Use of Wastewater in Agriculture

Fatemeh Karandish
Ph. D. candidate of irrigation and drainage, Tarbiat Modarres University
Karandish_h@yahoo.com

Abstract

Many communities in most developing countries do not have reliable access to supplies of clean water. As the demand for water increases, making more efficient use of water becomes more important. At the same time the volume of sewage effluent is increasing, and safe disposal can be difficult. The use of reclaimed wastewater for irrigation is the obvious solution, but few people have expertise in the full range of technology involved. Municipal wastewater is made up of domestic wastewater, industrial wastewater, storm water, and by groundwater seepage entering the municipal sewage network which contains organic matter, nutrients, inorganic matter, toxic chemicals and pathogens. Reusing sewage sludge and wastewater in agriculture could have different effects on human healthy, soil and plant characteristics and ground water quality. Thus, wastewater can be considered as both a resource and a problem. In this paper, Opportunities and challenges of using wastewater in agriculture has been discussed.

Key Words: effluent, sewage sludge, soil characteristics, Plant characteristics.

1. It is urgent to use wastewater in agriculture.

Many communities in most developing countries do not have reliable access to supplies of clean water. As the demand for water increases, making more efficient use of water becomes more important. Water re-use should be seriously considered before water availability is matched by water demand (Figure 1).

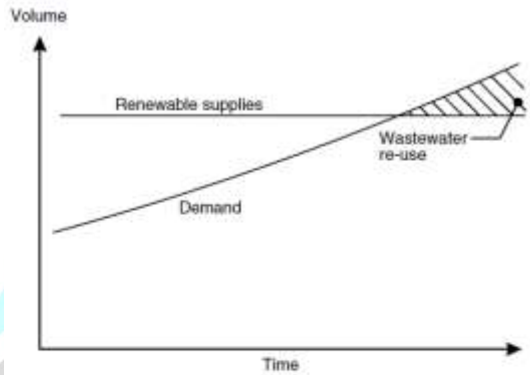

Fig. 1: Water availability and demand

2. Is wastewater treatment the best option?

Affluent countries regard wastewater treatment as vital to protect human health and prevent the contamination of lakes and rivers. But for most developing countries this solution is prohibitively expensive. In this case, applying wastewater to agricultural lands is a more economical alternative—and more ecologically sound than uncontrolled dumping of municipal and industrial effluents into lakes and streams.

3. Sources of wastewater

In general, municipal wastewater is made up of domestic wastewater, industrial wastewater, storm water, and by groundwater seepage entering the municipal sewage network. Domestic wastewater consists of effluent discharges from households, institutions, and commercial buildings. Industrial wastewater is the effluent discharged by manufacturing units and food processing plants. In Faisalabad, a large proportion of municipal wastewater from some sections of the city consists of industrial wastewater discharges. Unlike in some developed cities where the systems are separate, here, the municipal sewage network also serves as the storm water sewer. Due to defects in the sewerage system, there is groundwater seepage as well, adding to the volume of sewage to be disposed.

4. Composition of Wastewater

Though the actual composition of wastewater may differ from community to community, all municipal wastewater contains the following broad groupings of constituents:

- Organic matter
- Nutrients (Nitrogen, Phosphorus, Potassium)

• Inorganic matter (dissolved minerals)
• Toxic chemicals
• Pathogens

5. Types of waste water reuse

Wastewater can be used directly or indirectly in the community. Wastewater can be treated and be used in different parts of a society. But using water resources which have received sewage or sewage of effluent such as rivers, lacks or aquifer is a kind of indirectly use of waste water (Fig 2).

