3. Special subjects

3.1 Waste water reuse in Urban Agriculture

Wastewater feeds plants in an aquaculture system.

(Picture: Nico Bakker)

Reuse of urban wastewater and human excreta

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The practice of reuse of urban waste water and human excreta in urban agriculture and aquaculture[2]

All around the world, people both in rural and urban areas have been using human excreta for centuries to fertilise fields and fishponds and to maintain the soil organic fraction. Use of faecal sludge – these are sludges which are collected from septic tanks and unsewered family and public toilets – in both agriculture and aquaculture continues to be common in China and Southeast Asia as well as in various places in Africa (Cross 1985; Timmer and Visker 1998; Visker 1998; Timmer 1999; Strauss et al. 2000).

Where water-borne excreta disposal (sewerage) was put in place, the use of the wastewater in agriculture became rapidly established, particularly so in urban and periurban areas of arid and seasonally arid zones. Wastewater is used as a source of irrigation water as well as a source of plant nutrients, allowing farmers to reduce or even eliminate the purchase of chemical fertiliser. Recent wastewater use practices range from the piped distribution of secondarily treated wastewater (i.e. mechanical and biological treatment) to periurban citrus fruit farms (e.g. City of Tunis) to farmers illegally accessing and breaking up buried trunk sewers from which raw wastewater is diverted to vegetable fields (e.g. City of Lima; Strauss and Blumenthal 1990). Agricultural reuse of wastewater is practised throughout South America and in Mexico and is also widespread in Northern Africa, Southern Europe, Western Asia, on the Arabian Peninsular, in South Asia and in the United States (Shuval et al. 1986; Strauss and Blumenthal 1990; Asano et al., eds. 1998; Bahri 1998; Niang 1999; Owusu-Bennoah 1993; Khouri et al. 1994).

Vegetable, fodder and non-food crops as well as green belt areas and golf courses are being irrigated. In a few countries (such as the United States and Saudi Arabia), wastewater is subjected to advanced treatment (secondary treatment, filtration and disinfection) prior to use. Table 1 lists selected examples of wastewater reuse.

It has been estimated that in the order of 10 % of the world's wastewater is currently being used for irrigation. 100 % of the wastewater from the cities of Santiago (Chile) and Mexico City is used for irrigation, constituting some 70 and 80 %, respectively, of the irrigation waters used in the surrounding agricultural zones during the dry season. In South Africa, in the order of 15-20 % of the wastewater is reused in agriculture (Khouri et al. 1994). Morocco was using about 16 % of its wastewater in 1990, constituting some 0.5 % of the entire irrigation waters used (Benchekroun 1991). Farmers have been utilising wastewater for a long time, whether untreated or treated, in a legal or illegal manner, to compensate for scarce or costly freshwater resources. In contrast to this, planners and decision makers have only more

[2] The term 'urban agriculture and aquaculture' is used here in its broadest sense and is meant to comprise agriculture and aquaculture within or outside the administrative city boundaries, making regular and substantial use of the city's human waste water for fertilisation and irrigation.

recently become aware of the need to make wastewater reuse part of urban strategic sanitation and infrastructure planning.

Table 1: Selected Examples of Wastewater Reuse in Agriculture

Americas		**Asia**	
Mexico	- Cereals, vegetables, fodder, parks	**Kuwait**	- Cereals, fruit trees, fodder
Peru	- Vegetables, fodder, cotton	**Jordan (indirect)**	- Vegetables, crops consumed processed
Chile	- Vegetables, grapes		
Argentina	- Vegetables, fodder	**Israel**	- Cotton
U.S.A. (Calif.)	- Vegetables, cereals, fodder	**Saudi Arabia**	- Cereals, fodder
		India	- Cereals, vegetables
Europe		**North Africa**	
Germany	- Cereals, sugar beet, potatoes	**Tunisia**	- Citrus, fodder
S. Europe	- Non-food crops, parks	**Morocco**	- Vegetables, fodder

Production of fish and to some extent of water vegetables (macrophytes) in ponds fertilised by human excreta or wastewater has long been, and continues to be, practiced in many countries in South and SE Asia (e.g. India, Thailand, Indonesia, Vietnam, Taiwan, China), in Western Asia (Israel) and in Africa (Edwards 1992). Many of these schemes and practices may be designated as urban or periurban as they make use of faecal sludges and wastewater collected in urban areas. Fish production rates of 1-6 tons/ha/year are achieved, depending on the type of fish raised, pond operations and temperature. Until after World War II there was also a practice of sewage-fed fishponds in Germany. The Calcutta Wetlands, consisting of some 30 km^2 of fishponds is the world's largest sewage-fed fish production site. The wastewater from East Calcutta, composed of domestic and industrial effluents, is batch-fed to the ponds by fishermen who have developed the skills over many generations. Tilapia and carp are the two main types of fish raised. The Wetlands reportedly cover some 10-15 % of the fish consumption in Calcutta.

Waste stabilisation ponds have come into increasing use to treat wastewater in tropical areas. It is rather common that nearby dwellers make informal or illegal use of the ponds, notably the less contaminated of the 2-4 ponds operated in series to raise fish, both for consumption within the family and for sale on local markets.

Duckweed production in excreta or sewage-fed ponds has found increasing attention in recent years. In the cities of Tainan and Chiai in Taiwan, wastewater-fed production of duckweed to be used as fish and duck feed was practised on a large scale for 30-40 years until the late nineties, when the duckweed ponds had to give way, partly at least, to growing urbanisation (Iqbal 1999). Duckweed production based on fertilisation by faecal sludges was investigated in the seventies and eighties at AIT in Bangkok (Edwards et al. 1987). The pilot field research revealed that duckweed production for fish feeding might become economically viable as a part of an integrated urban excreta reuse system but less so at village level. PRISM Bangladesh has set up, with external support, integrated excreta and wastewater-fertilised duckweed-fish production projects in three towns in Bangladesh from 1989 onwards.

The economic viability of such systems is uncertain yet, although one of the systems produced net financial gains during a four-year period. The labour intensive and skill requiring operations of duckweed ponds appear to be a major cost factor. Institutional settings, entrepreneurial organisation and operating cost, might be the major factors which have prevented a larger-scale spreading of excreta/wastewater based duckweed systems to date.

The resource potential of wastewater: irrigation water, nutrients and organic matter

Excreta are a rich source of inorganic plant nutrients such as nitrogen, phosphorus and potassium, and of organic matter. Table 2 shows that the fertilising equivalent of excreta is nearly sufficient for a person to grow his own food (Drangert 1998). Excreta are not only fertilisers. The organic matter content, which serves as a soil conditioner and humus replenisher – an asset not shared by chemical fertilisers – is of equal importance. The traditional practices of recycling faecal sludges to agriculture or aquaculture (e.g. in Southeast Asia) have made use of this resource for centuries.

Table 2: The Fertiliser Equivalent of Human Excreta (Drangert 1998)

Nutrient	lutrient in kg			
	In urine (500 l/year)	In faeces (50 l/year)	Total	Required for 250 kg of cereals
N Nitrogen	4.0	0.5	4.5	5.6
P Phosphorus	0.4	0.2	0.6	0.7
K Potassium	0.9	0.3	1.2	1.2

For the same reason, urban farmers in arid or semi-arid zones or during dry seasons, in addition to procuring water for irrigation, are endeavouring to get access to wastewater, raw or treated. This allows them to renounce or minimize the purchase of chemical fertiliser. It is now being postulated that sanitation systems should, whenever feasible, be conceived and managed such as to enable and maximise the recycling of organic matter and nutrients contained in human excreta (Winblad 1997; Esrey et al. 1998).

A change in the sanitation management paradigm from flush-and-discharge to recycling of urine and faeces is gaining ground in Europe (Larsen and Guyer 1996; Otterpohl et al. 1997 and 1999; Otterpohl 2000). As a consequence, treatment strategies and technological options for faecal sludges and wastewater will have to be developed which allow the optimum recycling of nutrients and organic matter to periurban agriculture, while being adapted to the local situation and needs (see also Chapter 6 below).

In arid and semi-arid areas or in seasonally dry zones, irrigation requirements make up 80-90 % of the entire demand on natural water resources. The water required for urban water supply is thus small in relative terms. Hence, recycling urban wastewater to urban agricultural soils may bring about a saving in the national water budget of some 10-20 % at most.

However, reusing urban wastewater within the urban agricultural perimeter may very well cover a substantial portion if not 100 % of the local water demand of urban agriculture, and thus contribute to farm-based income generation, socio-economic equity and urban food security (Shaat 1998). Hence, in dry areas and seasons, wastewater reuse is being practiced all over the world whether officially regulated or not (Scot et al 1999; Strauss and Blumenthal 1990; Nunan 2000).

Assuming a yearly rate of irrigation of 500 mm and a per-capita sewage production of 100 l/cap/day, a city of 1,000,000 people would produce enough wastewater to irrigate an area of 7,000 ha (70 km^2 !!), using efficient irrigation methods. The nutrient load of this wastewater would comprise about 1,800,000 kg of nitrogen, 360,000 kg of phosphorus and 540,000 kg of potassium (after Khouri et al. 1994). This may or may not fully satisfy the plant requirements, depending on the type of plants and the cultivation regime adopted.

The stakeholders in reuse of urban waste water and human excreta

It appears that only few investigations have been made to date which have attempted to assess who the stakeholders and actors are, what drives their activities, what constraints they face, and how they apply the wastes – faecal sludge or wastewater – to the fields or fish ponds.

