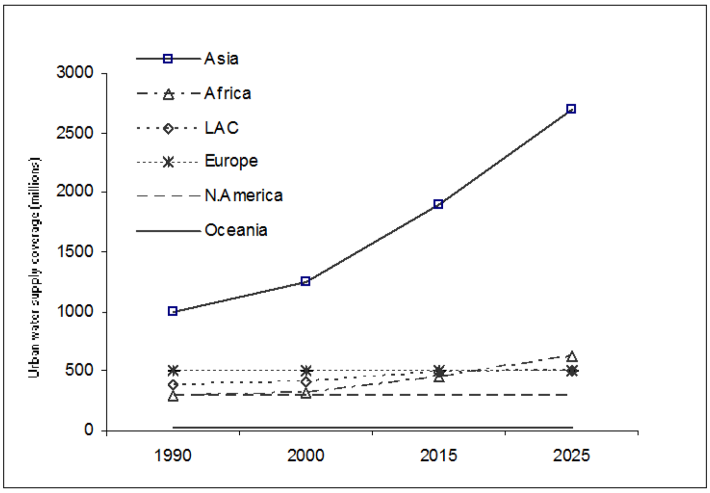
There is a small but expanding set of literature on biophysical, social, public health, political and economic aspects of wastewater and its use for agriculture. These studies are being used to inform practitioners and policymakers of the reasons for the use of wastewater, the different types of wastewater (including raw, diluted, treated to primary/ secondary/ tertiary level), the likely increase in its use and possibilities for mitigating the multi-dimensional risks associated with wastewater and its use.

Freshwater availability for agriculture

As the world population increases, the competition for freshwater resources between domestic demands, industry, commerce, institutions such as hospitals, and agriculture is intensifying. Water demand has tripled since the 1950s (Brown 2003). Figure 1 illustrates that increases in urban water supply coverage have been and will continue to be greatest in Asia followed by Africa, where absolute population figures as well as population growth are the highest (Scott *et al* 2004). Imminent water shortages, however, are less likely to be visible than other natural resource disasters such as deforestation and soil erosion to both the public and policymakers. This is due to the fact that much of the water scarcity is induced by groundwater overdraft for agriculture, industry and domestic use made possible by increased electricity coverage, power subsidies for diesel and electricity, and the extension of cheap credit (Shah & Scott 2004). A huge increase in the number of wells and over-pumping with increasingly powerful diesel and electrical pumps is leading to falling water tables. Particularly serious over-pumping is occurring in China, India, USA, Pakistan, Mexico, Iran, South Korea, Morocco, Saudi Arabia, Yemen, Syria, Tunisia, Israel and Jordan. Surface water from rivers is also tapped for freshwater and major rivers either completely dry up before reaching the sea or contain only a very small volume of water. Such over-exploited rivers include the Colorado river, the Yellow river, the Amu Darya, the Nile, the Indus and the Ganges. Currently, 70 per cent of surface and groundwater is used for agriculture, however with increasing competition between agriculture, industry and domestic demand, agriculture is beginning to receive less water (Brown 2003).

Figure 1 Growth in urban water supply coverage by world region



Source: Scott et al 2004

Water reuse is not a new phenomenon; it has been a worldwide practice for centuries. Agricultural wastewater, sewage wastewater (including grey water and black water) and industrial wastewater have been used directly or after treatment and/or dilution in urban and peri-urban areas for agriculture, especially in drought years. With the dwindling supplies of fresh surface and groundwater, water reuse and recycling assumes a greater role than before to keep up with the increasing population growth and the demand for increased quality and additional quantities of food.

Wastewater production by growing cities

The quantities of wastewater produced by cities are rising steadily with urban growth. As cities grow, the water supply to these cities also grows, resulting in ever-increasing quantities of wastewater produced by urban residents and industries. Municipalities, farmers, and irrigation and agriculture departments are ill-equipped, however, for the very sharp rise in urban-rural water transfers (Buechler and Scott 2006). The sources of wastewater include sewage drains, storm drains used as sewage channels, surface water sources like rivers, lakes and natural streams polluted with wastewater from city sewage and drainage channels, ponds and tanks, shallow wells, house drainage spouts and channels, wastewater treatment plants etc. The composition of the wastewater varies according to its origin. There is storm water and other urban run-off, grey water (domestic water that is wastewater without urine and faeces) or black water (domestic wastewater with urine and faeces), industrial wastewater, wastewater generated by hospitals and other institutional/ commercial establishments and combinations of all of these (each with varying concentrations of waste). The volumes of wastewater generated in Asia in the late 1990s are seen in Table 1. An example of urban growth far exceeding the capacity of sewage collection and treatment is Delhi, India. Only about 40% of the capital city of Delhi has sewerage at present, and of that less than half actually delivers sewage for treatment. Most is simply channelled through open drainage canals to the main river (the Yamuna) untreated. Despite investments in new treatment plants, the growth rate of the city is so rapid that progress in proportion to this growth has been very slow (Ganges River Partnership Project 2002).

