Ecotoxicological Assessment of Textile Industry Effluent Using Artemia salina: Acute, Chronic and Developmental Toxicity Evaluation

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Abstract:

Textile industries generate large volumes of wastewater containing dyes, salts, suspended solids, and chemically resistant organic compounds that pose serious threats to aquatic ecosystems. The present investigation evaluated the toxicological impact of textile industry effluent on the brine shrimp Artemia salina, an established model organism for ecotoxicological studies. Physicochemical characterization of the effluent revealed high pollution load, with elevated pH (9.49), alkalinity (316.71 mg/L), total hardness (383 mg/L), total dissolved solids (1462.86 mg/L), total suspended solids (339.29 mg/L), biological oxygen demand (220.71 mg/L), and chemical oxygen demand (691.43 mg/L). Acute toxicity analysis demonstrated relatively low mortality, reaching only 12.86% in undiluted effluent. However, prolonged exposure produced severe chronic toxicity, resulting in 97.1% mortality after 96 hours. The calculated 96-hour LC_{50} value was 16.89%, indicating substantial long-term toxicity. Hatching success decreased progressively with increasing effluent concentration, demonstrating developmental inhibition and delayed embryonic emergence. The findings indicate that textile effluent poses significant ecological risks and emphasize the necessity of effective wastewater treatment prior to environmental discharge.

Introduction:

Industrialization has significantly contributed to economic growth, but it has also increased the release of pollutants into aquatic environments. Among various industrial sectors, textile industries are recognized as major contributors to water pollution due to the generation of large quantities of wastewater containing dyes, surfactants, salts, suspended solids, and non-biodegradable organic compounds. The discharge of untreated textile effluent into natural water bodies adversely affects aquatic ecosystems by altering physicochemical characteristics and inducing toxicity in aquatic organisms.

Conventional physicochemical analyses provide information regarding pollutant concentrations; however, they do not adequately reflect biological impacts. Consequently, biological toxicity assays have become important tools for environmental monitoring. Artemia salina is widely used as a model organism because of its ease of culture, rapid life cycle, high sensitivity to pollutants, and suitability for toxicity evaluation.

The present study was undertaken to evaluate the toxic effects of textile industry effluent on Artemia salina through physicochemical characterization, acute toxicity assessment, chronic toxicity evaluation, determination of LC_{50} values, and hatching success

analysis. The objective was to determine the ecological risks associated with textile wastewater and assess its potential impact on aquatic organisms.

Materials and Methods

The present study was conducted to evaluate the toxicological effects of textile industry effluent on Artemia salina under controlled laboratory conditions. The investigation included physicochemical characterization of the effluent, acute toxicity assessment, chronic toxicity evaluation, determination of LC_{50} values, and hatching success analysis.

Collection of Textile Effluent

Textile effluent samples were collected from textile industrial discharge sources and transported to the laboratory in sterile polyethylene containers. Samples were stored at 4°C and analyzed within the recommended holding period to minimize physicochemical alterations.

Physicochemical Analysis

The collected effluent was analyzed for various physicochemical parameters including color, odor, temperature, pH, acidity, alkalinity, total hardness, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), biological oxygen demand (BOD), and chemical oxygen demand (COD) following standard APHA methods.

Test Organism

Brine shrimp (Artemia salina) cysts were procured commercially and used as the test organism. The cysts were stored under refrigerated conditions until use. Artemia salina was selected because of its sensitivity to environmental pollutants, ease of culture, rapid development, and widespread application in ecotoxicological studies.

Preparation of Artificial Seawater

Artificial seawater was prepared by dissolving 25 g of rock salt and 1.5 g sodium bicarbonate in one liter of distilled water. The prepared medium maintained suitable salinity and pH conditions for hatching and culturing Artemia nauplii.

Acute Toxicity Test

Different concentrations of textile effluent (10%, 20%, 40%, 60%, and 100%) were prepared using artificial seawater. Ten Artemia cysts were introduced into each concentration and maintained under laboratory conditions. Mortality was recorded after 24 hours of exposure. All experiments were conducted in triplicate along with an untreated control group.

Chronic Toxicity Test

For chronic toxicity assessment, nauplii were continuously exposed to various concentrations of textile effluent for 96 hours. Mortality observations were recorded at 24, 48,

72, and 96-hour intervals. The cumulative mortality data were used to evaluate long-term toxic effects and calculate LC_{50} values.

