

Impact and Control of Industry Effluents on Physical, Chemical, and Biological Aspects of Soil Characteristics

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Abstract: *There is a growing public concern over the potential accumulation of heavy metals in soil and water, due to rapid industrial development. In this era of urbanization and modernization, industrial pollution has been and continues to be a major cause of our environmental degradation. So, it is necessary to have a look upon our natural recourses. There must be a balance between industrial development and agriculture. This review presents the effects of different industries (e.g., pulp and paper mill and chemical industries) and glass and polymers effluents disposal on water and soil characteristics in the vicinity of their respective industries. Among various toxic substances released by industrial activities, heavy metals have been seen as a key marker because they can be analysed effectively and consistently in most environmental matrices. Unlike organic pollutants which may degrade to less harmful components as a result of biological or chemical processes, metals are not degradable by natural processes especially when elemental metallic content is considered. Use of heavy mechanical vehicles leads to an increase in soil stress, higher bulk density, and decrease in saturated hydraulic conductivity and water holding capacity of soil due to soil compaction. This review shows that soils were polluted most significantly by heavy metals and in most cases, metal levels in the studied areas were found to exceed the common regulation guideline levels. It is thus important to keep systematic and continuous monitoring of heavy metals and their derivatives to manage and suppress such pollution. Treatment processes of industrial effluents are also requires a huge amount of chemicals and water. So there is need of controlled treatment process of effluents and better method of disposal of solid wastes.*

Keywords: soil compaction, agricultural vehicles, waste water treatment

1. Introduction

Soil is the backbone of agriculture and original source of nutrient that are needed by plants and crops to grow and survival. Plants are grown in the soil and the nutrients in the soil are transferred to the crops and automatically to the animals and human beings in the form of food. As a result, the toxic materials present in the soil are also transferred to living beings through food chain. Soil is a very dynamic and complex system depends upon living and dead organism, decaying and residual organic matter, mineral, air, and water. The various physical, chemical, and biological processes taking place in soil are difficult to understand.^{1, 2} It is need of present situation to know the characteristic of that soil, where we want to grow our food. Healthy soil produces healthy food for us. Soil is composed of mineral constituents, organic matter (humus), living organisms, air, and water, and it regulates the natural cycles of these components. Soil is not only a medium for plant growth but has become a pool to dump undesirable material in this present era. This waste may be agricultural, domestic, or industrial. Alteration in soil parameters depends upon the type of wastes dumped inside it for a long time. Soil has become a medium to transmit many pollutants to food, surface water, ground water, and atmosphere.³

It takes thousands of years for soil to form through the multifarious interaction of a number of forces acting over the years, including parent material, climate, organisms etc. But most of the soils are still forming and over the time some of the soil forming factors like climate conditions, environment, and vegetation are changing. Composition and type of soil decides its fertility for various type of crops. Soil fertility is the ability of soil to provide plant nutrient

and other essential minerals in a proper proportion to the plants for their growth and reproduction. There are various factors, that affects the soil composition and its fertility, some are natural factors and others are anthropogenic means caused by us like deforestation, industrial effluents, overuse of fertilizers, use of heavy mechanical agricultural vehicles, etc. Out of these the main factor is industrial development; no doubt the industrial activities will increase the rate of development and one of the major contributors to the economic growth of a country. But this would have adverse effect on soil health and cause environmental degradation. Use of heavy mechanical vehicles is one of the factors responsible for soil compaction. Decreased saturated hydraulic conductivity and water holding capacity of soil is the after effects of soil compaction caused by heavy farm vehicles used in agriculture.⁴ Various industries emit waste water that may contain various toxic elements, if disposed untreated. It is the area of thrust to analyse the positive and negative effects of industrialization on the soil health. Various industries are developing day by day like paper and pulp, leather, sugar mill, distillery, glass, mining and smelter, dyeing industries etc. In this paper we are summarizing the effects of these industries effluents on the soil health that may be positive or negative.

