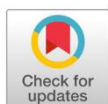


Evaluation of aquatic insects as bioindicators of water quality in industrial areas of Surabaya, East Java

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Abstract

In the industrial area of Surabaya, water quality monitoring is crucial for maintaining environmental sustainability and human health. Aquatic insects have been identified as effective bioindicators for assessing water quality in this context. This article aims to explore the biological characteristics of aquatic insects, their role as bioindicators, and their relationship with water quality parameters near the industrial area of Surabaya. Through a literature review approach, relevant sources were analyzed to obtain comprehensive insights. The biological characteristics of aquatic insects, such as abundance, species diversity, tolerance to pollution, and life cycle and reproduction, enable them to provide indications of pollution levels and the industrial impact on aquatic ecosystems. Pollution-sensitive aquatic insects, including certain species of Ephemeroptera, Plecoptera, and Trichoptera (EPT), tend to decline in abundance and diversity when water quality deteriorates. Conversely, the dominance of pollution-tolerant species, such as Chironomidae (non-biting midges), may indicate the impact of industrial pollution on water quality. Additionally, disruptions to the life cycle and reproduction of aquatic insects can signal water quality issues near Surabaya's industrial zone. A decrease in reproduction or delayed growth in aquatic insects may indicate the presence of toxic substances or unsuitable environmental conditions. Water quality monitoring should not solely rely on aquatic insect bioindicators. Other parameters, such as pH, dissolved oxygen, turbidity, and chemical indicators, are essential for a more comprehensive analysis.

Keywords: Aquatic, bioindicator, water quality

Introduction

Water quality refers to the physical, chemical, and biological conditions of an aquatic ecosystem. Key parameters include water temperature, pH, turbidity, dissolved oxygen levels, nutrient concentrations, and the presence of pollutants. Maintaining good water quality is essential to sustain aquatic life and provide safe water for human use¹. Aquatic insects, which spend all or part of their life cycle in water, inhabit various aquatic environments such as rivers, lakes, wetlands, and ponds. They



have evolved specific adaptations for surviving and interacting with aquatic environments, such as waterproof exoskeletons and the ability to breathe underwater². Bioindicators of water quality are living organisms used to evaluate water conditions based on their biological responses to environmental changes. Unlike physical and chemical assessments alone, bioindicators provide a more holistic understanding of aquatic ecosystems. They reflect the impacts of pollution, temperature shifts, and pH variations on water quality.

The Surabaya industrial area, East Java, is a rapidly growing industrial hub. The expansion of this area impacts the surrounding environment, including water quality in adjacent aquatic systems. Industrial pollution in Surabaya is attributed to various sources, including: industrial wastewater, production processes often generate hazardous chemical-laden wastewater containing heavy metals, organic compounds, and other contaminants; uncontrolled waste disposal, lack of proper waste management systems leads to untreated industrial waste being directly discharged into water bodies; airborne particulate deposition, industrial emissions containing harmful particles may be carried by wind and deposited into aquatic ecosystems; hazardous chemicals, accidental spills or improper handling of chemicals during production can contaminate nearby water bodies. Given these challenges, regular water quality evaluations around industrial areas are imperative³.

In water quality monitoring efforts, bioindicators serve as an effective tool for assessing and maintaining water quality in industrial areas. Bioindicators are living organisms that provide information about environmental conditions based on their responses to changes in their surroundings. Aquatic insects are among the most commonly used bioindicators in water quality studies due to their life cycles, which are closely tied to aquatic habitats, and their sensitivity to environmental changes⁴.

Research conducted by Suwarno (2015)⁵ identified aquatic insects from Danau Laut Tawar comprising 22 genera, belonging to 18 families and 6 orders. The composition of aquatic insect communities varied across different locations, depending on habitat conditions. The order Odonata dominated with eight genera, followed by Coleoptera and Trichoptera, each with four genera. The genus *Ischnura* was the most abundant (21.74%), followed by *Aeshna* (11.74%) and *Pantala* (10.43%). The diversity of aquatic insect genera in Danau Laut Tawar was classified as moderate, with a Shannon-Wiener diversity index (H') value of 2.68. Species from the orders Ephemeroptera, Trichoptera, and Lepidoptera (*Elophila*) were identified as indicators of clean water.

