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REMEDIATION OF SOIL POLLUTED WITH TEXTILE EFFLUENTS UTILIZING IRON NANOPARTICLES

Surya Kant Gautam M. Tech Environmental Engineering MUIT, Lucknow, Uttar Pradesh, India
Anupam Kumar Gautam Assistant Professor Department of Civil Engineering, School of Engineering & Technology, MUIT, Lucknow, Uttar Pradesh, India

ABSTRACT
The world is facing a water quality crisis due to industrialization causing illegal discharge of contaminated water. Textile industry generates colored wastewater that is difficult to treat and often discharged untreated, posing major threats to the environment. Soil column study showed heavy contamination of soil by textile wastewater and accumulation of residues till 12 cm depth. Electrokinetics was used to remediate the soil, with Fe-Gr electrodes at 5.5cm distance and 5V/cm electrical potential gradient showing the best results of removing 83% EC and 80% TOC in 4 hours. SR3 (electrokinetics integrated with GP-nZVI injection into cathode reservoir) demonstrated maximum removal of TOC (83%) and EC (80%). The cost of treatment using GP-nZVI was found to be lower than proposed electrokinetics and integrated electrokinetics methods, making it an efficient, economic, and eco-friendly option for remediation.

Keywords:
Waste Water, Textile, Soil Polluted, Treatment, Remediation

1. Background
Iron nanoparticles have a long-standing history in the treatment of textile wastewater, dating back to the latter half of the 20th century when initial research efforts explored their potential efficacy. During this era, scientists delved into the unique adsorption and catalytic properties of iron nanoparticles, laying down the groundwork for their application in mitigating environmental impacts associated with textile production. As understanding of nanotechnology and materials science advanced, so did iron nanoparticle capabilities. Throughout the 2000s and 2010s, significant strides were made in engineering these particles with tailored characteristics optimized for wastewater treatment purposes, leading to their subsequent scale-up and commercialization. This period witnessed collaborative endeavors between academia and industry that drove development of cost-effective as well as eco-friendly solutions aimed at addressing pressing challenges posed by textile wastewater pollution. Furthermore, increasingly stringent regulatory requirements coupled with growing environmental concerns propelled adoption of iron nanoparticle-based treatment technologies by textile manufacturers worldwide - aligning them with broader sustainability initiatives. Looking ahead, ongoing research aims to further enhance efficiency and versatility of these methods while ensuring continued contribution towards promoting cleaner waterways along with healthier environment for future generations.

2. INDUSTRY OF TEXTILE
The textile sector presents a significant environmental challenge due to its wastewater discharge, which primarily stems from the extensive application of chemicals in processes such as dyeing and finishing. These chemicals, comprising dyes, bleaches, and finishing agents, are rinsed off during production and contaminate water bodies through wastewater streams. Additionally, heavy metals like chromium and cadmium present in textile dyes further exacerbate pollution risks. Alongside chemicals, organic pollutants and microplastics originating from synthetic fibers contribute to the deterioration of water quality. The industry's colossal water consumption worsens this issue while substantial energy usage releases pollutants into the atmosphere that eventually find their way into water bodies. Mitigation

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efforts include deploying advanced technologies for treating wastewater alongside eco-friendly dyeing methods coupled with stricter regulations. Ultimately promoting sustainable practices coupled with consumer awareness can drive the industry towards a more environmentally friendly approach that preserves our planet's resources.

2.1. MANUFACTURING PROCESS OF TEXTILE

The production process of textiles is a multifaceted expedition that commences with the meticulous procurement of raw materials. Whether it pertains to natural fibers such as cotton, silk or wool, or synthetic fibers like polyester and nylon, each material undergoes specific preparation techniques. Natural fibers are cleansed and processed through methods such as ginning and shearing, whereas synthetic fibers are manufactured through chemical processes. These fibers are then transformed into yarns utilizing various techniques including spinning and twisting. The yarns are subsequently woven or knitted to form fabrics; weaving involves the interlacing of warp and weft yarns while knitting employs interlocking loops. Following this stage, fabrics may be subjected to dyeing and printing procedures in order to add coloration and designs respectively. Finishing techniques such as washing, bleaching, and coating serve to enhance the fabric's appearance along with its performance capabilities. Throughout this intricate manufacturing journey, rigorous quality control measures ensure that the fabric meets specified standards prior to being packaged for distribution among wholesalers, retailers or garment manufacturers; culminating in an array of diverse textiles available on the market today. This sophisticated process fuses technology alongside craftsmanship whilst maintaining strict quality control mechanisms aimed at producing textiles which adorn our lives in myriad ways.