Table 1 Estimated volumes of wastewater (million m^3/year) in Asia

Country	Sewage in urban Areas	Industrial Effluents	Total Wastewater
Bangladesh	525	200	725
Bhutan	3.9	0.3	4.2
China	37 290	22 672	59 962
Hong Kong, China	NA	NA	840
India (23 cities only)	3250	140	3390
Islamic Republic of Iran	2000	600	2600
Japan	NA	NA	17 100
Kyrgyzstan	83.8	21.6	105.4
Malaysia	1400	2.9	1 402.9
Maldives	3.7	0	3.7
Mongolia	NA	NA	82.9
Myanmar	16.6	0.5	17.1
Pakistan	NA	NA	NA
Philippines	7500	NA	NA
Republic of Korea	5 939	956	6 895
Singapore	NA	NA	470
Sri Lanka	350	225	950
Thailand	NA	NA	NA
Turkmenistan	268	913	1181
Uzbekistan	1 083	4 580	5663
Vietnam	540	350	890

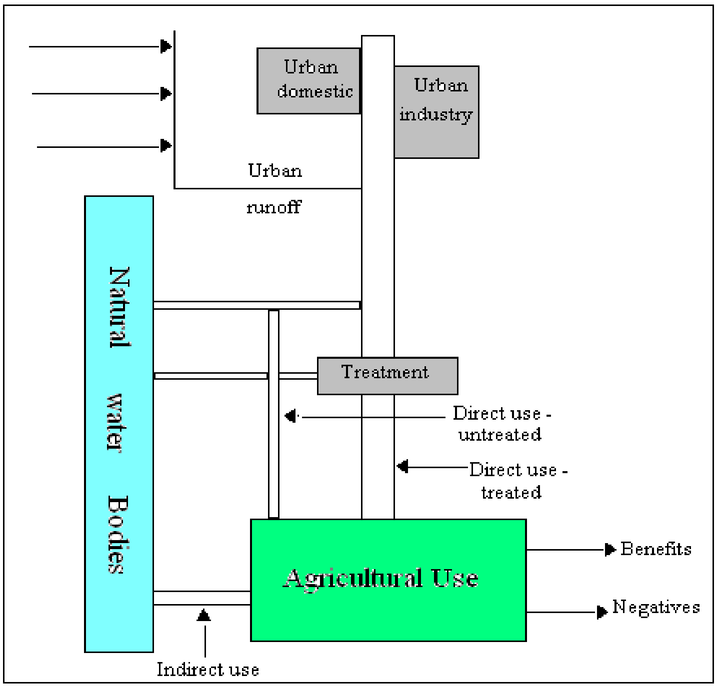
Source: Economic and Social Commission for Asia and the Pacific. 2000.

According to the United Nations Economic and Social Commission for Asia and the Pacific and the International Water Management Institute (IWMI), wastewater treated to primary or secondary levels is used for irrigation, in industry and cooling, whereas untreated wastewater is used mainly for agriculture. Wastewater treatment is costly, and even those cities that are currently able to procure funding to build treatment plants only treat a small percentage of the total volume of wastewater. The rest is left to flow into natural water bodies. Most of the water only receives primary treatment. The majority of developing countries treat less than 15 per cent of the wastewater they produce (Davis & McGinn 2001).

Many treatment plants in cities in the South go into disuse after a short period of time due to insufficient funds for operation and maintenance. This is the situation in cities like Vadodara, the third largest city in Gujarat state, India, where none of the three treatment plants is fully functional (Bhamoriya 2004); in Kathmandu, Nepal, where many of the valley's treatment plants are in poor condition (Rutkowski *et al* n.d.) and in Cochabamba, Bolivia, where the one treatment plant that exists is overloaded and therefore not working properly, and most residential septic tanks and Imhoff tanks are not functioning (Huibers *et al* 2004). The percentage of the population with full water-borne sewerage connections in sub-Saharan African is very low. Harare, Zimbabwe, is one of the cities in Sub-Saharan Africa with the highest coverage while Lagos, Nigeria, has one of the lowest. In Lagos (Nigeria), Africa's largest city, with a population of 10 million, only 5% of its population is connected to the sewage system and treatment of sewage is below recommended standards. Only 2% of the cities in sub-Saharan Africa have sewage treatment, and only 30% of these systems are operating satisfactorily. In Addis Ababa, with a population of 2.5 million, the sewage system serves only 35,000 people (www.unep.or.jp).