1) Paper and Pulp Industries

Paper and pulp industries are the highest consumer of fresh water and in turn discharge high volume of effluents.⁵ Discharge of these effluents without treatment affects our atmosphere, soil quality, and aquatic life. The pollutants from paper and pulp mills can alter the soil chemical, biological, and physical properties and degrade the soil quality. Industries are using a huge amount of water in distillation and processing of products and a large amount of

waste water is also generated. As we know level of ground water is also under threat, so a major problem is scarcity of irrigation water. In some areas, waste water from various industries is used for irrigation. Paper mill effluents are found to have high COD and BOD values. This waste water adds toxic substances in the soil profile. But studies have proved that the waste water can be used for productive purpose as it contains some nutrients having potential use in agriculture⁶.⁷Waste water can be used as an alternative to organic fertilizers to improve the soil fertility. Soil irrigated with waste water shows higher organic content, cation exchange capacity, and nutrient value than the soil irrigated with ground water. However, untreated waste water and long use of waste water for irrigation may increase the risk of accumulation of heavy metals in soil. Treated waste water can be used for cultivation of vegetables.⁵ Pulp mill waste water, if used in irrigation can introduce various elements and affect their relative mobility in soil.^{7,8}Vinod Kumar et al have studied the area nearby the paper and pulp mill at Haridwar, Uttaranchal. Results shows that paper mill effluents had increased the toxicants/nutrients in nearby soil. Presence of various heavy metals (Cr, Cd, Pb, Zn, Cu, and Fe) was recorded in the soil samples. Chromium concentration was reported highest and concentration of iron was lowest among the present heavy metals. The concentration of heavy metals in contaminated soil were found to be below the permissible limits of Indian standards, but if the effluent disposal will continue for long time, the metal contamination may exceed the acceptable limits and can degrade the fertility of soil.⁵ Studies have showed the alteration in organic carbon content, available K, EC, exchangeable cations, and anions of soil but high salinity of soil is a matter of concern due to pulp effluents.⁹

Manju Sharma et al had compared the soil samples in vicinity of paper mill, sugar mill, and thermal power plant in order to assess the soil quality of Yamuna Nagar. Results showed that the soil samples in the vicinity paper mill were found to have higher concentration of heavy metals (Ni, Cr, and Cu) than the soil samples from the vicinity of sugar mill and thermal power plant. EC, pH, and potassium concentration were also found higher in paper mill soil samples.¹⁰Vinod Kumar et al had studied the effect of paper mill effluent on the growth of Fenugreek (Methi) plant. They used the effluents of Shamli Paper Mill Muzaffarnagar (Uttar Pradesh) for irrigation of Fenugreek (Methi) crop with different concentration i.e., 5%, 10%, 25%, 50%, 75%, and 100% with Borewell water (control) and analyse the agronomical properties of Methi. Results shows that the paper mill effluents are rich in nutrients and also affects the soil parameters. Effluents are found to increase the EC, pH, chlorides, phosphates, nitrates, sulphates, calcium ions, potassium ions, and sodium ions of the soil under investigation. However, they had increased the water holding capacity, bulk density, and moisture content of the soil. On the other hand, irrigation with the effluents had improved the nutrient status of the soil. The irrigation with 25% effluents concentration shows the maximum plant growth. The seed germination, shoot length, root length, and other properties of plants were found to be increased with the effluents concentration up to 25% but decreased with further increase in the concentration of effluents. They conclude that the paper mill effluents are rich in nutrients

and can be used for irrigation after proper dilution. They can reduce the use of fertilizers up to an extent and helps the farmers to reduce the overall cost over farming.¹¹

2) Distillery and Leather Industries

A large amount of waste water from distillery has been discharged on land and into other water streams. Distillery water contains a high percentage of inorganic and organic materials, and has high BOD and COD values and low pH. Distillery effluents are found to disturb the physiochemical parameters of soil and affect the fertility of soil. Untreated waste water from distillery effluents is found to decrease the soil productivity. High osmotic pressure and high content of pollutants in these effluents are found responsible for decrease in seed germination of the wheat crops. An investigation was carried out by Jibril Goli et al to study the effect of distillery effluents on the seed germination, shoot length, and root length of various crops. Results showed the inverse ratio of seed germination with the percentage of effluents. Fresh weight, and root length of wheat crop were also found to decrease with increase in the percentage of effluents.¹²Chhonkar et al has compared the N, P, K contents in paper effluents and distillery waste water. They have found that the N and K contents are low in paper mill effluents than distillery waste water. Use of industrial effluents on soil shows significant increase in available N, P, K, organic carbon, EC, and exchangeable Na of soil. Soil irrigated with paper mill effluents is also reported increase in available N, P, K and micronutrients, pH, organic carbon and cation exchange capacity and shows adverse effect on seed germination and seedling growth of various crops.⁴Irrigation with the post methanation distillery effluents results a load of organic and inorganic ions to the ground water. As these ions may leached down to ground water from soil. Continuous addition of these ions would create a serious threat to quality of ground water.¹³

