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A review on waste water impact on soil properties

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Abstract
There is a gradual decline in availability of fresh water to be used for irrigation in India. So we require another way to improve this situation. The objective of this was to provide knowledge of composition of waste water compare with fresh water. The present status of waste water in India and their effect on soil and health. The use of waste water, how to improve the agricultural productivity. Every country in the world facing the problem of waste water. The composition of sewage water varied from site to site, these changes occur due to which type of industries present there. Sewage water contained higher amount of N, P, K, OC, micronutrient and soil microbial count as compare to non-sewage water. The electrical conductivity although increased due to sewage irrigation, it was within the tolerance limit to cause any soil salinity hazard. Sewage water was found to higher amount of heavy metals like Cd, Cr, Pb, and Ni. Continuous application of waste water improve the phyico-chemical properties of soil but the concentration of heavy metals give adverse effect soil and plant health. Long term of waste application increase the toxic metals concentration which are not good for health and soil. Therefore, it can be concluded that in the scarcity of irrigation water, sewage water can be used in the critical period of growth for life saving of the crops and the savings in terms of micro-nutrient deficiency amelioration practices can be done without expending on expensive nutrient supplements in plants.

Keywords: Long-term waste irrigation, heavy metals, soils, groundwater, crops

1. Introduction

In India, sewage water generation is 29000 million liters per day against the existing treatment capacity of 6000 million liters per day (Central Pollution Control Board, 2004) [9]. The use of treated sewage in irrigation was emphasized in the Water. Due to lack of facilities; untreated sewage water is being used by farmers to satisfy crop water needs. This indiscriminate continuous use of such effluent for crop production could result in the concentrations that may become phytotoxic (Ghafoor *et al.,* 1999) [15]. The reuse of wastewater for agricultural irrigation purposes reduces the amount of water that needs to be extracted from water resources (USEPA, 1992; Gregory, 2000) [31, 17]. It is the potential solution to reduce the freshwater demand for zero water discharge avoiding the pollution load in the receiving sources. It is the necessity of the present era to think about the existing urban waste water disposal infrastructure, wastewater agriculture practices, quality of water used, the health implications and the level of institutional awareness of wastewater related issues (Rutkowski, 2006) [30].

The use of waste water for irrigating agricultural soil has been shown to be associated with a number of potential beneficial change such as an increase in organic carbon, available nitrogen, phosphorus, potassium, and magnesium contents in soil as compared to the clean ground water irrigated soil (Rai *et al.,* 2011) [27]. Organic carbon, total nitrogen, microbial biomass C and N and microbial activities increased with increase in the time duration of waste water. Since some of these effluents are a rich source of plant nutrients, therefore soil provides the logical sink for their disposal. But many untreated and contaminated sewage and industrial effluents may have high concentration of several heavy metals such Cd, Ni, Pb and Cr (Arora *et al*., 1985; Narwal *et al.*, 1993) [5, 25].

The practice of reuse is the necessity of the present time. Sewage has affected adversely both soil health and crop productivity. Sewage has resulted in improved physiochemical characteristics of soil. In the agricultural practices, the irrigation quality of water is believed to have an effect on the soil characteristics, crops production and proper management of water (Shainberg and Oster 1978).

The increased competition for freshwater among urban and semi-urban centres, industries and agriculture, particularly irrigated agriculture under severe pressure as irrigation has been the largest user of water (Van der Hoek *et al*., 2002) [32]. Therefore, the use of treated, partially-treated or untreated wastewater has received more attention (Dheri *et al*., 2013) [12]. Bouwer (1994) [8] stressed about the need of water management on local, regional, national and international level. Keeping the above facts in view, the study was undertaken to evaluate the chemical composition of sewage and non-sewage water of peri-urban area of Haryana state so as to use this water for agricultural purposes.

2. Review of Literature

With the increasing emphasis on industrialization and urbanization, the sewer system has become the most important aspect for the disposal of waste waters and other materials of the society. Raw sewage water is a mixture of domestic, commercial and industrial activities which done by human being for their on purposes. Currently more than 450 cities in India generate more than 17 million cubic meters of raw sewage water per day (Bijay-Singh, 2002) [7]. Since the raw sewage water is rich in organic matter and essential nutrients, sewage farming is quite common in all urban areas. The unwise use of such sewage and industrial waste water for irrigation has continuously elevated the levels of available heavy metals in the cultivated layer of the soil and make them unfit for crop production.

