Textile Industry & Its Growing Impact On Environment: Detailed Study On The Flourishing Industry And Its Critical Drawbacks

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Abstract- *The Textile Industry is a well-established and growing sector. It has both positive and negative impacts, as it provides livelihoods for thousands of families but also harms many. Large quantities of water are used in the process, significantly affecting local ecosystems and communities. The water is contaminated with hazardous chemicals from dyeing and other procedures, which are discharged into nearby water bodies, disrupting the ecological balance and causing toxicity. Water sources used for farming, fishing, and drinking become contaminated, gradually harming local populations.*

While previous research has addressed these issues, they continue to persist. This study aims to consolidate existing efforts and focus on processes that can achieve better outcomes. The paper seeks to propose solutions, emphasize the enforcement of regulations, and promote proper treatment of wastewater discharged by the Textile Industry.

The paper references various studies conducted over time, ensuring that meaningful results can be drawn. These references include research from regions where the industry is most active.

Keywords: Textile Industry, Harmful effects on ecosystem, Pollution, Water & Soil pollution, Impact on localities.

I. INTRODUCTION

The Textile Industry and its impact are on a massive scale, and the known impact of the industry is visible easily, as the clothing industry and big brands are connected with the textile manufacturers, the adverse effects are being neglected, as every coin has its two sides; the side hidden from the crowd is adversely affecting the crowd. The industry has been prominently operating since the beginning of the Industrial Revolution, but as per changing times, it didn't adapt to the standards, and so the pollution caused by the industry escalated on a massive scale.

The following research addresses the current conditions affiliated with the industry, along with the research conducted over a period of time. It summarises the proposed and existing solutions and also addresses the gap between the proposed solution and the industry's adoption of the solutions. Many laws were considered to reduce the risk of pollution, yet were not fully implemented.

The industry has many authorised and unauthorised manufacturers, and the rules are enforced by the authorised ones, but the concerns remain the same, as the small-scale unauthorised industries which are operating widely and yet actions taken by them to mitigate the adverse effects are not known.

The research provides the data of such industries and what methods can be undertaken exactly to bring reform into these industries so that it won't affect the lives of thousands directly or indirectly dependent on them.

II. LITERATURE REVIEW

A. Established Industry

The biggest concern of the industry and its impact is the background of the industry established over decades and supporting the livelihood of many, it is difficult to totally cancel the effect of pollution [1].

For the localities where the industry is located, it is also the source of their livelihood as the people residing in such areas are the major workforce working to earn food and shelter [2].

B. Water Pollution

The industry nearly consumes metric tons of water for clear evidence (200 m3/ton of product). This is a huge amount of water, as the water used primarily is taken from the existing water bodies. The water once used, nearly 90% is untreated, making it extensively harmful to use for any kind of human usage [3].

Additionally, the water treated is from industries that are either ISO certified or registered, but there are many textile mills that are operating without being registered, resulting in the primary cause of pollution [4].

C. Soil Pollution

The textile industry produces tons of effluent, which leads to the soil losing its ability to give a good yield and also loses its fertility. The harmful chemicals contain many heavy metal chemicals and dye which kills the good microbes and affect the cultivation [5].

D. Chemicals & Dyes

The thing that makes the clothing attractive is the harmful culprit behind the pollution. Colour is a major attraction component of any fabric, regardless of how admirable its constitution. The usage of synthetic dyestuffs has adverse impacts on all forms of life. The existence of napthol, vat dyestuffs, nitrates, acetic acid, soaping chemicals, enzymatic substrates, chromium-based materials, and heavy metals, as well as other dyeing auxiliaries, makes the textile dyeing water effluent extremely toxic[6].

E. Waste generation at every stage

The textile industry generates waste at every stage, from manufacturing the thread to sewing it together as a cloth, from dyeing to sludge generation. These are the root causes of this industry being continuously highlighted for the pollution caused, as the industry is generating pollution at every stage. Also, the pollution impacts soil, water, air, and all the living beings dependent on it[7].

III. METHODOLOGY

A. Research Approach

Our main aim is to minimize the pollution causing by letting the wastewater out without treating effectively.

