

TECHNIQUES AND METHODS FOR REUSE OF WASTEWATER FOR IRRIGATION: A REVIEW

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Abstract: Ground water resources in most areas of world are shrinking at an alarming rate and may not meet the ever increasing demands from agriculture and industry in future. Wastewater reuse is an option for the alleviation of the ever increasing irrigation water scarcity in many countries and for recycling plant nutrients. Countries suffering from water shortages are forced to use treated wastewater. Estimates revealed an annual production of ~30 million tons of wastewater in the World, of which ~70% is consumed as an agricultural fertilizer and irrigation source. In India, estimates revealed that ~73,000 hectares land were irrigated with wastewater during early nineties and presently the area under waste water irrigation is on the rise. Studies have documented that direct disposal of effluents to land and water bodies has potential to contaminate air, surface, ground water as well as soils and crops grown on these soils which will have bearing on human health. Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in biosystems through contaminated water, soil and air due to the discharge of large amounts of metal contaminated wastewater from various sources including industrial wastewater that produced by metal plating facilities, mining operations, battery manufacturing processes, the production of paints and pigments, and the ceramic and glass industries. Their high solubility in the aquatic environments, heavy metals can be absorbed by living organisms. Once they enter the food chain, large concentrations of heavy metals may accumulate in the living organisms. If the metals are ingested beyond the permitted concentration, they can cause serious health disorders. Therefore, it is necessary to treat metal contaminated wastewater prior to irrigation.

Removal of heavy metals such as Pb, Cd, Cr, Ni, etc from wastewater effluent can be achieved by conventional treatment processes such as chemical precipitation, ion exchange, and electrochemical removal. Recently, numerous approaches have been studied for the development of cheaper and more effective technologies, both to decrease the amount of wastewater produced and to improve the quality of the treated effluent. Adsorption has become one of the alternative treatments, in recent years, the search for low-cost adsorbents that have metal-binding capacities has intensified. The adsorbents may be of mineral, organic or biological origin, zeolites, industrial byproducts, agricultural wastes, biomass, and polymeric materials. This article presents an overview on beneficial and harmful effects of wastewater application in soil-plant-water system and various physico-chemical treatments for removal of heavy metals from wastewater.

Key Words: Heavy metals, Wastewater, reuse, irrigation, low cost absorbents

1. Introduction:

Globally, agriculture takes about 70% of all freshwater withdrawals. Countries suffering from water shortages are forced to use non-conventional resources, mainly water harvesting and treated wastewater. Irrigation using treated wastewater has been a common practice worldwide. It could be used directly or indirectly Treated waste water is normally used for irrigation purposes in countries suffering

from water shortages to narrow the gap between supply and demand. The concept behind this is to save water consumed for agricultural activities, which consumes most of the water, for municipal and industrial uses (Al-Ansari, 2013). Irrigation with wastewater increases available water supply and releases better quality water supplies for alternative uses (e.g. drinking and sanitation). In addition to

these, its fertilizer value is important. According to an FAO report in 1992, “a typical wastewater effluent from domestic source could supply all the nitrogen and much of the phosphorus and potassium that are normally required for agricultural crop production. Due to the discharge of large amounts of metal-contaminated wastewater, industries bearing heavy metals, such as Cd, Cr, Cu, Ni, As, Pb, and Zn, are the most hazardous among the chemical-intensive industries. Because of their high solubility in the aquatic environments, heavy metals can be absorbed by living organisms. Once they enter the food chain, large concentrations of heavy metals may accumulate in the human body. If the metals are ingested beyond the permitted concentration, they can cause serious health disorders. Therefore, it is necessary to treat metal contaminated wastewater prior to its discharge to the environment. Heavy metals cause serious health effects, including reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death (Barakat 2010). In India, treatment of crops with wastewater caused increased uptake of heavy metals, namely Fe, Mn, Pb, Cd, Cr, Cu, and Ni, in cauliflower, mustard, radish, celery, spinach etc. (Al-Ansari, 2013). Wastewater may contain pathogens such as viruses, bacteria and protozoa; parasites such as helminthes; inorganic salts, toxic chemicals (or pesticides) and heavy metals in combination with its plant nutrients. Therefore, use of wastewater in farms could enrich soils with heavy metals which bio-accumulates in plants to concentrations that may pose health and ecological risks, and can also contaminate farm produce with harmful microbes which transmit infectious diseases. The use of wastewater in agriculture is gaining tremendous popularity because of its wide range of benefits. Its agronomic, economic and environmental benefits cannot be overstated. These benefits include water conservation, provision of reliable water supply during dry seasons and periods of drought, and preservation/prevention of downstream rivers (and communities) from contamination with municipal and industrial drainages/wastewater and their environmental and health impacts. However, the study recommended that adequate treatment schemes must always be designed to eliminate, or at least minimize the potential risks of disease transmission. Pathogen contamination due to wastewater reuse has been the contamination of soil and subsequent entry of pathogen into groundwater.