2.1 Chemical Composition of Sewage Water

The constituents in sewage water depend on the composition of municipal water supply, nature of wastes added during the use and degree of treatment which waste water is receiving (Asamo, 1994) [6]. The composition of sewage water also depends upon the dietary habits of the locality, population density and bi-product impurities of the industrial units which are added in the sewer system.

Antil and Narwal (2005) [5, 25] analysed the sewage waters of different locations in Haryana and found that the pH, EC, organic carbon, TSS and BOD ranged from 1.1 to 8.0, 0.64 to 4.4 dSm^{-1}, 15 to 105 mg L^{-1}, 700 to 3000 mg L^{-1} and 36 to 127 mg L^{-1}, respectively. The soluble N, P, K, Cu, Zn, Fe and Mn concentration in sewer waters ranged from 0.13 to 2.70, 0.88 to 17.25, 16.0 to 500, Tr-1.0, 0.1-6.8, Tr-56.5 and Tr-8.0 mg L^{-1}, respectively.

Minhas (2005) [22] studied the composition of sewage waters of Haryana and found that the pH, EC, TDS and BOD ranged from 7.1 to 8.3, 0.9 to 3.2 dSm^{-1}, 60 to 330 mg L^{-1} and 176 to 345 mg L^{-1}, respectively. The soluble Cu, Zn, Fe and Mn concentration of these sewage waters ranged from 10 to 415, 10 to 330, 130 to 1887 and Tr.-420 µg L^{-1}, respectively.

Chhonkar *et al.* (2000) [11] study that textiles industries effluent and noticed that the tannery effluents are slightly acidic (pH 6.0) with a variety of dissolved cations and suspended particles (57 mg l^{-1}), tannin (127 mg l^{-1}), Na (5380 mg l^{-1}), Mg (1543 mg l^{-1}), K (638 mg l^{-1}), BOD (7678 mg l^{-1}) and COD (9589 mg l^{-1}) were high, whereas Zn (2.56 mg l^{-1}), Ca (4 mg l^{-1}), Mn (0.67 mg l^{-1}) and Pb (0.23 mg l^{-1}) concentration were low while Cu and Fe were not affected. The effluent from textile processing unit was also characterized with high salinity (SAR 82), BOD (400-800 mg l^{-1}) and COD (900-1500 mg l^{-1}), excessive concentration of sodium and carbonate ions (RSC 42 meq l^{-1}), high alkalinity (pH 10.0-11.5) and unduly low concentration of calcium (Gupta and Jain, 1992) [18].

Narwal and Kuhad (2005) [24] analysed the sewage waters of some cities of India and reported that Cu, Zn, Fe, Mn, Cd, Pb, Ni and Cr content in these sewage waters ranged from 0.18 to 6.30, 0.14 to 11.00, 4.10 to 205.00, 0.10 to 37.80, 0.01 to 5.80, 0.03 to 40.00, 0.35 to 6.40 and 0.18 to 29.30 mg L^{-1}, respectively.

Dubey *et al.* (2007) [13] conducted a state level survey to characterize the sewage waters of Haryana and reported that most of the sewage waters were rated suitable for irrigation as they were having electrical conductivity 0.9 to 3.2 dS m^{-1}, sodium adsorption ratio 1.4 to 6.2 (m mol $L^{-1})^{1/2}$ and residual sodium carbonate 0 to 8.6 meq L^{-1}.

Rusan *et al.* (2007) [29] studied that treated waste water contains 952 mg L^{-1} TDS, 29.4 mg L^{-1} NO_3-N, 15.5 mg L^{-1} PO_4, 33.3 mg L^{-1} K besides Cu (0.01 mg L^{-1}), Zn (0.19 mg L^{-1}), Fe (0.87 mg L^{-1}), Mn (0.07 mg L^{-1}), Cd (0.02 mg l^{-1}) and Pb (0.77 mg L^{-1}), respectively.

2.2 Effect of sewage water irrigation on soil health

2.2.1 Effect of sewage water irrigation on physico-chemical properties of soil

Unwise use of sewage water may deteriorate soil physical environment due to accumulation of toxic elements. Uncontrolled use of sewage water for irrigation can result in accumulation of the potentially toxic metals in soil and may effect physico-chemical properties of soil.

