WATER CONSERVATION TECHNICAL BRIEFS

TB7 – Wastewater use in agriculture

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Wastewater is gaining importance for productive use in agriculture throughout the world. An estimated of 20 million hectares (aprox 7%) of land is irrigated using wastewater worldwide. Some reasons for its use are water scarcity, reliability of wastewater supply, livelihood and economic dependence, proximity to markets for perishable food items, and nutrient value of the water.

The use of wastewater has also important health and environmental implications. Investments in water supply far outpace those in sanitation, particularly in developing countries, that can ill afford the excessive costs of treatment facilities. This technical brief attempts to give an overview of the use of wastewater in agriculture, the advantages and disadvantages of its use, and wastewater characterisation. This brief also provides some recommendations on treatment options for quality improvements at a farm level where funding for major improvements in wastewater collection and treatment are limited.

The structure of the technical brief is as follows: Section 1 describes the use of wastewater in agriculture in the world. Section 2 provides a brief introduction of the important groups of microorganisms in wastewater treatment and reuse. Sections 3 and 4 outline the drivers of its use and describe the benefits and disadvantages of its use. Section 5 presents the WHO (World Health Organisation) guidelines for the safe use of wastewater irrigation. Section 6 set outs some health control measures through the food supply chain, whilst Section 7 focuses measures to reduce microbiological level at a farm level. Waste stabilization ponds and wastewater storage and treatment reservoirs are presented as good treatment options prior to wastewater re-use in agriculture. Section 8 recommends some simple and lost cost measures to reduce wastewater health risk to farmers and consumers, specifically in developing countries. Section 9 outlines a case study in Ghana. Finally, Section 10 recommends some further reading.

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SECTION 1: WASTEWATER USE WORLDWIDE

Wastewater has long been used as a resource in agriculture. Today an estimated 20 million hectares (approximately 7%) of land is irrigated using wastewater worldwide[1], particularly in arid and semiarid regions and urban areas where unpolluted water is a scarce resource. The use of contaminated water in agriculture can be managed through the implementation of various barriers which reduce the risk to both crop viability and human health.

Land application of wastewater, sludge and excreta is a widespread practice worldwide. In many European and North American cities, wastewater was disposed of in agricultural fields before the introduction of wastewater treatment technologies to prevent pollution of water bodies. In developing countries like China, Mexico, Perú, Egypt, Lebanon, Morocco, India and Vietnam, wastewater has been used as a source of crop nutrients over many decades.

The figure below depicts countries reporting the use of wastewater or polluted water for irrigation (identified with white squares). As shown in the figure, Bolivia, Brazil, China, India, Pakistan, and several countries of Africa report wastewater irrigation or polluted water use in agriculture.

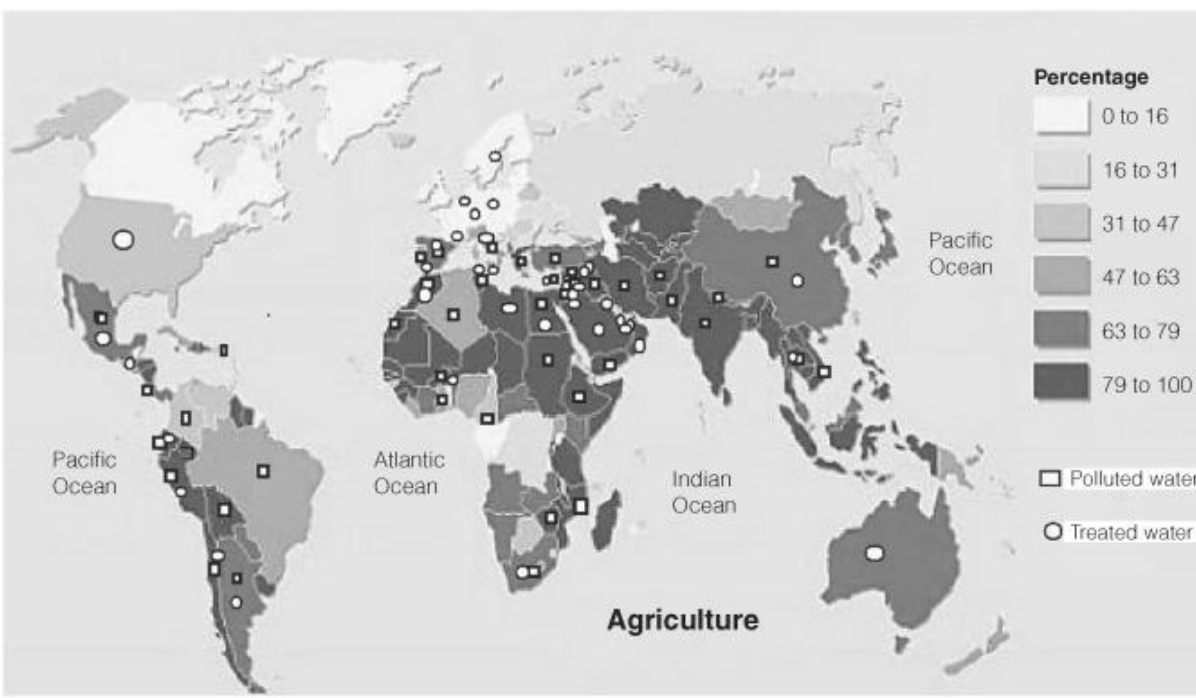

Figure 1: *Freshwater withdrawals for agricultural use in the year 2000 and countries reporting the use of wastewater or polluted water for irrigation.*[2]

According to the World Health Organization (WHO), 10% of the world's population relies on food grown with contaminated wastewater[3]. In this term, there are clear advantages related to production of food (mainly vegetables) to urban populations. For example, in Pakistan, about 26% of the total vegetable production is irrigated with urban wastewater.[4]

Much of the wastewater use in agriculture is not intentional and is the consequence of water sources being polluted due to poor sanitation and waste-disposal practices in cities. The majority of wastewater use is reported to be used in developing countries, where 75% of the world's irrigated land is located.[5] Low and middle income countries such as India, Mali, Jordan, Palestine, South Africa, Nepal, Sri Lanka, Costa Rica and Malaysia are using grey water for gardening and irrigation of non-edible crops (such as fodder and olive trees).[6]

Wastewater irrigation seems to be common reality. It is used in around 4 of every 5 cities in developing countries, and one in 10 cases use untreated than treated wastewater. The figure below depicts the raw and treated wastewater irrigated area by country. China, Mexico and India are the countries with a high intensity of wastewater use. On other hand, Chile, Mexico and Israel are the countries with more use of treated wastewater for irrigation.[7]