Heavy metal removal from inorganic effluent can be achieved by conventional treatment processes such as chemical precipitation, ion exchange, and electrochemical removal. These processes have significant disadvantages, which are,

for instance, incomplete removal, high-energy requirements, and production of toxic sludge. Recently, numerous approaches have been studied for the development of cheaper and more effective technologies, both to decrease the amount of wastewater produced and to improve the quality of the treated effluent. Adsorption has become one of the alternative treatments, in recent years, the search for low-cost adsorbents that have metal-binding capacities has intensified. The adsorbents may be of mineral, organic or biological origin, zeolites, industrial byproducts, agricultural wastes, biomass, and polymeric materials. Membrane separation has been increasingly used recently for the treatment of inorganic effluent due to its convenient operation. There are different types of membrane filtration such as ultra filtration (UF), nano filtration (NF) and reverse osmosis (RO). Electro treatments such as electro dialysis have also contributed to environmental protection. Photo catalytic process is an innovative and promising technique for efficient destruction of pollutants in water (Barakat 2010).

This paper examines the health impact of wastewater use for irrigation in India. The use of waste water for irrigation exposes consumers as well as producers at various health risks. This article also presents an overview of various physico-chemical treatments for removal of heavy metals from wastewater.

2. Use of wastewater in agriculture:

2.1 Global status:

Beneficial use of wastewater has been practiced in California since the 1890s, when raw sewage was applied on 'sewer farms'. By 1987, more than 0.899 Mm³/d of municipal wastewater (7-8% of the production) were being used for the applications (California State Water Resources Control Board 1990). Historically, agricultural use has dominated, and continues to do so, but over the past decade reclaimed wastewater has been increasingly used for landscape irrigation in urban areas and for groundwater recharge. Most of the reclaimed water (78%) is used in the Central Valley and South Coastal regions of California. Two hundred reclamation plants throughout California produce the volume of treated effluent indicated above and save 0.759 Mm³/d of fresh water.

Agricultural irrigation has, by far, been the largest reported reuse of wastewater. About 41 percent of recycled water in Japan, 60% in California, USA, and 15% in Tunisia are used for this purpose. In developing countries, application on land has always been the predominant means of disposing municipal wastewater as well as meeting irrigation

needs. In China for example, at least 1.33 million hectares of agricultural land are irrigated with untreated or partially treated wastewaters from cities.

In Mexico City, more than 70, 000 hectares of crop land outside the city are irrigated with reclaimed wastewater (Fig. 1).

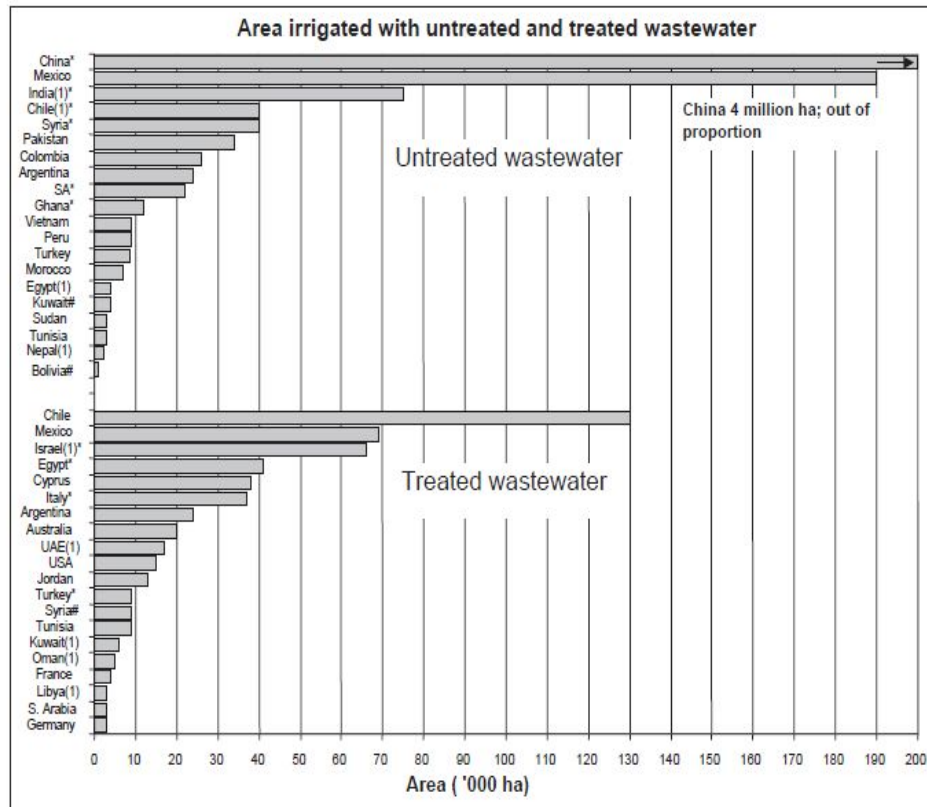


Fig 1: Countries with greatest irrigated areas using untreated or treated wastewater

