

Odonata as Bioindicators of Wetland Health: Assessing the Correlation Between Dragonfly Diversity and Heavy Metal Concentration in Industrial-Adjacent Wetlands of Aligarh, Uttar Pradesh

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ABSTRACT

Heavy metal pollution from tanneries and lock factories and electroplating units which together create the industrial base of Aligarh, Uttar Pradesh, puts increasing stress on wetlands which exist in India's developing industrial areas. This study investigates the potential of Odonata (dragonflies and damselflies) to function as bioindicators for wetland degradation in this specific regional context through its analysis of odonate species diversity and heavy metal concentrations found in water and sediment. Researchers conducted surveys at six wetland locations which extended from industrial areas to rural zones, measuring species richness and abundance and determining assemblage composition while they performed water and sediment tests to detect lead and chromium and cadmium and zinc and nickel presence. The study results show that odonate diversity decreases with increasing heavy metal pollution because industrial sites which receive wastewater discharge show diminished native species populations which include pollution-resistant common species. The areas which received waste from industrial activities showed higher odonate diversity which created more complex odonate habitats. The research demonstrates that Odonata function as affordable wetland health indicators which provide ecological insights for peri-urban and industrial areas throughout the Indo-Gangetic Plain, with results that directly affect wetland conservation regulations in Uttar Pradesh.

Keywords: Wetland health, odonata, heavy metal contamination, odonate diversity, bioindicators

I. Introduction

There is a pond on the southeastern edge of Aligarh city that most residents probably do not think about. The pond exists behind a group of small lock-manufacturing factories which show its surface through a thin layer of metallic waste that creates iridescent reflections. The wandering glider which scientists call *Pantala flavescens* still hovers above the water margin during good morning conditions. The bad conditions make the surface remain silent because wetlands should never behave this way.

Aligarh occupies a complicated ecological position. The city is famous across India and internationally for its lock industry but it also hosts one of the largest concentrations of tanneries in Uttar Pradesh which operates together with electroplating units brass foundries and chemical processing facilities. The industries release wastewater which contains high levels of chromium lead cadmium nickel and zinc through drainage systems that lead to the city wetlands and ponds and temporary water bodies. The Aligarh region sits within the broader Indo-Gangetic Plain which represents one of the most densely populated areas

in the world and an agriculturally vital region. The wetlands of this area provide numerous essential services which include groundwater recharge and flood control and bird breeding grounds and support for local fishing operations.

Despite this ecological importance, systematic monitoring of wetland health in and around Aligarh remains inadequate. Chemical analysis of water quality is conducted irregularly, tends to focus on a narrow range of parameters, and rarely integrates biological indicators that capture the cumulative, ecologically relevant effects of pollution rather than a single-point chemical snapshot.

This is where Odonata come in. Dragonflies and damselflies are not just charismatic insects — though they certainly are that. They are ecologically sensitive, taxonomically tractable, and intimately tied to aquatic systems throughout their larval development. Their diversity and assemblage structure respond predictably to a range of water quality parameters, including heavy metal contamination. Globally, Odonata have gained considerable credibility as bioindicators, but their

application in industrially impacted wetlands of northern India — and specifically in the Aligarh context — remains underdeveloped.

This article presents findings from a structured survey of six wetland sites in and around Aligarh, comparing odonate diversity metrics with measured heavy metal concentrations. The goal is both scientific and practical: to assess whether odonate assemblages reliably track heavy metal pollution in this specific regional context, and to make the case for incorporating Odonata-based monitoring into routine wetland management in Uttar Pradesh.

II. Background: Odonata as Ecological Indicators

2.1 Why Dragonflies Make Good Monitors

The process of using Odonata as bioindicators becomes simple to understand after people learn about their life cycle. The most visible dragonflies to the public are adult dragonflies which display their fast flying ability through their sparkling wings as they patrol nearby ponds while they hover above the water. The most crucial period for monitoring purposes exists during the larvae stage of development. Odonate larvae, referred to as naiads or nymphs, spend their entire life cycle within aquatic environments which last from several months to multiple years depending on their specific species. The fish use gills for respiration and they consume tiny aquatic animals while their defensive abilities remain low because they cannot escape dangerous water conditions which adult fish can flee through flight.

