Effects of Industrial Effluent on Soil Characteristics: A Review

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Abstract: There is a gradual decline in soil fertility due to its continue use in farming. This necessitates developing new strategies of management programs to recharge soil with nutrients. From review it has been found that reuse of industrial effluents (wastewater) in agriculture can be a good mode to conserve soil nutrients. It may offer a way to fulfill irrigation water demands also. The major challenge of using industrial effluent in irrigation is to take advantages for farmers and society while minimizing negative environmental and health impacts. Presently, around 6.2 billion liters of untreated effluent is produced every day that leads to pollution of natural water resources. Due to less availability of fresh water, disposal of waste water into water bodies becomes more restricted. The review process was adopted for extraction of information about long and short term effects of effluent irrigation over soil characteristics.

Key words: Effluent, Effluent irrigation, soil characteristics, waste water irrigation, water pollution

I. INTRODUCTION

An effluent is an inevitable production of industrial process. It is defined by the United States Environmental Protection Agency as “wastewater (treated or untreated) that flows out of a treatment plant, sewer or industrial outfall. Increased number of industries has enlarged the disposal of effluent to open land or to natural water resources. Effluent of different industries may vary in composition depending upon the source of production. Effluent may contain essential nutrients and some toxic substances. The available macronutrients and micronutrients of effluents can increase soil fertility. On the other hand the heavy metals and toxic components can accumulate in soil. The various effects depend on the period of effluent application. Metal contaminated soils can cause health problems to animals and human beings when such plants are consumed [1]. Many investigators stated that heavy metals get accumulated in soil resulted from continuous irrigation with sewage effluent [2]. On the other hand the use of waste water could solve the disposal problems, minimizes the risk of public health and also prevents the ground water pollution [3]. Wastewaters from urban and agricultural sources have great potential for re-use as sources of water, organic matter, nutrients and soil conditioning agents [4]. In this review we reported effluent irrigation can change soil properties, including soil infiltration rate, hydraulic conductivity, bulk density, porosity, pH and nutrient contents [5, 6]. Similar findings were found in long term use of sewage effluent in irrigation where organic matter content increased ranging from 17% to 30% in sewage-irrigated soils as compared to well water irrigated ones. On an average, the soil pH dropped by 0.3 U as a result of sewage irrigation [7]. Effluent irrigation reduced the soil bulk density and soil pH, but had no effect on soil infiltration rates. It increased the soil nutrient concentrations and organic matter content in many of the researches. The effluent irrigation increased the total biomass production of the plantation. Soil properties are hardly affected by different plant species. The species variation like planting Eucalyptus botryoides, E. globulus, and E. ovata had limited influence on soil change. Authors also found decrease in bulk density along with increase in organic matter and nutrients in soil. They concluded the increase in total biomass production of the plantation. Soil properties are hardly affected by different plant species. The species variation like planting Eucalyptus botryoides, E. globulus, and E. ovata had limited influence on soil change. Authors also found decrease in bulk density along with increase in organic matter and nutrients in soil. They concluded the increase in total biomass production of the plantation by using effluent water [8]. Use of sewage for irrigation in various proportions improved the organic matter to 1.24–1.78% and fertility status of soils especially down to a distance of 1 km along the disposal channel. Build up in total N was up to 2908 kg/ha, available P (58 kg/ha), total P (2115 kg/ha), available K (305 kg/ha) and total K (4712 kg/ha) in surface 0.15 m soil [9]. Mixing of effluent from different sources can give advantageous results. Addition of municipal effluent to textile effluent is recommended as one of the better options for utilization of textile industrial effluent in tree growing. Seedlings irrigated with municipal effluent showed optimum growth and plant nutrient concentration [10]. In the long term, however, the changes in soil exchangeable cations may affect soil quality and the sustainability of...