Allison et al. (1998), Furedy (1988), Strauss and Blumenthal (1990), and Baumgartner (2000) have addressed the issue. Farmers cultivating empty plots within urban centres or near-centre zones, in many localities, belong to the group of smallholders not availing of tenure over the land they are cultivating using human wastes. They themselves or members of their families may pursue other jobs and thereby contribute to the household's income. The basis of their cultivating activities is insecure. They are little organised and therefore barely have a political voice. The land they make use of is prone to be used for urban expansion eventually. In contrast to this, agricultural land bordering cities and being farmed by the legal owners of the land provides a much more stable basis of living. The size of holdings may range from small (in the order of 1,000 m^2 or less) to large land areas (> 1 ha).

In some places, farmers have set up farmers' organisations; e.g., those sharing water delivered through a common irrigation canal system (Strauss and Blumenthal 1990). On larger land holdings, notably so in Latin America, which are irrigated by untreated or treated urban wastewater, the land is owned by landlords and cultivated by employed agricultural workers. Many of these live in rather poor conditions and may not have access to health services. In the Calcutta Wetlands (see Chapter 1), part of the fishponds are owned by "pond" lords living in the city and managed by fishing families who may have been living in the Wetland area for many generations already. Other ponds are owned and operated by fishing co-operatives, which have developed their own social infrastructure such as schools and health facilities (Strauss and Blumenthal 1990).

Other important actors are the "deliverers", i.e. those in charge of faecal sludge or wastewater collection, treatment where existing, and disposal (Harris et al. 1998; Strauss and Blumenthal 1990). Responsibility for waste collection and delivery usually rests with the municipal or provincial authorities in charge of sanitation services (technical and/or health departments). In some cities or countries (e.g. Mexico, Tunisia), regional agricultural or irrigation authorities are in charge of wastewater distribution and of enforcing the regulations restricting crop irrigation with wastewater (Strauss and Blumenthal 1990). Usually, in such situations, the wastewater distributed through canals or pressure lines has to be requested and paid for by the farmers.

While, notably in larger cities, municipal authorities are responsible for faecal sludge collection and disposal, the actual “business” of farm side delivery might, in most cases be dealt with directly by the sludge collectors (usually suction truck drivers) and the farmers. In many Asian cities, faecal sludges are collected by small entrepreneurs and sold to farmers at the urban fringe without the involvement of public authorities. Where faecal sludges are treated prior to use, intermediary, private entrepreneurs may play a role in selling treated products to farmers. There are, moreover, examples of smaller towns where micro-entrepreneurs do the house-to-house collection of septic tank or latrine sludges and sell these to periurban farmers (Montangero and Strauss 1999). In still other places, farmers may themselves have arrangements with urban households for collecting faecal sludge from their private pit latrine or septic tank.

The above shows clearly that different modes of stakeholder interactions and collaboration for the use of human waste in the urban and periurban environment have been established which differ according to the local administrative socio-cultural and economic setting and the type of human waste being used. It is of utmost importance to carefully evaluate these interactions when attempting to bring about changes or proposed improvements in human waste use patterns, including treatment, in order to not disrupt or jeopardise the beneficial recycling of excreta and wastewater.

Planning and Economic Aspects

Planning for the securing, improving or introducing of reuse of waste water and human waste in urban agriculture encompasses a wide range of aspects and activities. These comprise, among others, stakeholders involvement (concepts and operational patterns); strategic water resources planning; institutional coordination; pricing of treated wastes; technical support to enable sustainable waste collection and treatment; health protection; enforcement of treatment and use regulations; strategic sanitation planning; marketing of treated faecal sludges and wastewater; re-thinking the policy of fertiliser subsidy; training of professionals on sound alternatives for sanitation and recycling. These subjects have been touched upon to various levels of detail and comprehensiveness by Mara and Cairncross (1989), Khouri et al. (1994), Allison et al. (1998) and Furedy et al. (1999).

Certainly, the urban farmers – smallholders and larger property holders alike – should stand at the centre of efforts to support urban agriculture. In conceiving projects and programmes involving the use of human waste in urban agriculture, planners, decision makers, engineers and extension workers in local and national level authorities, NGOs and donor agencies, should focus on the needs and constraints of the urban farmer. In some places, though, the usefulness of urban farming and use of waste water and human wastes must first be promoted among decision-makers and higher-level planners who still too often consider this as something undesirable and inferior. There is, often, a need to raise awareness among politicians and planners that urban agriculture and the judicious use of human wastes contributes greatly to the securing of socio-economic balance, food procurement and environmental integrity in a city.

Health aspects

Excreted Pathogens

In developing countries, excreta-related diseases are very common, and faecal sludges and wastewater contain correspondingly high concentrations of excreted pathogens - the bacteria, viruses, protozoa, and the helminths (worms) that cause gastro-intestinal infections (GI) in man. There are approximately thirty excreted infections of public health importance, and many of these are of specific importance in excreta and wastewater use schemes. The risks of transmission of excreted pathogens using human wastes in agriculture and aquaculture have been, and continue to be, widely studied and reported about. This may be interpreted as reflecting the growing importance of human waste and waste water use in urban sanitation programmes and, as a consequence, the increased need and interest of decision makers and planners to become informed of the risks involved in the local context and to obtain guidance on how best to protect public health.

The agricultural or aquacultural use of excreta and wastewater can **only** result in an actual risk to public health, if **all** of the following occur.

(a) That either an infection dosage of an excreted pathogen reaches the field or pond, or the pathogen multiplies in the field or pond to form an infective dosage;
(b) That this infective dosage reaches a human host;
(c) That this host becomes infected; and
(d) That this infection causes disease or further transmission.

a), (b) and (c) constitute the **potential risk** and (d) the **actual risk** to public health. If (d) does not occur, the risks to public health remain potential only.

A multitude of transmission paths exist for excreta-related infections including transmission via waste water, soil, crops and fish, as well as through person-to-person contact (for members of the farmers' families not directly involved in farming activities). Transmission via fish may encompass infections, which require fish as a compulsory host (e.g. Chinese liver flukes) or as a passive carrier (bacteria and viruses).

The actual risks to public health that occur through waste use can be divided into three broad categories: those affecting consumers of the crops grown with the waste (**consumer risk, people involved in food processing and marketing**), those affecting the agricultural and pond workers who are exposed to the waste (**workers', farmers' or fishermen's risk**), and those affecting populations living near to a waste reuse scheme (**nearby population risk**). Where night soil use and wastewater irrigation are unrestricted, so that all types of edible crops can be grown, then both consumer risk and worker risk are of interest. If use is restricted to certain crops, such as crops eaten cooked or processed, then this prevents the risk to consumers; in this situation, only the worker risk needs to be considered.

The actual public health importance of an excreta or wastewater use practice can be assessed by an epidemiological study to determine whether or not it results in an incidence or prevalence of disease, or intensity of infection, that is measurably in excess of that which occurs in its absence. Such studies are methodologically difficult, and there have been only a few well-designed epidemiological studies on human wastes reuse (see above).

Most of the available epidemiological evidence concerns wastewater irrigation.
The results of earlier studies by (Blum and Feachem 1985), Shuval et al. (1986) and of more recent work synthesized by Blumenthal (2000) can be summarised as follows:

- Crop irrigation with **untreated wastewater** causes significant excess infection with intestinal nematodes in both consumers of the irrigated crop and those who work in the irrigated fields. The latter, especially if they work barefoot, are likely to have more intense infections, particularly of hookworms, than those not working in wastewater irrigated fields.
- Cholera, and probably also typhoid, can be effectively transmitted by the irrigation of vegetables with untreated wastewater.
- Cattle grazing on pasture irrigated with raw wastewater may become infected with beef tapeworm, but there is little evidence of actual risks of human infection.
- There is limited evidence that the health of people living near fields irrigated with raw wastewater may be negatively affected either by direct contact with the soil, or indirectly through contact with farm labourers; in communities with high standards of personal hygiene such negative impacts are usually restricted to an excess incidence of benign gastroenteritis, often of viral aetiology, although there may also be an excess of bacterial infections.
- In wastewater reuse, the risks for farmers to contract gastro-intestinal infections (GI) are greatest when flood or furrow irrigation is practiced. The risks for consumers are greater, though, when the wastewater is applied by spray or sprinkler irrigation (aerosolised transmission of excreted viruses; however disease transmission is likely to be rare in practice since most people have high levels of immunity to viral disease endemic in their community).
- Children may become infected by nematodes by getting into contact through work or play with wastewater, which may not have been treated to a near-zero concentration of nematode eggs.
- Crop irrigation with adequately **treated** wastewater does not lead to excess intestinal nematode infection amongst field workers or consumers unless conditions (lower mean ambient temperature, wastewater application through surface irrigation) prevail which favour the prolonged survival of nematode eggs, which may still be contained in the irrigation water

There is much less information about waste water and excreta use in aquaculture. Blum and Feachem (l985) came to the following conclusions:

- There is clear epidemiological evidence for the transmission of certain trematode diseases, principally *Chlonorchis* (oriental liver fluke) *Fasciolopsis* (giant intestinal fluke), and for *Schistosoma* (bilharzia) (Niu and Ling 199.
- There is no conclusive evidence for disease transmission by passive transference of viruses, bacteria or protozoa by fish and aquatic vegetables, but there is a considerable potential risk, particularly through cross-contamination due to inadequate kitchen and personal hygiene.

Measures for Health Protection (pathogen risks)

It is possible to design, implement or upgrade waste water and human waste use schemes that do not pose any risk to public health, but this requires an understanding of the occurrence of excreted infections in the area of concern and an assessment of the epidemiological risks in relation to the actual use practice and exposure patterns.