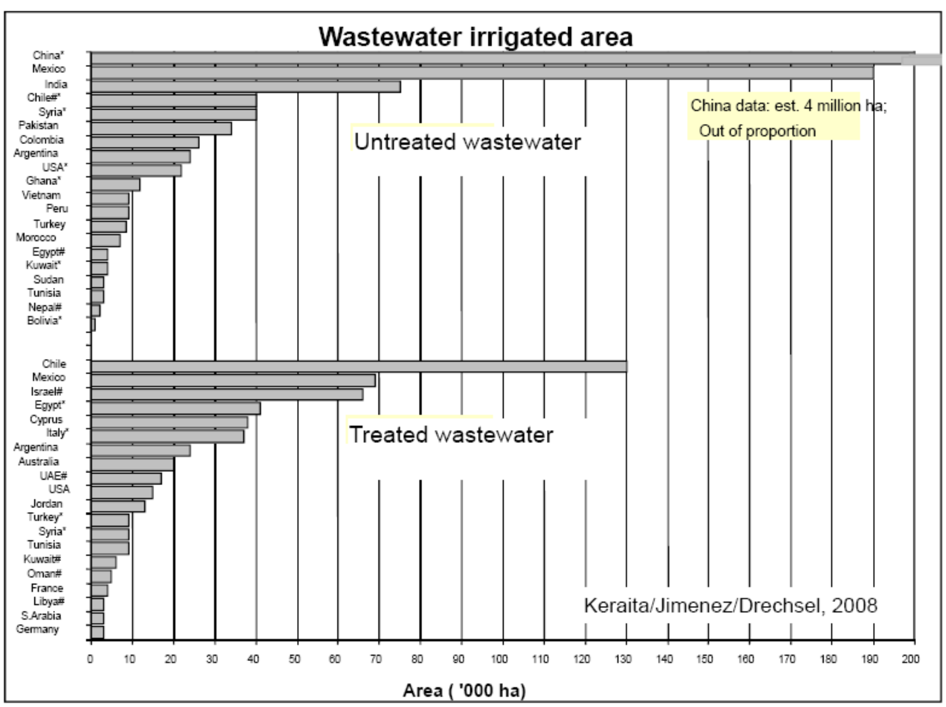

Figure 2: Untreated and Treated wastewater irrigation by country[8]

Section 2: Wastewater characterisation

The wastewater is generally characterised by organic and inorganic contaminants; originating from dissolved contents of fertilisers, chemical runoff (such as pesticides), human waste, livestock manure and nutrients. However, untreated wastewater or improperly treated wastewater may contain a range of pathogens including bacteria, parasites, viruses, protozoans, fungi and worms. Most of these pathogens use the faecal/oral route to spread disease.[9] In addition, toxic chemicals such as heavy metals and organic chemicals can be found in wastewater from agriculture, industry and domestic sources.

Micro-organisms (often simply called 'microbes') are small single-celled organisms and can be categorised into: viruses, bacteria, micro-algae and protozoa.

- Viruses are extremely small parasitic microbes which can reproduce only by invading a host cell whose reproductive processes they redirect to manufacture more viruses. The structure of viruses is extremely simple: they comprise a core of either DNA or RNA surrounded by a protein

- E. coli (Escherichia coli) are bacteria that normally live in the intestines of animals, including humans. Some rare strains of E. coli can cause serious illness[10]

- Protozoa, especially flagellates protozoa are present in very large numbers in wastewater treatment processes

- Helminths (worms) are important because a few of them cause disease and because a group of them are highly tolerant of pollution and oxygen depletion in freshwaters. All worms fall into one of three types: nematodes (roundworms), cestodes (flatworms) and trematodes (flukes)

Section 3: What are the drivers of wastewater use?

The main drivers of wastewater use in irrigated agriculture are a combination of the following aspects:[11]

- Limited capacities of cities to treat their wastewater, causing pollution of soils, water bodies and traditional irrigation water sources
- Lack of alternative (cheaper, similarly reliable, available or safer) water sources in the physical environment
- Urban food demand and market incentives favouring food production in the proximity of cities, where water sources are usually polluted

In developing countries, the limited financial and physical resources to treat wastewater, the socio-economic situation and the context of urbanization create the conditions for unplanned and uncontrolled wastewater use.

SECTION 4: WHAT ARE THE ADVANTAGES AND DISADVANTAGES OF WASTEWATER USE?

The use of wastewater in irrigated agriculture presents some advantages and disadvantages as described below.

Advantages

There are clear advantages on the use of wastewater in agriculture, mainly related to the availability and reliability of water resources and the affordability and security of food production. Some advantages include:

- Source of additional irrigation water
- Saving of high quality water for other beneficial used in condition of water stress
- Low cost source of water supply
- Economic way to dispose wastewater and prevent pollution and sanitary problems
- Reliable, constant water source allows multiple cultivation cycles and flexibility of crops planted[12]
- Effective use of plant nutrient contained in the wastewater (such as nitrogen and phosphorus)
- Provides additional treatment of the wastewater before being recharged to the groundwater
- Allow higher crop yields, a yearly production, and increases the range of crops that can be irrigated, particularly in arid and semi-arid areas[13,14]
- Can also reduce the demand for fertilisers especially where the wastewater is not diluted, i.e. make crop nutrients more accessible to poor farmers

Disadvantages

The use of wastewater for irrigation without an adequate management can pose a serious risk. Also, the risks are not limited to farmers, it can also be observed in crop workers, consumers of crops or meat and milk coming from cattle grazing on polluted fields, and those living on or near the areas where wastewater is used. Farm workers that are into direct contact with wastewater can be affected through faecal-oral transmission pathways or contact with disease vectors in the water.

Some disadvantages are:

- Wastewater not properly treated can create a potential public health problems
- Some of the soluble constituents in the wastewater could be present at concentrations toxic to plants
- The treated wastewater could contain suspended solids at level that may cause clogging
- Health risk from pathogens. The risk is related to the nature of the pathogen in the wastewater and it can vary locally. Figure 3 shows the concentration of microorganisms excreted in one litre of wastewater. Salmonella, Vibrio cholerae, Enteric virus, rotavirus can be found in wastewater[15]

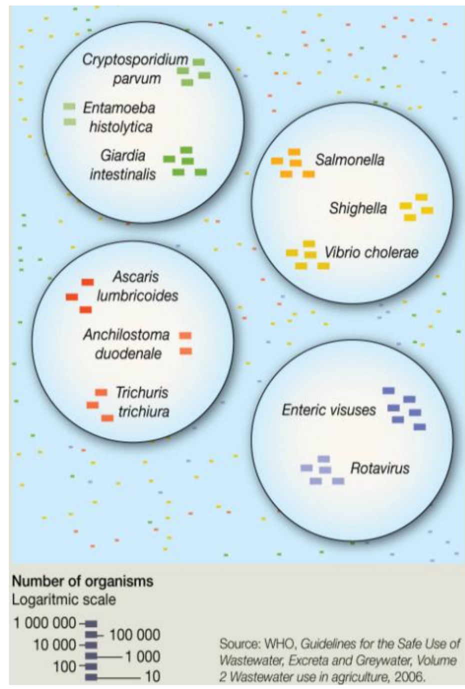

Figure 3: Number of organisms found in wastewater.