2.2 Use in India:

Water used in Agriculture-92%, Domestic-5%, Industrial-3%. The overall water demand is supposed to increase from 552BCM to 1050 BCM by 2025. Demand from the industrial and domestic sectors is expected to increase with the growing population, urbanization and industrialization. Cities account for a production of 29,000 million litres of wastewater but there is only a management capacity for 6000 million litres. More than 300 cities with a population of and above 100,000 are completely without sewers. As of 2003, it was estimated that only 30% of India's wastewater was being treated, with the remainder flowing into rivers and groundwater. Total utilizable water resource in the country has been estimated to be about 1123 BCM (690 BCM from surface and 433 BCM from ground), which is just 28% of the water derived from precipitation. About 85% (688 BCM) of water usage

is being diverted for irrigation (Figure 2), which may increase to 1072 BCM by 2050. Major source for irrigation is groundwater. Annual groundwater recharge is about 433 BCM of which 212.5 BCM used for irrigation and 18.1 BCM for domestic and industrial use (CGWB, 2011). By 2025, demand for domestic and industrial water usage may increase to 29.2 BCM. Thus water availability for irrigation is expected to reduce to 162.3 BCM. The major 18 rivers in India were polluted due to discharges from agricultural, domestic and industrial uses because the effluent is not pre treated prior to discharge. Groundwater is contaminated and depleted day by day. Diarrhea alone causes more than 1600 deaths daily. 21% of the communicable diseases are water related.

It is estimated that in India about 73,000 ha of (Strauss and Blumenthal, 1990) peri-urban agriculture is subject to wastewater irrigation (Fig. 1).

In peri-urban areas, farmers usually adopt year round, intensive vegetable production systems (300-400% cropping intensity) or other perishable commodity like fodder and earn up to 4 times more from a unit land area compared to freshwater (Minhas and Samra, 2004).

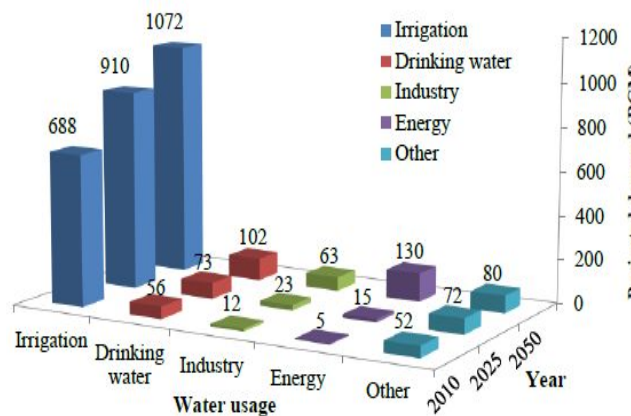


Fig 2: Projected water demand by different sectors (CWC, 2010)

Major crops being irrigated with wastewater are:

Cereals: Along 10 km stretch of the Musi River (Hyderabad, Andhra Pradesh) where wastewater from Hyderabad is disposed-off, 2100 ha land is irrigated with wastewater to cultivate paddy. Wheat is irrigated with wastewater in Ahmedabad and Kanpur.

Vegetables: In New Delhi, various vegetables are cultivated on 1700 ha land irrigated with wastewater in area around Keshopur and Okhla STPs. Vegetables like Cucurbits, eggplant, okra, and coriander in the

summers; Spinach, mustard, cauliflower, and cabbage in the winters are grown at these place. In Hyderabad, vegetables are grown in Musi river basin all year round which includes spinach, amaranths, mint, coriander, etc.

Flowers: Farmers in Kanpur grow roses and marigold with wastewater. In Hyderabad the farmers cultivating Jasmine through wastewater.

Avenue trees and parks: In Hyderabad, secondary treated wastewater is used to irrigate public parks and avenue trees.

Fodder crops: In Hyderabad, along the Musi River about 10,000 ha of land are irrigated with wastewater to cultivate para grass, a kind of fodder grass.

Aquaculture: The East Kolkata sewage fisheries are the largest single wastewater use system in aquaculture in the world.

Agroforestry: In the villages near Hubli-Dharwad in Karnataka, plantation trees viz., sapota, guava, coconut, mango, areca nut, teak, neem, banana, ramphal, curry leaf, pomegranate, lemon, galimara, mulberry, etc. are irrigated with waste water.

Wastewater- irrigated fields generate great employment opportunity for female and male agricultural laborers to cultivate crops, vegetables, flowers, fodders that can be sold in nearby markets or for use by their livestock. In downstream rural areas of Vadodara in Gujarat, wastewater supports annual agricultural production worth Rs. 266 million. It has been estimated that in India sewage waters can annually irrigate about 1 M-ha (Sengupta, 2008) to 1.5 M-ha of land area and have a potential to contribute about one million tonnes of nutrients and 130 million man-days of employment (Minhas and Samra, 2004).



(a)



(b)



(c)



(d)

Fig 3 (a-d): Use of Wastewater in agriculture

3. Wastewater generation in India and its use in agricultural practices:

The wastewater generation increased from 7,000 mld in 1978-79 to 17,000 mld in 1994-95 in Class I cities. 39% of wastewater was treated in the year 1978-79. But, in the year 2003, only 26% of wastewater generated in cities was treated 27 cities have only primary treatment facilities.

Domestic: 423 class I cities and 499 class II towns harboring population of 20 crore generate about 29,000 mld of wastewater of which only 7044 mld is treated. Domestic sewage is the major source of water borne diseases.

