International Journal of Geography, Geology and Environment

P-ISSN: 2706-7483
E-ISSN: 2706-7491
IJGGE 2024; 6(1): 391-395
https://www.geojournal.net
Received: 14-01-2024
Accepted: 19-02-2024

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The impact of industrial waste on water pollution: A detailed analysis

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DOI: https://doi.org/10.22271/27067483.2024.v6.i1e.245

Abstract
This study looks into how industrial waste affects water pollution, with particular attention to the kinds and sources of pollutants, how they enter water bodies, and how they affect aquatic ecosystems and public health. To determine the concentration and distribution of contaminants, the study combines statistical techniques, laboratory analysis, and field sampling. The results underline the need for better waste management procedures since they show a considerable level of contamination in water bodies close to industrial locations.

Keywords: Water pollution, human health, industry waste, hg, turbidity, dissolved oxygen

1. Introduction
Over 70% of our nation's fresh water supply that is in liquid form is rendered unfit for human use (Dwivedi, 2017) [3]. One serious environmental problem is the polluting of water by industrial waste (Johnson and Smith, 2021) [5]. Even though they are essential for economic growth, industrial operations are a major cause of water contamination (Beckerman, 1995) [1]. With an emphasis on the chemical composition, distribution, and ecological repercussions of industrial waste, this study seeks to comprehend the scope and impact of waste on water bodies. Mercury (Hg) contamination from industrial wastewater is a growing environmental concern (Wagner-Döbler, 2003) [8]. Using field sampling, laboratory analysis, and statistical methods, this research quantifies mercury concentrations in water bodies near industrial sites and assesses the ecological and health risks associated with mercury pollution (Harris *et al*., 2017) [4].
The objective of this research study was to determine the primary contaminants, assess their influence on human health and aquatic ecosystems, and quantify the impact of industrial waste on water quality.

2. Materials and Methods
2.1 Study Area
The study was conducted in the industrial region of (Haldia, West Bengal, India), characterized by heavy manufacturing activities, including chemical production, metal processing, and pharmaceuticals.

2.2 Sampling Sites
Water samples were collected from three sites: three near industrial discharge points (East Site-A, West Site-B, South Site-C) and one control sites located upstream (Control).

2.3 Sampling Procedure
- **Water Samples:** Collected using pre-cleaned polyethylene bottles.
- **Sediment Samples:** Taken using a grab sampler from the riverbed at each site.
- **Biological Samples:** Fish and aquatic plants were collected to assess bioaccumulation.

2.4 Laboratory Analysis
- **Chemical Analysis**: Heavy metals (Hg and Pb) were measured using atomic absorption spectroscopy (AAS) (Dalman *et al*., 2006) [2].
- **Physical Parameters**: Temperature, pH, dissolved oxygen (DO), and turbidity were measured in situ using portable meters (Silva *et al*., 2022) [7].

2.5 Statistical Analysis

Data were analyzed using ANOVA to compare pollutant levels between sites and correlation analysis to assess the relationship between industrial activities and pollutant concentrations.

3. Results

Table 1: Hg (mg/L) level of water of control and experimental site

Site	Hg (mg/L)	Pb (mg/L)	p^H	Dissolved Oxygen (DO) mg/L	Turbidity (NTU)
Control Water	0.001	0.0005	7.1	7.5	5
A	0.15	0.07	6.3	3.5	6
B	0.16	0.08	6.2	3.6	7
C	0.14	0.07	6.1	3.4	6

Descriptive statistics	Control	A	B	C
Mean	0.001333	0.1500	0.1600	0.1400
Std. Deviation	0.0005774	0.01000	0.01000	0.01000
Std. Error of Mean	0.0003333	0.005774	0.005774	0.005774

Table 2: ANOVA of Hg (mg/L) level of water of control and experimental site

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	0.05033	3	0.01678	F (3, 8) = 223.4	*P*<0.0001
Residual (within columns)	0.0006007	8	7.508e-005		
Total	0.05093	11			

Table 3: Significance difference of Hg (mg/L) level of water of control and experimental site

ANOVA summary	
F	223.4
P value	<0.0001
P value summary	****
Significant diff. among means (*P*< 0.05)?	Yes
R square	0.9882