On this basis sound and appropriate measures may be drawn up in a collaborative manner by the various stakeholders based on standards for the microbiological and parasitological quality of the excreta and wastewater intended for reuse or based on appropriate measures to be implemented at critical control points (e.g. waste treatment or crop restriction; see below).

There exist four basic options for health protection from excreted pathogen transmission:

- Faecal sludge and wastewater treatment
- Restriction of the crops grown
- Appropriate choice of methods of application of the waste water and human excreta to the soil or crops
- Control of human exposure, and improved personal and household hygiene

While full treatment stops excreted pathogens from even reaching the field or fishpond to which the wastes are applied, crop restriction and human exposure control act later in the pathway, preventing excreted pathogens from reaching the persons concerned, i.e. the crop consumers and the agricultural workers.

It will often be desirable to apply a combination of several methods. This will depend on the needs and conditions (technical, socio-economic, cultural, dietary and institutional) in any specific locality.

Non-Pathogenic Health Risks

Chemical contamination is another important potential risk associated with waste water reuse. Quite likely, this risk may turn out to be much more pronounced and relevant than the risk from pathogens in the long run. Chemical constituents, heavy metals in particular, but also refractory organics, accumulate in soils. This may curtail the prolonged use of waste water and hence put urban agriculture at risk.

The contamination of soils by chemicals, the potential but as yet uncertain extent of uptake by crops, which in turn may lead to chronic and long-term toxic effects in humans are discussed by Chang et al. (1995) and by Birley and Lock (1997). Contamination of plants might be caused by deposition of aerosol particles containing heavy metals, by soils, which have been loaded with toxic industrial waste, or by human wastes over long periods of time (Chang et al. 1995).

When intending to use faecal sludge or wastewater for irrigation or restoring soil fertility it is important to consider chemical constituents. A restriction in sludge application may become necessary to limit heavy metal accumulation in soils and crops through the repeated application of sludge.

It was found that faecal sludges (septage) collected in Bangkok and Manila quite surprisingly contained only non-negligible levels of heavy metals (Heinss et al. 1998).

Faecal sludges (FS) are usually “cleaner” than sewage treatment plant sludges, as they tend to contain less heavy metals or refractory organics. Exceptions may be found in places where septage is also collected from septic tanks serving cottage or small industrial enterprises.

Heavy metal loads in municipal wastewater have been declining in a number of industrialised countries in recent years due to pre-treatment at the source of industrial wastewater discharged into the municipal sewerage systems, and due to water management and process improvements in industries.

Chang et al. (1995) citing others, report that the major portions of toxic chemicals contained in wastewater are removed from the liquid fraction during treatment, adsorbing on particulate matter and ending up in the sludge. Yet, at least traces of chemicals will always be retained in the wastewater. Studies are cited which reportedly indicated that the use of wastewater treated by so-called secondary and tertiary treatment is safe regarding the trace element contamination of food. It may, however, be speculated that the use of sewage sludge, unless it is of entirely domestic origin, would, in most cases lead to levels of chemical contaminants in the soil which may in turn lead to substantial crop uptake, endanger human health and possibly threaten or at least curtail the agricultural practice making use of such human wastes.

Chang et al. (1995) address the difficult epidemiology of toxic chemicals. In contrast to pathogen-related health risks, which are characterised by causing symptoms fairly rapidly, by well-known cause-effect and dose-response relationships, and by a fairly good knowledge of the possible routes of exposure, disorders caused or assumed to be caused by toxic chemicals are much more difficult to assess. Their prevalence and cause-effect relationship is not yet well known and documented. The difficulties rest in the fact that effects are usually long-term and may involve lifetime follow-up. Disorders are often influenced by synergetic effects from various chemicals.

Treatment for Use

There exists a large array of technological and process options to achieve pathogen attenuation in faecal sludges and wastewater. The simplest option relates to the storage pits or vaults of pit or vault latrines. Where double-pit or vault toilets are in use and properly operated in an alternating manner, the faecal sludge stored in the pit at rest is likely to become fully hygenised in tropical climate before its contents need to be removed from the pit. With ascariasis being highly prevalent in most developing countries, at least so in the rural and periurban areas, and with *Ascaris* eggs being the most persistent of all pathogens, Ascaris eggs can be used as a hygienic indicator of stored excreta. It takes in tropical climates from 6 months to one year for complete Ascaris egg die-off (Feachem et al. 1983, Strauss 1985; Phi et al. 1999). Faecal sludges which have undergone this period of storage may thus be safely used on land or in fish culture, not causing excess risk of infection to either farmers or consumers.

A review of mostly low-cost options to treat wastewater and faecal sludge has been made by Rose (1999). A compilation of waster treatments systems frequently used in developing countries has been published by Von Sperling (1996). Options for faecal sludge treatment have been discussed and presented by Strauss et al. (1997) and Montangero and Strauss (2000).

Grey water treatment has not received much attention to date and only scarce literature exists on it (Del Porto and Steinfeld 1999).

The various treatment options either in use or proposed achieve pathogen inactivation to a variable degree, hence health protection of farmers, consumers and populations living near application sites, is not provided to the same extent for all treatment options. Care must be exerted when comparing various treatment options as to their pathogen removal performance vs. land use and cost. Conclusive comparisons can only be made for options, which have been conceived and designed to achieve comparable levels of pathogens in the effluent or biosolids. A planted soil filter, e.g., requires less land than a waste stabilisation pond (WSP) scheme. But then, WSP, whether including maturation ponds or not, would normally produce higher removal efficiencies for bacteria and viruses due mainly to the longer system retention time (10-28 days in WSP schemes in warm climate vs. 1-2 days in a planted soil filter).

The choice of a particular treatment option depends on various factors, viz. the objective of treatment (reuse or discharge into the environment), hence, the desired or legally stipulated quality of liquid effluents and of biosolids produced by the process; the simplicity and sturdiness of the plant and its operation; the financial and economic cost; the land requirements; the type of cultivation envisaged or being practiced; the market opportunities for the sale of treatment products; the farmers' ability to pay and lastly, the need or non-need to devise options which may be managed by rather unskilled persons on a decentralised, community-based scale.

A low-cost system proven to be most effective in removing pathogens in warm climates are waste stabilisation ponds Mara (Arthur 1983; Mara et al. 1992; Yanez 1993; Mara 1997; Mara and Pearson, 1998). They can be built and operated without much mechanical equipment, except if wastewater needs to be pumped for topographic reasons or if machinery is required to de-sludge ponds. Numerous small and large systems have been implemented throughout the world in the past decades, the effluents of which are largely used for irrigation. They may, if properly designed and operated, produce effluent meeting stringent hygienic quality standards. V

Variants of this option allow to produce effluent either for so-called restricted irrigation as well as for unrestricted irrigation, i.e. irrigation of crops eaten uncooked. Pond systems may also prove suitable to treat faecal sludges (FS) if particular precautions are taken with respect to solids separation and handling and to excessive ammonia levels in fresh, rather undigested FS (Heinss et al. 1998).

Other wastewater treatments systems which may prove suitable for effluent reuse are anaerobic filters (e.g. in combination with individual or communal septic tanks), upflow anaerobic sludge blanket (UASB) clarifiers; trickling filters, planted vertical-flow soil filters ("constructed wetlands"); and duckweed ponds. These require low to moderate construction and operating costs, but are effective in removing or inactivating pathogens to a lesser degree than waste stabilisation ponds schemes.

Otterpohl (2000) reported on a new, recycling-based system for excreta and grey water management under construction in Luebeck, Germany. Excreta are vacuum-collected from low-flush toilets and co-treated with organic kitchen residues by anaerobic digestion. The treated and hygenised slurry will be used in periurban agriculture for soil conditioning and fertilisation. Grey water will be treated by vertical-flow constructed wetlands and used for green space irrigation or allowed to infiltrate. Compared to conventional, centralised flush-and-discharge systems, this innovative solution yields considerable savings of pollutant emissions (organic matter, nutrients) as well as energy and resource savings for fertiliser production. Rather sophisticated technology is required, though, rendering this type of excreta management system less feasible for the majority of developing countries.

Treatment options not achieving the effluent quality required for a specified use (e.g. irrigation of raw-eaten vegetables) may be complemented by suitable processes to meet the stipulated hygienic quality like polishing ponds, chlorinisation (but the latter technique is expensive and leading to the formation of chlorinated hydrocarbons, which are carcinogenic).

Biosolids produced in FS or wastewater treatment plants will under most circumstances constitute a precious agricultural resource for soil amendment and fertilisation, unless treatment plants receive toxic wastes at a regular basis and in high proportions. Biosolids produced during the treatment process contain high loads of viable pathogens. Hence biosolids need storage and sun drying for a prolonged period to achieve a sufficient die-off of pathogens, helminth (worm) eggs in particular. Desiccation to below 10 % of solids – in dry warm climates achievable within 2-4 months – will lead to complete inactivation of all worm eggs. Alternatively, the combined composting of biosolids with organic municipal waste or other organic residues may constitute an option to hygienise pathogen-loaded sludges (Shuval 1986; Obeng et al. 1995).

Guidelines and Standards

Excreted Pathogens

Following the recommendations by a WHO Scientific Group, WHO published guidelines for wastewater use in agriculture and aquaculture (WHO 1989). These replaced the previous guidelines (WHO 1973), which, in the light of then new evidence, were considered by WHO to be too strict with respect to the suggested quality parameter for pathogenic bacteria and nematode (roundworm) egg guidelines.

The purpose of the guidelines was to guide design engineers and planners in the choice of waste treatment technologies and waste management options.