Industrial: About 57,000 polluting industries in India generate about 15250 mld of wastewater out of which nearly 60% is treated. With rapid expansion of cities and domestic water supply, quantity of gray/wastewater is increasing in the same proportion. As per CPHEEO estimates about 70-80% of total water supplied for domestic use gets generated as wastewater. The per capita wastewater generation by the class-I cities and class-II towns, representing 72% of urban population in India, has been estimated to be around 98 lpcd while Delhi alone (discharging 3,663 mld of wastewaters, 61% of which is treated) is over 220 lpcd (CPCB, 1999). As per CPCB estimates, the total wastewater generation from Class I cities (498) and Class II (410) towns in the country is around 35,558 and 2,696 MLD respectively while, the installed sewage treatment capacity is just 11,553 and 233 MLD, respectively thereby leading to a gap of 26,468 MLD in sewage treatment capacity. Maharashtra, Delhi, Uttar Pradesh, West Bengal and Gujarat are the major contributors of wastewater (63%; CPCB, 2007a). Further, as per the UNESCO and WWAP (2006) estimates (Van-Rooijen *et al.*,

2008), the industrial water use productivity of India (IWP, in billion constant 1995 US\$ per m³) is the lowest (i.e. just 3.42) and about 1/30th of that for Japan and Republic of Korea. It is projected that by 2050, about 48.2 BCM (132 billion litres per day) of wastewaters (with a potential to meet 4.5% of the total irrigation water demand) would be generated thereby further widening this gap (Bhardwaj, 2005).

In India, there are 234-Sewage Water Treatment plants (STPs). Most of these were developed under various river action plans (from 1978-79 onwards) and are located in (just 5% of) cities/ towns along the banks of major rivers (CPCB, 2005a). In class-I cities, oxidation pond or Activated sludge process is the most commonly employed technology, covering 59.5% of total installed capacity. This is followed by Up-flow Anaerobic Sludge Blanket technology, covering 26% of total installed capacity. Series of Waste Stabilization Ponds technology is also employed in 28% of the plants, though its combined capacity is only 5.6%. A recent World Bank Report (Shuval *et al.* 1986) came out strongly in favour of stabilization ponds as the most suitable wastewater treatment system in developing countries, where land is often available at reasonable opportunity cost and skilled labour is in short supply.

Apart from domestic sewage, about 13468 MLD of wastewater is generated by industries of which only 60% is treated. In case of small scale industries that may not afford cost of waste water treatment plant, Common Effluent Treatment Plants (CETP) has been set-up for cluster of small scale industries (CPCB, 2005b). Treated industrial waste water from CETPs mixed disposed in rivers. For example, 10 CETPs from Delhi with capacity of 133 MLD dispose their effluent in Yamuna River.

Fig 4: Wastewater generation and treatment (mld) in class-A and Calss II cities in India

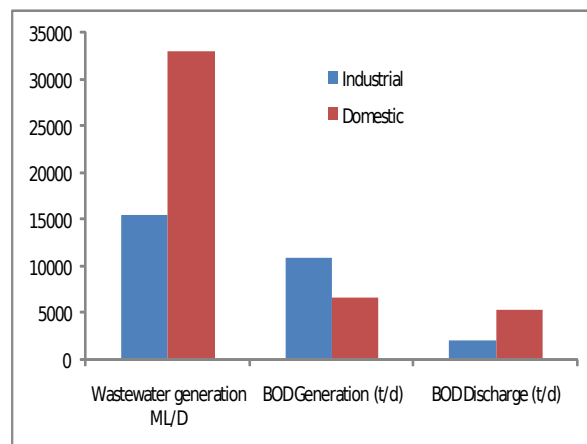
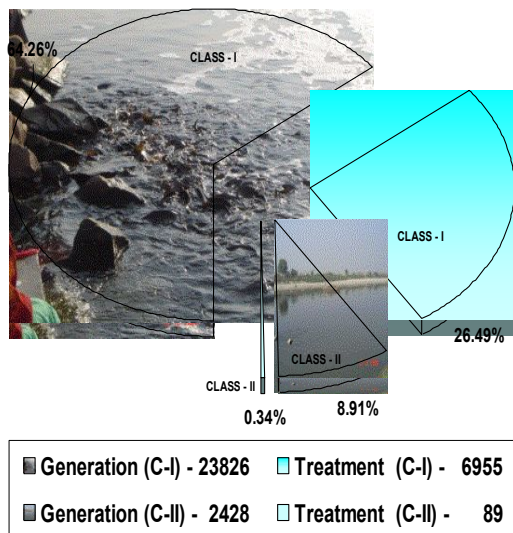


Fig 5: Comparision of pollution load generation from domestic and industrial sources

Fig 6: Water supply and sewage disposal status in class I cities

Fig 7: Water supply and wastewater generation and treatment in class II towns of India

4.0 Impact of wastewater on agricultural products & its consumption:

Wastewater is used to irrigate in many forms. It can be used as treated (reclaimed water) or non treated

(raw wastewater) and it can be applied directly to crops or indirectly after discharge and dilution with water from rivers or reservoirs.