A study by Pranatasari and Adii (2017)⁶ further highlighted the use of macroinvertebrates as bioindicators for water quality monitoring. The research concluded that surface water quality at the Arboretum Sumber Brantas in Tulungrejo Village, Bumiaji Subdistrict, Batu City, part of the upper Brantas watershed, was still excellent, with a Family Biotic Index value of 3.05. The study identified six orders and eight families of macroinvertebrates in the area. Habitat and riverbank observations revealed a health score of 2.6 (moderately healthy), with a riverbed substrate classification of B (sufficient) and river health disturbances classified as A (good). Previous research has consistently demonstrated that aquatic insects can provide valuable insights into water quality. Changes in aquatic insect communities, including species diversity, abundance, and the presence of specific taxa, can indicate variations in water quality, such as pollution or environmental degradation.

Although significant research has been conducted on the use of aquatic insects as bioindicators, studies specifically focusing on the industrial area of Surabaya, East Java, remain limited. Therefore, this

research aims to evaluate aquatic insects as bioindicators of water quality in the vicinity of Surabaya's industrial zone. It is expected that the findings will enhance understanding of the industrial impact on water quality in the region. Additionally, the study aims to offer actionable recommendations for effective water quality monitoring and management in industrial areas.

Material and methods

This study employs a conceptual framework approach to evaluate aquatic insects as bioindicators of water quality. The methodology emphasizes analytical exploration of ideas and theories surrounding the use of aquatic insects as bioindicators, without relying heavily on intensive fieldwork. The approach focuses on the development, comprehension, and critical analysis of concepts relevant to the subject matter. A thorough evaluation and analysis of selected literature were conducted, emphasizing methodological quality, reliability, and relevance of the studies reviewed. Key findings, ideas, and arguments were synthesized and systematically presented. Throughout this process, a critical appraisal of the strengths and limitations of the analyzed literature was undertaken. The literature review methodology provides a comprehensive summary of existing knowledge within the field, serving as a robust foundation for future research⁷.

Research

Aquatic insects are a specialized group of insects adapted to aquatic environments. They exhibit a range of physical and behavioural adaptations that enable them to survive and reproduce in water. Aquatic insects inhabit diverse aquatic habitats, including rivers, lakes, swamps, ponds, and water pools². Examples of aquatic insects include dragonfly larvae (Odonata), which live in water as nymphs before transitioning into adult dragonflies; waterfly larvae (Diptera), commonly found in freshwater and marine environments; and water beetle larvae (Coleoptera), which possess specific adaptations for aquatic life⁸. Aquatic insects play a critical role in aquatic ecosystems. They contribute to food chains as predators or prey, facilitate nutrient cycling, and aid in the decomposition of organic matter. Additionally, they are widely recognized as indicators of ecosystem health due to their sensitivity to changes in water quality and pollution.

The taxonomy of aquatic insects provides insights into their classification and ecological roles. Generally, aquatic insects belong to: Kingdom Animalia, Phylum Arthropoda, Class Insecta. Aquatic insects belong to the class Insecta, which encompasses insects with distinct anatomical characteristics, including three pairs of legs, a pair of antennae, and a clearly segmented body comprising the head, thorax, and abdomen. Within the Insecta, aquatic insects are further classified into several orders commonly found in aquatic environments, such as Odonata (dragonflies and damselflies), Diptera (flies), Coleoptera (beetles), Hemiptera (water bugs), Trichoptera (caddisflies), Ephemeroptera (mayflies), and Plecoptera (stoneflies). Each order exhibits unique morphological and ecological characteristics, making them valuable potential bioindicators for assessing water quality. Within these orders, more specific family-level groupings exist, and aquatic insects can be identified down to the species level based on detailed physical traits. This precise classification enhances their utility in monitoring and evaluating environmental conditions.