- Contamination can occur, in the case of metals and some organic chemicals, through absorption from the soil, which strongly depends on the location (possible contamination sources), the environmental conditions (particularly the soil), bio-availability (in the case of some contaminants), type of plant and agricultural practices (quantity of water applied and irrigation method). For more detail on health risk and diseases see Appendix A.
- Potential contamination of groundwater. The quality and depth of groundwater prior to wastewater irrigation determine the detrimental effects of salts, nitrates, metals and pathogens reaching groundwater. The deeper the groundwater, the longer it will take to have such effects[16]
- Excessive concentrations of nitrogen can lead to over-fertilization and cause excessive vegetative growth, delayed or uneven crop maturity and reduced quality[17]

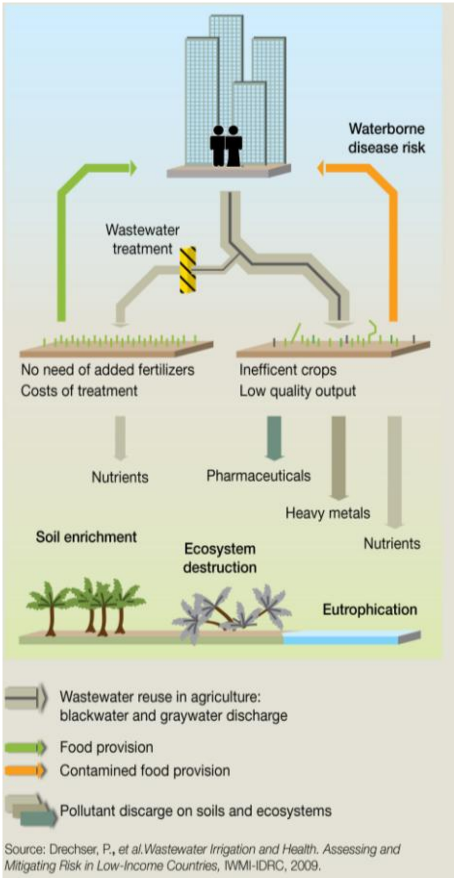

Figure 4: Wastewater in urban agriculture: Resource or threat?

The advantages and disadvantages are graphically depicted in Figure 4. The use of treated wastewater can enrich soils, replaces the use of fertilisers and provide food supply to urban areas.

The reduction on fertiliser use improves water quality and therefore reduces grey water. On the other hand, if not properly manage wastewater use can pose risks to the environment and society. The rich content of nutrients of wastewater can produce eutrophication of water and ecosystem destruction.

In addition, crops contaminated with wastewater can produce health effects on society.[18]

Section 5: Wastewater health guidelines

Wastewater treatment must be done for a specified purpose – for example, to produce an effluent suitable for agricultural reuse, or to produce an effluent that can be safely discharged into water courses.

Some countries do have national guidelines for the acceptable use of wastewater for irrigation, however there are some countries which do not. The WHO guidelines on the safe use of wastewater, excreta and grey water in Agriculture[19] provide a comprehensive framework for risk assessment and management that can be applied at different levels and in a range of socio-economic circumstances. The guideline aims at protecting the health of farmers and also the consumers who eat wastewater-irrigated crops against excessive risks of viral, bacterial and protozoan infections.
The main characteristics of the approach are: the establishment of health-based targets, which allow local authorities to set risk levels that can be handled under the country conditions and capacities; the application of microbial risk assessment (for pathogenic viruses and bacteria) as a cost-effective way of assessing health risks; the identification of all risk points through the entire supply chain including agriculture to final consumption; the design of a combination of health risk management measures, to be applied along the same chain of events, with the aim of ensuring health protection as a result of incremental risk reduction.[20]

The guidelines can be summarised in the table below which depicts health based targets for agriculture under unrestricted and restricted irrigation. In general terms, the guidelines[21] are ≤1 human intestinal nematode eggs/l for unrestricted and restricted irrigation and if children under 15 years are exposed, ≤0.1 egg/l. The table also indicates the pathogen reduction (in $\log_{10}$) necessary to achieve the 10^{-6} DALY targets for rotavirus for different exposures (Unrestricted irrigation, restricted irrigation and labour intensive).[22]

Table 1: WHO guidelines for microbiological quality of treated wastewater used for crop irrigation. Source: http://eprints.whiterose.ac.uk/9085/1/Understanding_and_Updating_the_2006_WHO_Guidelines_for.pdf

Exposure scenario	Health-based target (DALY per person per year)	Log 10 pathogen reduction needed	Number of helminth eggs per litre[a]
Unrestricted irrigation	$\leq 10^{-6}$		

[a] WHO recommends considering additional waste treatment or health protection measures when children less than 15 years old are exposed in the field (≤0.1 egg/l).

Lettuce		6	≤1
Onion		7	≤1
Restricted irrigation	$\leq 10^{-6}$		
Highly mechanised		3	≤1
Labour intensive		4	≤1
Localised irrigation	$\leq 10^{-6}$		
High-growing crops		2	No recommendation
Low-growing crops		4	≤1

Source: WHO 2006

SECTION 6: OVERVIEW OF WASTEWATER CONTROL MEASURES[23]

There are different wastewater control measures to achieve the health guidelines for the microbiological quality of treated wastewaters used for crop irrigation. The level of health protection can be met by at a farm level (e.g. by wastewater treatment and the use of personal protective equipment such as shoes and gloves to protect workers) or further through the supply chain (e.g. by washing or cooking the crops to protect final consumers from raw vegetables). Also they can be achieved by a particular treatment or by a combination of wastewater treatment.