Hatching Success Assay

Approximately twenty Artemia cysts were exposed to different effluent concentrations (0%, 10%, 20%, 40%, 60%, and 100%). Hatching percentages were recorded at regular intervals up to 96 hours. The assay was conducted in triplicate to evaluate developmental toxicity and hatching inhibition.

Morphological Assessment

For morphological evaluation, newly hatched nauplii were exposed to LC_{50} concentrations of textile effluent. The organisms were examined under a compound microscope (10× magnification) for abnormalities including eye formation, digestive tract asymmetry, abdominal deformities, color changes, and mouthpart abnormalities. Digital images were recorded for documentation and analysis.

Statistical Analysis

Mortality data were converted into percentage mortality and subjected to Probit analysis for determination of LC_{50} values. Chronic toxicity data were analyzed based on concentration-response relationships and time-dependent mortality patterns.

Results and Discussion

Physicochemical Characteristics of Textile Effluent

The physicochemical analysis revealed that the textile effluent possessed characteristics indicative of substantial pollution load. The effluent exhibited an orange color and pungent odor, suggesting the presence of high concentrations of dyes and volatile contaminants.

The pH of the effluent was recorded as 9.49, indicating highly alkaline conditions that exceed permissible discharge limits. Elevated alkalinity (316.71 mg/L) and total hardness (383 mg/L) further confirmed the chemically aggressive nature of the wastewater. Electrical conductivity was measured at 1359.57 µS/cm, indicating a high ionic load.

Total dissolved solids and total suspended solids were recorded as 1462.86 mg/L and 339.29 mg/L, respectively. High TDS values contribute to osmotic stress in aquatic organisms, whereas elevated TSS levels increase turbidity and may impair respiration.

Furthermore, BOD and COD values were found to be 220.71 mg/L and 691.43 mg/L, respectively. These values greatly exceeded recommended discharge standards and indicated the presence of substantial organic and chemical pollution. The COD/BOD ratio of

approximately 3.13 suggested the occurrence of non-biodegradable and chemically resistant compounds commonly associated with textile wastewater.

Acute Toxicity Effects

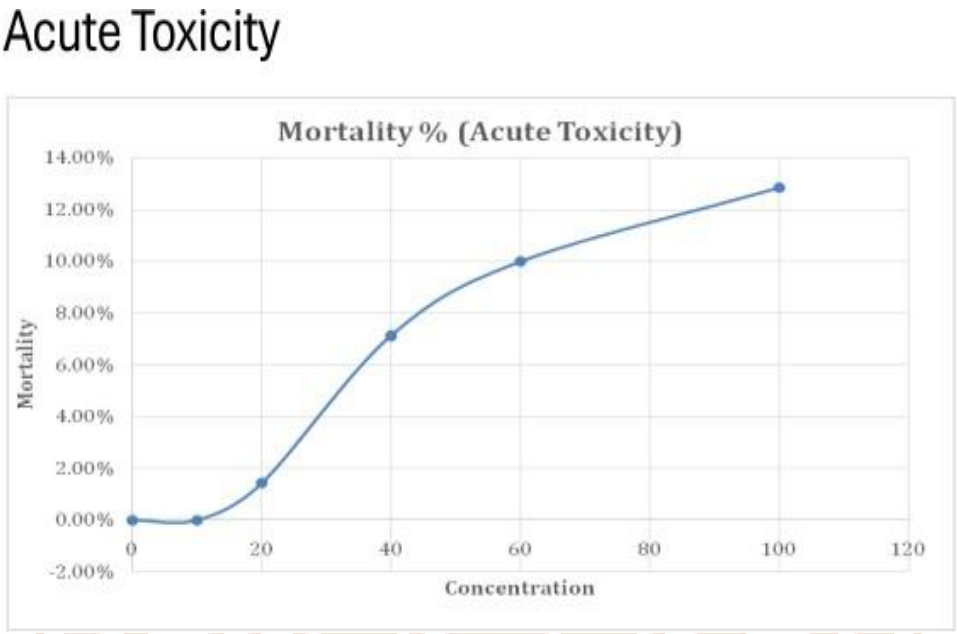

Figure: 1 Acute Toxicity

The acute toxicity assay demonstrated a concentration-dependent increase in mortality of Artemia salina. No mortality was observed in the control and 10% effluent treatments, indicating that highly diluted effluent had minimal immediate toxic effects. However, mortality increased progressively with increasing concentration.