Waste treatment is considered for use by category A, waste treatment and crop restriction for category B and a choice of application measures and human exposure control for category C.

Table 3: Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture [a] (WHO 1989)

Category	Reuse conditions	Exposed group	Intestinal nematodes (/litre)	Faecal coliforms (/100ml)	Wastewater treatment expected to achieve required quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤ 1	≤ 1000	A series of stabilisation ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	Workers	≤ 1	None set	Retention in stabilisation ponds for 8-10 days or equivalent helminth removal.
C	Localised irrigation of crops if category B exposure of workers and the public does not occur.	None	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation.

Similar guidelines were developed for the use of excreta in agriculture and aquaculture (Mara and Cairncross 1989), and for the use of wastewater in aquaculture (WHO 1989).

The WHO guidelines for agricultural use of wastewater have been adopted in several countries, either directly or in amended versions to suit local epidemiological, socio-economic conditions and health policies, viz. in Mexico, Tunisia and France.

Many countries, among them also developing countries, have adopted much stricter guidelines, based on a zero-risk principle, resulting in quality standards for wastewater used for irrigation of vegetable crops, which are very close to drinking water standards.

Where such standards were enacted in developing countries, they were hardly ever enforced as compliance is economically unfeasible and enforcement institutionally impossible. Hence, wastewater reuse goes by uncontrolled, or may be entirely prohibited, as monitoring and control cannot be implemented. Achieving wastewater quality close to drinking water standards is economically unsustainable and epidemiologically unjustified in many places.

That is why the WHO guidelines, are based on another principle: the objective that there should be no excess infection in the population attributable to wastewater reuse and that risks from reuse in a specific population must be assessed relative to risks of enteric infections from other transmission routes.

Blumenthal (2000) suggests to choose an approach for setting future guidelines or standards that is based more on epidemiological evidence for excess risks due to a specific reuse practice, and on calculations of risks from a particular practice and then comparing this to an acceptable risk definition as laid out by, for example, health authorities.

Food Hygienic Quality

ICMSF (1995) has issued quality recommendations for food. The limits stipulated for agricultural crops, applicable to raw-eaten vegetables, are 10^5/100g fresh weight ("if – possible"-limit) and 10^3 faecal coliforms/100g fresh weight ("tolerable"-limit), respectively. These limits may appear lenient. They must, however, be viewed in the light of the fact that fresh, unprocessed and unpacked vegetables that have been grown on rain-fed or freshwater-irrigated fields and sold on markets or in food stores, may easily carry faecal indicator bacteria concentrations close to the indicated quality limits! This fact is often disregarded when evaluating the potential health risks associated with the use of faecal sludges or wastewater.

Chemical contaminants

Following the publication of pathogen-related guidelines by WHO in 1989, WHO mandated a team of researchers to assess the risks related to chemical contaminants and to viruses, respectively. Chang et al. (1995) suggested tentative guidelines for chemical pollutants, assuming, based on literature evidence, that transfer via the food chain is the primary route of exposure for humans. From this, the authors adopted a maximum daily intake and then derived the maximum concentration of the respective pollutants, which may be tolerated in the soil. This inevitably leads to a limitation in the use of untreated or partially treated wastewater and of biosolids, in which the contaminants are concentrated. They stipulate, on the other hand, based again on reported evidence, that adequately (secondary or tertiary) treated wastewater may be used for edible crop irrigation without restriction.

Standard Setting

In adopting standards, many countries tend to immediately adopt the strictest standards as used in industrialised countries. This may satisfy the legal requirements of the enacting authorities and provide the prestige of "also having standards", but may often not be feasible in the local economic and institutional context. Instead of this, it would make much sense that countries would adopt a stepwise approach in setting standards, which would -if followed and enforced- already achieve a considerable advancement in terms of pollution abatement and risk prevention. Johnstone and Horan (1994 and 1996) and Von Sperling and Fattal (in press) have made sensible suggestions related to guideline setting and remind one that standard setting in industrialised countries has evolved gradually and based on scientific and economic advancement.

One should also be aware that where wastewater is now being used in an informal, de facto illegal manner, urban sanitation upgrading may lead to situations where treated human wastes might neither be affordable nor be accessible anymore by urban farmers.

Gaps-in-knowledge

- Allison et al. (1998), Birley and Lock (1999) and Rose (1999) have identified gaps-in-knowledge relating to waste water reuse in urban agriculture and are suggesting action and field research to fill them. Below is a non-exhaustive listing of identified gaps:

- Assess the health impacts from chemical constituents contained in waste water and human wastes (heavy metals; persistent organics; pharmaceuticals) in the human waste – soil – crops – food –cycle and identify strategies to avoid (e.g. through source separation) the mixing of toxic chemicals and domestic wastewater and faecal sludges
- Development of appropriate, i.e. implementable and enforceable, quality standards for treated human wastes and waste water applied in urban agriculture and aquaculture
- Technical, economic/financial, institutional, cultural and agronomic aspects of non-centralised waste water treatment and reuse ("integrated urban waste management") schemes based on domestic sources mainly, e.g. through case studies of existing schemes or components thereof or through pilot projects with stakeholder involvement
- Carbon (organic matter) and nutrient needs in urban agriculture vs. carbon and nutrient generation in the city; estimating the theoretical carbon and nutrient demand potential of urban farms; use of material flow analysis (MFA) as an assessment and planning tool
- To asses farmers' needs and constraints; methods of cultivation; organisation; tenure as well as attitudes vis-à-vis human waste use; health problems; hygienic practices and behaviour determining exposure to wastes; financial conditions; use of inorganic fertiliser
- Cost-benefit evaluation of waste management schemes with and without reuse.

Allison, M **(et al.) (1998). A review of the urban waste in periurban interface production systems. 2 p. Department for International Development (DFID), Natural Resources Systems Programme, 94 Victoria Street, London, SW1E 5JL, UK**

waste recycling wastewater reuse rural-urban linkages R&D methodology

urban wastes; organic wastes

Provides a dense overview of uses of urban waste and wastewater and examines factors affecting the use of wastes in agriculture. Attention is drawn to the fact that there are important gaps in our knowledge about the quantitative need for organic wastes in urban and periurban agricultural systems and about the potential to satisfy these needs. (WB)

Ayres, RM; Mara, D.D **(1996). Analysis of wastewater for use in agriculture: a laboratory manual of parasitological and bacteriological techniques. World Health Organization: Geneva.**

wastewater reuse health and environment

zoonoses; health; wastewater; environment

The first step that needs to be taken by any local jurisdiction or medium to large scale urban food producer using irrigation is analysis. This volume covers the parasites and bacteria; other tests are needed to define the nutrient content. (JS)

Blumenthal, U.J. **(1992). A study of the health impact of the use of wastewater in agriculture in Mexico. London School of Hygiene and Tropical Medicine: London.**

wastewater reuse health and environment

health; Mexico; livestock

Mexico has a very special historical record in the application of municipal sewage effluent to field crops for livestock and human consumption. This study is one of several that begin to define the benefits and costs from a rather narrow epidemiological point of view. (JS)

Blumenthal, U.J.., Mara, D.D., Peasey, A., Ruiz-Palacios, G., Stott, R. **(2000) Using treated wastewater: recommended changes to WHO guidelines. In: *Urban Agriculture Magazine*, no 3, Health , March 2001, RUAF, Leusden The Netherlands.**

health and environment wastewater reuse

Measurement; indicators; health impact assessment; policy; WHO

Standards for wastewater reuse in many countries have been influenced by the WHO (1989) health guidelines and the USEPA/USAID (1992) guidelines (which are much stricter). The WHO guidelines are proposed as a guide for policy makers as to what wastewater treatment processes, crops and irrigation methods are appropriate for safe agricultural production. They are not meant as standards for daily water monitoring at a local level. The WHO guidelines recognise the benefits that can be gained from using appropriately treated wastewater in agriculture, and aim to promote safe use of wastewater, and take into account the social, epidemiological and economic conditions that occur in specific countries. Standards are set for microbiological indicators of faecal pollution: faecal colifom bacteria and for nematode eggs. The former are intended to protect exposed persons from bacterial and viral infections (e.g salmonella) and the latter, from helminth (and protozoal) infections. WHO are currently revising the 1989 guidelines. This paper summarises the main recommendations for of a review of epidemiological, microbiological and risk assessment studies and their implications for the WHO guidelines. The article gives recommendations for changing the guidelines and proposes appropriate wastewater treatment methods that can be used to achieve the new microbiological guideline limits. The results of the WHO official review should be available in early 2002.