Omron *et al*. (2012) evaluated the long-term effect of sewage irrigation on soil properties and heavy metals concentrations in the soils of the date palm at Al-Hassa Governorate, Saudi Arabia. They reported that sewage effluents were found to contain higher content of Pb, Zn, Cu, Co, Cr, As, Cd, Fe, Mn and Ni compared to well water. The heavy metals as well as the organic matter were found to be increased in the soil samples irrigated with wastewater as compared to the soil irrigated with well water. The soil salinity ranged from 3.58 to 20.7 dSm^{-1} with an average of 7.9 dSm^{-1} due to irrigation with well water. While the respective soil salinity due to irrigation for long period with the treated sewage effluent ranged from 2.5 to 3.69 dSm^{-1} with an average of 2.8 dSm^{-1}. There was an increase in organic matter content ranged from 17 to 30 per cent in sewage-irrigated soil samples as compared to well water-irrigated ones. On an average, the soil pH dropped by 0.3 U.

Rai *et al.* (2011) [27] studied the effect of sewage water and canal water irrigation in soil. They observed that concentration of Pb, Cu, Zn were below the Indian standards except Cd. The enrichment factors calculated for sewage water irrigated soil in Pb (3.79), Zn (4.12), Cu (3.12) and Cd (2.21) were moderate enrichment while pollution index values in the samples were calculated to be lower than permissible pollution limit of 1.0. Muamar *et al.* (2014) [23] determined the quality of soil when irrigated with waste water. Total waste water was compared with soil irrigated with ground water. The pH of the soil decreased from 8.16 in soil irrigated with ground water to 7.70 in soil irrigated with wastewater. The values of EC, TDS, Na, N, P and K is higher in waste water irrigated soil compared to ground water irrigated soil. The Microbiological counts was higher in all samples irrigated by waste water with an averages of 4.6 x 10^7, 1.3 x 10^5, 1.2 x 10^3, 2.9 x 10^5, 2.5 x 10^4 and 6.4 x 10^3, for total aerobic plate counts, total coliforms, fecal coliforms, *Staphylococcus aureus*, yeast and mould counts, respectively. *Salmonella*, *Shigella* and *Clostridium* bacteria were also detected in all tested samples. On the other side, this research showed that the soil irrigated with waste water has higher content of organic matter, which was equal to (2.00%) compared to (0.74%) soil irrigated with groundwater.

Antil (2014) [3] reported that continuous use of sewage and industrial waste water irrigation recorded improvement in water retention, hydraulic conductivity, organic C and build-up of available N, P, K, micronutrient status, and soil microbial count with the electrical conductivity although increased due to sewage irrigation but it was within the tolerance limit to cause any soil salinity hazard. The heavy metals like Cd, Cr, Pb and Ni were found higher in soil and plant due to long-term use of sewage and industrial wastewater irrigation. The concentration of these metals was higher in leafy vegetables than in grain crops. This warrants the potential hazard to soil plant health suggesting necessity of their safe use after pre-treatment as a cheap potential alternative source of plant nutrients in agriculture.

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Wafula *et al*. (2015) [34] reported that fresh water scarcity and regulations on wastewater disposal had necessitated the reuse of treated wastewater (TWW) for soil irrigation, which has several environmental and economic benefits. However, irrigation with treated waste water could cause nutrient loading to the local environments. They assessed the bacterial community structure and associated biogeochemical changes in soil plots irrigated with nitrate-rich TWW for periods ranging from 13-30 years. Total bacterial and denitrifier gene abundances were estimated by qPCR, and community structure was assessed by 454 massively parallel tag sequencing (MPTS) of SSU rRNA genes along with TRFLP of *nir K*, *nir S*and*nos Z* functional genes responsible for denitrification of the TWW associated nitrate. Soil physico-chemical analyses showed that regardless of the seasons pH and moisture contents (MC) were higher in the irrigated (IR) pivots relative to the non-irrigated plots; organic matter (OM) and microbial biomass carbon (MBC) were higher as a function of as compared to ground water irrigated soil. MPTS analysis showed that TWW loading resulted in: a) an increase in the relative abundance of *Proteobacteria*, especially β-, and γ-*proteobacteria*; b) a decrease in the relative abundance of *Actinobacteria*; c) shifts in the communities of Acidobacterial groups, along with a shift in the *nir K*and*nir S*-denitrifier guilds as shown by the TRFLP analysis, respectively. Additionally, bacterial biomass estimated by genus/group-specific real-time qPCR analyses revealed that higher numbers of total bacteria, *Acidobacteria*, *Actinobacteria*, α-proteobacteria and the *nirS*-denitrifier guilds were present in the IR pivots relative to the NIR plots. Identification of the nirK-containing microbiota as proxy for the denitrifier community indicated bacteria belonged to α-proteobacteria from the *Rhizo biaceae*family within the agro ecosystem studied. Multivariate statistical analyses further confirmed some of the above soil physico-chemical and bacterial community structure changes as a function of long term TWW application within this agro ecosystem.