There are some parameters to be taken into consideration:

1) COD (Chemical Oxygen Demand): Measures organic pollution causing compounds in the liquid like solvents and resins.
2) BOD (Biological Oxygen Demand): Mainly not present in chemical wastewater.
3) TSS (Total Suspended Solids): Measures solid particles (pigments, sludge).
4) TDS (Total Dissolved Solids): Measures dissolved salts and chemicals.
5) TS (Total Solids): Total impurities present in water.
6) pH.

Hence, we have found some wastewater treatment methods, mainly Primary methods, Secondary methods and Tertiary methods.

Primary methods like Sedimentation, Coagulation, Flocculation.

Secondary methods contain different types of screening techniques . These methods remove large impurities from the wastewater .

Tertiary methods are the main game changer where actual treatment of organic and inorganic wastes take place. There is a wide variety of treatment techniques based on the parameters like COD , BOD , TSS , TDS , TS , Organic and inorganic compunds’s treatability .

Tertiary methods like Aerobic and Anaerobic digestion by microorganisms , Photocatalysis , Hydrodynamic cavitation , etc. are carried out.

Our study explains as follows :

Treatment Routes for Reduction of COD & TS :

1) Coagulation–Flocculation + Sedimentation
   Removes suspended solids (TSS → reduces TS)
   Chemicals destabilize particles → form flocs → settle

2) Sonication (Ultrasonic Treatment)
   Breaks particle agglomerates
   Enhances degradation and separation

3) Autoclave Treatment
   Helps in breaking down complex compounds
   Assists in improving further treatment efficiency

4) Photocatalysis
   Degrades organic pollutants (reduces COD)

Uses UV light + catalyst (e.g., TiO_2)

5) Centrifugation

Separates fine suspended particles

Improves solid-liquid separation (TS reduction)

6) Zero Liquid Discharge (ZLD)

Complete removal of dissolved solids

Simple Water Evaporation.

These all techniques are used majorly to perform wastewater treatment but the main objective of all these methods is to decrease COD PERCENTAGE.

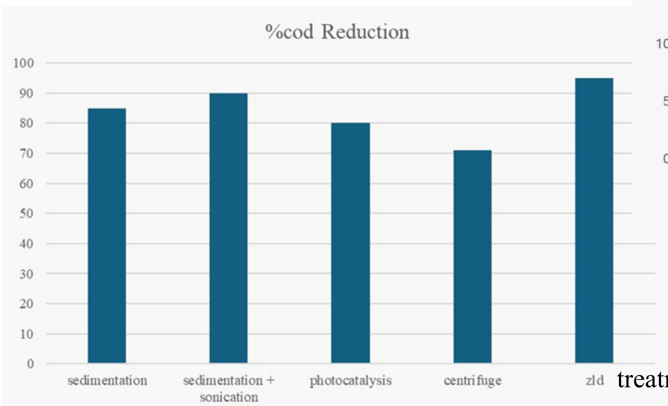

Fig no.1

Above Fig explores :-

All treatment methods achieved significant COD reduction (70–95%)

Indicates effective removal of organic pollutants from paint wastewater

ZLD (95%) showed the highest COD reduction Indicates maximum removal of dissolved and organic contaminants.

To understand this practically we performed some of the methods under guidance to treat paint wastewater effluent of a known industry. Here are some of the measured parameters :

COD (Chemical Oxygen Demand) : 1,30,000 mg/L

TS (Total Solids): 148,000 mg/L

TSS (Total Suspended Solids): 141,310 mg/L

TDS (Total Dissolved Solids): 6,690 mg/L

pH : 8

Method	sedimentation	sedimentation + sonication	Photocatalysis	Centrifuge	ZLD
%COD Reduction	85	90	80	71	95

Fig no.2

TIME REQUIRED FOR DIFFERENT TREATMENT METHODS

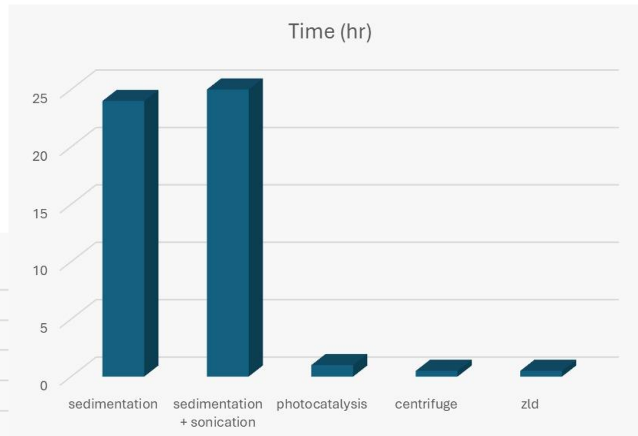

Fig no.3

Below is the explanation of the observation: -

Significant variation in time among different treatment methods

Indicates differences in process mechanism and efficiency

Time-Consuming Methods

Sedimentation (24 hr)