4.1 Effect on human health:

Wastewater contains pathogenic microorganisms such as viruses, bacteria and parasites which have potential to cause disease and impact human health. Protozoa and helminthes eggs are most virulent and they are most difficult to remove by treatment processes they are often implicated in a number of infections and gastrointestinal disease in developing and developed countries (Hanjara, 2012). Chemical compounds in wastewater are the major health concern due to metals. Many of them are biologically beneficial in small quantities but become harmful at high levels of exposure. Hexavalent chromium is rapidly reduced to trivalent chromium, which forms a less solid phase in wastewater or soils. Cadmium is the metal that causes the largest risk. Its uptake can increase with time, depending on soil concentration, and is toxic to humans and animals. Absorbed cadmium is stored in the kidney and liver (Pescod, 1992). Under non-controlled conditions pathogens contained in wastewater can cause health problems for humans and cattle. Some substances that may be present in wastewater can be toxic to plants, cattle or humans consumption crops, reduce soil productivity and infiltration of wastewater to aquifers may cause aquifer pollution with pathogens and organic matter. Examples of this abound over decades, including the "itai-itai disease" in Japan (1912-1946) caused by eating rice highly contaminated with cadmium. The rice paddies were irrigated with wastewater discharged from upstream zinc mines and many of the victims died of kidney failure and bone-softening. The fish in the river downstream also died as result of the heavy pollution of the surrounding water and soil a situation that was not completely remedied until 2012. Another example in Japan is the "Minamata disease" caused by the heavy metal, mercury, in industrial wastewater which ended up in local fishery and caused both human and animal deaths between 1932 and 1968. More recent happenings include a 1970 cholera outbreak in Jerusalem traced to the consumption of wastewater-irrigated vegetables, typhoid infections in the 1970s and 1980s and cholera outbreak in the early 1990s in Santiago, Chile also linked to the consumption of wastewater-irrigated salad crops; and the Mwea Rice irrigation project in Kenya where wastewater use was linked with a significant increase in schistosomiasis infection and death. A study in Ghana reported "that typical microbiological and pesticide contamination levels of vegetables in Ghanaian markets pose a threat to human health." In Nigeria the situation is not different, as a quick survey prior to a personal research work last year showed that wastewater is indiscriminately used by farmers (Oyo state) especially the vegetable farmers.

4.2 Effect on soils:

Soil is very complex mixture of minerals and organic substances in concentration that may widely in different regions and climates. Irrigating with wastewater enriches the humic content by supplying organic matter, which increases soil humidity retains metals and enhances microbial activity (Ortega-Larrocea et al, 2002). Irrigating with wastewater also increase metal content which can damage to crops and eventually to consumes.

4.3 Effect on crops:

When nitrogen applied to plants when it is not needed may induce more vegetative than fruit growth and also delay ripening. These have been observed for beets, cane, and rice (Pescod 1992; Morishita 1988). High contents of phosphorus reduce copper, iron, and zinc availability in alkaline soils. Boron is toxic to several crops. Salinity increases salt content in crops and crop appearance is affected by chlorides and carbonates. Both compounds burn leaves when sprinklers are used to irrigate (Pescod, 1992). Crops can be contaminated with microbes, heavy metals and organic toxic compounds. Contamination can happen by direct contact of irrigation water with edible parts or in the case of metals, through adsorption from soils, depending on environmental conditions and type of plants. Pollution depends also on the type of crops.

4.4 Effect on water

Irrigating with wastewater modifies not only the quality of the wastewater itself but also affects surface and water bodies. Foster et al. (2004) analyzed recharge from wastewater used to irrigate in a number of locations (Miraflores, the peri-urban area of Lima, Peru; Wagi Dhuleil, Jordan; Mezquital Valley, Mexico; Leon, Mexico; and Hat Yai, Thailand) and estimated that at least 1,000 millimeters per year of water is recharged, a value that in many cases exceeds the local pluvial precipitation. The impact on groundwater quality depends on several factors, such as the irrigation rate, the irrigation wastewater quality, the vulnerability of the aquifer, the form in which irrigation is performed, the rate of artificial compared to natural recharge, the original quality of underground water and its potential use, the time under irrigation, and the type of crops (Foster et al. 2004). According to Leach et al. (1980) the most toxic metals to humans cadmium, lead, and mercury were absent in groundwater at five sites in the United States after 30–40 years of applying

secondary and primary effluents at rates between 0.8 m/yr and 8.6 m/yr to different crops. The reason given was that the initial metal content and a soil pH greater than 6.5 precipitated metals.

Foster et al. (2004) found that in aquifers recharged with wastewaters the potential of tri halo methane (THM) formation oscillates between 20 and 45 micrograms per milligram of TOC and can produce disinfected water with a concentration of up to 100 micrograms per liter. Due to the infiltration of wastewater to aquifers, in the long term, salt content in aquifers will always increase. Based on the original quality, present and future use, as well as interconnections between the aquifer and other water bodies, this effect may or may not be relevant (Farid et al. 1993).

5. Wastewater recycling techniques for use in irrigation

Wastewater treatment is needed to reduce pollutants. The conventional wastewater treatment processes are expensive and require complex operations and maintenance. It is estimated that the total cost for establishing treatment system for the entire domestic wastewater is around Rs. 7,560 crores (CPCB, 2005a), which is about 10 times the amount which the Indian government plans to spend (Kumar, 2003). Due to improper design, poor maintenance, frequent electricity break downs and lack of technical man power, the facilities constructed to treat wastewater do not function properly and remain closed most of the time (CPCB, 2007b). A performance evaluation of STPs carried out by CPCB in selected cities has indicated that out of 92 STPs studied, 26 STPs had not met prescribed standards in respect to BOD thereby making these waters unsuitable for household purpose. As a result, though the waste water treatment capacity in the country has increased by about 2.5 times since 1978-79 yet hardly 10% of the sewage generated is treated effectively, while the rest finds its way into the natural ecosystems and is responsible for large-scale pollution of rivers and ground waters (Trivedy and Nakate, 2001).