Lal *et al*. (2015) [20] reported that continous application of sewage water improves the soil organic carbon and available nitrogen and phosphorus. Soil microbial biomass carbon (MBC) and activities of dehydrogenase, urease and phosphatase enzymes also improved substantially with use of sewage water. The most of nitrate-N was retained in the surface 0.3 m soil especially its leaching was minimal under agro-forestry system (AFS). Overall results indicated for improvement in the awareness of the growers for adjusting NP doses and non-dependent on water guzzling crops like paddy to minimise the fertiliser costs and the contamination of groundwater.

Varkey *et al.* (2015) [33] studied the effects of application of domestic sewage water for over four decades on physical, chemical and biological properties of soils. Long-term use of sewage water improved soil physical properties in terms of decrease in bulk density and dispersion index and increase in aggregate stability and water holding capacity compared to the un-irrigated check. Despite long-term irrigation with sewage water with an EC of 1.0 dSm^{-1}, the EC of soils was low (0.20–0.45 dSm^{-1}). However, the available Zn, Fe, Cu and B increased slightly except Mn which increased substantially. In general, there was a decreasing trend of organic carbon, available N, P, K and S with distance away from the stream course. Despite no heavy metals in sewage water, they were detected in soils but not at toxic levels.

Hazarika *et al.* (2007) [19] studied that content of total exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) in effluent irrigated soil was about 4 times higher than those found in the shallow tube well water irrigated soils. Further, they also revealed that the exchangeable sodium percentage (ESP), sodium adsorption ratio (SAR) and chloride content of effluent irrigated soil were 170%, 120% and 358% more than the soil of STW irrigated field.

2.2.2 Effect of sewage water irrigation on nutrient status and trace elements accumulation in soil

Long term application of sewage waste water on agricultural land often increased the levels of macronutrients and trace elements (micronutrients and toxic metals) in soils.

Rattan *et al.* (2005) reported that sewage effluents contained 5.5, 3.6, 6.4 and 1.3 times more micronutrients like Zn, Cu, Fe, Mn, Mo, and Ni, respectively as compared to ground water were 1.42, 30, 74, 127, 159, 49,and 85 μgl^{-1}, respectively and corresponding values for sewage effluents were 1.53, 33, 85, 97, 106, 49, and 53 $\mu g\ l^{-1}$ of Cd, Cr, Ni, and Pb respectively. Although, concentration of micronutrients and potential trace toxic in sewage effluents are low, long term application of waste water on agricultural land had to be viewed from point of potential build-up of these metals in soils because of their long residue time in soil environment which have risk of entry into the food chain

Lisoval *et al.* (1981) [21] observed an increase in nitrogen phosphorus and potassium content in soil with sewage application. Singh and Bhati (2005) reported that the concentration of DTPA-extractable Cu, Zn, Fe and Mn in soils of Jodhpur city receiving tube well water were 0.25, 0.51, 2.30 and 3.30 mg kg-1, respectively, while 1.36, 2.89, 12.14 and 12.40 mg kg^{-1} in soils receiving municipal effluents.

Anonymous (2006) [1] noticed that DTPA-extractable concentration range of Pb, Cd, Ni, Co, Cr, Fe, Mn, Zn and Cu in the sewage irrigated surface soil was 3.5-6.8, 0.15-0.40, 2.56 to 5.58, 1.59 to 3.89, 0.45 to 0.55, 3.5 to 15.8, 3.6 to 8.5, 1.2 to 3.6 and 1.53 to 6.59 mg kg^{-1}, respectively. Continuous sewage irrigation resulted in accumulation of Pb, Cd, Ni, Co, Cr, Fe, Mn, Zn and Cu in surface 0-15 cm layer by 5, 6, 0.4, 8, 0.6, 3.16, 5, 2 and 3 times more, respectively, compared to adjoining tube-well irrigated soils.