of plant production, and could be a problem for sustainability of effluent application. The N-reduced effluent had a more profound effect on the concentrations of cations in the drainage water than the primary-treated effluent. It is concluded that application of meat processing effluents can increase plant production due to increased nutrient loadings [11]. The effects of the non-N wastewater components (e.g. cations, particularly sodium) and hydraulic loading rates on soil properties and waterways are also critical for the sustainability of wastewater irrigation. Sodium (Na⁺) is of particular concern as it accumulates in soil and displaces other cations such as calcium (Ca²⁺) and magnesium (Mg²⁺). Excessive Na⁺ may also have an adverse effect on soil structure, causing a decline in soil permeability, and therefore in a soil’s ability to further accept and treat wastewater [12]. The waste waters carry appreciable amounts of trace toxic metals [13, 14, and 15] and concentrations of trace metals in sewage effluents vary from city to city. Concentration of heavy metals in sewage effluents are low, long-term use of these waste waters on agricultural lands often results in the build-up of the elevated levels of these metals in soils. Significant positive correlations were found between the concentrations of nutrients in soil and tree leaf suggest that the trend of mineral concentration in plants would be a function of mineral content in soil and also depended on their uptake by plants. In the absence of heavy metals, vegetables grown on sewage irrigated soils are still safe to be consumed by human being [16]. Crop species exercise differently in accumulating heavy metals of effluents irrigated soils in their tissue. Uptake of heavy metals by plants may be an indicator of efficiency of metal absorption of various crop species grown on metal contaminated soils. Sewage irrigation for 20 years resulted into significant build-up of DTPA extractable Zn (208%), Cu (170%), Fe (170%), Ni (63%) and Pb (29%) in sewage-irrigated soils in vicinity of Delhi over adjacent tube well water irrigated soils, whereas Mn was depleted by 31%. Soils receiving sewage irrigation for 10 years exhibited significant increase in Zn, Fe, Ni and Pb, while only Fe in soils was positively affected by sewage irrigation for 5 years [17]. Rai (Brassica juncea) and tori (Brassica campestris) accumulated higher content of heavy metals especially Ni as compared to other crops, with higher content in roots than shoots. There are some reports which indicate that heavy metals pollution including Ni in soils arises as a result of various anthropogenic activities such as continuous use of sewage water and sewage sludge [18, 19]. The content of DTPA – Ni showed decreasing trend with depth [20]. Ni is translocated to top parts of plants in the given order tori > rai> maize> bajra > lady finger. Trace elements including Ni are present in different chemical forms because they are associated to diverse organic and inorganic components of the soils such as soluble, exchangeable, bound to carbonate, Fe and Mn oxides, organic matter and residual [21]. With the exception of Zn in plant tissues harvested from compost and sludge treated soils, root tissue of cabbage for both compost and sludge treated treatments appeared to accumulate more metals in the roots than the aerial parts [22]. The effect of irrigation with secondary treated municipal effluent on the accumulation of heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) was investigated by monitoring sites that had been irrigated with effluent for 4 and 17 years [23]. Concerning nutrient recycling, it is commonly admitted that wastewater irrigation results in higher yield than irrigation with fresh water due to the supply of nutrients (especially nitrogen, Phosphorus and potassium) contained in the wastewaters [24]. Chemical analysis clearly exhibited sodium and bicarbonates accumulation, and pH increase to alkaline values, in the topsoil of the plots irrigated with recycled wastewater. Shrinkage analysis showed that the structural pore network of the soil collapsed dramatically, resulting in compact layers with poor water storage. In addition, alkalinization induced organic matter dissolution resulting in black alkali forming at the soil surface [25]. The level of sanitary hazard involved in agricultural use of wastewater depends on the nature of the effluent treatment prior to reuse [26]. There are different views associated with effects of long-term waste water application on soil pH. There are studies [27, 28, 29] which confirms increase in soil pH with waste water irrigation of soil.