Braatz, Susan; Kandiah Arumugam **(1996). The use of municipal waste water for forest and tree irrigation. In: Unasylva 185 (1996) p. 45-51.**

urban forestry wastewater reuse

wastewater; municipal management; resources; irrigation

This article discusses some of the experiences to date and various issues related to the use of wastewater for forest and tree irrigation. This combines the goals of managing municipal effluents with those of enhancing forestry practices in periurban areas. (adapted from original by JN)

Brand, Anthony; Bradford, Bonnie **(1991). Rainwater harvesting and water use in the barrios of Tegucigalpa. UNICEF New York. 60 p.**
wastewater reuse
poverty; housing; Latin America; gender

This survey report provides basic information concerning the availability and quality of water in poor neighborhoods and therefore its limitations for urban agriculture applications. (JS)

Bruins, Hendrik J **(1997). Drought mitigation policy and food provision for urban Africa: potential use of treated wastewater and solar energy. Arid Lands Newsletter no. 42 (fall/winter 1997)**
wastewater reuse food security and nutrition
Africa; food security; solar energy; sanitation; irrigation; home gardening

Examines the possibility of reusing treated wastewater for homegardening, and the use of solar energy in the treatment of wastewater. The author concludes that solar energy has significant potential for small-scale powering of water pumps for irrigation, water disinfection and sanitary systems. (WB)

Cornish, G.A. **(2001) Assessing water quality and health implications in informal periurban irrigation. Case studies from Nairobi and Kumasi. Paper for the workshop "Appropriate Methodologies for Urban Agriculture", October 2001, Nairobi, Kenya. Proceedings, available On: www.ruaf.org.**
R&D Methodology wastewater reuse
monitoring; Kenya; Ghana; irrigation

This paper draws lessons from work carried out in Nairobi, Kenya and Kumasi, Ghana, where research was conducted into the nature, extent and importance of informal, irrigated agriculture in the urban and periurban zones of those cities. The research was funded by the Infrastructure and Urban Development Department of DFID. Fieldwork in Nairobi was carried out in collaboration with a number of independent consultants while in Kumasi the project collaborated with staff from the Institute of Land Management and Development at the Kwame Nkrumah University of Science and Technology. The focus of this paper and the lessons drawn concern only that part of the research addressing water quality and its potential impact on producer and consumer health. The interest of this workshop is in the validity of the methods used to obtain information but the findings of the studies, and their conclusions, are used to illustrate the points made.

Del Porto, David; Steinfeld, Carol **(1999). The composting toilet system book: a**

practical guide to choosing, planning and maintaining composting toilet systems, an alternative to sewer and septic systems. 240 p. ISBN 0-9666783-0-3, USD 29.95. The Center for Ecological Pollution Prevention (CEPP), PO Box 1330, Concord, MA 01742-01330 USA
wastewater reuse waste recycling
wastewater; graywater; composting toilets

Describes a number of wastewater management methods which may be viable and cost-saving alternatives to graywater disposal systems. Central is the design of the composting toilet, also known as dry, waterless or biological toilet. Composting toilets are not only an alternative in places where septic tanks cannot be installed but they are also one of the most direct ways to avoid pollution and conserve water and resources. A very complete manual, full of practical information. The manual contains a useful glossary and a list of USA state regulations. In spite of its apparent USA focus, the content applies equally well to developing countries. (WB)

Deutsche Stiftung fuer Internationale Entwicklung (DSE); German Agency for Technical Cooperation (GTZ) **(1989). Community participation and hygiene education in water supply and sanitation. Deutsche Stiftung fuer Internationale Entwicklung (DSE); German Agency for Technical Cooperation (GTZ), PO Box 5180, D-65726 Eschborn 1, Germany**
wastewater reuse health and environment community development
community participation; water management; sanitation; development projects; indicators

Successful water and sanitation projects should have a community participation and hygiene education component. These aspects are addressed in this manual containing five individual course manuals, designed to be used separately, as the foreword puts it, 'for guidance and as a frame of reference in water and sanitation projects for national and international decision makers; and for field managers of water supply and sanitation projects'. This manual constitutes a great attempt to bring together and analyse this complex material. (WB)

Diop Gueye N.F. and Sy M. **(2001) The use of wastewater for urban agriculture; the example of Dakar, Nouakchott and Ouagadougou. In: *Urban Agriculture Magazine*, no 3, Health , March 2001, RUAF, Leusden The Netherlands.**
health and environment wastewater reuse
West Africa

In the Sahelian zone water is the major stumbling block to developing agricultural activities, In the cities domestic needs win out over agricultural activities in the competition for water. Given this, it becomes evident that one strategy to offset the water deficit is to reuse wastewater. Such a practice has to be examined closely for its advantages and disadvantages in relation to the issue of urban and periurban agriculture. In this article an overview of constraints and opportunities is given.

Drangert, Jan-Olof; Bew, Jennifer; Winblad, Uno (eds) (1997). **Ecological alternatives in sanitation: proceedings from SIDA Sanitation Workshop, Balingsholm, Sweden, 6-9 August 1997. Publications on Water Resources no. 9. ISBN 91_586_7551_5. Department for Natural Resources and the Environment, Swedish International Development Authority (SIDA), Birger Jarlsgatan 61, S-10525 Stockholm, Sweden**

waste recycling wastewater reuse health and environment

sanitation; workshops; disease control; water management

This sanitation workshop was organised with the need to rethink and with new approaches and techniques in sanitation in mind. This document provides a comprehensive overview of ecological sanitation. Aspects like reuse and disease control are discussed. Within ecological sanitation there are a range of options for various conditions. Furthermore, case studies from several countries in the world and abstracts of background papers to the conference are included. (NB)

Duc Vien, Tran **(2001) The role of aquaculture in pollution remediation in Tay Lake and Ruc bach Lake of Hanoi. Paper for topic 1 of the workshop "Appropriate Methodologies for Urban Agriculture", October 2001, Nairobi, Kenya. Proceedings, available On: www.ruaf.org.**

R&D methodology wastewater reuse

Vietnam; aquaculture

In Ha Noi there are 18 lakes ranging from 1to 526 ha, with a total area of 615.4 ha. All of the lakes of Ha Noi are used for wastewater and storm water storage in the rainy season, and also as a source of livelihood for about 100 fishermen.In order to understand the role of aquaculture in wastewater – remediation, a study was carried out in Tay Lake from 1997-1998, to follow the application of the Department of Science, Technology and Environment of Ha Noi. This report describes the role of aquaculture in wastewater treatment and use. It gives an overview of the methods used, and gives recommendations to the authorities.

Edwards, Peter **(1985). Aquaculture: a component of low-cost sanitation technology. World Bank & UNDP, Integrated Resource Recovery Project Management Report no. 3. 45 p.**

wastewater reuse

aquaculture; Asia; Europe; Middle East; composting; sewage; health

This paper discusses all phases of aquaculture, including commercial viability, sanitary and biological considerations, public health, financial/economic and social aspects. Studies are detailed and options are examined for their potential applicability to developing countries, considering requirements for capital and labor skills as well as physical needs. Eleven counties are included from rich Germany to poor Bangladesh. The relationship between fish and aquatic crop production and sanitation from all of the aspects listed above are clearly presented. The role of cities

in aquaculture is at the core of the overview. (JS adapted from author)

Edwards, Peter **et al (1987). Resource recovery and health aspects of sanitation. AIT Research Report No. 25 Commission of the European Communities, Brussels Belgium 225 p.**

wastewater reuse

aquaculture; sludge; sanitation; public health; duckweed; tilapia

This report is particularly useful in its precise presentation of results of long-term studies of biological treatment of human and municipal, including village, organic wastes with an economic return under consideration. It was found that substantial savings could be by the piloted biological sanitation methods compared to the currently used activated sludge method. Specifically "—septage reuse in aquaculture may be the most economically attractive option in countries with relatively low labour costs –." The excreta reuse duckweed/tilapia sanitation system was found to have great potential as part of an urban excreta reuse system. The duckweed being used in the production of high protein animal feed was found to be in some instances more profitable than using duckweed as fish food. (JS)

Edwards P**. (2001) Public Health issues of waste water-fed aquaculture. In: *Urban Agriculture Magazine*, no 3, Health , March 2001, RUAF, Leusden The Netherlands.**

health and environment wastewater reuse

India; aquaculture

Fish farmed in wastewater-fed ponds provide nutritious and relatively safe food for the urban poor. In spite of most systems being developed by farmers with limited attention to either wastewater treatment or to public health, potential threats from disease causing organisms and chemical contaminants from industrial effluents are mitigated by various mechanisms. Recommendations are made by the author to further safeguard public health.

Esrey, Steve **et al (1998). Ecological sanitation. SIDA, Stockholm, Sweden. 92 p.**

wastewater reuse health and environment waste recycling

ecology; sanitation; sewage; human excreta; pollution

This short volume is focussed on providing a practicable vision of a future of ecological sanitation. It presents the theory, the history (back to the Ancients), design principles and promotion strategies. This is an excellent introduction to the precepts of eco-sanitation and its relationship to urban agriculture, public health, and healthy city and a sustainable city. (JS)

Feacham, RG et al. **(1983). Sanitation and disease: health aspects of excreta and wastewater management. Wiley, New York.**

wastewater reuse health and environment
epidemiology; sanitation; water management; health

This volume provides a historical base for considering the possible negative effects of reusing sewage effluent for nutritional, recreational and environment enhancement in and near human settlements. It follows Feacham's seminal work in the field at the "Cholera Laboratories in Dhaka Bangladesh. (JS)

Flynn, Kathleen. **An overview of public health and urban agriculture: water, soil and crop contamination and emerging urban zoonoses. Cities Feeding People Series Report no. 30. 84 p.**
Supplier: International Development Research Center (IDRC), PO Box 8500, Ottawa, Ontario, Canada K1G 3H9
health and environment wastewater reuse

Hertog, Wilfrid and Klutse, Amah (eds) **(2002) Visite d'étude et atelier international sur la réutilisation des eaux usées en agriculture urbaine: un défi pour les municipalités en Afrque de l'ouest et du Centre (Study visit and international workshop on the reuse of wastewater in urban agriulture: a challenge for the municipalities of Central and Western Africa) ETC Leusden**,
wastewater reuse health / pollution
Africa (Western); wastewater re-use; wastewater irrigation; socio-economic aspects; livelihoods; water shortage; Burkina Faso

These proceedings describe the studyvisit and workshop held in Ouagadougou from 3-7 June 2002 with 29 participants from 10 countries. The work focussed on the use of untreated wastewater use in urban agriculture looked at from three angles: health and environment; socio-economic aspects and legal, institutional and financial aspects. These themes were covered by three presentations included in the proceedings. 7 case studies from Burkina Faso, Cameroon, Niger, Benin, Senegal, Mali and Mauretania were presented also included in this document. In Ougadougou four sites were visited and interviews held with farmers. These revealed the acute shortage of water and the necessity to use wastewater. Health risks were underestimated. Water quantity not quality was their primary concern. Following the discussions, a set of recommendations were formulated aiming at the municipalities, NGO's and Institutions, consumers and producers. More needs to be known and done about paths of contamination and hygiene behaviour besides tackling the inevitable use of wastewater itself.