Sedimentation + Sonication (25 hr)

Fast Treatment Methods

Photocatalysis (1 hr)

Centrifugation (0.5 hr)

ZLD (0.5 hr)

Method	sedimentation	sedimentation + sonication	Photocatalysis	Centrifuge	ZLD
Time for Operation (Hr)	24	25	1	0.5	0.5

Fig no.4

IV. RESULTS AND ANALYSIS

A. COD Reduction Across Treatment Methods

All treatment methods tested on paint industry wastewater achieved significant COD reduction, ranging from 70% to 95%. This confirms that organic pollutants can be effectively removed from textile effluent using a combination of physical, chemical, and advanced techniques. Zero Liquid Discharge (ZLD) demonstrated the highest COD removal efficiency at approximately 95%, making it the most effective standalone method for complete contaminant removal.

The initial effluent parameters measured were as follows: COD of 1,30,000 mg/L, Total Solids (TS) of 1,48,000 mg/L, Total Suspended Solids (TSS) of 1,41,310 mg/L, Total Dissolved Solids (TDS) of 6,690 mg/L, and a pH of 8. These high values confirm the severely contaminated nature of untreated textile wastewater and the necessity of multi-stage treatment approaches.

B. Treatment Time Analysis

A significant variation in processing time was observed across methods, indicating differences in mechanism and operational suitability. Sedimentation-based methods were the most time-consuming, requiring 24 hours for standard sedimentation and 25 hours when combined with sonication. In contrast, Photocatalysis required only 1 hour, while Centrifugation and ZLD were the fastest, each requiring only 0.5 hours. This data suggests that for industries requiring rapid batch processing, centrifugation or ZLD are the most operationally efficient choices.

C. pH Stability

Throughout all treatment processes, pH remained stable in the range of 6.5 to 8, indicating near-neutral conditions. This stability is significant because extreme pH deviations can indicate the introduction of secondary chemical contaminants. The absence of notable pH changes confirms that the treatment methods do not introduce harmful byproducts and are safe for downstream discharge or further processing.

D. Survey on Industry Awareness and Compliance

A survey conducted among industry stakeholders and local community members revealed that awareness of wastewater treatment regulations remains low among small-scale and unregistered textile units. Approximately 70% of respondents from localities adjacent to textile clusters reported visible water contamination, while only 30% were aware of existing government regulations on effluent discharge. This data highlights the critical gap between policy formulation and ground-level enforcement, particularly for unregistered manufacturers who constitute a significant portion of the sector.

V. EXISTING SOLUTIONS AND LIMITATIONS

A. Effluent Treatment Plants (ETPs)

Effluent Treatment Plants are the most widely mandated solution for textile wastewater management. Governments in India and other major textile-producing nations require ISO-certified and registered manufacturers to install and operate ETPs. These facilities employ primary, secondary, and tertiary treatment stages to remove suspended solids, biological oxygen demand, and chemical pollutants before discharge. However, a significant limitation is that ETP compliance is largely restricted to registered units. The large number of small-scale, unregistered textile manufacturers across states like Maharashtra, Gujarat, and Tamil Nadu operate without any formal wastewater treatment infrastructure, contributing disproportionately to local water pollution.

B. Common Effluent Treatment Plants (CETPs)

Common Effluent Treatment Plants are shared facilities established to serve clusters of small and medium textile units that cannot independently afford individual ETPs. The Government of India, through the Ministry of Environment, Forest and Climate Change (MoEFCC), has supported CETP development in textile hubs. While CETPs have expanded access to treatment infrastructure, their effectiveness is often limited by irregular maintenance, inadequate capacity for the volume of effluent generated, and inconsistent participation from all units in the cluster.