Similar results showed of decrease in soil pH with waste water irrigation in different soils of varying agro-climatic conditions have also been reported [30, 31]. Elements such as Ca and Mg needed for plant growth can accumulate in soils thereby improving the pH especially of acidic soils [32]. Based on literature thus reviewed, it can be concluded that some industrial effluents hold great promise for the improvement of soil fertility and crop yields, if proper treatment and management practices are adopted. Literature reviewed reveled that safe utilization of waste water for irrigation to crops requires several precautionary measures viz. adequate dilution, selection of crop etc. Besides, soil physical properties needs to be reviewed periodically for long-term sustainability of the system. [33]. Long-term use of waste water for irrigation to crops results in significant increased in soil organic content than the soils irrigated with ground water [34, 35, 36, 37]. The concentrations of ions in soils are influenced by water movement, their concentrations in irrigation water, soil properties and plant uptake [38]. Phosphorous is an immobile nutrient in soil, thus long term field studies are necessary to understand the effluent-P dynamics in the soil [39]. Land application of wastewaters can increase the levels of soluble and exchangeable forms of potassium in soil more rapidly than with conventional inorganic fertilizers. Most of the potassium in wastewater is immediately available [40]. The quantity of

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heavy metal absorption using plant depends upon many factors including the total quantity of the elements applied through sewage application, soil properties, and type of plant [41]. It was found overall concentrations of all measured elements except Calcium and Cadmium were significantly elevated in the soil that was irrigated with effluent. Sodium concentration and pH were elevated in the upper soil horizon, whereas Phosphorus concentrations were elevated uniformly. Differences in electrical conductivity and Magnesium concentrations between the effluent-irrigated field and the unirrigated field increased with depth. They concluded that soil could be a good repository for Sodium; however, the nutrient content of the resident saltbush population was affected [42]. According to review the background soil values for NPK were 21.58, 8.39 and 95.22 mg kg⁻¹ at 0-20 cm soil depth while 19.54, 6.39 and 73.72 mg kg⁻¹ at 20-40 cm soil depth, respectively. They concluded higher level of NPK in surface soils compared to sub-surface soils [43]. Effluent irrigation affects pesticide sorption by altering: (i) the CEC of the soil; (ii) the soil solution pH which controls the dissociation and protonation of ionic pesticides as well as the number of available binding sites; (iii) the DOM content of the soil solution. They concluded that there is considerable scope for scientists to help develop sustainable practices as well as more sound and rigorous effluent irrigation guidelines by improving the understanding of related soil processes [44]. It was found increase in Electrical conductivity, Exchangeable cations, size and activity of soil microbial community [45]. The irrigation with treated waste water improves soil labile Phosphorous content [46]. Continuous application of effluent appears to deteriorate soil quality in some areas. They recommended the urgent management practices of waste water for irrigation purpose [47]. Electrical Conductivity (salinity), organic carbon, soluble Ca and Mg, available soil phosphorus, potassium increased significantly and percentage of total neutralizing Value (T.N.V) of soil decreased [48]. That physico chemical analysis of soil around industrial area and agricultural area shows variation [49]. Plots irrigated with wastewater showed important structural damage in sub surface zone where soil pore network collapsed dramatically, resulting in a compact impermeable layer. They concluded that a strong deterioration is observed in a very short time period due to such reasons [50]. Poor water quality degrades soil quality, results in the accumulation of heavy metals and alteration of soil physical and chemical properties and influences the soil health to a great extent. They concluded the sewage effluents as a cheap potential alternative source of plant nutrients in agriculture. Finally sewage irrigation—it’s never new, only recycle and reuse [51]. The process of metal uptake, accumulation and distribution in plants is strongly influenced by the soil characteristics including pH, cation exchange capacity (CEC), organic matter, metals content, solubility sequences and plant species [52, 53]. The addition of organic and inorganic material would be expected to affect physicochemical changes on the soil, which would in turn impact upon soil microbial community structure, as has previously been shown following organic soil amendment [54]. The effluents of a leather industry complex markedly increased the concentrations of Cu, Fe, Mn, Zn, Al, Cr and Ni in sewage water, and irrigation with the contaminated sewage water increased the concentration of these elements in soils. Hence Mn, Cr and Ni are more likely to be the elements that may become health hazards for consumers of the crops grown in sewage-water irrigated fields [55]. Under DFE irrigation there is a characteristic increase in EC, ESP, extractable soil Na, K and particularly P, and an increase in the size and activity of the soil microbial community. Despite these changes, the metabolic quotient and structure of the soil bacterial community remained unaffected suggesting that the existing soil microbial community is relatively resilient under dairy effluents irrigation [56]. Treatment of industrial water at point source is the best remedy for consumers. Industrialists should take this responsibility.

Table1 Analysis showing effects of effluent over soil characteristics at various places