Primary treatment: Physical and/or chemical process involving settlement of suspended solids, or other process in which the BOD₅ (the amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter)

of the incoming wastewater is reduced by at least 20 percent and the total suspended solids of the incoming wastewater are reduced by at least 50 percent before discharge (Eurostat, 2003). Primary treatment processes can include: i) sedimentation tank, ii) septic tank, iii) skimming, iv) chemical enhanced primary treatment.

Secondary treatment: process generally involving biological treatment with a secondary settlement or other process, resulting in a BOD (biochemical oxygen demand) removal of at least 70 percent and a COD (chemical oxygen demand) removal of at least 75 percent before discharge (Eurostat, 2003). The following processes are characterized under secondary treatment: i) aerated lagoon, ii) activated sludge, iii) up-flow anaerobic sludge blanket, iv) trickling filters, v) rotating biological contactors, vi) oxidation ditch, vii) settling basin digester. For the purpose of this database natural biological treatment processes are also considered under secondary treatment as the constituents of the effluents from this type of treatment is similar to the conventional secondary treatment. Natural biological treatment refers to the process other than conventional wastewater treatment (primary, secondary and tertiary). This treatment makes use of natural biochemical processes to treat wastewater. The treatment can include the following: i) waste stabilization pond, ii) constructed wetlands, iii) overland treatment, iv) nutrient film techniques, v) soil aquifer treatment, vi) high-rate algal pond, vii) floating aquatic macrophyte systems.

Tertiary treatment: Process in addition to secondary treatment of nitrogen and/or phosphorous and/or any other specific pollutant affecting the quality or a specific use of water: microbiological pollution, colour etc. This treatment is meant to remove at least 95 percent for BOD and 85 percent for COD and/or a nitrogen removal of at least 70 percent and/or a phosphorus removal of at least 80 percent and/or a microbiological removal (Eurostat, 2003). Tertiary treatment process can include the following: i) membrane filtration (micro-, nano-, ultra- and reverse osmosis), ii) infiltration/percolation, iii) activated carbon, iv) disinfection (chlorination, ozone, UV).

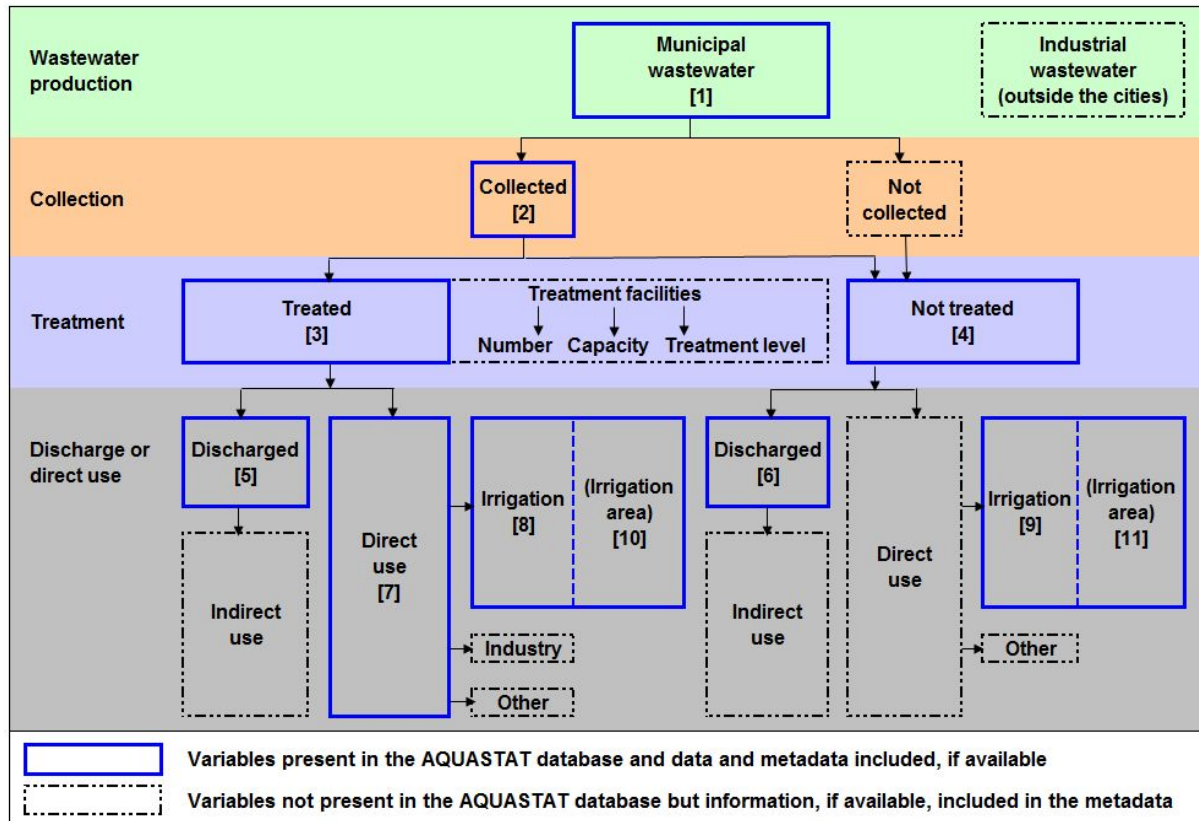
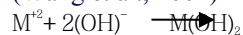