The extended time that larvae spend underwater makes them highly vulnerable to any changes in water quality. Odonate larvae experience heavy metal effects through multiple channels which include the direct gill tissue damage and the halting of their molting and metamorphosis processes and the bioaccumulation through the food web and the disturbance of adult reproductive signaling which affects their egg-laying behavior. Species exhibit different levels of sensitivity because generalists can handle moderate pollution while specialists with specific environmental needs vanish when their surroundings start to deteriorate. The sensitivity variation among different organisms renders their group structure useful for research purposes. A site with twenty species tells a different story than one with three, even if both have water in them.

Adult Odonata are also useful for a more practical reason: they are relatively easy to survey. Trained observers can identify many species in the field from a reasonable distance, and standardized

transect-based survey methods produce reliable, repeatable diversity estimates without requiring destructive sampling. In resource-limited monitoring contexts — which describes most of rural and peri-urban Uttar Pradesh — this matters a great deal.

2.2 Heavy Metals and Aquatic Invertebrates

Heavy metals enter wetlands through different routes of entry. The most direct route of industrial effluent discharge leads to wetlands whereas three other routes atmospheric deposition and agricultural runoff and contaminated soil leaching all lead to metal entry into wetlands. Metals enter aquatic systems and distribute themselves between water and sediment. Sediment builds up metals through time which produces an contamination history that water column assessments cannot detect. Benthic organisms such as odonate larvae experience their main contact with metals through their habitat because they spend most of their time on the bottom of aquatic environments (Jain et al., 2005).

The Aligarh area suffers from buried chromium as its main environmental problem. The harmful tannery waste contains Cr⁶⁺ hexavalent chromium which exists in its most hazardous state because it combines high solubility with high aquatic organism absorption. The industrial drainage system of Aligarh receives typical contaminants which include lead from battery recycling and soldering lead and cadmium from electroplating and zinc and nickel from multiple manufacturing processes. The individual metal contaminants show different impacts on aquatic invertebrates but their combined presence results in a cumulative toxicity which destroys sensitive species while maintaining a population of generalist organisms that lack sensitivity (Srivastava & Sinha, 2009).

III. Study Area and Methods

3.1 Aligarh's Wetland Landscape

Aligarh district sits in western Uttar Pradesh, roughly midway between Agra and the Gangetic floodplain. The landscape is predominantly agricultural, punctuated by a network of seasonal and perennial water bodies — locally called *taals* or *jhils* — that fill during the monsoon and persist through varying portions of the dry season. Urban expansion and industrial development have progressively encroached on many of these wetlands, modifying their hydrology, reducing their area, and altering their water chemistry.

Six study sites were selected along a gradient from high industrial influence to relatively low anthropogenic impact. Sites 1 and 2 lie within or immediately adjacent to active industrial zones in

the city's southern and southwestern quarters, receiving drainage from tannery clusters and electroplating units. Sites 3 and 4 are located in peri-urban areas with mixed land use — some industrial activity but also agricultural fields and residential areas. Sites 5 and 6 are rural wetlands approximately 20 to 35 kilometers from the city center, representing the lower end of the industrial impact gradient while still situated within the same river drainage system.

All six sites are shallow, seasonally to permanently inundated water bodies with emergent and marginal vegetation, making them potentially suitable odonate habitat in the absence of contamination. This design choice was deliberate: comparing fundamentally similar habitat types ensures that differences in odonate assemblages reflect water quality differences rather than gross habitat dissimilarity.

3.2 Survey and Sampling Methods

Odonate surveys were conducted using 100-meter standardized transect walks along wetland margins, repeated four times across the study period to capture seasonal variation — once in pre-monsoon (April–May), once during peak monsoon (August), and twice in the post-monsoon period (October and December). Adult identification followed Kumar & Prasad (2008) and Subramanian (2009). Larval sampling using kick-net methods provided supplementary data and confirmed the presence of breeding populations rather than transient visitors at each site.

Water samples were collected monthly from three locations within each site and composited for analysis. Sediment cores to 10 centimeters depth were collected quarterly. Both matrices were analyzed for total chromium, lead, cadmium, zinc, and nickel using flame atomic absorption spectrophotometry, following standard methods (APHA, 2005). A pollution index was calculated for each site by summing normalized metal concentrations relative to freshwater quality guidelines published by the Bureau of Indian Standards.