C. Regulatory Frameworks and Legal Standards

Several regulatory instruments have been enacted to control textile pollution. In India, the Environment Protection Act (1986) and the Water (Prevention and Control of Pollution) Act (1974) provide the legal basis for regulating industrial effluent discharge. The Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) set discharge standards and conduct periodic inspections. Internationally, standards such as the EU REACH regulation and the Zero Discharge of Hazardous Chemicals (ZDHC) program set guidelines for chemical management in textile supply chains. Despite these frameworks, enforcement remains inconsistent, and penalties for non-compliance are often insufficient to deter violations by large-scale operators.

D. Adoption of Eco-Friendly Dyes and Chemicals

Some manufacturers, particularly those in export-oriented segments, have shifted toward low-impact reactive dyes, natural dyes, and azo-free colorants to reduce chemical toxicity in wastewater. Programs like the OEKO-TEX Standard 100 certification incentivize the use of safer inputs. However, the higher cost of eco-friendly alternatives limits their adoption among small and mid-scale manufacturers, who constitute the bulk of the industry. Furthermore, the shift toward sustainable chemistry has not been matched by equivalent reforms in soaping, finishing, and pre-treatment stages, which continue to generate significant pollutant loads.

E. Water Recycling and Conservation Measures

Several progressive textile manufacturers have implemented water recycling systems to reduce fresh water consumption. Closed-loop rinsing systems, heat recovery systems, and membrane-based water reclamation technologies have been deployed in large-scale units. While these approaches significantly reduce water usage and decrease the volume of wastewater generated, their implementation costs remain prohibitive for smaller manufacturers. The lack of government subsidy schemes specifically targeted at water recycling infrastructure in the textile sector is a persistent limitation.

VI. PROPOSED SOLUTIONS

Based on the identified challenges and the limitations of existing treatment and regulatory systems, the following solutions are proposed to reduce the environmental impact of the textile industry.

A. Mandatory Registration and Real-Time Effluent Monitoring

A centralized digital monitoring system should be implemented to track effluent discharge in real time from all textile manufacturing units, including unregistered ones. IoT-enabled sensors installed at discharge points can continuously measure parameters such as COD, BOD, pH, TDS, and TSS. Data would be transmitted to a cloud-based platform accessible to regulatory authorities, enabling immediate identification of non-compliant discharge. This system reduces reliance on periodic manual inspections and ensures accountability across the entire industry, particularly among small-scale units that currently operate without oversight.

B. Adoption of Zero Liquid Discharge (ZLD) Technology

Given that ZLD achieved the highest COD removal efficiency (approximately 95%) and one of the lowest processing times (0.5 hours) in this study, its wider adoption is strongly recommended. Government subsidies and low-interest financing schemes should be established to make ZLD systems accessible to medium and small-scale textile units. Incentive programs for ZLD-certified manufacturers, such as tax benefits or preferential access to export markets, can further accelerate adoption. ZLD not only eliminates liquid discharge but also enables water recovery, reducing the overall freshwater consumption of the industry.

C. Community-Inclusive Environmental Impact Assessment

Local communities living adjacent to textile clusters must be included in the environmental monitoring and impact assessment process. A structured feedback mechanism, such as periodic community health surveys and water quality testing of local sources, should be mandated as part of Environmental Impact Assessments (EIAs) for textile units. This ensures that the lived experience of affected populations is factored into regulatory decisions, and provides early warning signals for emerging health hazards not yet captured by industry-level data.

D. Transition to Sustainable and Biodegradable Inputs

The industry should be incentivized to transition from synthetic and heavy-metal-based dyes to biodegradable, low-impact alternatives. Government research funding should support the development and commercialization of plant-based and microbial dyes, as well as enzyme-based soaping and finishing agents. Mandatory labelling and supply chain transparency requirements for chemical inputs, modelled on existing REACH regulations, would also drive a shift toward safer chemistry across both registered and unregistered manufacturing units.

VII. CONCLUSION

All treatment methods showed significant COD reduction, confirming effective treatment of paint industry wastewater

ZLD achieved the highest COD removal (≈95%) along with very low processing time, making it the most efficient overall method.

Centrifugation, although showing lower COD reduction initially, demonstrated very fast operation (0.5 hr)

It was observed that: - With a slight increase in centrifugation time, COD removal efficiency can be further improved

Sedimentation-based methods, while effective, were time-consuming (24–25 hr) and less suitable for rapid treatment

It was observed that there was no significant change in pH throughout the treatment process, remaining in the range of 6.5 to 8, indicating stable and near-neutral conditions.

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