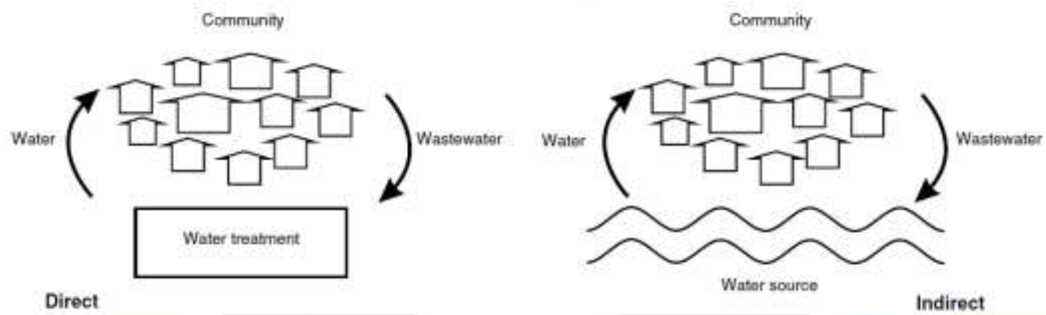

Fig. 2: direct and indirect use of wastewater

6. Wastewater treatment

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Irrigation with wastewater is both disposal and utilization and indeed is an effective form of wastewater disposal (as in slow-rate land treatment). However, some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture. The quality of treated effluent used in agriculture has a great influence on the operation and performance of the wastewater-soil-plant or aquaculture system. In the case of irrigation, the required quality of effluent will depend on the crop or crops to be irrigated, the soil conditions and the system of effluent distribution adopted. The procedure of treating wastewater is illustrated in Fig 3.

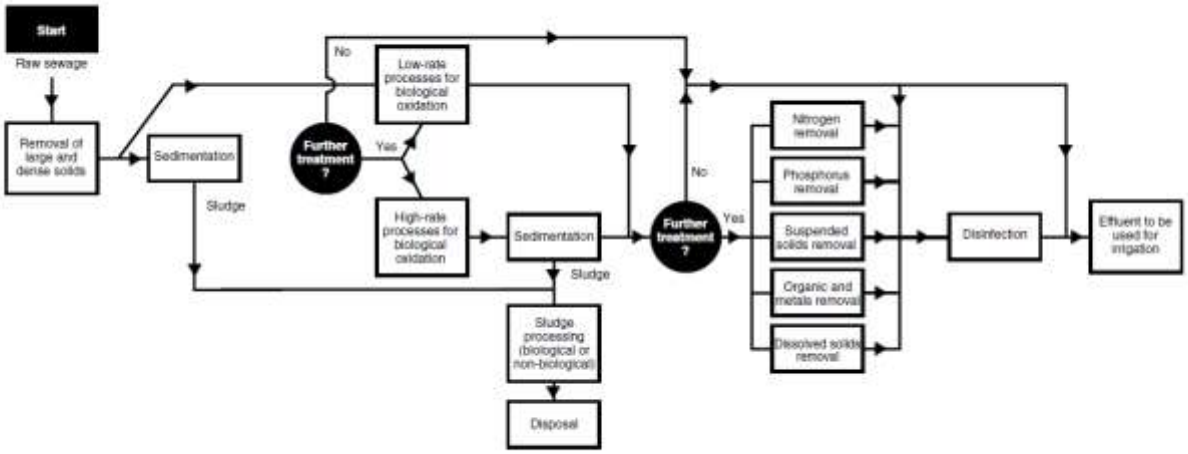

Fig 3. Procedure for treating wastewater

7. Using nanotechnology in treating wastewater

Nano particles are expected to play a crucial role in water purification (Stoimenov et al, 2002). The environmental fate and toxicity of a material are critical issues in materials selection and design for water purification. No doubt that nanotechnology is better than other technique used in water treatment but today the knowledge about the environmental fate, transport and toxicity of nano-materials (Colvin, 2003) is still in infancy. Advances in nanoscale science and engineering suggest that many of the current problems involving water quality could be resolved or greatly diminished by using nano-technology in treating waste water (Mamadou and savage, 2005). An example of treating wastewater using nano-materials has been illustrated in Fig 4.