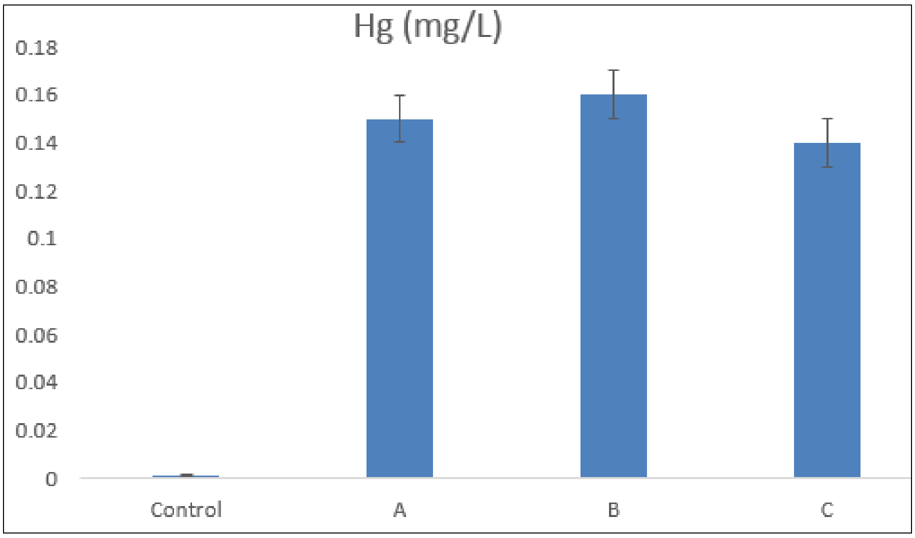

Fig 1: Graphical representation of Hg (mg/L) of water of control and experimental site

Table 4: Pb (mg/L) level of water of control and experimental site

Descriptive statistics	Control	A	B	C
Mean	0.0005000	0.07000	0.08000	0.07000
Std. Deviation	0.0001000	0.01000	0.01000	0.02000
Std. Error of Mean	5.774e-005	0.005774	0.005774	0.01155

Table 5: ANOVA of Pb (mg/L) level of water of control and experimental site

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	0.01214	3	0.004045	F (3, 8) = 26.97	P=0.0002
Residual (within columns)	0.001200	8	0.0001500		
Total	0.01334	11			

Table 6: Significance difference of Pb (mg/L) level of water of control and experimental site

ANOVA summary	
F	26.97
P value	0.0002
P value summary	***
Significant diff. among means (*P*< 0.05)?	Yes
R square	0.9100

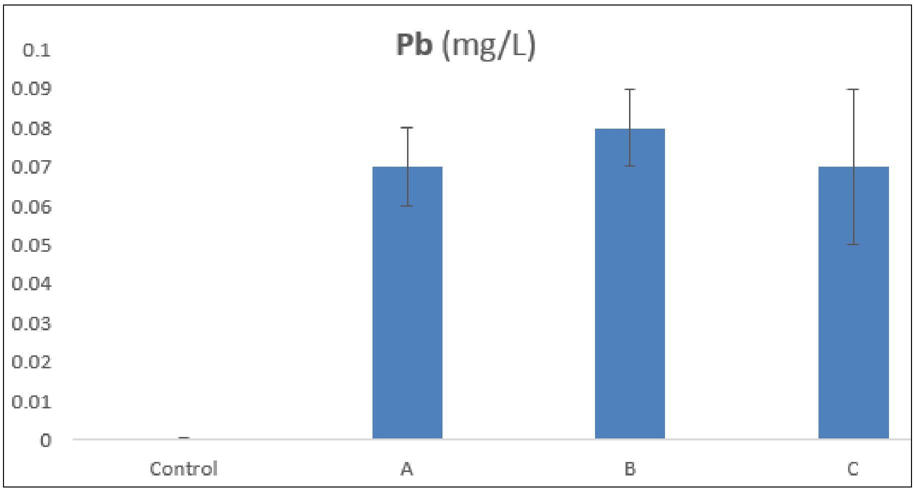

Fig 2: Graphical representation of Pb (mg/L) of water of control and experimental site

Table 7: pH level of water of control and experimental site

Descriptive statistics	Control	A	B	C
Mean	7.100	6.300	6.200	6.100
Std. Deviation	0.2000	0.1000	0.1000	0.02000
Std. Error of Mean	0.1155	0.05774	0.05774	0.01155

Table 8: ANOVA of pH level of water of control and experimental site

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	1.883	3	0.6275	F (3, 8) = 41.56	*p*<0.0001
Residual (within columns)	0.1208	8	0.01510		
Total	2.003	11			

Table 9: Significance difference of pH level of water of control and experimental site

ANOVA summary	
F	41.56
P value	<0.0001
P value summary	****
Significant diff. among means (*P*< 0.05)?	Yes
R square	0.9397