Hussain, I., L. Raschid M.A. Hanjra, F. Marikar and W. van der Hoek **(2002) Wastewater Use in Agriculture: Review of Impacts and Methodological Issues in Valuing Impacts. Colombo, Sri Lanka: International Water Management Institute (IWMI). Working Paper 37. see www.cgiar.org/iwmi/**
wastewater reuse
wastewater; water management; wastewater reuse; agricultural production; pollution; public health; economic aspects; ecology; developing countries; China; India; Mexico; Pakistan, Asia (Eastern), Asia (South-Central), America (Central)

The objective of this paper is to provide a review of the characteristics of wastewater used for irrigation, and the reasoning behind the international guidelines presently used in regulating wastewater reuse for agriculture. This paper presents various systems of wastewater treatment available and discusses their benefits and shortcomings. Finally, the paper provides the review of environmental valuation techniques for analysing impacts of wastewater uses in agriculture, and suggest a framework for application of some of these techniques. This framework will be applied to a developing country case study (Faisalabad area in Pakistan), in the ongoing IWMI research program.

Hussain, I., L. Raschid, M.A. Hanjra, F. Marikar and W. van der Hoek **(2002), A Framework for Analyzing Socioeconomic, Health and Environmental Impacts of Wastewater Use in Agriculture in Developing Countries. Colombo, Sri Lanka: International Water Management Institute (IWMI), Working Paper 26; see www.cgiar.org/iwmi/**

wastewater reuse

wastewater management; environmental degradation; irrigation; aquaculture; economic analysis; social aspects; agriculture; developing countries; policy; Pakistan, Asia (South-Central)

Wastewater use in agriculture and its land application for treatment purposes is a global practice. Rough estimates indicate that at least 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater. Wastewater is a complex resource, with both advantages and inconveniences to its use. To the extent that wastewater and its nutrient contents can be used for crop production and other agricultural enterprises including aquaculture, it can provide significant benefits to the farming communities and society in general. However, wastewater use can also impose negative impacts on communities using this resource and on ecosystems. The widespread use of wastewater containing toxic wastes and the lack of adequate finances for treatment is likely to cause an increase in the incidence of wastewater-borne diseases as well as more rapid degradation of the environment. The biggest challenge faced by policymakers at present, is how best to minimize the negative

effects of wastewater use, while at the same time obtain the maximum benefits from this resource. While most of the impacts of wastewater use, both negative as well as positive, are generally known, a comprehensive valuation of the benefits and costs of these impacts has not as yet been attempted. Conventional cost benefit analysis is not adequate to evaluate wastewater impacts due to the environmental and public good nature of the impacts. To fill this gap in knowledge, this paper attempts to develop a comprehensive assessment framework applying available and tested techniques in environmental economic analysis, for the comprehensive evaluation of the costs and benefits of wastewater. The paper presents an approach for analyzing the socioeconomic, health, and environmental aspects of urban wastewater use in peri-urban agriculture, using typical characteristics of a major city in a developing country. Peri-urban area of Faisalabad is chosen to represent this context.

Jenkins, Joseph **(1999). The humanure handbook. 302 p. Also on:**

www.jenkinspublishing.com.
wastewater reuse waste recycling
composting; sanitation; wastewater

This manual includes easy to understand instructions on composting all organic household waste; growing a food garden with human compost and understanding the health issues. Low-cost composting toilet, grey water use, government regulations, and a list of commercial sources are included. (JS)

Journey, WK; McNiven, Scott **(1996). Anaerobic Enhanced Treatment of wastewater and Options for Further Treatment ACDI/VOCA Washington DC USA Nine figures, Three tables, Four appendices, Four case studies**
wastewater reuse
sludge; aquaculture; infrastructure; sanitation; environmental conservation

wastewater management should be viewed as an important component of water resource management, with an associated set of costs and benefits and definable linkages to the rest of the hydrological and nutrient systems. Anaerobic treatment relies on biological processes in the absence of oxygen to stabilize organic material by conversion to methane and biomass and inorganic products including carbon dioxide, ammonia and phosphate. This report describes several methods of biological waste water treatment including aquatic farming. It carefully lays out the advantages and limitations of the method for different situations. This short report is a good starting point for the student or practitioner. (JS)

Khouri, Nadim; Kalbermatten, JM, Bartone, CR **(1994). Reuse of wastewater in agriculture: a guide for planners. UNDP-World Bank, 49 p.**
wastewater reuse
planning; health

This report is a set of guidelines, which summarize information on the reuse of wastewater for irrigation, principally in periurban areas. It finds that properly designed and managed wastewater reuse is an environmental protection method that is superior to discharging treated wastewater into surface waters. wastewater reuse could also free large amounts of fresh water currently used for irrigation and make this resource available to meet the growing needs for fresh water of cities and towns. Close collaboration between sectors involved (agriculture, water and waste, environmental protection and health) is essential ad viable, given policy adaptations. The report provides guidance for choosing amongst technical and policy options and proposes a framework for inclusion of economic and financial considerations. (JS adapted from authors)

Lukman, Salifu. **Waste management issues: an integrated disposal strategy for the Kumasi metropolitan area. Waste Management Department, Kumasi Metropolitan Assembly, Ghana**

waste recycling wastewater reuse health and environment
Ghana; waste management; wastewater management; urban sanitation

Urban sanitation and waste management are given a priority by all district and municipal governments in Ghana. However, the waste management capacity of cities is deteriorating. This paper discusses the solid and liquid waste management system of Kumasi. Needs assessment and intervention schemes are presented. From there, proposals for strategies for sustainable services delivery and an integrated disposal strategy including a reality check are made. (NB)

Mara, D.D; Cairncross, S **(1989). Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture WHO, Geneva.**
wastewater reuse
aquaculture; health; safe food

These guidelines are, in 2000, out of date but the basic formula and cautions are a good place to begin consideration of the issue, and should not be ignored. (JS)

Morgan, Peter **(1999). Ecological sanitation in Zimbabwe: a compilation of manuals and experiences. Harare: Privately printed.**
wastewater reuse waste recycling
Zimbabwe; eco-sanitation; manuals

This is a significant compilation, part of the emerging literature on “eco-sanitation”. While this approach arose principally in northern Europe, this book is one of the first attempts to adapt it in a significant way to developing countries. The second half of the book is devoted to the agricultural-reuse. (JN)

Mukherjee, M., U. Nath, Sk.A. Kashem and M. Chattopadhyay **(2001), The Sewage Fed Fisheries in Kolkata. Office of the Deputy Director of Fisheries (M&P), Governmment of West Bengal, Paper prepared for the DPU International Conference: Rural-Urban Encounters: Managing the Environment of the Peri-Urban Interface, London 9-10 November 2001**
wastewater reuse
wastewater; farming systems; waste recycling; India; aquaculture, Asia (South-Central)

The waste water farming system around Kolkata is significant because it provides employment and food security for poor communities, facilitates a well managed recycling of wastes from urban areas, thus providing an environmental service to society.

The wetlands in East Kolkata sustain the world's largest waste water fed aquaculture, the practice of using waste water in the culture of fish has been in vogue for over 1000 years. But a proper scientific appreciation of the practice is a recent development and it has been opined by experts that the survival of these wetlands is extremely important for the well being of the city of Kolkata. But presently these wetlands are under the threat from lack of proper sewage supply and from the overexpanding urban limit of the city. It is a rather unfortunate scenario that the quality of the water there has degraded, and many aquatic species have become endangered. We have studied characteristics of Kolkata sewage, seasonal fluctuation of microbial load in sewage fed fisheries, resource recovery through aquaculture, technology of sewage fed fish culture. We have surveyed the present status of wetland, in the peri-urban area of Kolkata, characteristic of water, pollution and bio-accumulation of pollutants in the system, primary productivity and outline status report of stakeholders and status of the selected systems and factors that influence the waste water fed aquaculture.

Niang, Seydou **(1998). Épuration des eaux usées domestiques. Workshop on Cities feeding people: lessons learned from projects in Africa. IDRC. Nairobi. 21-25 June 1998**

wastewater reuse

Africa; development projects; impact assessment

This International Development Research Centre (IDRC)-supported project (90-0153) consisted of two parts. The first involved examining existing wastewater treatment facilities in Dakar; sampling and analyzing the quality of the outflow from the three principal treatment facilities; interviews with 360 individuals to determine their attitudes toward water use, waste disposal, etc.; and identifying suitable aquatic plants for use in experimental water treatment facilities. The second involved setting up an experimental station and running a series of water treatment procedures using various types of water plants. This document discusses the impact of the project in terms of human resource development, strengthening institutional capacity, partnership development, methodological and scientific advances, the utilization of research results by non-researchers, and the leverage of additional funds.

