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Assessment of Water Quality Using Nemerow Water Pollution Index (NWPI): A Case Study of Urban Slum

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Abstract: ***Water quality assessment is crucial for monitoring and ensuring the safety of drinking water. This study employs the Nemerow Water Pollution Index (NWPI) to evaluate water quality at five locations during different seasons in an urban slum characterised by high population density and inadequate sanitation infrastructure. The NWPI is a comprehensive method that considers selected water parameters' maximum and average pollution indices. ANOVA was conducted to identify significant seasonal variations. Physicochemical parameters such as TDS, turbidity, conductivity, ORP, pH, DO, alkalinity, total hardness, calcium, magnesium, chloride, fluoride, and sulphate were analyzed. Results revealed that some of the sampling sites exhibited slight pollution (NPI > 1). The study emphasizes the urgent need for continuing monitoring, targeted policy interventions, and advanced action strategies to reduce water pollution, ensuring compliance with national and international***

Keywords: Drinking water, Pollution Index, Environmental Monitoring, Statistical Analysis, Slum

1. Introduction

Water pollution is a growing problem that threatens both ecological stability and human well-being, having a long-lasting impact on the natural world and global health [1]. Traditional water quality evaluations tend to focus on single factors, such as dissolved oxygen, bacterial counts, or specific chemical contaminants. However, this method often overlooks the intricate interactions between different contaminants, providing significant understanding of water safety [2]. Despite an abundance of research on water contamination, there is a notable scarcity of studies that examine the seasonal fluctuations of water quality specifically within urban slums. These slums have challenging environments, particularly susceptible to pollution due to a potent mix of inadequate sanitation facilities, uncontrolled runoff of industrial waste from nearby factories, and a dense, often impoverished population [3]. The absence of proper sewage systems and waste management results in substantial contamination of water sources, aggravating health risks [4]. Howard & Bartram studied on broader urban areas, overlooking the unique challenges faced by slum residents [5]. In this regard, the Nemerow water pollution Index (NWPI) becomes an essential tool, providing a comprehensive assessment that integrates the worst-case contamination scenarios with a general view of water quality, thus revealing the true condition of aquatic health [6,7].

The study aims to bridge this critical research gap by applying the NWPI to five selected sites within a specific urban slum. The study will help uncover patterns in water quality, identify the sources of various pollutants, and assess the looming health risks that residents face daily. The study also compared the NWPI findings against national water quality standards established by the Bureau of Indian Standards [8] and the internationally recognized guidelines set by the World Health Organization [9]. The studied slum is characterized by limited access to clean, piped water, deteriorating sewage systems struggling to manage waste, and the encroachment of small-scale industrial operations releasing pollutants into the surrounding environment. These factors collectively contribute to an alarming rise in water pollution[10,11].

2. Methodology

2.1 Study Area and Sample Collection

Water samples were collected from five predetermined sites within an urban slum environment, designated as Govalak, Morarji Vasahat, Banjaravas, Halpativas, and Ambedkarnagar. At all the locations, piped water was the sample supplied by Surat Municipal Corporation (SMC) for drinking purposes in the studied slums. In Banjaravas, boring water was also used as an alternate source and was sampled as well. Sampling was conducted during the pre-monsoon and monsoon seasons to assess seasonal variability in water quality. At each site, water samples were collected in sterile, pre-cleaned polyethylene bottles, ensuring minimal contamination. Samples were immediately stored in insulated coolers at 4 ± 1 °C and transported to the analytical laboratory.

2.2 Physicochemical Parameter Analysis

The collected water samples were analyzed for key physicochemical parameters, including: pH, Total Dissolved Solids (TDS), Turbidity, Conductivity, Oxidation-Reduction Potential (ORP), Dissolved Oxygen (DO), Alkalinity, Hardness, Chloride, Fluoride, and Sulphate, following the standard method [12]. Analytical methods were based on BIS, WHO and EPA guidelines, ensuring compliance with standard water quality assessment protocols [8,9,13].