Policymakers' current focus is on wastewater regulation and treatment. However, to make realistic policies, information must be gathered on where wastewater irrigation takes place, the reasons for and extents of its use, the socio-economic characteristics of the main actors deriving direct and indirect livelihood benefits from this use, the risks to livelihoods and human and animal health of this use and the different types of wastewater use. A common typology of wastewater use that addresses aspects such as direct use (i.e. 'end-of-pipe' sewage irrigation), dilution of wastewater with natural surface water before use, and the relative contributions of domestic wastewater, industrial effluent, and storm water to urban wastewater is required. Van der Hoek (2004) has developed a typology (See Figure 2) that categorises wastewater use into three types: direct use of untreated wastewater where wastewater is directly applied to land from a sewage system; direct use of treated wastewater where treated wastewater is channelled to a particular area for irrigation; and indirect use of wastewater where wastewater is taken from another receiving water body such as a pond, lake, canal, tank or river.

Figure 2 Basic types of wastewater use



Source: Wastewater Typology developed by Wim van der Hoek, IWMI (2004)

Wastewater use in urban and peri-urban agriculture and its contribution to livelihoods and food security

Urban and peri-urban farmers from different caste and class groups in developing countries in Asia and Africa derive their livelihoods by using wastewater for various activities such as horticulture, fodder production for dairy activities, agroforestry, orchard keeping, floriculture, aquaculture and cereal production. There are also many areas in which the government runs sewage farms near treatment plants which are hired out to farmers for cultivation such as those around Madurai, South India (documented by Chandran *et al* 2003) and around Hyderabad, India (Buechler & Devi, field observations).

To date, assessments of the extent of wastewater irrigated areas have been carried out in Pakistan, India, Vietnam, China, Mexico and Jordan. In Pakistan an IWMI study estimated that there were 32,500 hectares irrigated directly with wastewater (Ensink *et al* 2004). Strauss and Blumenthal (1990) estimated that 73,000 hectares were irrigated with wastewater in India. However, Buechler and Devi (2002) estimated that just only along the Musi river that runs through Hyderabad city in Andhra Pradesh state and the canals and tanks off this river approximately 16,000 hectares of land is irrigated with urban and industrial wastewater (2003). An estimated Rs 1 million per day at least (personal communication by IRDAS, the NGO) is generated due to wastewater irrigated urban agriculture in Hyderabad. In the down stream of Vadodara, third largest city in Gujarat, India, alone, wastewater supports annual agricultural production of Rs 266 million (US $ 5.5 million) (Bhamoriya 2004:127).

In Ghana, it was estimated that if just 10% of the 280 million m^3 of wastewater from urban Ghana could be (treated and) used for irrigation, the total area irrigated with wastewater alone could reach 4600 ha. At an average dry season farm size of 0.5 ha, this could provide livelihood support for about 9,200 farmers in the peri-urban areas of Ghana (Agodzo *et al* 2003). In Vietnam, at least

9,000 hectares of land were found to be irrigated with wastewater mostly to grow paddy, and in and around 93% of the cities wastewater is used in agriculture or aquaculture (Rachid-Sally *et al* 2004:81). Mara and Cairncross (1989) estimated that 1.3 million hectares were irrigated with wastewater in China (187). For Mexico, estimates of the number of hectares irrigated with wastewater vary greatly between studies. Castelán has estimated the number irrigated with domestic wastewater at 344,000 ha, but states that in 1997, 403,000 ha of restricted crops (i.e. crops that are illegal to grow with wastewater as the produce is eaten raw) were cultivated (2000:25). Scott *et al* (2000) has put the number at closer to 500,000 ha.