Fig8: Flow chart of wastewater treatment techniques

5.1 Chemical Precipitation: Precipitation of metals is achieved by the addition of coagulants such as alum, lime, iron salts and other organic polymers. The large amount of sludge containing toxic compounds produced during the process is the main disadvantage. The mechanism of heavy metal removal by chemical precipitation is presented in Eq. (Wang et al., 2004)



where M^{2+} and OH^{-} represent the dissolved metal ions and the precipitant, respectively, while $M(OH)_2$ is the insoluble metal hydroxide. Adjustment of pH to the basic conditions (pH 9–11) is the major parameter that significantly improves heavy metal removal by chemical precipitation. Lime and limestone are the most commonly employed precipitant agents due to their availability and low-cost in most countries (Mirbagherp and Hosseini, 2004; Aziz et al., 2008). Lime precipitation can be employed to effectively treat inorganic effluent with a metal concentration of higher than 1000 mg/L. Ion exchange is another

method used successfully in the industry for the removal of heavy metals from effluent. An ion exchanger is a solid capable of exchanging either cations or anions from the surrounding materials. Commonly used matrices for ion exchange are synthetic organic ion exchange resins. The disadvantage of this method is that it cannot handle concentrated metal solution as the matrix gets easily fouled by organics and other solids in the wastewater. Electrolytic recovery or electro-winning is one of the many technologies used to remove metals from process water streams. This process uses electricity to pass a current through an aqueous metal-bearing solution containing a cathode plate and an insoluble anode. Positively charged metallic ions cling to the negatively charged cathodes leaving behind a metal deposit that is strippable and recoverable. A noticeable disadvantage was that corrosion could become a significant limiting factor, where electrodes would frequently have to be replaced (Kurniawan et al., 2006).

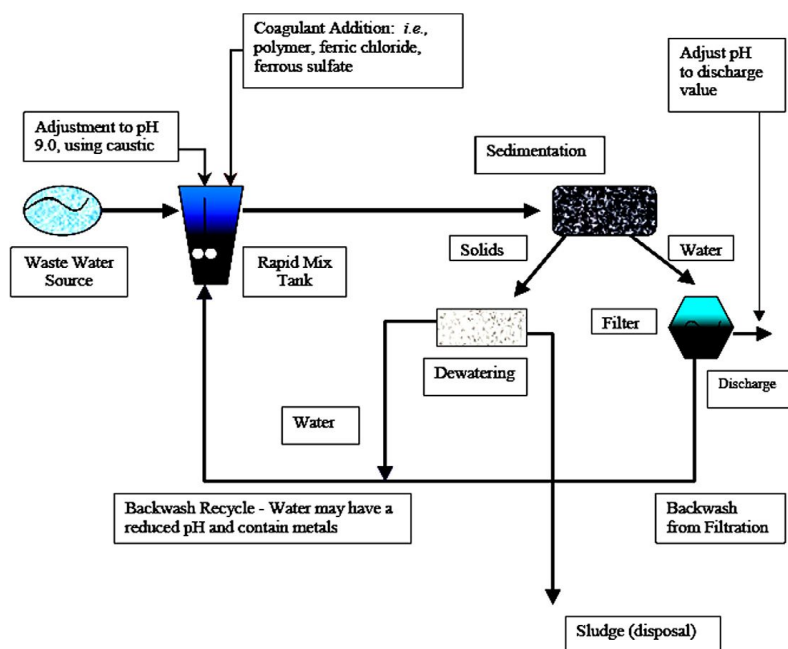


Fig: 9 Flow chart of showing chemical precipitation process

5.2 Adsorption on adsorbents: Industrial by-products such as fly ash, waste iron, iron slags, hydrous titanium oxide, can be chemically modified to enhance its removal performance for metal removal from wastewater. Recently, a great deal of interest in the research for the removal of heavy metals from industrial effluent has been focused on the use of agricultural by-products as adsorbents. The use of agricultural by-products in bioremediation of heavy metal ions, is known as bio-sorption. This utilizes inactive (non-living) microbial biomass to bind and concentrate heavy metals from waste streams by purely physico-chemical pathways (mainly chelation and adsorption) of uptake (Igwe et al., 2005). New resources such as hazelnut shell, rice husk, pecan shells, jackfruit, maize cob or husk can

be used as an adsorbent for heavy metal uptake after chemical modification or conversion by heating into activated carbon.

5.3 Electrodialysis: Electrodialysis (ED) is a membrane separation in which ionized species in the solution are passed through an ion exchange membrane by applying an electric potential. The membranes are thin sheets of plastic materials with either anionic or cationic characteristics. When a solution containing ionic species passes through the cell compartments, the anions migrate toward the anode and the cations toward the cathode, crossing the anion exchange and cation-exchange membranes (Chen, 2004), Fig.10 shows the principles of electrodialysis.