The control measures can be classified into:

- Wastewater treatment: e.g. sedimentation, clarification, filtration
- On-farm solutions: e.g. on-farm wastewater treatments, method of irrigation, time of harvest, etc. See section 5 for further detail.
- Post-harvest options at local markets
- In-kitchen produce/preparation options: e.g. disinfection, peeling, cooking, boiling

Some examples of control measures can be found in the table 2 below. The table depicts an overview of the measures to control wastewater microbiological content and its pathogen reduction.

Table 2: Control measures and pathogen reduction.

Control Measure	Pathogen Reduction (log units)	Notes
A. Wastewater treatment	1-7	Pathogen reduction depends on type and degree of treatment selected
B. On-farm options		
Crop restriction (i.e., no food crops eaten uncooked)	6-7	Depends on the effectiveness of local enforcement of crop and comparative profit margin of the alternative crop.
On-farm treatment		
(a) Three-tank system	1-2	Operated in sequential batch-fed mode.
(b) Simple sedimentation	6-7	Sedimentation for 18 hours approx.
(c) Simple filtration	1-3	Value depends on the system used.
Method of wastewater		

application		
(a) Furrow irrigation	1-2	Crop density and yield may be reduced.
(b) Low-cost drip irrigation	2-4	2-log unit reduction for low-growing crops and 4-log unit reduction for high-growing crops.
(c) Reduction of splashing	1-2	Farmers trained to reduce splashing when watering cans used (splashing contaminated soil particles on to crop surfaces which can be minimised).
Pathogen die-off	0.5-2 per day	Die-off between last irrigation and harvest (value depend on climate, crop type, etc)
C. Post-harvest options at local markets		
Overnight storage in baskets	0.5-1	Selling produce after overnight storage in baskets (rather than overnight storage in sacks or selling fresh produce without overnight storage).
Produce preparation prior to sale	1-2	Rising salad crop, vegetables and fruits with clean water.
	2-3	Washing salad crops, vegetables and fruit with running tap water.
	1-3	Removing the outer leaves on cabbages, lettuces, etc.
D. In-kitchen produce-preparation options		
Produce disinfection	2-3	Washing crops, vegetables and fruit with an appropriate disinfectant solution and rinsing with clean water.
Produce peeling	2	Fruits, root crops.
Produce cooking	5-6	Option depends on local diet and preference for cooked food.

Modified from: Mara et al 2009[24] and Mara 2003[25].

SECTION 7: WASTEWATER MANAGEMENT ON-FARM[b]

As shown in table 2, there exist several wastewater treatment processes that can achieve a pathogen reduction at a farm level. It is important to distinguish between large-scale agricultural use of wastewater (e.g., where the wastewater from a large city is treated and then used for irrigation) and the much smaller-scale urban agriculture. For large schemes anaerobic and facultative ponds would be sufficient in most cases, and for small schemes (as in urban agriculture, for example) processes such as a three-tank system would be suitable (on any one day one tank is filled, one allowed to settle, and one is used).

Decentralised wastewater treatments are treatments to collect, treat and reuse clean wastewater. They operate at a low scale and they are generally cheaper than municipal systems. The purpose of wastewater treatment units is designed to reduce loads of microbial pathogens, specified heavy metals and total suspended solids.

Initial improvements in water quality can be achieved in many developing countries by at least primary treatment[c] of wastewater, particularly where wastewater is used for irrigation. Secondary treatment[d] can be implemented at reasonable cost in some areas, using methods such as waste-stabilization ponds (WSP), constructed wetlands, infiltration-percolation, and up-flow anaerobic sludge blanket reactors.[26] This section focuses on measures that help reducing health risks at a farm level in a small-scale. These measures can play a complementary role to wastewater treatment and other post-harvest measures as shown in table 2.

Waste stabilization ponds, wastewater storage and treatment reservoirs, crop and irrigation selection and scheduling can be good options prior to wastewater re-use in agriculture as described below. They can help achieve the required microbiological quality and, when treating domestic wastewater, also achieve the required physicochemical qualities.

a. **Waste stabilization ponds[27] (WSO)***:* WSP are large shallow basins enclosed by earth embankments in which raw wastewater is treated by entirely natural

[b] The options of farm based measures for health risk reduction presented here are biased to experiences gained in West Africa. Further studies are required to address other smallholder irrigation systems and crops to develop new measures or adapt the ones presented here.

[c] Primary treatment is a chemical or physical process which reduces the BOD by at least 20% before it is discharged. It involves the settlement of suspended solids.

[d] Secondary treatment is a biological process where bacteria are used to break down the biodegradable matter in waste water.

processes involving both algae and bacteria. The rate of oxidation is slower, and as a result hydraulic retention times are longer (days rather than hours) than in conventional wastewater treatment (e.g. electromechanical treatment processes such as activated sludge).

Pond systems are widely used as simple biological wastewater treatment systems in many developing countries as they are cheaper than most conventional systems. Pathogens such as helminth[e] eggs and protozoa cysts are removed by sedimentation, while pathogenic bacteria and viruses are removed by a combination of various factors that create an unfavourable environment for their survival in the pond.

What are the advantages and disadvantages?

WSPs can be an important method of wastewater treatment in developing countries where sufficient land is available and where the temperature is favourable for their operation.

The advantages of WSP are that they are simple, low-cost, highly efficient and robust. WSP that are properly designed and then properly operated and maintained do not have odour problems, and they will not have odour problems until they become overloaded.

A disadvantage of the pond is that in drier climates, the evaporation can increase the salinity of the pond, which makes it less suitable for crop production. In addition, pond systems can be important breeding sites for mosquitoes, which are vectors for a number of diseases. WSP do require much more land than conventional treatment processes such as oxidation ditches or activated sludge WSP effluents can be high in BOD and suspended solids (SS), but most of this effluent BOD and SS is due to the algae in the pond effluent.

If WSP effluents are used for crop irrigation, the algae are very useful: they act as slow-release fertilizers and over time increase the organic content of the soil and thus its water-holding capacity.

Types of WSP There are three principal types of WSP[f]: anaerobic, facultative and maturation ponds. Anaerobic ponds and facultative ponds are designed for BOD[g]

[e] The infection is caused by a parasitic worm. Inflammation of the gut may also occur, resulting in cyst-like structures forming around the egg deposits throughout the body. The host's lymphatic system is also increasingly taxed the longer helminths propagate, as they excrete toxins after feeding. These toxins are released into the intestines to be absorbed by the host's bloodstream. This phenomenon makes the host susceptible to more common diseases such as seasonal viruses and bacterial infections.

[f] The macrophyte ponds and 'advanced pond systems' are not generally applicable in developing countries.