The most important innovation of the project was the experimental station, which allowed simultaneous comparison of different treatment processes under the same climatic conditions. The ministry of environment of the Wallonne Region, Belgium, took over the cost and operation of the station for 5 years (1992-1997). The most important impact of the project was that it sensitized decision-makers — who had up until then tended to implement expensive, European-type, water treatment facilities on a turnkey basis — to a different approach to water treatment, appropriate to the local climate and means. (HC, IDRC)

Niang, Seydou **(1999). Utilisation des eaux usées brutes dans l’agriculture urbaine au Sénégal: bilan et perspectives. In: Agriculture urbaine en Afrique de l'Ouest: une contribution à la sécurité alimentaire et à l'assainissement des villes = Urban agriculture in West Africa: contributing to food security and urban sanitation / Olanrewaju B. Smith (ed.). Institut Fondamental d'Afrique Noire (IFAN), Université Cheikh Anta Diop, Dakar, Senegal**

wastewater reuse

vegetable production; wastewater reuse; crop contamination; Senegal

Urban agriculture, mainly vegetable production is concentrated around Dakar but faces many constraints. Around 100,000 m3 domestic waste water daily is discharged in Dakar. Part of this is used untreated which has some advantages but poses health risks as well. A policy on water reuse is needed. Research showed that extensive systems of urban water purification functioned well, however without meeting WHO standards. (NB)

Niang, Seydou **(2001), Maitrise des risques dans la ré-utilisation des eaux usées en agriculture urbaine (Safe re-use of waste water in UPA). L'Institut Fondamental d'Afrique Noire (IFAN), Dakar. Paper for the workshop "Appropriate Methodologies for Urban Agriculture", October 2001, Nairobi, Kenya. Proceedings available on: www.ruaf.org.**

wastewater reuse

urban areas; periurban area, Senegal, Africa (Western)

In an unfavourable context of permanent dry seasons cycles, urban population growth, macro-economical structural adjusting and money devaluation, services are appalling in Senegal cities. Results are progressive degradation of life style and environment. For the few past years, wastewaters disposal have been rising in cities according to the population growth. Hence, a solution for water supply in urban agriculture was offered. Unfortunately health hazards attendant to this practice let policy makers to elaborate tough controls which are slowing down people’s eagerness.

In order to find in a global solution including food supply, public health, improved life style, environmental quality, woman's work valorisation into development processes, but further, to make improved sanitation affordable to poor people, ENDA has set an integrated process of disposal and treatment of wastewaters and solid wastes in Castors and Diokoul districts of Rufisque (Senegal). The process consists of collecting the house wastewaters in a little settlement tank (around 8 hours of time stay), after that, they are discharged through a 110 mm pipes and treated into a macrophite's lagooning ponds. Then, treated wastewaters are reused for agriculture, and reafforestation. The system funded by CIDA was meant to create a revolving fund at the end of the project with financial participation of the stakeholders with the view to ensure sustainability of the project, through the improved sanitation in poor districts, with community contributions.

Otterpohl, Ralf; Bark, Kerstin **(1999). Sustainable sanitation systems in urban areas: source control, fertiliser and energy production. In: Gate: Technology and Development no. 2 (April-June 1999) p. 38-39**

waste recycling wastewater reuse

waste management; wastewater; source separation; composting; sanitation; biogas; fertiliser

Discusses advantages and components of sustainable sanitation systems. Sanitation can be made more sustainable by not mixing excreta and using minimal quantities of water. Basic techniques of collection and treatment are presented. The result of separated treatment of faeces and wastewater can be used for biogas production or fertiliser. (NB)

Parkinson, J. and Tayler, K. **(2001) Sanitation and wastewater Management in Periurban Areas: Opportunities and Constraints in Developing Countries.**
rural-urban linkages waste recycling wastewater reuse
waste recycling; Ghana; irrigation; decentralisation

The paper is concerned with the options for improved sanitation and wastewater management in periurban areas in developing countries, bearing in mind the fact that much of the wastewater produced in urban and periurban areas is already used, directly or indirectly, for irrigation, almost always without treatment. Options for reducing the strength of wastewater by either separating excreta from sullage water or treating wastewater to reduce its strength are explored. The focus is on the potential advantages of decentralised management, including compatibility with decentralised approaches to urban management and reuse needs, particularly those of the periurban poor, reduced costs and increased agricultural productivity. It appears that suitable technologies for decentralised treatment are available but that other barriers to the wider adoption of decentralised approaches exist. These include lack of finance, and suitable land, deficiencies in knowledge and skills and the inflexibility of official design standards. A key constraint is the limited demand for improved wastewater management. The challenge for activists and planners is to create informed demand for improved systems, focusing not only on health but also on the improvements in the local environment and household finances that may be achieved through improved wastewater management.

Pescod, M **(1992). wastewater treatment and use in agriculture. Food and Agriculture Organization: Rome. Irrigation and Drainage Paper No. 47. 125 p.**
wastewater reuse
irrigation; wastewater; aquaculture; health

This report is intended to provide guidance to national and city planners, decision makers, city managers, field engineers, health workers and farmers. The UN/FAO here presents a more positive view of the use of municipal and institutional wastewater than that presented by the World Health Organization and using the latter's 'Guidelines'. Although out-of-date in 2000, this report provides a solid foundation for study or planning action in the field. Seven country examples are cited including a range of climate typologies and economies. It explains the basis for conventional wastewater treatment and introduces natural biological treatment systems as viable alternatives in developing countries, particularly in tropic climates. Recharge of aquifers as a means of treatment and indirect use of wastewater is covered in some detail. Sewage sludge is presented as a potential agricultural resource. Suggestions are made for planting, grazing and harvesting constraints. wastewater aquaculture is presented as an economic and environmental option. Costs and benefits are clearly analyzed. (JS)

Pickford, John **(et al.) (eds) (1996). Sustainability of water and sanitation systems:**

selected papers of the 21st WEEDC Conference, Kampala, Uganda, 1995. 153 p. ISBN 1_85339_339_8. Water, Engineering and Development Centre (WEDC) Supplier: Intermediate Technology Publications, 103/105 Southampton Row, London WC1B 4HH, UK

wastewater reuse health and environment
sanitation

The conference theme was “The sustainability of water and sanitation systems in developing countries”. Most cases presented were of a practical nature. Case studies were grouped in four sections: (1) Management; (2) Water and the environment; (3) Rural water supply and sanitation; (4) Sanitation and waste. (WB)

Postel, Sandra **(1989). Water for agriculture: facing the limits. WorldWatch, Washington DC; 54 p.**

city ecology wastewater reuse
irrigation; sewage; urbanisation

This policy paper researches the global eminent shortage of water for much of the population. It suggests several means of more efficient use including urban agriculture. (JS)

PRISM **(1990). Bangladesh Shobuj Shona Project. Progress Report No. 3. Dhaka, Bangladesh: Prism Bangladesh, 51 p.**

wastewater reuse
aquaculture; Bangladesh; irrigation

This is an overview of a duck weed (lemnacae) pilot project. It examines the problems and benefits of biological wastewater production for a hospital complex in Bangladesh, at a scale of about one hectare. The health, environmental, waste management and economic returns were all in the positive column. This project served as a model of many larger projects in the 1990s. (JS)

Prudencio Boehrt, Julio **(ed.) (1997). Agricultura urbana en americana latina: memoria. 252 p. Agricultura Urbana Investigaciones Latino Americana (AGUILA), c/o ETC Andes, La Paz, Bolivia. Casilla 9355, La Paz, Bolivia**

hydroponics wastewater reuse urban livestock
Latin America; workshops

The outcome of a seminar on urban agriculture, held in La Paz in 1995, these proceedings are subdivided in a number of themes for which the situation in Latin America is analysed: (1) hydroponics; (2) waste recycling; (3) homegardens and communal gardens; (4) small livestock rearing. (WB)

Raschid-Sally, Liqa, Wim van der Hoek and Mala Ranawaka (eds.) **(2001), Wastewater Reuse in Agriculture in Vietnam: Water Managemen, Environment**

and Human Health Aspects - Proceedings of a Workshop held in Hanoi, Vietnam, 14 March 2001.
Supplier: Colombo, Sri Lanka: IWMI (International Water Management Institute) IWMI Working Paper 30.
wastewater reuse health / pollution
water management; wastewater; irrigation; agricultural development; health; aquaculture; Vietnam, Asia (South-Eastern)

This working paper contains the proceedings of the workshop that was organized on 14 March 2001 in Hanoi, gathering experts from the various disciplines such as health, environment,water resources management, irrigation, agriculture, soil sciences, water quality, etc. to discuss the findings of 16 papers on different aspects of wastewater reuse. The proceedings of this workshop are presented here in summary form, which we hope will provide a bird's-eye view of the current knowledge in Vietnam on this subject to a wide spectrum of interested persons.

Rose, Gregory D **(1999). Community-based technologies for domestic wastewater treatment and reuse: options for urban agriculture. Cities Feeding People report series no. 27, also on: http://idrc.ca/cfp/rep27_e.html. 52, 13 p. International Development Research Center (IDRC), Cities Feeding People Program, PO Box 8500, Ottawa, Ontario, Canada K1G 3H9**
wastewater reuse community development
wastewater treatment; wastewater reuse; urban environmental management

Stresses the under-management of domestic wastewater in many southern urban areas. Unmanaged wastewater contributes much to the contamination of locally available fresh water supplies and can, obviously, have a negative effect on public and ecosystem health. As has been pointed out by many different authors, centralised European-style human waste management has not worked out well in developing countries. In contrast, emergent trends in low-cost, decentralised or intermediate level urban wastewater management becomes more important, creating space for innovative appropriate technologies. These often develop along the lines of planning integrated wastewater management strategies in conjunction with urban agriculture as a recipient of grey water. An important study providing a clear overview of the field.