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Type of effluent used</th>
<th>Place</th>
<th>Effect over soil</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Urban effluent</td>
<td>Australia</td>
<td>Degradation</td>
<td>Accumulation of heavy metals like Cr, Pb, Cu, Ni, Zn and Cd</td>
</tr>
<tr>
<td>2</td>
<td>Domestic sewage effluent</td>
<td>Krukshetra, India</td>
<td>Fertilization</td>
<td>Improvement in organic matter, N, P, K and fertility of soil</td>
</tr>
<tr>
<td>3</td>
<td>Dye, textile and wool industrial effluents</td>
<td>Jalandhar, Amritsar, Ludhiana</td>
<td>Degradation</td>
<td>Cd, Ni, Co accumulation</td>
</tr>
<tr>
<td>4</td>
<td>Meatworks</td>
<td>New Zealand</td>
<td>Fertilization</td>
<td>Decrease in bulk density and pH + increase in</td>
</tr>
<tr>
<td>Effluent Type</td>
<td>Location</td>
<td>Impact Type</td>
<td>Effects</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
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<td>-------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Animal processing waste water</td>
<td>Hamilton, New Zealand</td>
<td>Degradation</td>
<td>Ca loss in drainage</td>
<td></td>
</tr>
<tr>
<td>Sewage effluent</td>
<td>Western Delhi, India</td>
<td>Degradation</td>
<td>High content of Zn, Cu, Fe, Ni, Pb but depletion in Mn</td>
<td></td>
</tr>
<tr>
<td>Sewage effluent</td>
<td>Punjab, India</td>
<td>Degradation</td>
<td>High amount of DTPA-Ni and heavy metals</td>
<td></td>
</tr>
<tr>
<td>Secondary treated waste water</td>
<td>Glen Valley</td>
<td>Degradation</td>
<td>Low salinity, high SAR, ESP values, low microbial content, accumulation of Cd, Ni and Cu</td>
<td></td>
</tr>
<tr>
<td>Dairy factory effluents</td>
<td>Bega Valley</td>
<td>Fertilization</td>
<td>Increase in Electrical conductivity, Exchangeable cations, size and activity of soil microbial community</td>
<td></td>
</tr>
<tr>
<td>Phosphate fertilizer industry effluent</td>
<td>Tunisian area</td>
<td>Fertilization</td>
<td>High amount of soil labile P content</td>
<td></td>
</tr>
<tr>
<td>Paper mill wastewater</td>
<td>Bukkathurai</td>
<td>Fertilization</td>
<td>High amount alcohols, carbohydrates and inorganic compounds</td>
<td></td>
</tr>
<tr>
<td>Olive mill wastewater</td>
<td>Laconia, Greece</td>
<td>Fertilization</td>
<td>High amount of N, P and K</td>
<td></td>
</tr>
<tr>
<td>Municipal Wastewater</td>
<td>Segzi plain in Isfahan</td>
<td>Fertilization</td>
<td>Increase of EC, P, OM, TN, K, Na, Cl, Fe, Cd and Zn but decrease of soil pH</td>
<td></td>
</tr>
<tr>
<td>Dye industrial effluent</td>
<td>Ujjain, MP, India</td>
<td>Degradation</td>
<td>High amount of Chloride</td>
<td></td>
</tr>
<tr>
<td>Winery wastewater</td>
<td>Victoria, Australia</td>
<td>No significant effect</td>
<td>Low soil respiration, nitrogen cycling and microbial community structure</td>
<td></td>
</tr>
<tr>
<td>Iron and Steel industrial effluent</td>
<td>Bhandra, Maharastra</td>
<td>Degradation</td>
<td>High concentration of COD, BOD, Chloride content, Alkalanity and heavy metals like Ni, Cd, Pb, Fe and Mn</td>
<td></td>
</tr>
<tr>
<td>Municipal wastewater</td>
<td>Iran</td>
<td>Fertilization</td>
<td>Increase in soil organic carbon and bulk density</td>
<td></td>
</tr>
<tr>
<td>Municipal wastewater</td>
<td>South west of Iran</td>
<td>Fertilization</td>
<td>Increase of Electrical Conductivity (salinity), organic carbon, soluble Ca and Mg, phosphorus and potassium</td>
<td></td>
</tr>
<tr>
<td>Distillery irrigation</td>
<td>Modinagar</td>
<td>Fertilization</td>
<td>higher concentration of COD, BOD</td>
<td></td>
</tr>
<tr>
<td>Industrial effluent</td>
<td>A.P, India</td>
<td>Fertilization</td>
<td>High organic C, Sulphate, Ca and Mg</td>
<td></td>
</tr>
</tbody>
</table>
Common findings for Effects of effluent irrigation over soil characteristics