2.3 Nemerow Water Pollution Index (NWPI)

The Nemerow Water Pollution Index was applied to determine the quality of drinking water at the selected sampling sites [14,15].

$$NWPI = (\sqrt{PIiavg^2 + PImax^2/2}$$

Where:
- PIi=Si / Csi (Pollution Index for parameter *i*)
- Csi = measured concentration of parameter *i* in the sample
- Si = standard permissible concentration of parameter *i*
- PImax = maximum Pollution Index among all parameters
- PIavg = arithmetic means of all Pollution Indices

2.4 NWPI Classification and Interpretation

The calculated NWPI values were categorized according to the classification system below, facilitating the interpretation of water quality data and allowing for the assessment of pollution levels.
- NWPI < 1: Excellent water quality
- 1 ≤ NWPI < 2: Good water quality
- 2 ≤ NWPI < 3: Slightly polluted
- 3 ≤ NWPI < 4: Moderately polluted
- NWPI ≥ 4: Heavily polluted

Table 1: Standard for studied parameters

Parameter	Standard Value (SI)
TDS (ppm)	500
Turbidity(ppm)	1
Conductivity((µS)	1000
ORP (mV)	250
pH	8.5
DO (ppm)	6
Alkalinity(ppm)	200
Total Hardness(ppm)	200
Calcium (ppm as Ca++)	75
Magnesium (ppm as Mg++)	50
Chloride(ppm)	250
Fluoride(ppm)	1.5
Sulphate(ppm)	200

3. Results and Discussion

Banjaravas Boring water exhibited the highest pollution levels (NWPI > 2.0) during the pre-monsoon season, primarily due to elevated TDS and turbidity, indicating potential contamination from industrial runoff and inadequate sewage. Halpativas and Ambedkarnagar recorded lower pollution levels but still require monitoring to prevent future contamination.

Table 1: NWPI and Quality status

Location	Season	Source	PImax	PI avg	NPI	Quality Status
Govalak	Premonsoon	Piped	2.20	0.81	1.66	Good water quality
Govalak	Monsoon	Piped	2.31	0.79	1.72	Good water quality
Morarji Vasahat	Premonsoon	Piped	1.79	0.78	1.38	Good water quality
Morarji Vasahat	Monsoon	Piped	2.16	0.76	1.62	Good water quality
Banjaravas SMC	Premonsoon	Piped	2.00	0.80	1.52	Good water quality
Banjaravas SMC	Monsoon	Piped	2.78	0.89	2.06	Slightly polluted
Banjaravas	Premonsoon	Boring	2.76	1.10	2.10	Slightly polluted
Banjaravas	Monsoon	Boring	2.13	0.80	1.61	Good water quality
Halpativas	Premonsoon	Piped	1.44	0.77	1.15	Good water quality
Halpativas	Monsoon	Piped	2.24	0.84	1.69	Good water quality
Ambedkarnagar	Premonsoon	Piped	1.48	0.75	1.17	Good water quality
Ambedkarnagar	Monsoon	Piped	1.81	0.78	1.39	Good water quality