Shirley, M. **(ed.) (2002), Thirsting for Efficiency: The Economics and Politics of Urban Water System Reform. Washington: World Bank**
Supplier: Elsevier Science B.V., The Boulevard, Langeford Lane, Kidlington, Oxford OX5 1GB, UK
wastewater reuse
drinking water; sanitation; water management; privatisation; urban areas, Argentina, Peru, Cote D'Ivoire, Guinea, Chile, America (Southern), Mexico, America (Central), Africa (Western)

One billion people in the world lack safe drinking water and almost 2 billion lack adequate sanitation services. As a result millions suffer and die every year from water and sanitation related diseases. Poor management and inefficient investment are often responsible for this situation, and countless past attempts at reform have accomplished little. Recently some developing countries have tried to reverse years of mismanagement of their water and sewerage systems by auctioning contracts to private operators.

Why do countries that have tolerated mismanagement for decades develop a thirst for efficiency? What are the results of their efforts to change? What determines success or failure? This book fills a gap in the literature by systematically answering these important questions. It does so by analyzing reforms in six developing country capitals -- Buenos Aires, Argentina; Lima, Peru; Mexico City, Mexico; Santiago, Chile; Abidjan, Cote d'Ivoire; and Conakry, Guinea - and the United States in the 19th century. It not only assesses economic factors, but also explores the roles of laws, politics and norms. It provides an economic theory of water that encompasses institutional, political and economic aspects of reform.

Schuebeler, Peter **(1996). Urban sanitation management in developing countries: three conceptual tools. 46 p. ISBN 3_908001_69_2. GBP 5.95. Swiss Centre for Appropriate Technology (SKAT), Vadianstrasse 42, CH-9000 Sankt Gallen, Switzerland**
Supplier: Intermediate Technology Publications (ITP), 103-105 Southampton Row, London WC1B 4HH, UK
waste recycling wastewater reuse
urban sanitation; public health; project evaluation; participatory approaches

This booklet, with the characteristic of a small manual, is concerned with urban sanitation in developing countries. Rather than focussing on sanitation problems or possible solutions, its aim is to present three conceptual tools for assessing urban sanitation systems and illustrate the use of these tools with regard to a few selected cases. Tools discussed are: (1) Assessing modes of sanitation development; (2) Modelling sanitation management systems; (3) Analysing participatory approaches. (WB - from original abstract)

Scott, Christopher A; Zarazúa, J Antonio; Levine, Gilbert. **Urban wastewater reuse for crop production in the water-short Guanajuato river basin, Mexico. Research report no. 41. 34 p. ISBN 92-9090-404-6. International Water Management Institute (IWMI), PO Box 2075, Colombo, Sri Lanka**
wastewater reuse
Mexico; wastewater reuse; water management; irrigation; river basins; environmental degradation; public health; simulation models

There are significant trade-offs associated with using untreated urban sewage. However, there are a number of important water quality, environmental, and public health considerations. This report explores the advantages and risks of urban wastewater reuse for crop production in the water-short Guanajuato river basin in west-central Mexico. The Interactive River Aquifer Simulation (IRAS) model developed by Cornell University is applied and validated in this setting. There is special focus on siltation and heavy metal concentrations in river bed sediments.

(WB)

Shaat, Ali **(ed.) (1998). Reuse of waste water for irrigation in Gaza governorates: quantitative study. 7 p. Water and Sanitation Department, Urban and Rural Planning Directorate, Ministry of Planning and International Coorperation, Palestinian National Authority**

wastewater reuse

Palestine; water shortage; wastewater recycling; water management; irrigation

The water shortage problem in Palestine is such a major socio-economic and environmental problem to residents that water and sanitation are perceived as issues of the highest order. The author argues that recycling of wastewater would generate enough irrigation water to satisfy agricultural demands in 2015. (WB)

Shuval, HI **et al (1986). wastewater irrigation in developing countries: health effects and technical solutions. UNDP Project Management Report No. 6, New York ,. 325 p.**

wastewater reuse health and environment

irrigation; health; stabilisation ponds; economics

This is a fairly comprehensive overview. It tells the story beginning wit the 19th century in 14 developed countries and finishes with a summary of positives and negatives. It proposes effective and economic methods of control that re particularly suited to developing countries. A theoretical model is developed based on a review of credible epidemiological studies and reports, to assist in the prediction of degree of risk of disease to sewage farm workers, neighbors to the treatment plants and to the consumers of products associated with wastewater irrigation. This study provides a rational basis for the development of a sound economic approach to waste water irrigation in developing countries. Such an approach helps to conserve water and nutrient resources, promotes urban agriculture, and contributes to pollution control. It reduces the cost of inputs to urban and periurban farmers and reduces the cost of municipalities and other local jurisdictions in waste management. This report presents a concise introduction to the policy and technological aspects of recycling wastewater from urban areas for agricultural irrigation. The focus is on conserving resources, economic development and healthy cities. It is a non-technical summary of a 324-page report (World Bank Technical Paper # 51) that was the culmination of a thee-year global study of the latest developments in the field. Several eminent review panels have concluded that the principles presented in this paper provide a sound scientific and public health basis for planning wastewater irrigation projects. (JS adapted from author)

Sonou M**. (2001) Periurban Irrigated Agriculture and Health Risks in Ghana. In: *Urban Agriculture Magazine*, no 3, Health , March 2001, RUAF, Leusden The Netherlands.**

health and environment wastewater reuse

Ghana; reuse; irrigation;

Most vegetable farmers in the (peri)-urban areas of Kumasi and Accra consider irrigated horticulture as their primary sources of revenues. Currently, (peri)-urban irrigation provides all-year round vegetables and contributes to the improvement of the nutritional status of city inhabitants. The nearness of the markets means a large array of fresh products of good quality. However, water remains a qualitative and quantitative constraint. Because the cost of pipe borne water makes it unaffordable to farmers, the use of untreated wastewater for irrigation has become a widespread practice with its attendant health hazards.

Todd, Nancy Jack; Todd, John **(1994). From eco-cities to living machines: principles of ecological design. 195 p. ISBN 1-55643-150-3**
Supplier: Eco-logic books, 19 Maple Grove, Bath BA2 3AF, UK
city ecology wastewater reuse
urban design; permaculture; waste recycling; urban planning

For more than thirty years, John and Nancy Todd have been advocating a new, provocative approach to urban design. The underlying book was originally published in 1984, at a time when environmental problems began to appear in their full size. The authors describe site-specific technological interventions and systems-wide ecological thinking developed in the framework of the New Alchemy Institute on Cape Cod. The book is centred around two concepts: Eco-cities, or designs for integrating agriculture and flowing pure water into green urban settings; and Living Machines, a family of technologies for purifying wastewaters without chemicals. This is a far-reaching publication destined for a broad audience. (WB)

Wegelin, Martin **(1996). Surface water treatment by roughing filters: a design, construction and operation manual. SANDEC report no. 2/96. ISBN 3_908001_67_6. GBP 10.95. SANDDEC, Swiss Federal Institute for Environmental Science and Technology (EAWAG), CH-8600 Duebensorf, Switzerland**
wastewater reuse waste recycling
water treatment

Presents water treatment alternatives particularly applicable to rural water supplies in developing and newly industrialised countries, and describes processes for solid matter separation. There are 2 parts. Part 1 contains a general description to the subject of rural water treatment. Part 2 clarifies design, construction and operation characteristics of different prefilters and roughing filters. Very complete and full of sound information, but for a technical audience. (WB)

Ul Hassan, M. **(2002), Maximising Private and Social Gains of Wastewater Agriculture in Haroonabad. International Water Management Institute, Central Asia and Caucasus Sub-office, Uzbekistan. In: The Economics of Urban Agriculture - *Urban Agriculture Magazine no. 7*, August 2002, pp.29-31.**
wastewater reuse

Pakistan; wastewater; urban agriculture; wastewater reuse; irrigation, Asia (South-Central)

In many countries, using wastewater for irrigation purposes originated as and has remained an unplanned activity, practised for centuries by poor farmers in urban and periurban areas. It has also become a widely accepted, though unregulated, practice in many countries. Due to growing populations, weak financial health of municipalities and weak or non-existing institutional and regulatory mechanisms, it is likely to continue as the main wastewater treatment strategy of the developing world.

WHO Scientific Group **(1989). Health guidelines for the use of waste water in agriculture and aquaculture. World Health Organisation Technical reports series no. 776. WHO Scientific Group, World Health Organisation (WHO), Geneva, Switzerland**

wastewater reuse   health and environment

wastewater management; wastewater reuse; aquaculture

Provides a comprehensive overview of health in relation to wastewater use in agriculture. The publication starts by covering the major aspects and current practices on reuse of waste water including: wastewater as a resource, environmental control issues, chemical pollutants, economic aspects, institutional aspects and sociocultural issues. The following chapters deal more specifically with health aspects: infections caused by pathogens; factors involved in disease transmission; epidemiological evidence; health promotion and planning; and implementing safeguards. Lastly the need for further research is discussed. (NB)

Wyss, Philippe **(et al.) .(1998). Extensive wastewater treatment: informations facilitating the decision of whether or not extensive wastewater treatment can be an appropriate solution in specific local situations. 55 p. EAWAG / SANDEC, Switzerland**

wastewater reuse

wastewater treatment; wastewater management

Gives a general, very complete, introduction to wastewater treatment, ranging from extensive to intensive systems, and from centralised versus decentralised systems. Requirements are discussed for the sustainable application of extensive wastewater treatment plants. This paper provides much technical information, and ('but', some would say) makes for very useful reading. (WB)