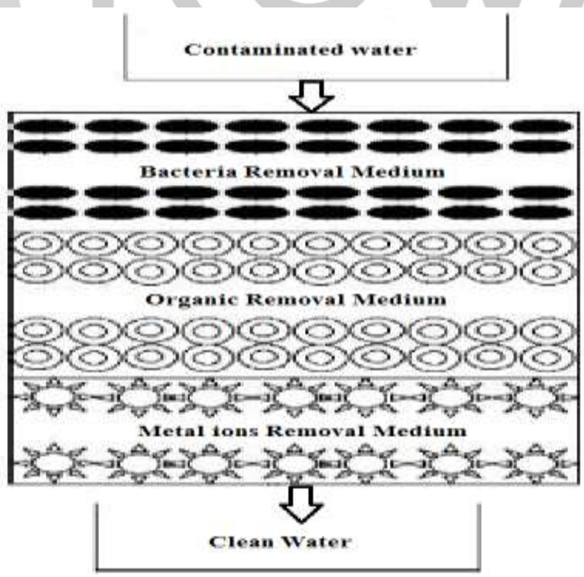

Fig 4. Schematic of a composite nanomaterial packed bed reactor for purification of water Contaminated by mixtures of (i) metal ions, (ii) Organic solutes and (iii) bacteria (Mamadou and savage, 2005)

Today nanoparticles, nanomembrane and nanopowder used for detection and removal of chemical and biological substances include metals (e.g. Cadmium, copper, lead, mercury, nickel, zinc), nutrients (e.g. Phosphate, ammonia, nitrate and nitrite), cyanide, organics, algae (e.g. cyanobacterial toxins) viruses, bacteria, parasites and antibiotics. Four classes of nanoscale materials that are being evaluated as functional materials for water purification: (1) dendrimers (2) metal-containing nanoparticles, (3) zeolites and (4) carbonaceous nanomaterials (Dhermendra et al, 2008). These have a broad range of physicochemical properties that make them particular attractive as separation and reactive media for water purification. Characterization of the interactions of the nanoparticles with the bacterial contaminant by Atomic Force Microscopy (AFM), Transmission Electron Microscopy (TEM) and laser confocal microscopy show considerable changes in the integrity of the cell membranes, resulting in the death of the bacteria in most cases.

8. Irrigation with waste water

Success in using treated wastewater for crop production will largely depend on adopting appropriate strategies aimed at optimizing crop yields and quality, maintaining soil productivity and safeguarding the environment. Basically, the components of an on-farm strategy in using treated wastewater will consist of a combination of (FAO, 47):

- **Crop selection:** Not all plants respond to wastewater in a similar manner. some crops can produce acceptable yields at more low water quality than others. Therefore a kind of crop should be selected which overcome salinity and toxicity hazard and prevent health hazard due to reusing wastewater or treated wastewater.
- **Selection of irrigation method:** in choosing an irrigation method to reuse wastewater, the choice of crops, the wetting of foliage, fruits and aerial parts, the distribution of water, salts and contaminants in the soil, the ease with which high soil water potential could be maintained, the efficiency of application, and the potential to contaminate farm workers and the environment should be concerned. Table 2 shows the evaluation of common irrigation methods in reusing treated wastewater.
- **Adoption of appropriate management practices:** Management of water, soil, crop and operational procedures, including precautions to protect farm workers, play an important role in the successful use of sewage effluent for irrigation.

9. Agricultural use of sewage sludge

Most wastewater treatment processes produce a sludge which has to be disposed of. Conventional secondary sewage treatment plants typically generate a primary sludge in the primary sedimentation stage of treatment and a secondary, biological, sludge in final sedimentation after the biological process. The characteristics of the secondary sludge vary with the type of biological process and, often, it is mixed with primary sludge before treatment and disposal. Approximately one half of the costs of operating secondary sewage treatment plants in Europe can be associated with sludge treatment and disposal. Land application of raw or treated sewage sludge can reduce significantly the sludge disposal cost component of sewage treatment as well as providing a large part of the nitrogen and phosphorus requirements of many crops (FAO, 47).