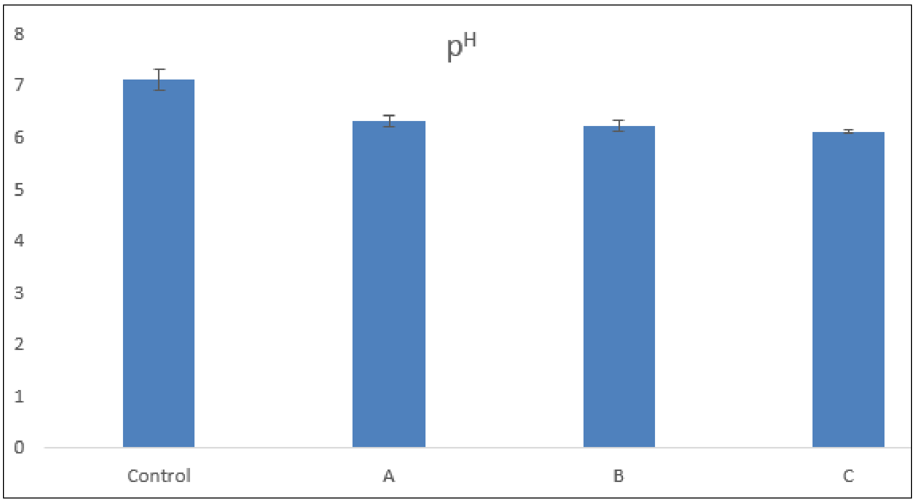

Fig 3: Graphical representation of pH of water of control and experimental site

Table 10: Dissolved Oxygen (mg/L) level of water of control and experimental site

Descriptive statistics	Control	A	B	C
Mean	7.500	3.500	3.600	3.400
Std. Deviation	0.1000	0.1000	0.1000	0.2000
Std. Error of Mean	0.05774	0.05774	0.05774	0.1155

Table 11: ANOVA of Dissolved Oxygen (mg/L) of water of control and experimental site

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	36.06	3	12.02	F (3, 8) = 686.9	$P<0.0001$
Residual (within columns)	0.1400	8	0.01750		
Total	36.20	11			

Table 12: Significance difference Dissolved Oxygen (mg/L) level of water of control and experimental site

ANOVA summary	
F	686.9
P value	<0.0001
P value summary	****
Significant diff. among means ($P< 0.05$)?	Yes
R square	0.9961

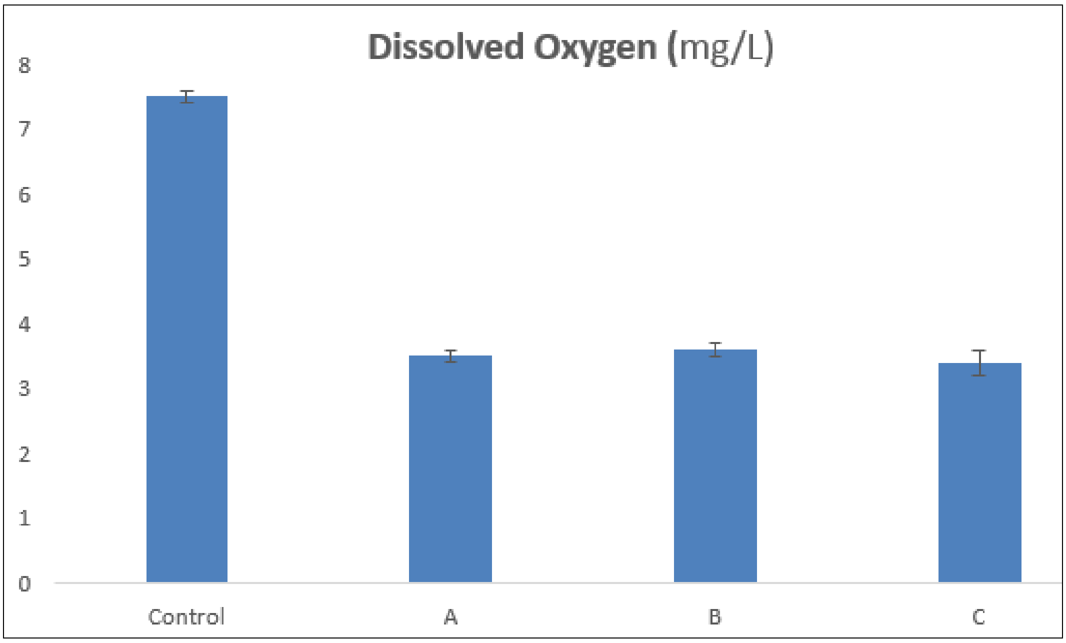

Fig 4: Graphical representation of Dissolved Oxygen (mg/L) of water of control and experimental site

Table 13: Turbidity (NTU) level of water of control and experimental site

Descriptive statistics	Control	A	B	C
Mean	5.000	6.000	7.000	6.000
Std. Deviation	1.000	1.000	1.000	1.000
Std. Error of Mean	0.5774	0.5774	0.5774	0.5774