Discussion

Aquatic insects possess distinctive biological traits and adaptations that enable them to thrive in aquatic environments. According to Tania et al. (2021)⁹, the key biological characteristics of aquatic insects include morphological adaptations, life cycle, feeding and ecology, replication and reproduction, bioindicator of water quality. Aquatic insects' exhibit specialized morphological adaptations for survival in aquatic habitats. Examples include water-repellent shields or hair-like structures on their bodies that help retain moisture and reduce friction with water. They also possess gills or other respiratory structures that facilitate underwater respiration. Additionally, they typically undergo metamorphosis, involving distinct larval and adult stages. The larvae often exhibit morphological features adapted for underwater respiration, feeding, and movement. These stages differ significantly from the adult form. Upon reaching adulthood, most aquatic insects emerge from the water to reproduce and complete their life cycle.

On the other hand, aquatic insects display diverse feeding behaviours. Some are predators, preying on small invertebrates or other aquatic insects, while others are herbivores that feed on algae or aquatic plants. Additionally, some function as detritivores, consuming organic debris in water. These feeding behaviours play vital roles in maintaining food web dynamics and nutrient cycling within aquatic ecosystems. Also, they employ various reproductive strategies. Some species lay their eggs directly in water, while others deposit them near aquatic environments or attach them to substrates using specialized structures. Embryonic and larval development generally occurs in water, where the insects spend most of their life cycle before undergoing metamorphosis into adults. These groups are widely utilized as bioindicators to assess water quality. The presence or abundance of specific aquatic insect species provides insights into the ecological conditions of aquatic habitats, including pollution levels, ecosystem sustainability, and overall water health. Species sensitive to environmental changes or pollution tend to decline or disappear, while the dominance of pollution-tolerant species can signal deteriorating water quality¹⁰.

Bioindicator are living organisms used to evaluate environmental quality or ecosystem conditions¹¹. These organisms provide insight into pollution levels, environmental changes, or ecological disturbances within a given area. Bioindicators encompass various types of organisms, including plants, animals, and microorganisms. The selection of bioindicators is based on their biological characteristics, which make them sensitive to specific environmental changes. For example, certain species of insects, fish, or plants have low tolerance to water pollution, while others, such as mosses or algae, may be more resilient to adverse conditions. By observing the population, presence, or condition of bioindicators in an area, scientists and environmental experts can assess the quality of water, air, or soil. Changes in their abundance or presence can indicate pollution, temperature fluctuations, acidity levels, and other conditions that affect living organisms.

The use of bioindicators offers several advantages. First, they provide a relatively inexpensive and straightforward method for monitoring environmental quality on a broad scale. Second, bioindicators reflect the combined effects of various environmental factors, offering a holistic view of ecosystem conditions. Finally, they are valuable for assessing the impact of environmental projects or human activities on ecosystems¹². Industrial areas are often potential sources of water pollution due to activities involving chemical usage and waste production. In such cases, bioindicators and water quality

parameters are critical tools for monitoring and evaluating the impact of industrial activities on water quality¹³.

According to Wahjono (2016)¹⁴, several key parameters are used to monitor water quality in industrial zones such as chemical substances, turbidity, organic matter, water pH, dissolved oxygen (DO), temperature, nutrients, and microorganism. Chemical substances parameter involves measuring various chemical substances, such as heavy metals (lead, mercury, and cadmium), organic compounds (pesticides, herbicides, and industrial chemicals), and other hazardous materials used or produced by industries¹⁵. These measurements help identify pollution levels and their impact on water quality. Aside, turbidity refers to the presence of dissolved or suspended solid particles in water. Industrial activities can generate solid waste or dust, increasing water turbidity. High turbidity levels can disrupt aquatic life and degrade water quality¹⁶.

Industries often produce organic waste, such as residues from food processing or industrial operations. High levels of organic matter can deteriorate water quality and affect aquatic ecosystems. Water pH can be altered by industrial discharges that are either acidic or basic. Significant pH changes can affect aquatic organisms and disrupt the balance of aquatic ecosystems. Beside, industries may impact DO levels in water through the release of waste containing oxygen-consuming substances. Low dissolved oxygen levels can harm aquatic life and lead to hypoxic conditions. It also can alter water temperature can rise due to the discharge of heated industrial waste. Significant temperature changes can negatively affect aquatic organisms and ecosystem dynamics³.