Wastewater users, who come from a wide range of socio-economic backgrounds, have a variety of motives for using wastewater for irrigation. In semi-arid and arid areas it is often the only source of water available in sufficient quantities for irrigation; it is also available year-round unlike freshwater from rainfall which is concentrated in the often short and sporadic rainy season. It is also an inexpensive source, not only of water but also of nutrients. In fact, farmers often need few or no additional fertilisers. Crop yields are often higher with wastewater than with freshwater. For example, in Haroonabad, Pakistan, it was found that wastewater farmers earn $US 300–600 more per year than non-wastewater farmers and that the majority of wastewater farmers were landless and leased in land for agricultural production (van der Hoek *et al* 2002). In Kumasi, Ghana, Danso *et al* (2002) found that urban market farmers can earn 2-4 times more than farmers who grow maize and cassava. Wastewater farmers in and around Kumasi earn an average of US$ 340/ha per season (Cornish and Kielen 2004). Wastewater can easily be channelled to the fields from city drains, from a river, or from broken sewer lines or carried to the fields in watering cans. Using this water is also attractive as UA fields are often conveniently located near city markets where the produce is sold, or are near urban-based buyers who purchase the produce directly from the (peri-)urban plots. As urban populations and incomes of the urban residents increase, so too does the demand for fresh vegetables and dairy products (Brown 2005). Often, nearly all of the perishable produce for urban consumption is grown in and around urban areas due to the lack of refrigerated transportation in cities. For example, 90% of the lettuce and spring onions consumed in Kumasi, Ghana, are produced in the city itself (Danso *et al* 2002).

Despite the widespread use of wastewater, municipalities and water boards underestimate its value, and for policymakers it's a non-issue. The lack of information and awareness both among producers and consumers about the inherent risks of wastewater use further compounds the problem. The difficulties faced in wastewater use for aquaculture relate to the non-availability of guidelines for selection of species and stocking density (Kaul *et al*, 2002:3). The compatibility of the reclaimed water with its intended usage is an important consideration in developing a wastewater reuse system. Higher level uses such as for irrigating public access lands (eg. Parks) and the cultivation of vegetables requires higher levels of treatment compared to lower level usage such as pasture maintenance, floriculture and agroforestry irrigation

Impact of wastewater irrigated urban and peri-urban agriculture on health

Fifty percent of all children in developing countries (10.4 million children) under the age of five die per year due to malnutrition (Rice *et al* 2000, WHO 2000). Healthy individuals make healthy communities and wastewater, if well-managed, can help alleviate malnutrition especially for children of poor households. According to the draft WHO report 2005, "Guidelines for Wastewater Use in Agriculture" wastewater use in agriculture may have important economic benefits for households and communities that can improve the health of families through better access to healthcare, education, nutritious food and improved access to both water and sanitation in the household. In Hyderabad, a wastewater reuse case study showed that vegetable producers in the urban and peri-urban areas save about 20% of their household expenditure which they would otherwise have spent on the purchase of vegetables. Most of the households with livestock in the urban and peri-urban areas of Hyderabad, India, use wastewater irrigated para grass as fodder and generate an income through the sale of the milk. Typically, 25% of the milk produced (assuming a household of 6 members owns one buffalo) is retained for household consumption and 75% is sold (Buechler *et al* 2003c). The Hyderabad and Kumasi case studies further elaborate on these topics.

On the one hand, wastewater can contribute to improved health of poor communities through income generation and increased access to food. On the other hand it can be associated with a number of health risks since most wastewater is untreated or contaminated with industrial and other wastes.

Negative impacts on farming families and local communities

The people who face potential risks from the use of wastewater for agriculture are agricultural field workers and their families, crop-handlers, consumers and those living near irrigated fields. Wastewater can have direct and indirect health impacts. Direct contact with untreated wastewater through flood or furrow irrigation can lead to increased helminth infection (mainly *Ascaris lumbricoides* -roundworm, *Trichuris trichiura* -whipworm, *Ancylostoma duodenale* and *Nector americanus* - hookworm). Two case studies that examined the impact of untreated wastewater on health, environment and income in Pakistan indicated higher hookworm infections in farmers and farm workers who use wastewater for irrigation than those who do not (Ensink *et al* 2004).The main risk for the public arises when vegetable or salad crops grown with untreated wastewater are consumed raw. This can be linked to cholera and typhoid as well as to faecal bacterial diseases, bacterial diarrhoea and dysentery among consumers of wastewater-irrigated produce. Municipal and industrial wastewater is a major source of chemical pollutants that could affect human health. Chemical contaminants that pose potential health concerns and identified in untreated wastewater are shown in Box 1.