A marked increase in mortality was observed between 20% and 40% effluent concentrations, where mortality rose from 1.43% to 7.14%. Despite this increase, the highest mortality recorded in undiluted effluent was only 12.86%, suggesting relatively low acute toxicity.

These findings indicate that short-term exposure to textile effluent causes limited mortality, possibly because toxic constituents require prolonged exposure to exert severe biological effects.

Chronic Toxicity Effects

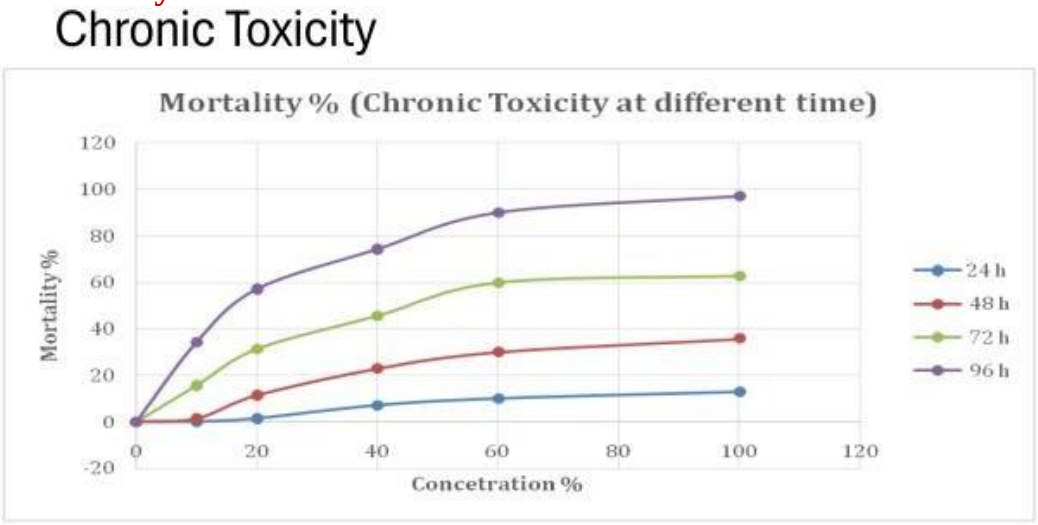

Figure: 2 Chronic Toxicity

In contrast to the acute toxicity results, chronic exposure produced pronounced concentration-dependent and time-dependent mortality. Mortality increased steadily with both exposure duration and effluent concentration.

At 10% concentration, mortality remained negligible during the early exposure period but increased to 34.3% after 96 hours. Similarly, 20% effluent concentration resulted in 57.1% mortality after prolonged exposure. Higher concentrations produced even more severe effects, reaching 74.3%, 90%, and 97.1% mortality at 40%, 60%, and 100% concentrations respectively.

The observed increase in mortality suggests cumulative physiological stress, bioaccumulation of toxic substances, and progressive impairment of metabolic processes.

LC_{50} Determination

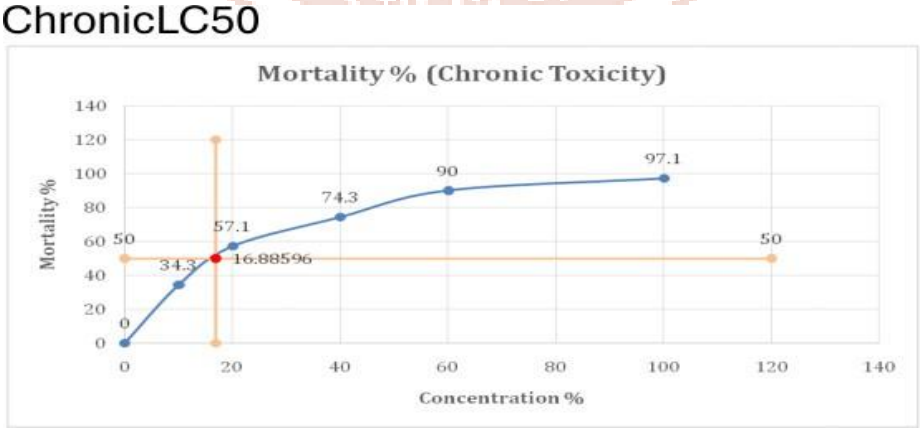

Figure: 3 Chronic LC50

The median lethal concentration (LC_{50}) for 96-hour exposure was calculated as 16.89% textile effluent concentration. This relatively low LC_{50} value demonstrates that chronic exposure to textile wastewater poses a serious threat even at diluted concentrations.