Table (1): evaluation of common irrigation methods in relation to the use of treated wastewater (Kandiah, 1990)

Parameters of evaluation	Furrow irrigation	Border irrigation	Sprinkler irrigation	Drip irrigation
1. Foliar wetting and consequent leaf damage resulting in poor yield	No foliar injury as the crop is planted on the ridge	Some bottom leaves may be affected but the damage is not so serious as to reduce yield	Severe leaf damage can occur resulting in significant yield loss	No foliar injury occurs under this method of irrigation
2. Salt accumulation in the root zone with repeated applications	Salts tend to accumulate in the ridge which could harm the crop	Salts move vertically downwards and are not likely to accumulate in the root zone	Salt movement is downwards and root zone is not likely to accumulate salts	Salt movement is radial along the direction of water movement. A salt wedge is formed between drip points
3. Ability to maintain high soil water potential	Plants may be subject to stress between irrigations	Plants may be subject . to water stress between irrigations	Not possible to maintain high soil water potential throughout the growing season	Possible to maintain high soil water potential throughout the growing season and minimize the effect of salinity
4. Suitability to handle brackish wastewater without significant yield loss	Fair to medium. With good management and drainage acceptable yields are possible	Fair to medium. Good irrigation and drainage practices can produce acceptable levels of yield	Poor to fair. Most crops suffer from leaf damage and yield is low	Excellent to good. Almost all crops can be grown with very little reduction in yield

The concentrations of potentially toxic elements in arable soils must not exceed certain prudent limits within the normal depth of cultivation as a result of sludge application. Maximum permissible concentrations of the potentially toxic elements in soil after application of sewage sludge are given in Table 2.

Table (2): maximum permissible concentrations of potentially toxic elements in soil after application of sewage sludge and maximum annual rates of addition.

Potentially toxic element (PTE)	Maximum permissible concentration of PTE in soil (mg/kg dry solids)				Maximum permissible average annual rate of PTE addition over a 10 year period (kg/ha)
	PH 5-5.5	PH 5.5-6	PH 6-7	PH >7	
Zinc	200	250	300	450	15
Copper	80	100	135	200	7.5

Nickel	50	60	75	110	3
Cadmium	3				0.15
Lead	300				15
Mercury	1				0.1
Chromium	400				15
Molybdenum	4				0.2
Selenium	3				0.15
Arsenic	50				0.7
Fluoride	500				20

10. Impacts of Wastewater Use in Agriculture

Different components of wastewater would have different effects on the plant and soil and water sources. The most important pollution and concentrations in the effluent and its effect through agricultural used is summarized in table 3.

Table 3:Asano et al, 1985. Pollutants and contaminants in wastewater and their potential impacts through agricultural use

Pollutant/ Constituent	Parameter	Impacts
Plant food nutrients	N, P, K, etc.	- Excess N: potential to cause nitrogen injury, excessive vegetative growth, delayed growing season and maturity, and potential to cause economic loss to farmer - excessive amounts of N, and P can cause excessive growth of undesirable aquatic species. (eutrophication) - nitrogen leaching causes groundwater pollution with adverse health and environmental impacts
Suspended solids	Volatile compounds, settleable, suspended and colloidal impurities	- development of sludge deposits causing anaerobic conditions - plugging of irrigation equipment and systems such as sprinklers
Pathogens	Viruses, bacteria, helminth eggs, fecal coliforms etc.	-can cause communicable diseases
Biodegradable organics	BOD, COD	- depletion of dissolved oxygen in surface water - development of septic conditions - unsuitable habitat and environment - can inhibit pond-breeding amphibians - fish mortality - humus build-up
Stable organics	Phenols, pesticides, chlorinated hydrocarbons	-persist in the environment for long periods - toxic to environment - may make wastewater unsuitable for irrigation
Dissolved inorganic substances	TDS, EC, Na, Ca, Mg, Cl, and B	- cause salinity and associated adverse impacts - phytotoxicity - affect permeability and soil structure
Heavy metals	Cd, Pb, Ni, Zn, As, Hg, etc.	- bio accumulate in aquatic organisms (fish and planktons) - accumulate in irrigated soils and the environment - toxic to plants and animals - systemic uptake by plants - subsequent ingestion by humans or animals - possible health impacts - may make wastewater unsuitable for irrigation
Hydrogen ion concentrations	pH	- especially of concern in industrial wastewater - possible adverse impact on plant growth due to acidity or alkalinity - impact sometimes beneficial on soil flora and fauna
Residual chlorine in tertiary treated wastewater	Both free and combined chlorine	- leaf-tip burn - groundwater, surface water contamination (carcinogenic effects from organochlorides formed when chlorine combines with residual organic compounds) - greenhouse effect

Impacts of using wastewater can be classified in groups including Public health, effecting crop characteristics, effecting soil properties, effecting groundwater resources, property values, ecological impacts and social impacts.