Strategies for Managing Health Risks

There is no single solution to the problems mentioned above. Combinations of different strategies that can reduce the health risk to humans need to be adopted. Pathogens and other inorganic contaminants in the fields do not necessarily represent a health risk if other suitable health protection measures are taken. The different health protection strategies as per the draft WHO report 2005 (currently being tested), “Guidelines for Wastewater Use in Agriculture” are:

Wastewater treatment: Most conventional domestic wastewater treatment plants focus on the removal of environmental pollutants (e.g. suspended solids, BOD - Biochemical Oxygen Demand-, COD - Chemical Oxygen Demand -, etc.) but not on pathogens, as the latter is more difficult and costlier and therefore not easy to undertake in developing countries. For the quality of treated water to meet the WHO standards, secondary treated water needs to be supplemented by tertiary treatment (disinfection) or retained in a maturation pond for five more days. Some research has been done to develop decentralised and cheaper treatment solutions. One example is the pilot project, “Ecology and Development with Sustainable Sanitation” (ECODESS) of the Urban Development Institute in the district of San Juan de Lurigancho near Lima, Peru. In this arid urban area on the Peruvian coast, where freshwater availability per person per year is projected to be five time less than the global average by 2025, and only 4 % of the sewage is currently treated, this project has set up a household and a community system to collect, treat and recycle wastewater. The treated wastewater is channelled into an underground irrigation network for use in green areas and urban agriculture (Calizaya 2002). Another economical model in Kolkata, India, for improving the quality of wastewater used in peri-urban aquaculture is the cultivation of dense plantations of crops or trees on the sides of wastewater canals, which controls soil erosion, absorbs some amount of the pollutants and provides nutrient-rich water for aquaculture (Mukherjee 2003).

Box 1: Selected chemicals of potential health concern identified in untreated municipal wastewater*

Chemical	Potential health effects
Heavy metals	
Arsenic	Gastrointestinal, skin, and nerve damage, cancer
Cadmium	Gastrointestinal, kidney and lung damage
Chromium	Lung and skin damage, cancer
Lead	Nervous and immune system and kidney damage, embryo/fetotoxic
Mercury	Brain and kidney damage, embryo/fetotoxic
Nickel	Lung, brain, kidney, liver, spleen and skin damage, cancer
Inorganic chemicals	
Cyanide	Brain and heart damage, shortness of breath, death
Fluoride	Dental and skeletal fluorosis
Hydrogen sulphide	Nausea, vomiting, mucous membrane irritation
Nitrate	Methaemoglobinaemia
Nutrients	
Nitrogen Phosphorus	Cause eutrophication which facilitates the growth of toxin-producing cyanobacteria and other harmful algae
Organic chemicals	
Benzene	Anaemia, dizziness, leukaemia
Phenol	Irritation of skin, eyes, and gastrointestinal tract, systemic toxicant
Toluene	Brain and kidney damage
Xylene	Confusion, dizziness, memory loss, embryo/fetotoxic
Other chemicals	
Endocrine disruptors	Reproductive/developmental effects in wildlife, various potential effects in humans
Pharmaceuticals	Reproductive/developmental effects in wildlife, various potential effects in humans

*The toxicity of a chemical depends on its concentration, the route of exposure to the chemical and the duration of exposure to the chemical. The health effects above include both acute toxicities (high chemical concentration and short exposure duration) and chronic toxicities (relatively low chemical concentration and long exposure duration) with all routes of exposure. Some of the toxicities may not be applicable to wastewater.

Sources: Chang, Page & Asano, 1995; National Research Council, 1998; WHO, 1999; WHO, 1992; WHO, 1991; WHO, 1989; ATSDR, 2000.

Choice of irrigation techniques: Farmers use different irrigation techniques depending on convenience and knowledge. However, farmers using wastewater for irrigation need to take some precautions during irrigation. Sprinkler/spray irrigation has the highest potential to spread bacterial and viral diseases and hence a buffer zone of 50–100 meters from houses or roads should be maintained to prevent health risks to local communities. Workers in the fields and their families should wear protective clothing in case of furrow or flood irrigation to prevent direct contact with wastewater. Localised irrigation techniques like bubbler/drip/trickle offer the best health protection but are expensive to implement. Still for all, drip irrigation is being taken up by some farmers as seen in Cape Verde and India (FAO 2001; Kay 2001). Vaz da Costas Vargas *et al* (1996) show that cessation of irrigation for 1-2 weeks prior to harvest, wherever possible, can be effective in reducing crop contamination.

Crop Selection: Water of poorer quality can be used to irrigate non-edible crops such as cotton or flowers, or crops that are cooked before consumption. Plants (eg.zucchini) with rough, textured surfaces, deep crevices or hairy surfaces that grow close to the ground may harbour bacteria or contaminated soil and should be avoided. But crop restriction cannot be a stand-alone solution. In Chile, the use of crop restriction, when implemented together with a general hygiene education programme, reduced the transmission of cholera related to the consumption of raw vegetables by 90% (Monreal 1993).