(biochemical oxygen demand) removal, and maturation ponds are designed for faecal bacterial removal. Some removal of faecal bacteria (especially of *Vibrio cholerae*) occurs in anaerobic and facultative ponds, which are also responsible for most of the removal of helminth eggs; and some removal of BOD occurs in maturation ponds, which also remove some of the nutrients (nitrogen and phosphorus).

Facultative and maturation ponds are photosynthetic ponds – that is the oxygen needed by the pond bacteria to oxidise the wastewater BOD is mainly supplied by micro-algae that grow naturally and profusely in these ponds (and thus give them their characteristic green colour); and the carbon dioxide needed by the algae is mainly provided by the pond bacteria as an end-product of their metabolism.

Figure 5: Ghana farmer collection wastewater to irrigate food crops. Available at www.iwmi.cgiar.org

Anaerobic ponds

Anaerobic ponds are usually the first type of pond used in a series of ponds. They function much like open septic tanks, and their primary function is BOD (biochemical oxygen demand) removal. BOD removal is achieved by the sedimentation of settleable solids and their subsequent anaerobic digestion in the resulting sludge layer.

Facultative ponds

Facultative ponds are of two types: primary facultative ponds which receive raw wastewater and secondary facultative ponds which receive settled wastewater (usually the effluent from anaerobic ponds). They are designed for BOD (biochemical oxygen demand) removal. In general, they are coloured dark green as a result of the large numbers of micro-algae in them, although they may occasionally appear red or pink (especially when slightly overloaded) due to the presence of anaerobic purple sulphide-oxidizing photosynthetic bacteria.

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[g] DBO is the amount of oxygen required for the oxidation of a wastewater by bacteria. It is therefore a measure of the concentration of organic matter in a waste that can be
Oxidised by bacteria ('bio-oxidised' or 'biodegraded').

Maturation ponds

The main function of maturation ponds is to reduce the number of excreted pathogens, principally faecal bacteria and viruses, present in the effluent of facultative ponds. BOD and suspended solids are removed only very slowly, and nutrient (nitrogen and phosphorus) removal is also quite slow, although in a well-designed and properly operated and maintained series of WSP (anaerobic, facultative and several maturation ponds), cumulative removals of BOD, suspended solids and nutrients can be high.

b. Waste storage and treatment reservoirs (WSTR): WSTR have traditionally been used as storage reservoirs[h] for pre-treated wastewater from WSP intended for irrigation use. During storage, further pathogen removal is achieved.

Storing reclaimed water in reservoirs improves the microbiological quality and provides peak-equalization capacity, which increases the reliability of supply and improves the rate of reuse. For example, the long retention times in the King Talal Reservoir in the Amman-Zarqa Basin of Jordan reduced faecal coliform levels in water downstream of the dam.[28] In addition, in Israel, single WSTR are mostly used for cotton irrigation to achieve microbiological quality for the treated wastewater.

c. Disinfection

There are other disinfection techniques, but these are not recommended by Duncan Mara[29] as

- in the case of ultra-violet disinfection, the high-intensity ultra-violet lamps are expensive imported items
- in the case of chemical disinfection, the chemicals are expensive (e.g. ozone) or needed in high doses (e.g. up to 20 mg chlorine/l), and even then they will not be effective in reducing the numbers of helminth eggs and protozoan cysts
- faecal bacterial regrowth may occur: a few resistant bacteria may survive to multiply in an environment that is much less competitive as most of the other faecal and non-faecal bacterial will have been killed
- environmentally harmful compounds can be produced, for example chlorinated organics, many of which are carcinogenic and/or teratogenic.

In Europe, onsite gravel filters, heavy metal removal device and UV disinfection have been applied on-site to treat wastewater for irrigation to reduce the parasites and microbiological load.[30]

[h] Also called effluent storage reservoirs

d. Irrigation methods[31]

Specific irrigation methods can contribute to the pathogen removal and they should be design in order to minimise the contact of pathogens. Overhead irrigation methods such as sprinkler irrigation and watering cans can have the highest potential to transfer pathogens to vegetables as water is applied on edible parts and due to the wider movement of pathogens through aerosols. Flood and furrow irrigation methods apply water on the surface and are less likely to contaminate high growing crops; but for low-lying crops and root crops contamination is still high. Localized techniques, such as drip irrigation, have minimal pathogen transfer to crop surfaces because water is directly applied to the roots.

Wastewater irrigation under micro-irrigation system is not recommended because of clogging. Gravel filters can be used can be used in to avoid clogging and it is not recommended for sprinkler or surface irrigation because of the high instantaneous flow required by these methods. [32] See table 2 for pathogen reduction levels under different irrigation methods.

e. Scheduling of water application: Timing and frequency of irrigation, including frequency are important for pathogen reduction. One of the most widely documented measures to reduce pathogens is cessation of irrigation, in which irrigation is stopped a few days before harvest. This results in exposure to conditions that are unfavourable to pathogen growth including heat, desiccation and sunlight. Pathogen inactivation on crops is more rapid in hot, sunny weather than in cool, cloudy or rainy conditions.

Figure 6: Watering can needs to be applied at low levels to avoid splashing of wastewater to the crops

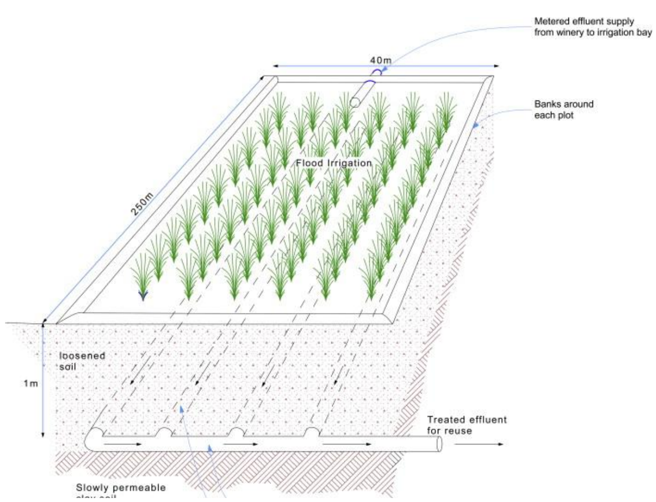
One disadvantage of irrigation cessation is that leafy vegetables and salad crops can lose their freshness and therefore their economic value. It is recommended to stop irrigation to fodder crops that do not have to be harvested at the peak of their freshness.

f. Crop Selection: Some crops are more susceptible to pathogens contamination than others. For example, crops with their edible parts more exposed to contaminated soils and irrigation water like low-growing leafy vegetables or root crops (e.g. carrots) will be more prone to pathogen contamination. This measure of control

will depend on the effectiveness of local enforcement of crop and comparative profit margin of the alternative crop.