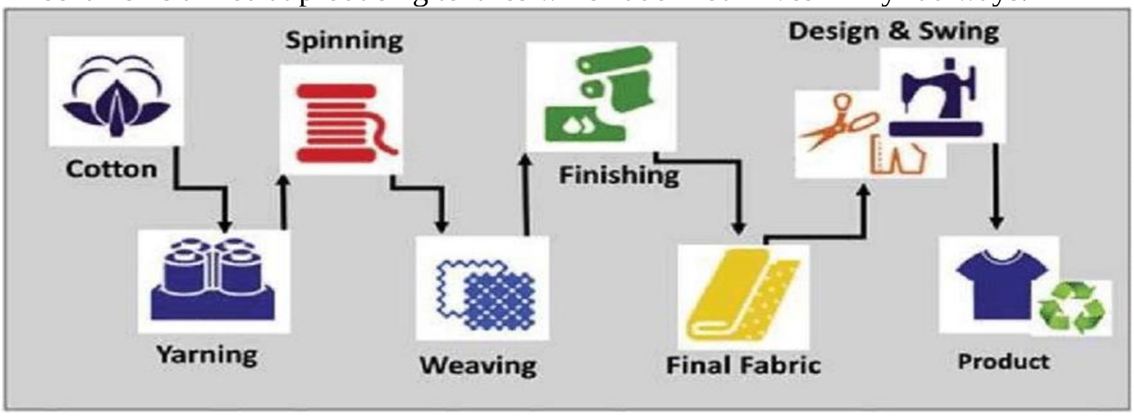

Figure-1: Process of the Textile Manufacturing.

2.2. EFFECTS OF TEXTILE EFFLUENTS ON SOIL QUALITY AND PLANT GROWTH

Textile effluents frequently contain an array of pollutants, such as heavy metals, synthetic dyes, and organic compounds. Upon discharge onto soil, these contaminants can accumulate over time and result in soil contamination. Heavy metals like chromium, lead, and cadmium - commonly present in textile mordants and dyes - have the capacity to persist in soil and disrupt nutrient uptake and metabolic processes thereby impeding plant growth. The presence of chemicals within textile effluents may degrade the structure of the soil along with its fertility; certain chemicals might even alter the pH levels of the soil which would then disturb microbial communities while reducing nutrient availability. Furthermore, organic compounds found within effluents can also reduce porosity levels within soils resulting in decreased water infiltration and aeration which ultimately leads to compaction thus reducing root growth potential. Textile effluent that is high in contaminant levels has been known to be toxic for plants whereby heavy metals tend to accumulate within plant tissues leading to effects on plant metabolism as well as growth rates. Moreover, some synthetic dyes or organic compounds could potentially have phytotoxic impacts by inhibiting seed germination rates alongside root elongation thereby affecting overall plant development negatively.

3. IRON NANOPARTICLES AS A REMEDIATION TECHNIQUE IN TEXTILE WASTE WATER

Iron nanoparticles have emerged as a promising technique for the remediation of textile wastewater due to their efficient adsorption and degradation capabilities. These nanoparticles possess a high surface area, which allows them to absorb dyes, heavy metals, and organic compounds present in the wastewater. Moreover, iron nanoparticles generate highly reactive hydroxyl radicals that facilitate the degradation of complex organic molecules into simpler and less harmful compounds via processes such as Fenton and photo-Fenton reactions. This approach is not only cost-effective but also environmentally friendly since iron is abundant and non-toxic. However, several challenges such as particle stability, optimization of treatment parameters, management of residuals, and scaling up from laboratory to industrial levels need addressing for widespread implementation. Despite these challenges though, iron nanoparticles offer a versatile and promising solution for remediating textile wastewater while providing an effective means to address pollution in this industry.