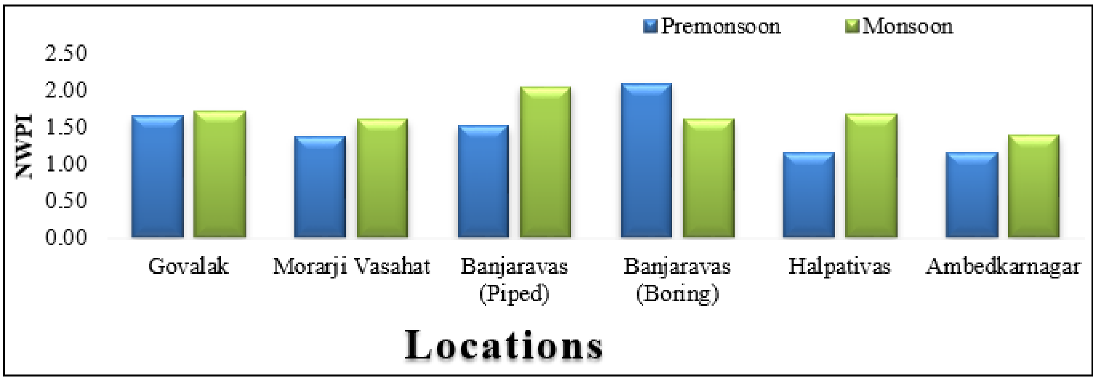

Figure 1: NPWI across studied locations

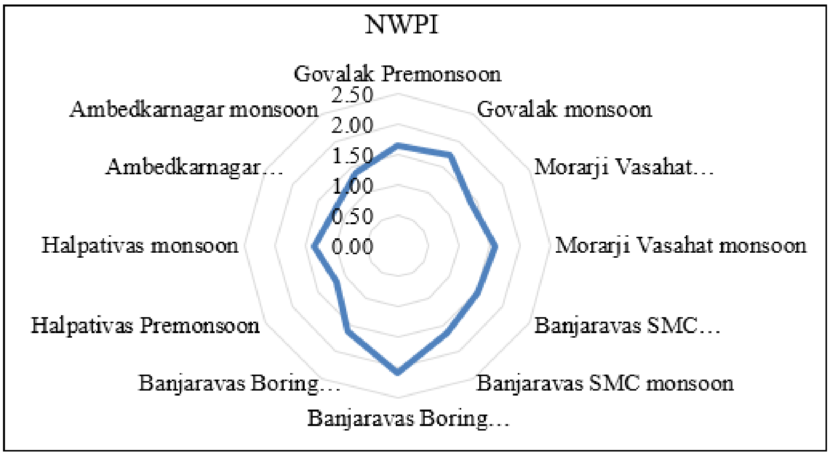

Figure 2: Radar Chart

A radar chart is used to display multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point. The axes are arranged radially, with equal angles between them. Each axis in this chart represents a specific location and season (pre monsoon/monsoon). The concentric circles represent values of the NWPI. The center is 0, and the outermost circle is 2.5. The blue line connects the NWPI values for each location and season, showing the overall pattern and variations. The blue line showed that the NWPI values are not uniform across all locations and seasons. This indicates variability in the measured parameter. The highest NWPI values were at Banjaravas Boring water during Premonsoon. Halpativas during Pre monsoon has the lowest NWPI, slightly above 1.0. Most values range between 1.0 and 1.8, suggesting moderate productivity across locations/ seasons. Premonsoon and Monsoon comparisons showed some variation in different sampling sites.

Generally, the premonsoon season seems to show higher NWPI values compared to the monsoon season in many locations. This could be due to factors like less dilution from rainfall or increased concentration of pollutants in the dry season. Monsoon: The monsoon season tends to have lower NWPI values, possibly due to dilution effects from increased rainfall

3.1 Statistical Analysis

- **Null Hypothesis (H0):** There is no significant difference in the mean NWPI values across different locations or between the premonsoon and monsoon seasons.
- **Alternative Hypothesis (H1):** There is a significant difference in the mean NWPI values across different locations or between the premonsoon and monsoon seasons.

The analysis showed a p-value (0.728), greater than 0.05, indicating no significant difference in NWPI across different locations. Similarly, the p-value was 0.09, also greater than 0.05, indicating no significant difference in NWPI between the pre-monsoon and monsoon seasons.

However, the increase in NWPI during the monsoon season aligns with findings from studies on urban runoff, which demonstrate that increased rainfall significantly elevates pollutant loads in aquatic systems [16,17]. Mallick et al. noted that seasonal variations in urban water quality are often directly linked to hydrological patterns [18].

The "Slightly Polluted" conditions at Banjaravas piped water supply and Banjaravas Boring water, particularly during the pre-monsoon period, indicate localized pollution hotspots. This aligns with research highlighting the impact of inadequate sanitation and waste management in densely populated urban slums [3,4]. The observed improvement in water quality at Banjaravas Boring during the monsoon, attributed to dilution, echoes the findings of studies that have documented the significant impact of rainfall on reducing pollutant concentrations in water bodies [2]. However, the persistent "Slightly Polluted" status at Banjaravas' piped water suggested that dilution alone may not be sufficient to mitigate pollution in areas with high pollutant loading.

4. Conclusion

This study highlights the effectiveness of NWPI in assessing water quality. Statistical analysis confirms seasonal variations, with pre-monsoon and monsoon seasons exhibiting higher pollution levels. High pollution indices, particularly in Banjaravas Boring, suggest the need for improved wastewater management, filtration systems, and continuous monitoring to ensure safe drinking water standards. Implement stricter regulations on industrial discharge and enforce compliance. improving sewage infrastructure to prevent contamination from untreated wastewater should be considered. Regular water quality monitoring programs with public access can be useful for long-term mitigation of water related issues.

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