Species richness, Shannon diversity index (H'), and Pielou's evenness index (J') were calculated for each site based on pooled survey data. Spearman rank correlation was used to assess relationships between odonate diversity metrics and the composite heavy metal pollution index, given the non-normal distribution of the data.

IV. Results

4.1 Heavy Metal Concentrations Across Sites

The six sites displayed clear variations in metal contamination which matched expected patterns based on their distance from industrial areas. The water at Sites 1 and 2 contained chromium at levels between 0.34 and 0.61 mg/L which exceeded the Bureau of Indian Standards drinking water limit of 0.05 mg/L and showed higher concentrations than freshwater ecotoxicological reference values established for invertebrates. Lead concentrations at these sites reached 0.18 to 0.29 mg/L in water and exceeded 280 mg/kg dry weight in surface sediments.

The contamination levels at Sites 3 and 4 reached an intermediate level between high and low contamination. The sites detected chromium and lead but their levels reached only one-third to one-half of the levels found at Sites 1 and 2. The sites detected cadmium and nickel at low levels which remained above zero. The metal levels at Sites 5 and 6 reached regional background levels while zinc showed a minor increase which scientists believed came from agricultural waste instead of industrial point-source emissions.

The composite pollution index provided a clear representation of the gradient which showed Sites 1 and 2 obtained scores of 8.4 and 7.9 on a scale that classified values above 5 as industrial multi-metal contamination. The scores for Sites 3 and 4 reached 4.1 and 3.7. Sites 5 and 6 scored 1.4 and 1.1 — within the range expected for moderately managed agricultural wetlands.

4.2 Odonate Diversity Patterns

Across all sites and survey rounds combined, 34 odonate species were recorded — 22 dragonfly species (Anisoptera) and 12 damselfly species (Zygoptera). The most frequently encountered species at contaminated sites were *Pantala flavescens*, *Crocothemis servilia*, and *Brachythemis contaminata* — all known generalist dragonflies with broad environmental tolerances. Sensitive species including *Pseudagrion microcephalum*, *Ceriagrion coromandelianum*, and *Ichnogomphus rapax* were restricted almost entirely to Sites 5 and 6.

Species richness showed a clear relationship with the pollution gradient. Site 1 supported only 7 odonate species across all survey rounds; Site 2 yielded 9. Sites 3 and 4 returned 16 and 18 species respectively. Sites 5 and 6 produced the richest assemblages, with 26 and 28 species recorded. Shannon diversity and evenness values followed the same pattern — highly contaminated sites were not

just species-poor but dominated by single abundant generalists, producing low evenness values that reflected community simplification rather than just species loss.

As shown in Figure 1, the inverse relationship between the composite heavy metal

pollution index and Shannon diversity index is consistent and statistically significant across the six sites, with the regression showing that pollution index scores explain approximately 91% of the variance in H' values.