The large difference between acute mortality and chronic LC_{50} values emphasizes the importance of long-term toxicity assessments when evaluating environmental risks associated with industrial effluents.

Effect of Textile Effluent on Hatching Success

Hatching success is considered one of the most sensitive indicators of developmental toxicity because embryonic stages are generally more susceptible to environmental stressors than adult organisms. In the present study, exposure of Artemia salina cysts to textile effluent resulted in a clear concentration-dependent reduction in hatching success.

The control group exhibited the highest hatching percentage and achieved nearly complete hatching within 96 hours. In contrast, cysts exposed to textile effluent displayed delayed hatching and reduced emergence rates. Although hatching percentages increased progressively with time in all experimental groups, the final hatching success remained significantly lower in higher effluent concentrations than in the control.

At 40% effluent concentration, only 38.75% of cysts hatched during the initial observation period. Even after 96 hours, hatching success reached only 52.50%, indicating substantial developmental inhibition. Higher concentrations produced even greater suppression of embryonic development. These findings suggest that toxic compounds present in textile wastewater interfere with normal embryogenesis and delay the transition from cyst to nauplius stage.

The reduction in hatching success may be attributed to the combined effects of elevated salinity, alkaline pH, suspended solids, and chemically resistant organic compounds present in the effluent. Such stressors can disrupt osmotic regulation, impair enzyme activity, and interfere with normal metabolic processes required for successful hatching.

The observed developmental toxicity indicates that textile effluent not only affects survival but also impacts reproductive and developmental stages, thereby posing a long-term ecological threat to aquatic ecosystems.

Morphological Abnormalities in Artemia salina

Morphological assessment was conducted to evaluate sub-lethal effects of textile effluent exposure on nauplii. Examination under a compound microscope revealed several structural abnormalities among exposed organisms compared to the control group.

Observed abnormalities included:

Irregular eye development

Digestive tract asymmetry

Abdominal deformities

Alterations in body coloration

Mouthpart abnormalities

Reduced motility and swimming behavior

These abnormalities were more frequently observed in organisms exposed to concentrations near the calculated LC_{50} value. Such deformities indicate that textile effluent exerts toxic effects not only at the physiological level but also during developmental processes.

The occurrence of morphological alterations suggests interference with cellular differentiation and tissue formation during larval development. Similar abnormalities have been reported in aquatic organisms exposed to industrial pollutants containing dyes, heavy metals, and recalcitrant organic compounds.

The presence of developmental abnormalities further confirms the ecotoxicological significance of textile wastewater and highlights the importance of incorporating sub-lethal endpoints in environmental risk assessment studies.

Conclusion

The present investigation demonstrated that textile industry effluent possesses substantial ecotoxicological potential and can adversely affect the survival, development, and reproduction of aquatic organisms. Physicochemical analysis revealed elevated levels of pH, alkalinity, total hardness, total dissolved solids, total suspended solids, biological oxygen demand, and chemical oxygen demand, indicating severe contamination of the wastewater.

Acute toxicity assessment showed relatively low mortality even at high effluent concentrations, suggesting limited short-term lethality. However, chronic exposure produced significant concentration-dependent mortality, reaching 97.1% after 96 hours. The calculated 96-hour LC_{50} value of 16.89% clearly demonstrates that prolonged exposure to textile effluent poses serious ecological risks even at diluted concentrations.

Furthermore, textile effluent significantly inhibited hatching success and induced developmental abnormalities in Artemia salina. These findings indicate that industrial wastewater affects not only organism survival but also critical developmental processes that contribute to population sustainability.

Overall, the study confirms that Artemia salina is an effective bioindicator for evaluating industrial wastewater toxicity. The results emphasize the urgent need for efficient treatment of textile effluents prior to environmental discharge and support the incorporation of biological toxicity assays into routine wastewater monitoring programs.

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