Another technique developed in CSIRO[a] is the Filtration and Irrigated cropping for Land Treatment and Effluent Reuse[a] (FILTER). It has been applied in Australia[a] and China. The system treats sewage and uses the nutrients from it for intensive annual crop-growing. By using this system, wastewater can be treated in a relatively small area of land with selected crops so that pollution of agricultural produce and health risks due to large-scale wastewater irrigation can be prevented. Figure 7 shows a conceptual diagram of the FILTER system. This is a controlled drainage system enabling the manipulation of the watertable, and hence controls the depth of the aerated and anoxic soil layers. A network of subsurface drains is installed to allow for the regulation of leaching rates through the soil.[a] The treated wastewater can be reused for irrigation or discharged to water bodies meeting the regulations requirements.

Figure 7: Filtration and Irrigated cropping for Land Treatment and Effluent Reuse model

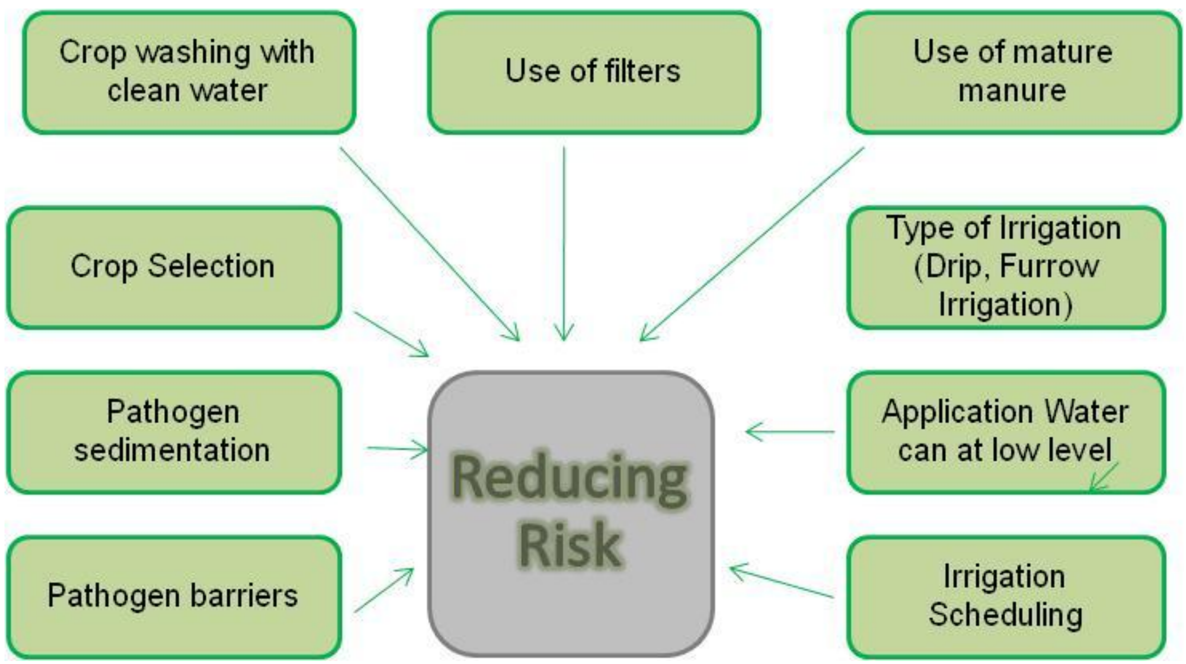


SECTION 8: RECOMMENDED MEASURES TO REDUCE WASTEWATER RISK AT A FARM LEVEL

The following are simple and low cost specific measures prepared by IWMI[33,34] to reduce the risk of wastewater use at a farm level. They are designed to reduce the risk of pathogens on farms irrigated by watering cans (extensively used in urban vegetable production) and farms irrigated by gravity-flow and furrow or flood irrigation systems (For example, regions such as Eastern Africa). Some of the recommendations below will fit a particular situation depending on local site characteristics and practices.

The following framework summarised some of the measures for low cost treatment methods for faecal sludge low-cost treatment in low income countries:

Figure 8: Low cost measures to reduce risk of pathogens at a farm-level. Source: Own eleboration



1. Crop selection: If farmers use wastewater or polluted water, they should select crops that are not eaten raw.
2. Using water from a pond: In case farmers obtain water from a pond that drains or a slowly moving stream (not stead), it is recommended to use water from the surface. Generally pathogens and worms earth settle to the bottom. Therefore by taken the water from the surface rather than from the ground it can be

avoided to take the water that contains pathogen. Also farmers should avoid moving or disturbing the water with their limbs.

3. Fetch water behind barrier: By putting a raw of sand bags in a stream, a poll is created that allows worn egg to settle. Water should only be fetch downstream of this line of bags.
4. Filter debris: Many pathogens are attached to debris. Filter debris such as a mosquito's net or pieces of clothes can reduce the level of pathogen on water. Filters can manually be installed in water cans. Farmers should clean the filter periodically to allow easy flow.
5. When using water can to irrigate crop, it is advisable to hold the water can low in order to reduce splashing and the contact of pathogen with the crop.
6. Furrow irrigation: The use of furrow irrigation reduces the contact of pathogens with the crop. The use of furrow irrigation can be applied when water can be channelled.
7. Drip irrigation: The use of drip irrigation reduces the contact of contaminated water with the crop. To avoid clogging is important to filter water.
8. Stopping irrigation before harvesting allows natural pathogen to die off by the effect of the sun. Farmers need to plan in advance and to know when the harvest is if they wish to reduce the level of pathogens. It is generally recommended to stop the irrigation before 2 to 4 days to reduce the level of pollution. However, longer periods can be more effective.
9. Use of mature manure. Farmers should use mature manure, since fresh manure contains life pathogens. Turning the fresh manure on a weekly basis over a period of 6 weeks allows that reduction of pathogens in the manure. After 6 weeks the manure can be safely applied. However, it is still recommended to apply the manure over the soil and not on top of the crop to avoid contact with it.
10. Settling or thickening tanks or ponds (non-mechanized, batch-operated): This treatment is a good way to introduce a primary treatment, such as settlement in a deep, anaerobic pond. This allow sedimentation of parasites such as the helminth eggs keeping the disease more or less under control[35]
11. Constructed wetlands: Constructed wetlands are among the recently proven efficient technologies for wastewater treatment. They are low cost, are easily operated and maintained, and have a strong potential by small rural communities[36]
12. Use of as low cost binding agents like moringa seeds[i] and certain types of clay[37]

[i] Moringa tree seeds, when crushed into powder, can be used as a water-soluble extract in suspension, resulting in an effective natural clarification agent for highly turbid and untreated pathogenic surface

13. Infiltration percolation techniques: Consist on infiltrating sewage through homogenous sand beds[38]
14. Stabilisation Ponds
15. Filters are recommended when land availability is limited
16. Unplanted drying beds[j]: An unplanted drying bed is a simple, permeable bed that, when loaded with sludge, collects percolated leachate and allows the sludge to dry by evaporation. Approximately 50% to 80% of the sludge volume drains off as liquid. The sludge however, is not stabilized or treated
17. Washing crops: It is recommendable to wash vegetables and crops with clean water.

water. As well as improving drinkability, this technique reduces water turbidity (cloudiness) making the result aesthetically as well as microbiologically more acceptable for human consumption.