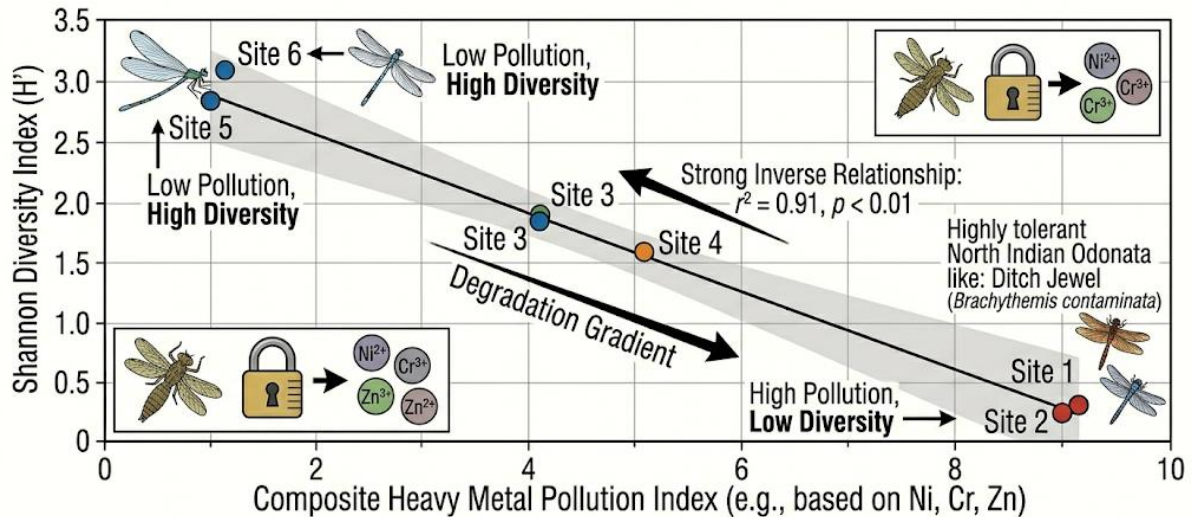


Fig.1: Inverse Relationship Between Composite Heavy Metal Pollution Index and Odonate Shannon Diversity Index (H') Across Six Aligarh Wetland Sites, Source: Author Generated

V. Assemblage Composition and Indicator Species

Contacting any street with every target except for one present remains impossible. The diagnostic value of an assemblage depends on both its diversity metrics and its actual assemblage composition. The non-metric multidimensional scaling process showed distinct pollution level patterns through species composition analysis which resulted in three distinct site groupings. The various species groups maintained their spatial organization throughout the four survey periods because their assemblage structure showed chronic pollution patterns instead of temporary environmental changes.

The following species emerged as positive water quality indicators because their presence indicates low metal contamination levels. The *Ictinogomphus rapax* dragonfly which has distinct visual features belongs to the clubtail family and exists only at Sites 5 and 6 which makes it a strong indicator species for wetlands with clean water and high oxygen levels that exist in this area. The *Pseudagrion microcephalum* damselfly which has a slender blue appearance demonstrates a distribution pattern that researchers studying clean water in South Asia observed.

Brachythemis contaminata which has a species name that describes its nature completely

became the most common organism at Sites 1 and 2 because it existed in much greater numbers than any other organism. Its presence at polluted locations makes it a probable negative indicator because its high numbers at contaminated sites show that the environment has become worse instead of maintaining its natural state.

VI. Seasonal Variation and Its Implications

One aspect of the results that deserves separate attention is the pattern of seasonal variation across sites. At clean Sites 5 and 6, odonate diversity peaked in the post-monsoon period — October and December surveys consistently recorded more species than the pre-monsoon and peak monsoon rounds. This matches what you would expect from the ecology: monsoon rains replenish wetlands, aquatic vegetation stabilizes, and the post-monsoon period supports high invertebrate prey density and stable water levels that favor a diverse suite of odonates.

At contaminated Sites 1 and 2, this seasonal pattern was almost completely absent. Diversity was uniformly low across all four survey rounds. The monsoon, rather than improving conditions by diluting pollutant concentrations, appeared to intensify contamination by flushing additional industrial runoff into the wetlands during heavy rain events. This is a practically important

finding for monitoring design: sampling contaminated industrial-adjacent wetlands in a single season may actually underestimate the chronic nature of the degradation, because even the nominally favorable post-monsoon window does not produce diversity recovery at highly polluted sites.

VII. Conclusion

Aligarh's wetlands are under pressure, and that pressure is measurable in the dragonflies above them — or rather, in their absence. The correlation between heavy metal contamination and odonate diversity documented in this study is strong enough to make a genuine case for Odonata-based biomonitoring as a practical tool for wetland management in industrial Uttar Pradesh.

Dragonflies have been around for approximately 300 million years, surviving conditions that ended the dinosaurs. Watching them disappear from ponds a few hundred meters from a tannery feels both ecologically significant and oddly personal. These are not obscure organisms requiring specialist expertise to appreciate — most people have watched a dragonfly hunt over water and found something compelling in the sight. That accessibility is actually an asset for conservation communication. Odonata can bridge the gap between technical ecological monitoring and public engagement with wetland health in ways that dissolved oxygen sensors and sediment core analyses simply cannot.

The path forward involves several parallel efforts: expanding survey coverage across Aligarh district and comparable industrial cities in western Uttar Pradesh; developing a validated regional indicator species list calibrated to local contamination profiles; integrating Odonata monitoring into the existing wetland assessment frameworks of the Uttar Pradesh Pollution Control Board; and building technical capacity in local universities to conduct and interpret these surveys. None of these steps requires extraordinary resources. What they require is recognition that the insects hovering above our most neglected ponds are trying to tell us something — and that we should probably start listening.

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