Human exposure control: Field workers are the most exposed to wastewater. The health risks faced by these individuals can be reduced by using appropriate irrigation techniques such as bed and furrow cultivation and protective clothing in the form of boots and gloves (van der Hoek et al 2002; Ensink et al 2004). Field workers should also be provided with sanitation facilities and drinking water. Provision of safe water in vegetable markets to wash produce is important to prevent further contamination of wastewater irrigated agricultural products. Consumers should wash fresh produce thoroughly and cook it before use. Governments should invest in employing additional health inspectors who do periodic checks on milk and meat products in the city. Finally, awareness campaigns on these issues would be of great help in minimising the health hazards of wastewater irrigation.

Treatment with chemicals and Vaccination: Immunisation against typhoid and hepatitis A for highly exposed groups is recommended (Carr et al 2004). This therapy for adults and children in particular at regular intervals can reduce helminth infections (Ensink et al 2004).

Developing alternatives: Improvement of sanitation, or use of innovations in the existing sanitation systems. One such innovation is Eco-Sanitation (see Box 2).

Box 2: Ecological sanitation

Ecological sanitation is a safe method of recovering nutrients from human excreta, then recycling them back into the environment and productive systems

A human being produces in the form of excreta exactly the amount of nutrients that is needed for growing his or her food (measured in crops) – 7.5 kg of nitrate, phosphorus and potassium for 250 kg of crops. Urine hardly contributes at all to the spread of diseases (e.g. bilharziasis) and contains approximately 88% of the nitrogen, 67% of the phosphorus and 71% of the potassium carried in domestic wastewater. Faeces contain 12% of the nitrogen, 33% of the phosphorus, 29% of the potassium and also 46% of the organic carbon, as well as most of the pathogens.

If separated, urine can easily serve as a fertiliser after it has been diluted with water. After faeces have been desiccated (dried-out), they are free from pathogens, diseases and odour. They can then serve as a soil conditioner for agriculture, returning a significant part of the nutrients and trace elements to the soil.

The remaining treated grey water may be used for irrigation and also for recharging the local aquifer. This closes the local cycle, helping to improve food security and to conserve soil fertility. At the same time, human health is improved due to the removal of disease sources from the domestic environment.

Source: http://www.thewaterpage.com/ecosan_main.htm

Farmer innovations to deal with poor water quality and degraded soils

Farmers have developed a variety of different innovations in order to adapt to deteriorating water quality and degraded soils. In order to maintain or increase yields and income and to lower their health risks, they continuously react to changes in water quality and quantity and soil productivity. Some examples of farmer innovations are the mixing of groundwater and wastewater (see Buechler and Devi, 2005; Faruqui *et al* 2004; Raschid-Sally *et al* 2004; Ensink *et al* 2002) and alternating the use of groundwater and wastewater according to the stage of plant growth (Buechler and Devi 2005). These strategies were found to increase yields, decrease pest attacks as well as decrease worm infections among wastewater irrigators and other agricultural labourers. Another adaptation made by farmers is in switching to new crops that are more suited to wastewater irrigation, for instance replacing paddy with fodder grass as it is more tolerant to higher levels of salinity, as is the case in wastewater (Buechler and Devi, 2005).

Users' needs and perceptions

Farmers' perceptions on the different aspects of wastewater - quality, economic value and health issues – should be brought to the attention of policymakers and urban authorities in fostering appropriate planning initiatives. By farmers we mean members (female and male of different ages) of farming households who carry out activities related to the production of crops using wastewater for irrigation. By focusing on the perceptions of members of these farming households, the different needs of wastewater-dependent households living in different locations and belonging to different socio-economic strata will be elucidated (Buechler 2004). Other factors that vary across locations and affect users' needs are: the sources of the wastewater and percentage of industrial effluent mixed with domestic sources; the *de jure* and *de facto* land tenure system; land values, land rental rates and land taxes; infrastructure (electricity grid); and the legal framework. Gathering and analysing farming household members' perceptions can facilitate the formulation of flexible "response scenarios". These could be developed for specific locations or for similar localities to identify appropriate risk reducing strategies that are technically, economically, socio-culturally and politically compatible. Users' perceptions of wastewater use have received only scant attention in studies to date.