Table 14: ANOVA of Turbidity (NTU) level of water of control and experimental site

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	6.000	3	2.000	F (3, 8) = 2.000	P=0.1927
Residual (within columns)	8.000	8	1.000		
Total	14.00	11			

Table 15: Significance difference of Turbidity (NTU) level of water of control and experimental site

ANOVA summary	
F	2.000
P value	0.1927
P value summary	ns
Significant diff. among means ($P< 0.05$)?	No
R square	0.4286

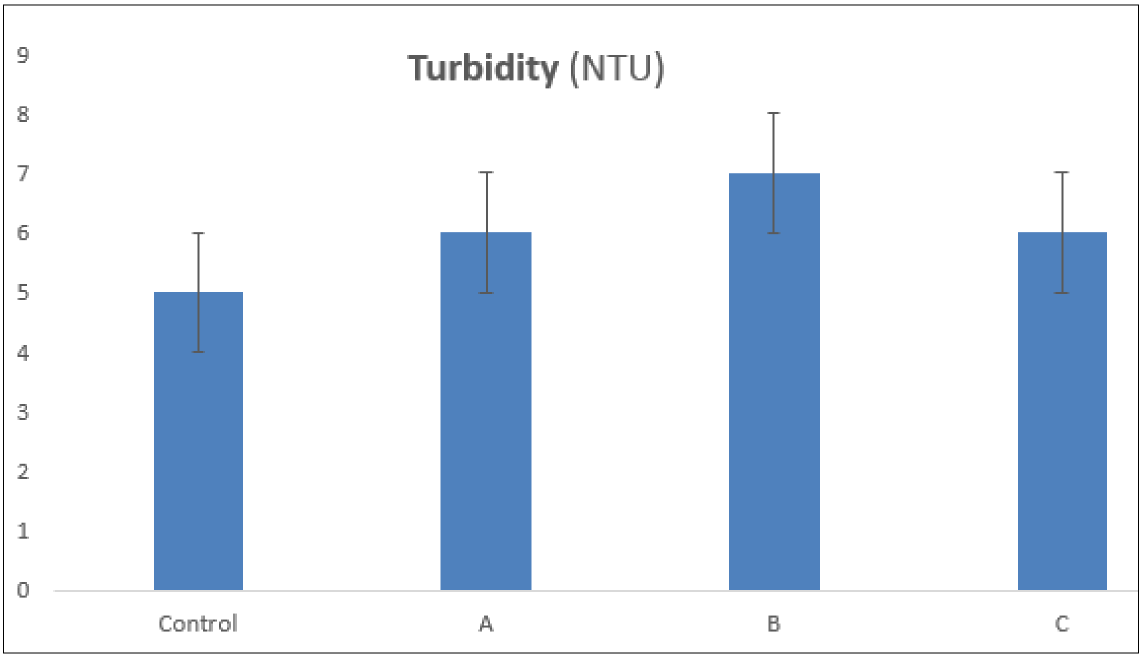

Fig 5: Graphical representation of Turbidity (NTU) of water of control and experimental site

3.1 Chemical Analysis

- **Heavy Metals:** Significantly higher concentrations of Hg, Pb, and as were detected at Sites A, B, and C compared to control sites. Hg levels at Site A (0.15 mg/L), B (0.16 mg/L) and C (0.14 mg/L) exceeded the WHO limit for drinking water (0.001 mg/L).

3.2 Physical Parameters

- **pH and DO:** Lower pH (6.2) and DO levels (3.5 mg/L) were observed near industrial discharge points, indicating acidic conditions and oxygen depletion.
- **Turbidity**: Higher turbidity values were recorded at Sites A (6 NTU), B (7 NTU), and C (6 NTU), suggesting increased particulate matter from industrial runoff than control (5 NTU).

4. Discussion

The elevated levels of heavy metals in industrial sites are attributed to direct discharge of untreated or partially treated effluents. The data suggest significant leaching of contaminants into the water bodies, exacerbated by poor waste management practices. The high concentration of pollutants negatively affects aquatic life, as evidenced by the bioassay results. Lower p^H and DO levels create a hostile environment for fish and invertebrates, disrupting ecological balance and biodiversity. Contaminated water poses severe health risks to local communities relying on these water sources for drinking, fishing, and agriculture.

Current regulatory frameworks need strengthening to enforce stricter discharge limits and promote the adoption of advanced treatment technologies. Public awareness and community engagement are crucial for sustainable waste management practices.

5. Conclusion

This study highlights the severe impact of industrial waste on water pollution, with significant ecological and human health implications. Immediate action is required to mitigate these effects through improved regulations, waste treatment, and community involvement.

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