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Environmental and Agricultural Consequences of Textile Effluents on Soil Fertility and Plant Growth

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Abstract

One of the biggest drivers of India's economy, the textile sector uses enormous amounts of chemicals and water during production, producing complicated effluents that pose serious health and environmental hazards. These effluents frequently contain levels of heavy metals like chromium, copper, zinc, and cadmium that are over allowable limits, along with dyes, surfactants, salts, acids, and alkalis. Textile wastewater changes physicochemical characteristics, lowers soil fertility, contaminates groundwater, and builds up toxicants in crops when it is released into soil and water bodies without treatment. According to published research, some plant species may benefit from partially diluted effluents in terms of germination, biomass, and chlorophyll content, but larger concentrations have a negative effect on seed germination, root elongation, plant biomass, and yield. Long-term irrigation with untreated wastewater increases the concentration of heavy metals in soils and plant tissues, endangering human health, ecological health, and food security. The dual effects of textile effluents on soil-plant systems are highlighted in this review, along with the pressing need for effective wastewater treatment techniques to reduce environmental damage and investigate safe reuse options.

Key words : Textile, Effluents, Chemical, Plant growth, Soil fertility.

Food is the most significant human want, followed by clothes. India is the world's largest producer of clothing and textiles. The textile sector generates little less than 14 percent of all industrial production, 4 percent of the country's GDP, and 27 percent of its foreign exchange[36]. The textile industry utilises a large amount of potable water and a wide range of synthetic chemicals during different stages of the production process.

These include bleaching agents, detergents, carriers (phenyl, phenols, chlorinated benzenes), mordants (alum, iron, tin, tannic acid), defoaming agents, crease inhibitors, dispersing agents, ultraviolet (UV) protective agents, salts, acids, bases, and surface active agents (softeners, wetting agents, emulsifiers). As a result, effluent is produced that could harm the ecosystem and all living things[35,51].

These contaminants' long-range movement and long-term persistence in the environment (soil, water) pose serious health risks to living organisms. Furthermore, they diminish soil fertility and aquatic plants' ability to photosynthesise, which leads to the development of anoxic conditions for aquatic plants and animals. The makeup of textile wastewater varies greatly. The dyeing and finishing procedures generate large quantities of hazardous and difficult-to-treat compounds that end up in wastewater[2,54]. Surfactants, salts, heavy metals, enzymes, oxidising and reducing agents, and other contaminants are all present in effluents.

These effluents have a detrimental impact on surface and groundwater resources, as well as soil quality, when they are discharged into soil and water[25]. The majority of the state's textile dying enterprises are centred around Pali, Balotra, Jodhpur, Sanganer, and Bagru. Both Sanganer and Jaipur, which have more than 600 textile dyeing companies each, are well-known for their age-old methods of printing and dying textiles. Since these businesses utilise a lot of water and chemicals for wet processes like dyeing, they generate a lot of chemically rich wastewater effluent[43].

Trace metals such as copper (Cu), zinc (Zn), arsenic (As), and chromium (Cr) are present in wastewater from dyeing plants. Furthermore, 75% of used salts end up in the environment. A significant amount of acids, alkalis, inorganic pollutants, caustic soda, and soda ash are also present in the effluent. Singh and colleagues, 2022. The waste water discharge has undesirable qualities due to the variety of pollutants present. The ratio of acids to alkalis in the effluents determines the water's pH, which ranges from acidic to alkaline and occasionally near neutral. The wastewater's electrical conductivity (EC) is high due to the substantial numbers of ions from different salts it contains[34].

The soil's quality is additionally deteriorated by the ongoing use of textile wastewater. Due to hard and barren soils, the high levels of sodality and alkalinity in the contaminated water have harmed the growth of a number of crops[22]. The study's foundation is a comparison of the chemical and morphological characteristics of the shrubs found in textile effluents.

1 *Characterization of textile wastewater :*

Wet processing and dry processing are the two types of textile mills that can be separated according to the waste and wastewater they generate. Cleaning wastewater, process wastewater, noncontact cooling wastewater, and steam water are among the wastewater produced by the textile industry.

The majority of textile wastewater is produced in wet processing facilities, while solid waste is typically produced in dry processing facilities. BOD, COD, TDS, colour, total suspended solids (TSS), heavy metals, and other characteristics can be used to describe raw textile dyeing wastewater. The pH (2–14), COD (50 ppm–18,000 ppm), TDS (50 ppm–6000 ppm), and colour of the textile wastewater vary greatly[53]. As table-1 illustrates, textile wastewater is difficult to treat due to fluctuations in several parameters, including pH, colour, temperature, TDS (total dissolved solids), TSS, and dissolved solids (DO)[17].

Table-1. Characterization of textile wastewater[17]

Category	COD (ppm)	BOD (ppm)	Temperature	Ph
Low	460	100	31	10
Average	970	270	28	9
High	1500	500	28	10

2. *Effect of textile pollution on soil :*

According to Emadodin *et al.*,[13], soil is a fundamental source of agricultural growth and affects practically every stage of the life cycle. Wastewater irrigation is widespread in tropical and subtropical areas worldwide[39]. The physical, chemical, and biological characteristics of the soil may change when agricultural areas use various industrial wastewaters[33]. Textile effluent still contains significant concentrations of a number of heavy metals, including chromium, copper, and zinc, which can have an impact on soil and the plant ecology[21]. By increasing the activity and diversity of microorganisms, agricultural fields watered by industrial effluents may have an impact on the physical and chemical characteristics of the soil as well as soil fertility[33]. The main source of nutrients in textile waste water is dye bath auxiliaries that contain nitrogen and phosphorus, such as urea, ammonium acetate, ammonium sulphate, and phosphate. Microbes can access more nutrients when industrial effluent irrigation is used[29].