One strategy to bring the perceptions and voices of wastewater users to various audiences is through documentary films (see Buechler *et al* 2003a). In order to integrate users' perceptions into written media, their responses to key questions regarding wastewater use for agriculture must be elicited, recorded and then transcribed. Selections from the transcriptions must be incorporated into the written text of articles and other written and visual outputs and disseminated to key actors and decision-makers who will use them to develop projects and policies as an integral part of other urban planning initiatives. Newspapers, television and radio are the most popular media in most countries and can be used to disseminate information to producers and consumers. For policy makers, fact sheets and policy briefs can be developed and distributed. School children can be given educational tours to make them aware of the environmental hazards of disposing organic and inorganic wastes in water. Women can be specifically be targeted for education on the importance of cleanliness during food preparation to prevent possible infections (i.e by washing away helminth eggs), further contamination of wastewater produce and proper cooking of food.

Gender issues

The experiences and roles of women and men in UA are gender related. Frequently, different agricultural tasks such as weeding, irrigation, harvesting and post-harvest activities that include making bundles, threshing, washing of produce, marketing etc. are divided by gender. In wastewater-irrigated agriculture, a gender division can also be discerned in the types of crops produced by men and women. The gender division of labour is context-specific. For example, in and around Hyderabad, India, mainly women are involved in both the cultivation and sale of leafy green vegetables in the surrounding wastewater-irrigated fields (Buechler & Devi 2002; Buechler et al 2003a). However, in and near the city of Kumasi, Ghana, most of the vegetable production is done by men while the marketing is done mainly by women (Keraita *et al* 2002). In Haroonabad, Pakistan, vegetable cultivation is mainly done by women and marketing of the produce mainly by men (van der Hoek *et al* 2002; Ensink, personal communication November 2004). In and around

Hyderabad, it was evident that women benefited in a myriad ways from wastewater-irrigated leafy green vegetable production; they benefited from the income derived from the sale of their produce and from improved nutrition for themselves and their household members. Women and children benefited also through employment created on the vegetable fields.

Vegetable vendors in urban and peri-urban markets, who are mainly women, benefited through their income from sales as well as through keeping some of the vegetables for home consumption or bartering these vegetables for other types of produce sold in the market (Buechler & Devi 2003d). Women play an important role in animal husbandry in urban and peri-urban areas in South and South-East Asia and in Latin America. Most activities associated with dairy production, for example, are performed within the domestic compound and are therefore done mainly by women, whose public space is often restricted by patriarchal social norms (Devi *et al* 2004). Fodder for these animals is often procured from wastewater-irrigated fields. Studies on wastewater use for UA and wastewater irrigation need to include gender as a variable. For example, very few studies on health risks associated with wastewater use have examined the particular risks of women versus men, or girls versus boys.

Women and girls spend more time in vegetable fields in many regions of the world than men and they perform tasks such as weeding which involves direct contact with the soil and, after irrigation, with water. Many are landless, migrant field labourers with little or no access to health care services. Women's access to and control of resources is also limited in most Asian and African countries. However, it has been seen that women have greater bargaining power when they are organised as groups. Through cooperative mechanisms, women can pool resources, information, time and energy, thereby increasing their chances of developing successful livelihood strategies in urban agriculture (Wilbers 2004).

Very few studies have focused on livelihoods of urban and peri-urban vegetable market vendors, who are predominantly women in regions such as Latin America (an exception is Brazil), Africa and South Asia. Many of these women depend on wastewater-irrigated crops for their income and household food security (Buechler & Devi 2003c). Yet little is still known about the ramifications of deteriorating wastewater quality on the sustainability of vegetable production and sale in and around urban areas.

Education, information and awareness-raising

Raising awareness among farmers, policymakers, polluters, marketers, consumers and other stakeholders is seen by many as the immediate and most important strategy to reduce the health risks associated with wastewater farming in most low-income countries.

Education and information sharing need to be tailored to each type of group that engages in wastewater dependent activities, as the user patterns of each set of actors is very different. IWMI Hyderabad has developed a series of posters translated into several local languages for dissemination to farmers and a documentary film on wastewater use and users. Consumers are also a heterogeneous group, using different types of wastewater-produced items. Producers, workers and consumers need to be included in information campaigns, training and information-sharing forums, so that hygiene can be improved and associated diseases prevented. Municipal authorities often do not include urban farmers as "real irrigation farmers" and therefore do not provide any extension services to them (see the Kumasi case). Awareness raising could diminish risks related to wastewater irrigation and possibly have a wider impact in combating hygiene-related diseases in general.

As the Hyderabad Declaration states, wastewater use for livelihood activities in urban and peri-urban areas is a reality that planners and policymakers must face. Financial resources should be made available to the relevant institutions to implement appropriate measures to protect and support these livelihoods as well as to improve the health of the environment, the users and the consumers.