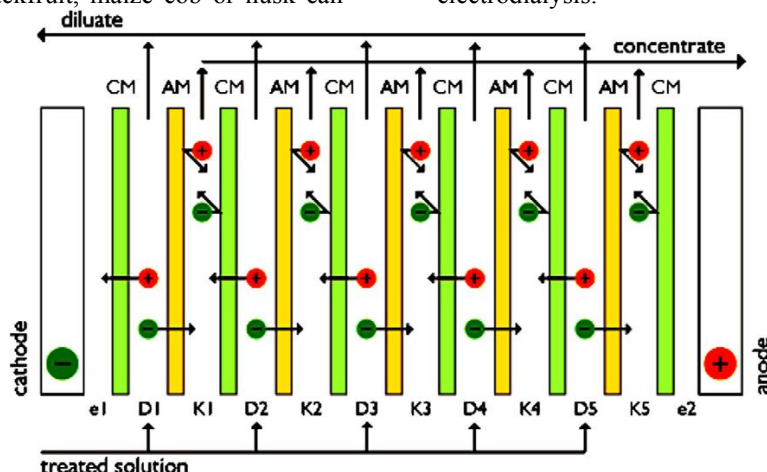


Fig 10: Schematic diagram Electrodialysis technique for ion removal

5.5 Phyto-remediation : Phyto-remediation is an eco-friendly bio-remediation process of removing pollutants/nutrients from an environment (soil, sediment, water) by using any green plant based system which is not only an energy saving but also a resource recovering system. Many surface floating aquatic plants like water hyacinth (*Eichhornia*) and duckweeds (*Spirodela*, *Lemna*, *Wolffia*) are well known for their phyto-remediation qualities (Wolverton 1981, Debusk and Reddy 1987, Akcin et al 1994, Sinha et al 1994, Vajpayee et al 1995,

Chandra et al 1997). They grow naturally in the village ponds and other nutrient rich standing waters in tropical and sub-tropical climates and are capable of extracting nutrients from these waters which otherwise go waste and cause 'Eutrophication'. Duckweeds hold an immense potential for both nutrient recovery from village ponds and utilization as animal fodder or feed due to its fast growth rate, efficient nutrient extracting capability, easy harvesting, high nutritive value and good digestibility (Leng 1999).

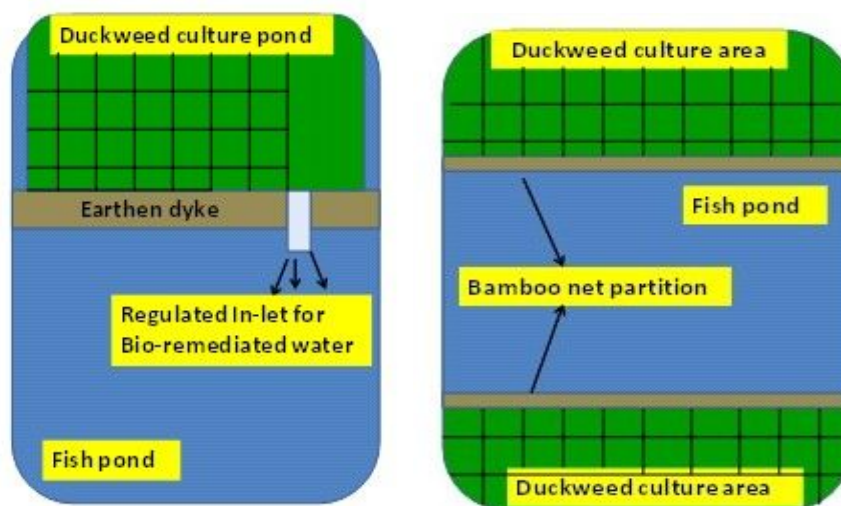


Fig 11: Rural Bio-remediation models for village ponds

6. CONCLUSION

Wastewater is an important source of water and nutrients for irrigation in developing countries, particularly but not restricted to those located in arid and semi-arid areas. While the use of wastewater has positive effects for farmers, mainly related to their income level, it also has negative effects on human health and the environment. The negative effects impact not only farmers but also a wide range of people. Because wastewater reuse is currently necessary, it is important for governments to put in place wise but feasible management practices, to improve the benefits while reducing and controlling the drawbacks. In order to implement sustainable reuse of wastewater and to contribute to food security, reuse projects need to be planned and constructed for the long term and based on local needs. In developing countries like India, the problems associated with wastewater reuse arise from its lack of treatment. The challenge thus is to find such low-cost, low-tech, user friendly methods, which on one hand avoid threatening our substantial wastewater dependent livelihoods and on the other hand protect degradation of our valuable natural resources. In recent years, a

wide range of treatment technologies such as chemical precipitation, adsorption, membrane filtration, and electrodialysis have been developed for heavy metal removal from contaminated wastewater. Agricultural by-product materials appear as effective and cheap sorbents for removal of heavy metals from wastewater. The removal of metal ions from effluents is important to many countries of the world both environmentally and for water re-use. Village ponds are rich source of nutrients like nitrate and phosphate which can be recovered by phyto-remediation. It is an affordable technology utilizing plants as environmental cleansers in wastewater management.

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