It has been found in the study made by Reddy et al that the discharge of effluents from leather industry changes the physiochemical properties of soil and enhanced the soil protease activity. Effluents generated from primary processing of leather were found rich in clay and slit content. The soil protease enzyme activity was found higher in the leather industry effluent discharged soil but the trend of soil incubation period was found same as in control soil. In the study carried out by Reddy et al, it was found that leather industry effluents altered the physiochemical properties of soil and increased its protease activity. EC of contaminated soil was found decreased due to accumulation of organic waste like acid, alkali, amino acid residues. The values of pH, OC, total N, K, P were found higher in the contaminated soil than the control soil. Two-fold increase was recorded in bacterial and fungal population in contaminated soil than the control sample. Effluents are found to affect the biological properties of soil and micro flora of soil.¹⁴

3) Mining and Smelter Industries

Metallurgical, mining, and smelter industries are becoming a huge source of metals discharged to the surrounding areas, which ultimately reaches to the agriculture land. It has been investigated that the metal concentrations discharged from mining industries were found to decrease with depth. Upper

soil is found to be more affected. However, the distribution of metal discharged depends upon the nature of metals and the type of industries from where it get exposed to the environment. Near some industries the difference between the metal concentration in the top soil and sub soil were found very small. But the horizontal distribution of metals discharged from mining and smelter industries found to be decrease with distance from the source. Distance, up to which the metal transported from the source, depends upon the nature of metals, volatility and the residence time of metal in the environment. As was found to deposits over a long distance from the source of emission and have less chances to get deposited near the source. Many factors are governing the distribution of metals from the mining sources.¹⁵ Metal deposition in soil is an alarming issue and if it persists for long time will give adverse results to the environment quality. Tailing generated from ore mills are generally found to dump in the nearby pond or soil. That may become very hazardous to soil as well as water health and ultimately human health. Zn, Pb, and Cd were documented as main pollutants in the soil receiving smelter effluents.¹⁶ As metals are non-biodegradable so will ultimately affect the trace element concentration of the soil and affects the soil health. The cost of remedial measures may affect the profit percentage of industrialists but it is the need of this hour of industrial development¹⁷ Leakage of chemicals from such industries may be possible and that also becomes the reason of contamination of nearby soil. Wastes from the mining industries should be recycled in order to reduce its dumping. That may be increase the cost factor but can save our environment as well as natural resources.

4) Sugar Mill Industries

Sugar industry is one of the prominent industrial sectors that help to raise the economy and employments of a nation at large scale. However, it also contributes to a major part of the waste water generated from industries. A team of researchers had tried to analyse the effect of sugar mill effluents on the soil fertility around the area of Sartaj sugar mill located in District Jhang, Punjab, Pakistan. They have tried to correlate the effect of sugar mill effluents with the seed germination of plant grown in the SME irrigated soil specially tomato and okara. These effluents also distress the soil. Highly toxic chemicals released from sugar mills will cause a serious threat to the soil microorganism that helps to maintain the soil fertility. Collected soil samples were treated with different concentrations of SME i.e., of 5%, 10%, 25%, 50%, 75%, and 100% along with bore well water (control). Seeding growth was observed on weekly basis. Seed germination percentage was observed higher in okra than tomato at the SME concentrations of 5%, 10%, 25%, and 50%. The concentrations of Cu, Fe, and Cd in SME were found above the limit. Soil samples irrigated with 5%, 10% and 25% of SME showed better results for seeding growth. Concentrated SME shows negative impacts on plants growth rate and soil fertility. However, the mean values of all the soil parameters were found in permissible limits. Okra plant is more vassal as compare to tomato with respect to effluent concentration. Waste water from floor cleaning of mill, from boiler, from cooling condenser, and cleaning of sugar (hydrochloric acid and caustic soda were used for cleaning), if used directly for irrigation, affects the rate of seed germination of crops. Use of diluted sugar mill

effluents in irrigation is found somehow good for cultivation of crops. Proper management of waste water is needed if used for irrigation and may increase the fertility of soil.¹⁸ Calcium and Sodium contents were found higher in sugar mill effluents than the paper and pulp effluents. High sodium content in soil may leads the increase in pH of the soil.¹⁰