4. TEXTILE EFFLUENTS COMPOSITION AND IMPACT ON SOIL

Textile effluents, which originate from the various processes involved in textile manufacturing, possess a complex composition consisting of synthetic dyes, chemical additives, heavy metals, organic compounds and salts. Upon discharge into the environment, these pollutants infiltrate soil and lead to several adverse effects. Soil contamination occurs as these pollutants accumulate over time and poses risks to both terrestrial and aquatic ecosystems. The presence of toxic chemicals and heavy metals disrupts soil fertility and microbial balance while impeding nutrient cycles leading to reduced crop yields. Moreover, alterations in soil pH towards either acidity or alkalinity exacerbate soil degradation resulting in harm to soil-dwelling organisms that further disrupt ecosystem functions and biodiversity. Apart from ecological consequences arising due to this activity, human health risks emerge as contaminants enter the food chain through crops grown on contaminated land.

To mitigate such impacts requires strict adherence by textile industries with environmental regulations along with adopting cleaner production techniques besides deploying effective wastewater treatment technologies within their operations. Additionally essential is proactive monitoring coupled with management of soil quality in affected regions for safeguarding environmental sustainability alongside maintaining good human health standards..

5. METHODOLOGY

To comprehensively investigate the research question at hand, this study employs a meticulous methodology consisting of two primary components. These components have been meticulously designed and implemented to ensure that all relevant factors are taken into account, resulting in accurate and reliable data. The methodology utilized in this study is essential to achieving our research objectives, as it provides a structured approach to analyzing complex phenomena under investigation. By decomposing the research process into two distinct parts, we can effectively address each component systematically and thoroughly, ultimately leading to a more comprehensive understanding of our subject matter.

1. Textile wastewater treatment by iron particles.
2. Laboratory scale remediation of textile wastewater contaminated soils.

5.1. IRON PARTICLES SYNTHESIS.

During the experimental procedure, a solution of sodium borohydride with a concentration of 0.94M was introduced to a solution of ferric chloride having a concentration of 0.18M while being vigorously stirred at 400 revolutions per minute. This chemical reaction resulted in the reduction of ferric ions into elemental iron, which was confirmed by the emergence of black precipitates. Equation (3.1)

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provides explicit evidence for this process taking place. To obtain synthesized nano iron particles (B-nZVI), these black precipitates were filtered using a polytetrafluoroethylene filter measuring 0.2 m as described in Figure 3.16 and vacuum filtration techniques were employed for isolation purposes. Subsequent to filtration, multiple washes were administered to thoroughly cleanse the particles with deionized water and ethanol before being stored within vials containing an ethanol medium for later use. It is important to emphasize that this methodology confirms our ability to generate nano iron particles via reduction reactions utilizing NaBH4 and FeCl3 solutions while underscoring how pivotal it is to adhere strictly to proper filtration protocols when isolating synthesized nanoparticles intended for further study or practical applications across various fields such as medicine or industry..

Figure-2: Create green iron particles.

5.2. Soil Collection and Characterization.

Soil sample from uncontaminated agricultural land was analyzed for various properties according to Indian standards. Ions were extracted using water and several factors such as pH level, TOC, and ion concentrations were also tested. Results showed specific gravity, particle size distribution, permeability rate, liquid limit, and ion concentrations. This study provides valuable insights into the physical and chemical characteristics of this particular soil type which can aid future research in agriculture or environmental science.

Figure-3: sampling and characterization of the Soil.

6. ANALYSIS OF RESULT

This section delves into a comprehensive analysis of the groundwater contamination status and agricultural soil quality in various locations throughout Lucknow. The study aims to determine the extent of pollution and identify potential solutions to mitigate this issue. Additionally, this chapter explores the utilization of nano iron particles for textile dye degradation and treatment of textile dyeing wastewater. The investigation results are meticulously discussed, highlighting the benefits associated with utilizing nano iron particles for environmental remediation purposes. Furthermore, this research examines how textile dyes and inorganic salts interact with soil through column studies, providing valuable insight into pollutant-soil dynamics. The findings from this research are presented in detail, shedding light on complex interactions between textile effluent and soil. Moreover, this chapter reports on a novel technique developed for remediating soil contaminated by textile effluent - the nano iron-electrokinetic technique - whose efficacy is evaluated, demonstrating its potential as an effective solution to remediate contaminated soils. This chapter offers a comprehensive overview of groundwater contamination status and agricultural soil quality within Lucknow while exploring innovative techniques for environmental remediation purposes that provide valuable insights into how pollution affects our environment while offering promising solutions to mitigate its impact effectively. By understanding these complex interactions between pollutants and our environment, we can work towards developing sustainable solutions that balance economic development with environmental preservation efforts.