[j] For more detail on unplanted drying beds See: http://www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/reed_beds.pdf

Section 9: Case studies

Practices of simple practices in Ghana to reduce microbiological risks[39]

Figure 11: Pond in Ghana

In most cases, the use of on-farm sedimentation ponds as a way to reduce they are used health risk. Ponds are storage reservoirs that surface run-off and wastewater effluents are channelled. Ponds are common in areas where irrigation water sources are far away. Farmers fill them manually or by pumping water from streams or tube wells. The key advantage of the ponds is the reduced walking distance, especially where watering cans are used. Depending on the size of the reservoir and irrigation frequency, refilling is done after one or several days. While the water is stored, sedimentation takes place. Studies in Ghana showed that these ponds are very effective in removing helminths (reduced to less than one egg per litre) when sedimentation is allowed for two to three days. Removal of faecal coliforms in the same period was about 2 log[k] units. In contrast to the reduction of worm eggs, the die-off of coliforms was only significant during the dry season.

Figure 9: Farmer in Ghana. Available at: http://www.idrc.ca/openebooks/475-8/f0200-01.jpg

In addition, Ghana farmers were advised to hold the watering can at low height and using an outflow rose to reduce water splashing of already contaminated soil on the crop.

[k] Logarithmic

SECTION 10: APPENDIXES

Appendix A: Health risks associated with wastewater use

The impact on health depends on location and the type of contaminant. The relative importance of health hazards in causing illness depends on a number of factors. The ability of infectious agents to cause disease relates to their persistence in the environment, minimum infective dose, ability to induce human immunity, virulence periods. The diseases of most relevance differ from area to area depending on the local status of sanitation and hygiene and the level to which wastewater is treated prior to use in agriculture.

The table below provides examples of the burden of some diseases of potential relevance to wastewater use in agriculture. However, it has been very difficult to differentiate the cause of diseases. It can be caused by wastewater use or poor sanitation, unsafe drinking water and poor hygiene.

Table 3: ***Global mortality and*** **DALYs** ***due to some diseases of relevance to wastewater use in agriculture***[40]

Disease	Mortality (deaths/year)	Comments
Diarrhoea	1,682,000	99.7% of deaths occur in developing countries; 90% of deaths occur in children;
Typhoid	600,000	Estimated 16,000,000 cases per year.
Ascariasis[l]	3000	Estimated 1.45 billion infections, of which 350 million suffer adverse health effects.
Hookworm disease[m]	3000	Estimated 1.3 billion infections, of which 150 million suffer adverse health effects.
Lymphatic flariasis[n]	0	Mosquito vectors of.lariasis (*Culex* spp.) breed in contaminated water. Does not cause death but leads to

[l] Ascariasis is an infection of the small intestine caused by Ascaris lumbricoides, a large roundworm. The eggs of the worm are found in soil contaminated by human faeces or in uncooked food contaminated by soil containing eggs of the worm.

[m] Human hookworm infection is a soil-transmitted helminth infection. It is a leading cause of anaemia and protein malnutrition, afflicting an estimated 740 million people in the developing nations of the tropics.

[n] Lymphatic Filariasis, known as Elephantiasis, puts at risk more than a billion people in more than 80 countries. Over 120 million have already been affected by it, over 40 million of them are seriously incapacitated and disfigured by the disease. One-third of the people infected with the disease live in India, one third are in Africa and most of the remainder are in South Asia, the Pacific and the Americas. In

		severe disability.
Hepatitis A	N/A	Estimated 1.4 million cases per year worldwide. Serological evidence of prior infection ranges from 15% to nearly 100%.

Source: Prüss-Ustün and Corvalan (2006); WHO (2006) in http://www.idrc.ca/en/ev-151656-201-1-DO_TOPIC.html

SECTION 11: FURTHER INFORMATION AND REFERENCES

Technical Papers

Sick Water. The central role of wastewater management in sustainable development. A rapid response assessment

www.grida.no/_res/site/file/publications/sickwater/SickWater_screen.pdf

This report identifies the main threats to human and ecological health and the consequences of poor wastewater management and degrading sewage systems.
UNEP, UN-Habitat. 2010

Coming clean on wastewater irrigation in *New Agriculturalist*, 2008

http://www.new-ag.info/pov/views.php?a=525

Decentralised wastewater treatment methods for developing countries

http://www.gate-international.org/documents/techbriefs/webdocs/pdfs/w8e_2001.pdf

Domestic Wastewater treatment in developing countries

Duncan Mara, Earthscan, London, 2003

This book details the design and performance of wastewater treatment processes suitable in low- and middle-income countries, such as waste stabilization ponds, wastewater storage and treatment reservoirs and constructed wetlands.

tropical and subtropical areas where lymphatic filariasis is well-established, the prevalence of infection is continuing to increase. A primary cause of this increase is the rapid and unplanned growth of cities, which creates numerous breeding sites for the mosquitoes that transmit the disease.

Understanding and Updating the 2006 WHO Guidelines for the Safe Use of Wastewater in Agriculture

Mara, D.D. and Sleigh, A. (2009) Understanding and Updating the 2006 WHO Guidelines for the Safe Use of Wastewater in Agriculture. In: Jornadas sobre la Reutilización de Aguas Regeneradas: Cuestiones Actuales y Retos de Futuro, 1–2 June 2009, Murcia. (Unpublished)

http://eprints.whiterose.ac.uk/9085/1/Understanding_and_Updating_the_2006_WHO_Guidelines_for.pdf

Dreschsel, P et al. Wastewater irrigation and health, Assessing and Mitigating Risk in Low-income Countries

http://www.iwmi.cgiar.org/Publications/books/pdf/Wastewater_Irrigation_and_Health_book.pdf

This book approaches the wastewater use problem from a practical and realistic perspective, addressing the issues of health risk assessment and reduction in developing country settings.