Waste water from these mills can cause alteration in soil parameters because large amount of chemicals and water is used in processing, washing, and purification process in these industries. In addition, to over use of ground water, waste water disposal (untreated) on the soil again degrades soil productivity and leads to transmission of various pollutants to food chain.

5) Petrochemical Industries

Natural vegetation and natural beauty are jewels of North eastern states of India. Tourism is one of the major sources of economy of these states but rapid industrialization may affect the natural resources. Local ecosystem and natural inhabitants are affected due to the pollution caused by large- and small-scale industries. Oil and natural gas plant in Assam is one of the major organisations of India. Another major petrochemical plant in Assam is BCPL (Brahmaputra Cracker and Polymer Limited). Surveys show that most of the industries are using their nearby river as dumping sites of waste water and materials. In addition, to destruction of natural beauty, they also impart harmful effects on the aquatic life as well as on the lives of local citizens. Soil of nearby area also get affected and express its deterioration in various ways. Oil spillage around nearby areas of oil refineries affects the physical properties of soil. Oil blocks the pores of soil and hence decreases its water holding capacity and saturated Hydraulic Conductivity (Ks). Macro porosity and bulk density of oil polluted soil is also reduced that results decline in crop yield.¹⁹ Environmental concern is must in addition to the development of a nation. Strict implementation of guidelines/policies to maintain the balance between nature and development is to be ensured in letter and spirit with the concerned organizations/industries. Awareness programmes towards conservation and restoration of natural resources among the people must be carried out.

2. Conclusion

The rate, with which man is degrading the environment quality in order to meet his desires, is really a matter of great concern and an alarming issue. There should be the balance between the human activities and nature. Over demanding nature of man has become a serious threat to the coming generation. The rate of consumption of natural resources is very high as compared to natural recovery of these resources. All the industries discharge their waste into soil ecosystem. All the industrial waste and effluents consist of appreciable amount of organic and inorganic materials and their by-products. Continuous use of industrial effluents on soil changes the various soil physiochemical parameters of the soil. Hence at many places the pollutants discharged into the environment has exceeded the assimilative capacity and caused severe degradations of environment and ultimately affected the livelihood of the people. Many industries like leather industry, mining, petrochemical and textile industries are discharging their wastes and affect the concentration of trace elements present in the soil. Though these trace

elements are present in the soil in a definite concentration but anthropogenic activities had increased their concentration. Direct exposure of some metals may cause serious illness. Type of disorders and symptoms depends upon the nature of heavy metals, form in which the metals are reaches to the food chain and their concentration. Top layer of the soil was found affected due to discharge of huge amount of metal concentration by metallurgical, mining and smelter industries. They may reach to agricultural land and alter composition of soil. Leather industries effluent are also found to increase the pH, OC, total N, K, P of the soil. Bacterial and fungal population in contaminated soil were also found increased in leather industries effluents contaminated soil. Lots of water is used in the processing, crushing, and cleaning in the industries. Disposal of effluent, molasses has become the serious threat to environment. Most of the sugar effluents were used for irrigation and definitely impart some effect on the soil parameters. Use of sugar mill effluent contaminated water for irrigation can affect the seed germination of plants and soil microorganisms, if used in high concentration. However, irrigation with diluted effluents shows some positive results for crop growth. As it was reported by studies that the paper mill effluents contain nutrients and may give positive results if the waste water is used in irrigation. Waste water can be used as resource of nutrient and lead to productive change in the crop growth. As they are found rich in nutrient so it is expected that they will increase productivity of soil. But there is need of analysis of the parameters of the soil, where these effluents are going to applied. After proper knowledge of the nutrient status of the soil, it can be predicted that which concentration of effluents will be better to meet the required need of nutrient level of soil. Proper understanding of the soil behaviour is must for its proper utilization. Soil characterization helps the scientist to compare the land of various places and provide the information about nutrient level and other properties of soil.

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