6.1. Variation of pH

Textile effluent is known to exhibit significant fluctuations in pH levels, which can be attributed to a multitude of factors. One primary reason for this is the alkaline nature of many dyeing and finishing processes, resulting in higher pH values ranging from 9 to 11. This is due to the frequent use of alkaline substances such as caustic soda, which are crucial for fixing dyes and improving fabric properties. Consequently, it becomes necessary to neutralize the effluent before discharging it into the environment by introducing acidic compounds that regulate pH levels within acceptable limits between 6 and 9 according to local regulations. It's important to note that variations in textile wastewater's pH levels can occur due to several factors such as type and quantity of dyes used, treatment system effectiveness, and inherent variability in production processes. Imbalanced pH levels can have severe environmental impacts on aquatic ecosystems; therefore, textile industries must monitor rigorously and employ treatment strategies that mitigate these effects. These strategies include neutralization using acidic compounds or bases depending on initial conditions followed by sedimentation or filtration treatments with biological methods if required ensuring compliance with environmental regulations while promoting responsible practices. Maintaining balanced pH levels in textile wastewater is crucial for minimizing negative environmental impacts while upholding responsible industry practices.

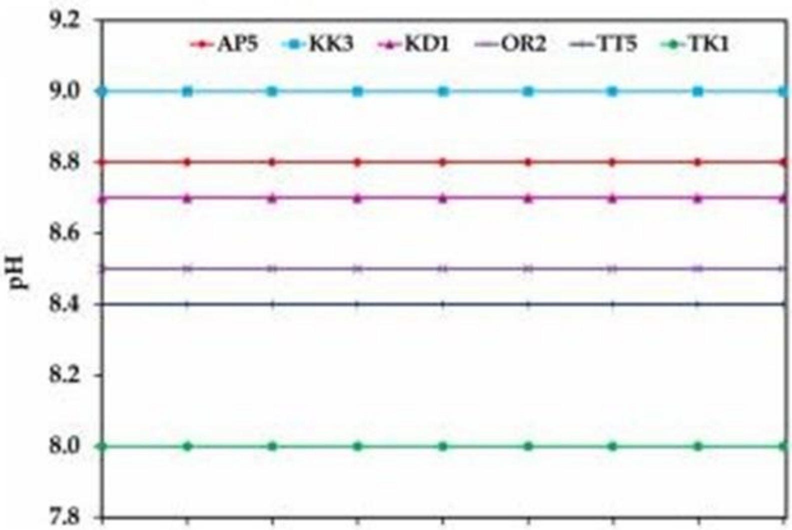

Figure-4: pH changes over time.

6.2. Temporal variation of TDS

TDS in textile wastewater is affected by production cycles, changes in processes, recycling systems, and seasonal fluctuations. Effective treatment systems are crucial for mitigating environmental concerns. Textile plants must monitor, optimize practices, and invest in advanced technologies to ensure compliance and uphold environmental stewardship. Sustainable practices benefit both business and the environment.

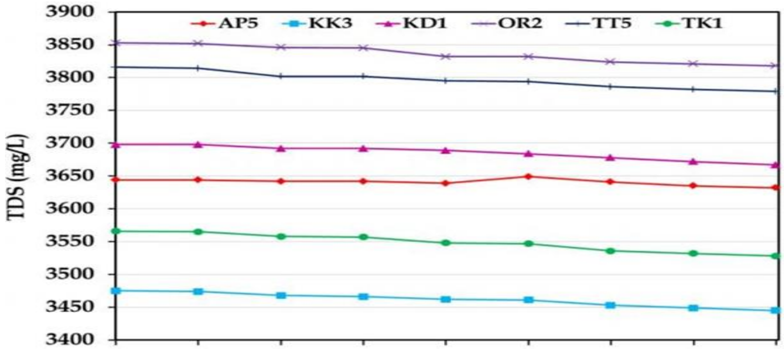

Figure-5: TDS Change over time.