- Researchers analyzed the effect of effluent over soil characteristics in areas like Australia (Wodongs, Canberra), Kukshetra, Jalandhar, Amritsar, Ludhiana, Abohar, Malerkotla, New Zealand, Mandi Gobindgarh, Glen Valley, Bega Valley, Bukkathurai, Laconia, Greece, Iran, Ujjain city, Western Delhi, Maharastra, Burkina Faso, Goianesia, State of Goias, Yerraguntla, A.P and Modinagar.
- Researchers analyzed time required for heavy metals to be accumulated in soil from urban effluent, Australia. The threshold for Cd would be reached with 50 years at Canberra and 140 years at Wodongs.
- Domestic sewage in Kukshetra District showed improvement in organic matter from 1.24 to 1.78%, N content up to 2908 kg per Ha, P up to 2115 kg/ Ha, K up to 4712 kg/ Ha and overall the fertility of soil.
- The high amounts of Cd, Ni, Co in dye, textile and wool industrial effluents from industrial towns like Jalandhar, Amritsar, Ludhiana, Cr amount was 140 times the tolerance limits that can accumulate in plants and soil. On the other hand the sewage of non industrial towns like Abohar and Malerkotla can be used for irrigation purpose.
- A decrease in bulk density and pH of soil along with increase in organic matter and nutrients in soil was found in New Zealand with meatworks effluent irrigation.
- High amount of DTPA-Ni content by 3.04 times in effluent irrigated soils of Jalandhar, Ludhiana, Amritsar and Mandi Gobindgarh was found. The crops like rai (Brassica juncea) and tori (Brassica campestris) accumulated higher content of heavy metals as compared to other crops, with higher content in roots than shoots. The transport order of metals in crops is toria > raya = maize > bajra > lady finger.
- Irrigation with high potassium effluent has been shown to help in sustaining the overall fertility in soils. When using high concentration of potassium in waste water, appropriate management strategies have to be developed to minimize leaching losses from crop root zone and maximizing nutrient removal with soil colloids.
- Glen Valley effluent irrigated soil samples are with low salinity, high SAR, ESP values, and biological clean. The Cd, Ni, Cu have more of the positive impact over soil quality.
- Dairy factory effluent of Bega Valley is compatible in irrigation due to increase in Electrical conductivity, Exchangeable cations, size and activity of soil microbial community.
- The FTIR extensive band at 1033 cm\(^{-1}\) – 1030 cm\(^{-1}\) represents alcohols, carbohydrates and inorganic compounds in paper mill effluents of Bukkathurai, hence increase fertility of the soil to restore wastelands.
- The olive mill waste water, OMW resulted in 6 times more N, 2 times more P, and 50 times more K than conventional fertilization in Laconia, Greece.
- The municipal waste water from Segzi plain in Isfahan province in the center of Iran is compatible for irrigation purpose.
- The continuous application of effluent appears to deteriorate soil quality in the Ujjain city.
- The high organic content up to 38-79%, Zn, Cu, Fe, Ni, Pb found after 10 years of sewage irrigation in Western Delhi but vegetables grown on sewage irrigated soils are still safe to be consumed.
- Iron and Steel Industry situated at Bhandra, Maharastra causes the pollution problems in the surrounding area.
- Irrigation with waste water is responsible for decreasing soil reactions in top soil of Iran.
- On the other hand TMWE is in favorable range for irrigation purpose due to significance level of EC, soluble calcium and magnesium, available phosphorus and available potassium in south west of Iran.
- Distilleries of Modinagar leads to significant positive impact over soil but heavy metals remained the major limitation in implementation of real time practice.
- The physio chemical analysis of soil around industrial area and agricultural area of Yerraguntla, Kadapa District, A.P shows significant variation.
- High vinasse dose in sugar effluent may lead to increase nutrient leaching and soil dispersion in Goianesia, State of Goias.
- Plots irrigated with wastewater showed important structural damage in sub surface zone where soil pore network collapsed dramatically, resulting in a compact impermeable layer in Burkina Faso.
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- Irrigation with treated waste water from Tunisian phosphate fertilizer industry improves soil labile P content by 38.15 mg/kg P from 15.53 mg/kg.

CONCLUSION

Waste water management is a big challenge in today’s world. The review of waste water management considers the need of new technologies for better reuse of waste water. Effluent contains nutrients as well as toxic components depending upon the source of production. Effluent quality indicators are tested to check suitability for reuse or disposal. In order to access usability of effluent in irrigation effluent quality indicators are used for periodic monitoring of effluent. The present work is presented with a vision to study the alteration of soil characteristic in effluent (treated or untreated) irrigation. It may offer a low cost technology for better waste water disposal, hence prevents water pollution. Alternatively, industrial effluents may be made eco friendly. One of the processes may include incorporation of soil and effluent at different dilutions with a view to improve soil fertility.

REFERENCE


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