Institutions

Various governmental agencies are involved in shaping the policy framework into which wastewater-related activities are incorporated. Often, there is little convergence between the laws and policies of these different institutions in relation to UA and wastewater use. Enforcement of laws such as those related to the environment is often lax (Raschid *et al* 2004b). Wastewater farmers often face a hostile legal and institutional environment of fines and imprisonment (Keraita & Drechsel 2004, Buechler & Devi 2002). Sometimes institutions even compete for the rights to allocate and/or sell wastewater (Bhamoriya 2004, Buechler 2001). There is a need for researchers, NGOs and urban farmers to engage with policymakers at various levels and officers from various different governmental agencies to encourage a well-integrated, supportive policy environment. Poverty reduction programmes could integrate the needs of urban and peri-urban farmers such as for land tenure security and health and agriculture-related training. There is also a need to strengthen local institutions such as farmers' associations and institutions involved in sewage collection and low-cost treatment systems, and to enact by-laws that can enhance safe urban vegetable (see the Kumasi case) and other agricultural and aquaculture-related production.

Membership in local institutions related to wastewater use for agriculture may be limited to those who own land. Separate institutions may exist for people of different caste, class, religion, gender and ethnic affiliations. These divisions and affiliations in membership and organizational type shape the constraints and opportunities faced by wastewater users (Buechler 2004). Linkages between organisations should be encouraged to strengthen them, as is currently being done in RUAF's Multi-stakeholder Action Planning and Policy-making process. Efforts should be made to give membership to wastewater users in local institutions who have been denied this right due to their status; or else they should be accommodated in new organisations. Laws prohibiting urban agriculture or the failure of governments to respect current land tenure rights allow temporary land use can harm the livelihoods of wastewater farmers. Laws and by-laws that support urban and peri-urban farmers and those that make a living off of wastewater produce can and need to be enacted.

Conclusions

Many challenges lie ahead for wastewater users involved in UA around the world. The rapid expansion of urban development will bring opportunities in terms of increased water supply for irrigation in the form of wastewater and a greater urban demand for their products. The demand will increase mainly in certain niche products for which consumers are ready to pay a premium on the freshness of the product, for example, milk, meat, fresh vegetables and fruits. However, overall land availability may decrease with urbanisation and agricultural land will certainly shift to areas that are further away from city centres. The quality of wastewater may well deteriorate if urbanisation takes place with concurrent increases in industrial, hospital and commercial effluents. Urban authorities in water and sanitation agencies, health care agencies, agriculture ministries, urban and industry planning agencies, development and welfare agencies will need to ensure that investments are made in relevant initiatives. These include domestic, hospital, commercial and industrial wastewater source separation and treatment options; promotion of water pollution prevention management techniques and technologies; provision of incentives for industries to reuse water and to use less water to minimise water pollution; preventative and curative health care measures; farmer extension services for both female and male urban wastewater farmers and farmer-to-farmer exchanges; and social programmes designed for each category of wastewater-dependent group (male and female landless labourer, land leaser, landowning farmer etc).

There are many gaps in wastewater research which hinder attempts by policymakers and practitioners to identify solutions to common problems faced by wastewater users. One such gap is the lack of knowledge of how wastewater users adapt to changes in wastewater quality and quantity over time. Innovations and adaptive mechanisms developed by farming households can be shared with other farmers in similar circumstances; these local innovations can be further refined and adapted by social and natural scientists in relevant institutions for developing effective, context-specific risk-mitigation strategies that can be promoted by governmental and non-governmental institutions. Another gap in current research is the lack of clarity on which social groups are involved in wastewater-irrigated agriculture and why. Without this information, policies and programmes that cater to the special needs of each group cannot be developed. The main risks and benefits for groundwater users in wastewater-irrigated areas are also not well understood and needs the attention of biophysical as well as social scientists. Lower-cost treatment options need further research in order to increase the capacity of urban sanitation authorities to manage their waste in a sustainable manner.

A major obstacle in the process of minimising the risks lies in the non-recognition of wastewater reuse and urban agriculture as an urban livelihood strategy. Wastewater is not a priority issue for policy makers and there is no coordination among the different institutions – municipalities, water boards, departments of agriculture, and departments of land use planning, quality control agencies – that have a stake in wastewater use. This inhibits the design of integrated solutions. The adoption of research programmes and risk-mitigation measures or enabling policies therefore depends on whether the authorities and policymakers give due recognition to urban agriculture. This will also ensure that sound legal and regulatory frameworks related to urban agriculture are sustained and enforced.

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