Filter technology: integrated wastewater irrigation and treatment, a way of water scarcity alleviation, pollution elimination and health risk prevention.

http://www.unescap.org/esd/water/publications/CD/escap-iwmi/wastewater_management/FILTER%20Technology.pdf

FAO Guidelines for evaluation of water quality and water quality standards for irrigation. http://www.fao.org/docrep/003/t0234e/T0234E01.htm#ch1.4

FAO Wastewater reuse

http://www.oas.org/DSD/publications/Unit/oea59e/ch26.htm

FAO Wastewater Database

http://www.fao.org/nr/water/infores_databases_wastewater.html It contains information on wastewater production, treatment, re-use, as well as economic information provided by member states.

FAO 2008 Water quality for agriculture

Wastewater treatment and use in agriculture – FAO Irrigation and drainage paper 47 http://www.cepis.org.pe/bvsair/e/repindex/repi84/vleh/fulltext/acrobat/wastew.pdf

FAO Quality control of wastewater for irrigated crop production.

http://www.fao.org/docrep/W5367E/W5367E00.htm

Low-cost Options for Treating Faecal Sludges (FS) in Developing Countries – Challenges and Performance. SANDEC, Department of Water and Sanitation in Developing Countries, Swiss Federal Institute of Environmental Science and Technology (EAWAG) http://www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/FS_treatment_Avignon.pdf

Low-cost sewerage Mara,D. 2006.
This book focuses on the technical aspects of planning and design of sewarage. It details the latest developments in the technology and management of low-cost sewerage, discusses affordable sanitation for low-income urban communities in tropical and developing countries and explores ways to reduce the high costs of conventional sewerage in industrialized countries.

The challenges of wastewater irrigation in developing countries Agricultural Water Management, Qadir et al., Volume 97, Issue 4, (2010) Comprehensive Assessment of Water Management in Agriculture

Wastewater irrigation management plan (WIMP) —a drafting guide for wastewater irrigators
http://www.epa.sa.gov.au/xstd_files/Waste/Guideline/guide_wimp.pdf

Water for Urban Agriculture in the Urban *Agriculture i*n September 2008
http://www.ruaf.org/index.php?q=node/1856

WHO 2003: Emerging issues in Water and Infectious Disease.
www.who.int/water_sanitation_health/emerging/emergingissues/en/index.html
This publications aims at broadening awareness of emerging issues in water and infectious disease and at guiding readers to sources of information that deal with these issues in greater depth.

WHO 2001: Water quality - Guidelines, standards and health: Assessment of risk and risk management for water-related infectious disease.
www.who.int/water_sanitation_health/dwq/whoiwa/en/
To date, the various WHO guidelines relating to water have been developed in isolation from one another. The potential to increase consistency in approaches to assessment and management of water related microbial hazards was discussed by an international

group of experts between 1999 and 2001. This book is based on these reviews, together with the discussions of the harmonised framework and the issues surrounding it.

WHO Guidelines for the safe use of wastewater, excreta and greywater. Wastewater use in agriculture, 2006

http://www.who.int/water_sanitation_health/wastewater/gsuweg2/en/index.html

This guideline explains requirements to promote safe use concepts and practices, including health-based targets and minimum procedures. It also covers a substantive revision of approaches to ensuring the microbial safety of wastewater used in agriculture

Useful Websites

For more case studies on wastewater irrigated agriculture at a farm level see: http://www.ruaf.org/node/254 and an example of India available at: http://www.ruaf.org/sites/default/files/Livelihoods%20and%20Wastewater%20Irrigated%20Agriculture.pdf

Waste Reuse in Agriculture (WRA)

This website of the Department Water and Sanitation in Developing Countries contains valuable material on waste water reuse and case studies.

http://www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_wra/index_EN

Wastewater Storage & Treatment

This website for the University of Leeds contains presentation, transgress and supporting material. http://www.personal.leeds.ac.uk/~cen6ddm/WSTR.html

Useful Videos at a farm level

Options for health risk reduction in wastewater irrigated urban agriculture.

http://video.google.com/videoplay?docid=-3530336707586348166&hl=en#

Good farming practices to reduce vegetable contamination as tested in waste water irrigated farms in urban Accra, Ghana. This video was produced by the International Water Management Institute (IWMI) and its partners as a training and awareness video for extension officers and farmers

Recycling Realities In African Cities - Towards Safe Wastewater Use In Agriculture

http://video.google.com/videoplay?docid=-8395461859469738471&hl=en#

In sub-Saharan Africa, where sanitation infrastructure does not keep pace with city growth, the use of polluted water for urban and peri-urban agriculture (UPA) is a common reality. While UPA puts consumers at risk; it also plays an important role in food supply and job creation. The question is how to preserve the benefits while minimising the risks? This short video clip gives voice to the people most closely involved, to articulate their own solutions to the challenges they face. This video was produced by IWMI and its partners to aid in knowledge sharing.

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[3] WHO (2006) Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Volume 2: Wastewater Use in Agriculture, World Health Organization, Geneva

[4] Wastewater irrigation and health : assessing and mitigating risk in low-income countries Drechsel, Pay. 2010

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[7]http://www.worldwaterweek.org/documents/WWW_PDF/2009/sunday/K16-17/WHO/Drechsel_Sunday_afternoon.pdf

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[9] http://www.kdheks.gov/nps/ww_options_manual/chapter2.pdf

[10] http://www.freedrinkingwater.com/water_quality/quality1/1-how-coliform-bacteria-affect-water-quality.htm

[11] Raschid-Sally, L. and Jayakody, P. (2008) 'Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment, Colombo, Sri Lanka', IWMI Research Report 127, International Water Management Institute, Colombo

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[16] http://www.iwapublishing.com/template.cfm?name=isbn1843399563

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[18] Wastewater in urban agriculture - Resource or threat?. (2010 March). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved 16:43, June 24, 2010 from http://maps.grida.no/go/graphic/wastewater-in-urban-agriculture-resource-or-threat.

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30 For detail and efficiencies on this units see Safe and High Quality Food Production using Low Quality Waters and Improved Irrigation Systems and Management (SAFIR) http://www.safir4eu.org/SAFIR.asp

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[37] Prof Thor Axel Stenström, chief microbiologist, Swedish Institute for Infectious Disease Control at http://www.new-ag.info/pov/views.php?a=525

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