The buildup of heavy metals in soil is influenced over time by the usage of both treated and untreated wastewater[8,52]. According to a number of studies, the ongoing use of industrial effluents to irrigate agricultural fields causes heavy metals to build up in the soil[8,19]. Heavy metal concentrations in the agricultural soils of Huizhou, China, including Cu, Zn, Ni, Cr, Pb, Cd, As, and Hg, ranged from 1.65 to 99.8, 16.8 to 248.8, 2.61 to 112, 1.12 to 81.1, 4.92 to 108.1, 0.01 to 1.12, 1.1 to 137.8, and 0.01 to 3.39 mg.kg-1, according to Cai *et al.*,[6].

Nonetheless, the Chinese National Environmental Monitoring Centre (1990) suggested that these heavy metals had reference values of 17, 47.3, 14.4, 50.5, 36, 0.056, 8.9, and 0.078 mg.kg-1, respectively. The greater concentration of heavy metals in effluent sludge necessitates a pre-treatment procedure to lower the metal content before the sludge may be applied to agricultural land as fertiliser or soil conditioner[21]. To safeguard agricultural land, water, and the environment, an efficient wastewater treatment system should be maintained operational and an essential component of the textile sector.

3. *Effect of textile pollution on plants :*

According to reports, 50% of the vegetables consumed in cities in Asia and Africa come from agricultural areas that are irrigated with wastewater. The nitrogen content of the text Begum *et al.,*[3] found that the tile effluent in two areas of Gazipur and Narayanganj, Bangladesh, was high, at roughly 0.05% and 0.07%, respectively. There were six treatments with varying effluent levels, fresh water fractions, and Recommended

Dose of Fertiliser (RDF) levels. On agricultural soils, it was shown that every treatment significantly improved the yield characteristics of jute vegetables as compared to the control. However, compared to the control, effluent irrigation had a detrimental effect on polluted soils[3].

The growth of sea marigolds planted in soil that was irrigated with partially diluted textile effluents was investigated by Ganesan and Chellappan[14]. The data demonstrated a favourable influence on plant shoot length and root length, plant biomass, chlorophyll content, and carotenoid of three different cultivars of wheat, as compared with raw effluent irrigated plants. Furthermore, the absence of textile effluent allowed the responsive plant to grow and develop to its full potential. While seeds sprouted in undiluted effluents did not survive for a longer amount of time, textile effluent did not hinder seed germination at low concentrations[26].

Several other studies found that when textile effluents were irrigated at low concentrations, they had comparable effects on the germination, biomass, chlorophyll pigments, and root growth of pea, lentil, and gramme seedlings as opposed to having a negative effect on plants when highly concentrated textile effluents were used[27]. Two types of peanuts were planted and irrigated using textile effluent, and the results showed an increase in chlorophyll content, growth yield, and germination that favourably contributed to root and shoot length, among other things[44].

Metals are necessary for the creation of colours, and numerous dyes frequently contain heavy metals as copper, zinc, chromium, lead, cobalt, nickel, and manganese[31]. Heavy metals have a dangerous impact on the ecology and pose an imminent threat to the contaminated area's food security[30,38]. Textile effluent has extremely high concentrations of zinc, copper, and cadmium (4.56, 2.69, and 2.49 mg), according to Gopalakrishnan and Jeyadoss[16]. L-1, generating a number of environmental issues and exceeding their respective permissible limits (Zn: 0.5 g mg.L-1, Cu: 0.05 mg. L-1, and Cr: 0.05 mg.L-1). Despite being a micronutrient that plants need in trace levels for growth, plants become poisonous when they absorb large amounts of copper. Similarly, cadmium exhibits toxicity via impeding plant growth[20].

In the context of soil-plant interaction, many plants, including alfalfa, lettuce, radish, and alpine pennycress, were negatively impacted by high soil concentrations of heavy metals, but those plants were only moderately affected by low concentrations[18]. Prior to being released into the environment, industrial effluent must undergo treatment because it is a major source of heavy metal accumulation in crops[8]. According to DalCorso *et al.* (2013), toxic metal ions and nutrients from the soil enter plant tissues, and an excessive buildup of heavy metals in plant tissue affects plant biomass, root elongation, seed germination, and chlorophyll biosynthesis, all of which have an effect on crop productivity[45].

As the concentration of textile effluents increased, the fresh and dry biomass of plants dropped; a high concentration of the effluent prevented plants from surviving[42]. If there is not enough water for irrigation, textile wastewater can be used safely to irrigate crops and plants after being properly treated[42]. The majority of research has demonstrated that irrigating plants with partially diluted effluents improves their growth and development of other morphological parameters. Conversely, the plants suffered from the extremely concentrated textile effluent.

The complex mixture of organic and inorganic contaminants, dyes, and heavy metals found in textile effluent poses serious hazards to the environment, plant health, and soil quality. Although the presence of nutrients in low or diluted concentrations of effluents may momentarily promote plant growth, their long-term and high concentration application causes toxicity, heavy metal accumulation, and soil degradation. The reviewed research repeatedly show that agricultural productivity and food safety are compromised by untreated textile effluents, underscoring the urgent need for efficient treatment strategies prior to disposal or reuse. Protecting soil health, ensuring safe crop production, and preserving ecosystems all depend on the adoption of sustainable wastewater management techniques and the rigorous implementation of environmental laws.

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