6.3. Temporal variation of COD

COD levels in textile wastewater are influenced by operational and environmental factors, with peaks often occurring during periods of intensified production. Seasonal variations can also impact COD levels. Efficient wastewater treatment systems and monitoring programs are necessary to mitigate COD variability and ensure compliance with regulatory standards. Textile plants must optimize their production processes to minimize waste generation and invest in advanced treatment technologies for environmental sustainability. Proactive approaches involving continuous monitoring and optimization efforts are essential for reducing pollution and meeting regulatory requirements effectively.

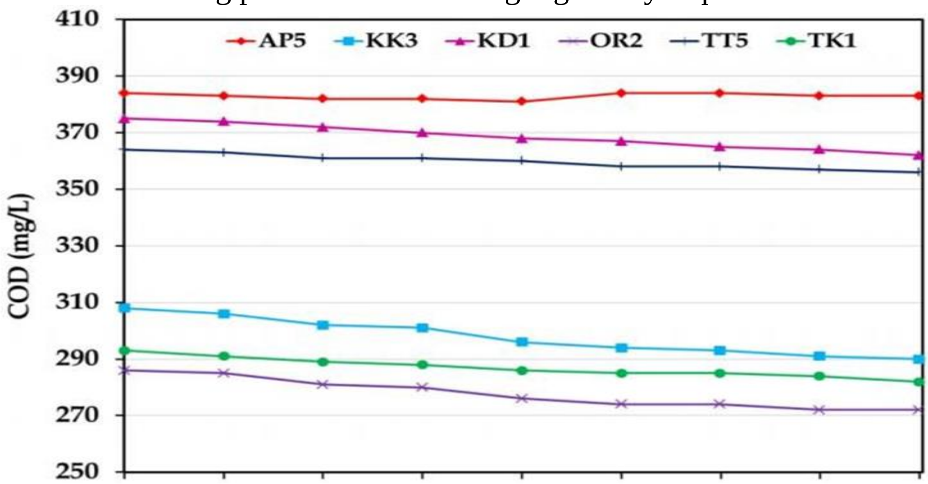

Figure-6: COD Change Over Time.

7. CONCLUSION

The court order for textile units to implement zero liquid discharge (ZLD) was a response to the detrimental impact of industrial pollution on groundwater and agricultural land, which had been brought about by public petitions and court cases. Skilled system operation and monitoring are critical for ensuring consistent RO system performance, given concerns over bio sludge disposal, mixed salts, and high energy costs associated with MEE feed that require cost-effective pretreatment techniques. Over the past three decades, rapid industrial growth has caused significant pollution in the Gomti River basin, resulting in adverse effects on groundwater and agricultural lands. Although TNPCB monitors CETPs in Lucknow for ZLD implementation purposes, remediation efforts must be undertaken to restore contaminated environments from textile wastewater discharges. Laboratory studies have assessed the status of soil contamination due to dye decolorization processes as well as iron particle-based treatment techniques aimed at addressing textile wastewaters. Contaminated soils underwent laboratory-scale remediation tests using electrokinetics integrated iron particles following investigations into textiles wastewater behavior in soils; this approach aims to confirm its feasibility. The findings from these studies have resulted in detailed recommendations regarding industry-oriented practices for field applications.

Iron nanoparticles can effectively remediate soil contaminants based on research findings from case studies that demonstrate their potential against heavy metals, organic pollutants, and radioactive materials. Iron nanoparticles possess unique characteristics such as large surface areas and high reactivity levels that enable efficient contaminant immobilization despite challenges like nanoparticle aggregation or limited iron sources; however long-term impacts on ecosystems or soil health remain a concern. Utilizing iron nanoparticles is an encouraging option for enhancing soil remediation technologies but requires further optimization along with sustainability testing before definitive conclusions can be made regarding real-world applications.

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