The use of untreated wastewater for irrigation would lead to a bad effect on human health. However, the degree of risk may vary among the various age groups. Untreated wastewater irrigation leads to relatively higher prevalence of hookworm (Feenstra et al. 2000), and Ascariasis infections among children (Cifuentes et al. 2000; and Habbari et al. 2000).

Wastewater is a rich source of nutrient and reusing it in agriculture would enhance crop growth. Most crops give higher than potential yields with wastewater irrigation, reduce the need for chemical fertilizers, resulting in net cost savings to farmers. Most crops need specific amounts of NPK for maximum yield (Zavadi et al, 2009; Michitsch, 2003; Javanovi, 2004). Once the recommended level of NPK is exceeded, crop growth and yield may negatively be affected. For example, when the total nitrogen delivery exceed than the real crop requirement. It would make yield losses due to extending the vegetative growth duration (Singh and Mishra 1987).

Impact from wastewater on agricultural soil, is mainly due to the presence of high nutrient contents (Nitrogen and Phosphorus), high total dissolved solids and other constituents such as heavy metals, which are added to the soil over time. In many studies, improving the soil permeability coefficient (Vogeler et al, 2005; Vinten et al, 2005), accumulation of heavy metals in the surface layer of soil (Abedi et al, 2006; Ghanbari et al, 2007; Feizi et al, 2001), increasing the soil exchangeable sodium and electrical conductivity (Pina et al, 2009; Vogeler et al, 2005) and maintaining the soil PH in a normal range due to using wastewater in agricultural lands has been reported.

Exceeded Nutrient leaching below the root-zone through applying wastewater would pollute the ground water sources in long term (NRC report 1996). In some regions, 50-70 percent of irrigation water may percolate to groundwater aquifer (Rashed et al. 1995). Despite poor quality, groundwater recharge through wastewater application can be a vital environmental and economic service in regions where freshwater supplies are limited and groundwater removal rates exceed replenishment rates.

When drainage water from wastewater irrigation schemes drains particularly into small confined lakes and water bodies and surface water, and if phosphates in the orthophosphate form are present, the remains of nutrients may cause eutrophication. This causes imbalances in plant microbiological communities of water bodies (Smith et al. 1999). This may in turn affect other higher forms of aquatic life and influence the presence of waterbirds and reduce biodiversity. The likelihood of heavy metals from wastewater affecting the food chain is addressed under soil resources. Soil usually acts as a filter and retains heavy metals in the soil matrix.

Social effect of reusing wastewater should be concerned as General concerns such as nuisance, poor environmental quality, poor hygiene, odor, noise, higher probability of accidents, etc, Social concerns such as food safety, health and welfare, impaired quality of life, loss of property values, and sustainability of land use and Natural resource concerns such as pollution of vital water resources, loss of fish, wildlife, exotic species, etc.

11. Conclusion

Many communities in most developing countries do not have reliable access to supplies of clean water. As the demand for water increases, making more efficient use of water becomes more important. At the same time the volume of sewage effluent is increasing, and safe disposal can be difficult. The use of reclaimed wastewater for irrigation is the obvious solution, but few people have expertise in the full range of technology involved. Municipal wastewater is made up of domestic wastewater, industrial wastewater, storm water, and by groundwater seepage entering the municipal sewage network which contains organic matter, nutrients, inorganic matter, toxic chemicals and pathogens. Reusing sewage sludge and wastewater in agriculture could have different effects on human healthy, soil and plant characteristics and ground water quality. Therefore it should be concerned to evaluate all different aspects of using wastewater in agriculture. Wastewater treatment would decrease the degree of negative effects on plants, soil and water sources through reusing wastewater in agriculture. Advances in nanoscale science and engineering suggest that many of the current problems involving water quality could be resolved or greatly diminished by using nano-technology in treating waste water. Therefore safety using of wastewater would make wastewater as a reliable source of water in agricultural use.

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