2.2.3 Change in MBC

Garcı´a-Gil (2000)conducted a long-term field experiment utilising barley received four different treatments prior to sowing: municipal solid waste (MSW) compost at either 20 t ha^{-1} (C20) or 80 t ha^{-1} (C80); cow manure (MA) at 20 t ha^{-1}; mineral fertilizer (MIN) or NPK (400 kg ha^{-1}); and NH_4NO_3 (150 kg ha^{-1}). The effects of these applications on soil enzyme activities and microbial biomass at crop harvest were measured after nine years. In comparison with the control (no amendment), MSW addition increased biomass C by 10 and 46 per cent at application rates of 20 and 80 t ha^{-1}, respectively, while MA treatment increased microbial biomass C by 29 per cent. The ratio of soil microbial C to soil organic C was the lowest at the high rate of MSW application. Oxidoreductase enzymes, such as dehydrogenase and catalase, were higher in the MSW treatments by 730 (C20) and 200 per cent (C80), respectively, and by 993 and 140 per cent in MA treatments than in the un-amended soil, indicating an increase in the microbial metabolism in the soil as a result of the mineralization of biodegradable C fractions contained in the amendments. The addition of MSW and MA caused different responses in hydrolase enzymes. Phosphatase activity decreased with MSW (62% at both rates) and MA (73%), to less than those in the mineral fertilization and the control treatments. Urease activity decreased by 21 per cent (C20) and 28 per cent (C80), possibly being affected by the heavy metals contained in the MSW. However, β-glucosidase and protease-BAA increased in all the organic treatments, especially with MA (by 214 and 177%, respectively). This is attributed to the microbial stimulation by the organic C and was correlated with the increase in dehydrogenase.

GÖÇMEZ and OKUR (2010) [16] reported that the application of sewage sludge, especially 5 t da^{-1}, significantly increased the microbial biomass-C, CO_2-production, N-mineralization, the activities of dehydrogenase, alkaline-phosphatase and β-glucosidase. The levels of the increases were between 19 to 35 per cent, 14 to 58 per cent, 32 to 125 per cent and 24 to 102 per cent for microbial biomass-C, CO_2-production, N-mineralization and enzyme activities, respectively. The positive effect of the applications on microbial biomass and enzyme activity of the soils were attributed to high organic matter content of the sewage sludge. The fact that the heavy metal level of the sewage sludge was under the highest limit allowed by the Soil Pollution Control Regulation (SPCR) and the sewage sludge was applied one time were play a great role on these increases. del Mar Alguacil (2012) [11] found that the effects of irrigation with treated urban waste water on the arbuscular mycorrhizal fungi diversity and soil microbial activities were assayed on a long-term basis in a semiarid orange-tree orchard. After 43 years, the soil irrigated with fresh water had higher arbuscular mycorrhizal fungi diversity than soils irrigated with waste water. Microbial activities were significantly higher in the soils irrigated with waste water (WW) than in those irrigated with fresh water. Therefore, as no negative effects were observed on crop vitality and productivity, it seems that the ecosystem resilience gave rise to the selection of arbuscular mycorrhizal fungi species better able to thrive in soils with higher microbial activity and, thus, to higher soil fertility.

Charlton *et al.* (2016) [10] reported that significant decreased in MBC population in the soils where the total concentrations of Zn and Cu fall below the current UK statutory limits. The effect of Zn appeared to increase over time, with increasingly greater decreases in MBC observed over a period. This might be due to an interactive effect between Zn and confounding Cu contamination which had augmented the bioavailability of these metals over time. Similar decreases (7.12%) in MBC were observed in soils receiving sewage sludge predominantly contaminated with Cu; however, MBC appeared to show signs of recovery after a period of 6 years. Application of sewage sludge predominantly contaminated with Cd appeared to have no effect on MBC at concentrations below the current UK statutory limit.

3. Conclusion

The above study reveals that waste water is a best source as an alternative to fresh water irrigation. Due to continuously increasing the quantity of waste water and decreasing the fresh water is a big problem present time. Waste water is a best opportunity to use as a irrigation purposes. Waste water contain high amount of essential nutrients which help to better growth of the crop. So waste water use as a source of fertilizers, since it has high contents of both organic matter and nutrients (N, P and K). Continuous use of waste waters irrigation resulted in improvement in the physical (water retention, hydraulic conductivity), chemical (organic C, available N, P, K, micronutrients), and biological soil microbial count) properties. But continuous use of waste water increases the toxic heavy metals like Cd, Cr and Ni by a regular use in the crop. These toxic metals give adverse effect on soil as well as plants health. These type of potential hazard effect the human and animal life. To avoid such type of problem, we continuous monitoring the quality of waste water and their impact on crops. Otherwise use the alternate term of waste and fresh water as a irrigation purpose to avoid the risk of toxic metals adverse effect.

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