Industrial discharges rich in nitrogen and phosphorus can alter nutrient levels in water. Excessive nutrients can lead to eutrophication and harmful algal blooms¹⁷. Industrial waste containing pathogenic bacteria or microorganisms can threaten water quality and human health. Measuring the type and quantity of bacteria or microorganisms provides insight into biological contamination levels¹⁸. These parameters serve as essential benchmarks for monitoring and evaluating water quality in industrial areas. Routine measurement and monitoring of these parameters facilitate the identification of pollution sources, implementation of necessary preventive actions, and compliance with applicable environmental regulations.

Bioindicator play a crucial role in identifying and assessing water pollution levels in industrial zones. Living organisms such as aquatic insects, fish, and microorganisms are utilized as bioindicators due to their high sensitivity to changes in water quality¹⁹. A significant decline or alteration in the population or presence of these bioindicators often signals water pollution within the industrial area. In addition to bioindicators, various water quality parameters are employed to measure pollution levels in industrial settings. These parameters include chemical assessments, such as measurements of heavy metal concentrations, organic compounds, and pH levels, as well as biological parameters like dissolved oxygen content and the presence of pathogenic bacteria. These measurements provide valuable insights into the extent of pollution and its impact on water quality in industrial regions. By integrating bioindicators with water quality parameter measurements, comprehensive monitoring of aquatic environments in industrial zones can be achieved. This integrated approach enables the identification of pollution sources, evaluation of pollution levels, and implementation of necessary actions to mitigate negative impacts on aquatic ecosystems.

Furthermore, the combined use of bioindicators and water quality monitoring helps industries assess their compliance with environmental regulations and pinpoint areas requiring improvement or pollution control. This proactive approach supports sustainable industrial practices and contributes to preserving the ecological balance of water resources.

Aquatic insects can serve as valuable bioindicators for monitoring water quality in areas near the industrial zones of Surabaya. As a densely industrialized city, Surabaya faces significant risks of water quality degradation due to industrial waste discharge. The use of aquatic insects as bioindicators provides crucial insights into pollution levels and their impact on aquatic ecosystems. Monitoring aquatic insects involves assessing their presence, abundance, and species diversity in water bodies near industrial zones. Key indicators include abundance and species diversity, pollution tolerance, as well as life cycle and reproduction⁴.

Good water quality typically supports a high abundance and diversity of pollution-sensitive aquatic insect species. Conversely, poor water quality results in reduced abundance and diversity, as sensitive species are less likely to thrive. Some aquatic insect species exhibit higher tolerance to pollution. A dominance of pollution-tolerant species may indicate the adverse effects of industrial pollution on water quality¹⁰.

Disruptions in the life cycles and reproduction of aquatic insects can signal water quality issues. For instance, reduced reproduction rates or delayed development may suggest the presence of toxic substances or unsuitable environmental conditions²⁰. Periodic monitoring of aquatic insects at representative sites near industrial zones in Surabaya is essential. Data collected through such monitoring can help evaluate the impacts of industrial activities on water quality, identify pollution sources, and implement measures to mitigate negative effects. While aquatic insect monitoring is a critical component of water quality assessment, it should be complemented by measurements of other water quality parameters, such as pH, dissolved oxygen, turbidity, and chemical composition. This holistic approach provides a more comprehensive understanding of water quality near industrial areas.

Conclusions

The use of aquatic insects as bioindicators of water quality enables a more comprehensive monitoring of environmental changes caused by industrial activities in the Surabaya area. The presence of pollution-sensitive aquatic insects, declining abundance, disrupted species diversity, and disturbances in their life cycles and reproduction can serve as clear indicators of water quality issues that require immediate attention. It is important to note that water quality monitoring should not rely solely on aquatic insect bioindicators. Additional parameters, such as pH, dissolved oxygen levels, turbidity, and chemical composition, must also be measured to provide a more complete understanding of water quality near industrial zones in Surabaya. By implementing comprehensive monitoring that integrates aquatic insect bioindicators with these water quality parameters, pollution sources can be identified, pollution levels evaluated, and effective measures taken to mitigate the negative impacts on water quality and aquatic ecosystems in industrial areas. Such efforts are essential for ensuring environmental sustainability and protecting human health associated with water resources.

Acknowledgments

Conflicts of Interest

The authors declare no conflict of interest

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