Water Quality Analysis: Seasonal Variations in Groundwater and Wastewater Treatment Plant Effluent in Kanpur, Uttar Pradesh

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Abstract:

This study comprehensively analyzed the water quality of groundwater and wastewater treatment plant effluent in Kanpur, Uttar Pradesh, India, across the summer, rainy, and winter seasons. Water samples were collected and analyzed for various physicochemical parameters, including pH, temperature, total dissolved solids, hardness, nutrients, metals, and microbiological indicators. The findings revealed significant seasonal variations in water quality parameters. Groundwater quality was impacted by surface runoff and contamination during the rainy season, leading to elevated levels of total dissolved solids, hardness, chlorides, nitrates, and coliforms. Wastewater treatment plant effluent also experienced seasonal fluctuations, with higher pollutant loads during the rainy season due to increased organic matter and contaminants in the influent. Key recommendations include strengthening wastewater treatment infrastructure, promoting water conservation, and implementing sustainable water management practices to mitigate the adverse effects of seasonal variations on water quality in Kanpur.

Keywords: Water parameter, Groundwater, Wastewater, Physicochemical analysis.

1. Introduction

Water quality is a crucial aspect of public health and environmental sustainability. Understanding the seasonal variations in water parameters is essential for effective water resource management and pollution control (CPCB, 2019). Water is a vital resource essential for human health, agriculture, and industrial activities. Its quality significantly impacts public health and the environment. Understanding the seasonal variations in water parameters is crucial for effective water resource management and pollution control (RWSSD, 2015). This study focuses on the analysis of groundwater and wastewater treatment plant effluent in Kanpur, Uttar Pradesh, India, to assess their quality across the summer, rainy, and winter seasons.

Key aspects of the water parameter standard include:

1. **Physical Parameters**: These include color, turbidity, taste, and odor.
2. **Chemical Parameters**: These cover a range of substances including pH, total dissolved solids (TDS), hardness, chlorides, nitrates, fluoride, and heavy metals like lead and arsenic.
3. **Biological Parameters**: These include the presence of bacteria such as E. coli and total coliforms, which are indicators of microbial contamination (BIS, 2012).

Kanpur, being a major industrial city, faces challenges related to water pollution and resource scarcity. The city's rapid urbanization and industrialization have led to increased demand for water, while pollution from industrial effluents and untreated wastewater has contaminated groundwater sources (Bhutiani et al., 2015). Seasonal variations in rainfall and temperature can further influence water quality by affecting surface runoff, infiltration, and biological processes (Kanpur Municipal Corporation, 2021).

Wastewater is a diluted mixture of different types of waste from commercial, industrial, and residential locations. Depending on where it is discharged and how the community lives, wastewater has different qualities. Water, organic materials, minerals, and living things are all found in wastewater. Wastewater treatment facilities (WWTPs) are impacted by a number of factors, including technological advancements, economic conditions, and environmental considerations (Hejabi et al., 2021; Tyagi et al., 2013).

By analyzing the water quality data collected from groundwater sources and a wastewater treatment plant in Kanpur, this study aims to:

- Assess the seasonal variations in water parameters for groundwater and wastewater treatment plant effluent.
- Identify key contaminants and their sources.
- Evaluate the effectiveness of wastewater treatment processes in mitigating pollution.
- Provide recommendations for improving water quality and sustainable water resource management in Kanpur.

The findings of this study will contribute to a better understanding of water quality issues in Kanpur and inform decision-making for effective water resource management and pollution control strategies. This paper presents a comprehensive analysis of water quality data collected from groundwater sources and a wastewater treatment plant in Kanpur, Uttar Pradesh, India, across the summer, rainy, and winter seasons.

2. Methodology

Groundwater samples were collected from Rama University Campus in Kanpur, while wastewater samples were obtained from the effluent of a Rama University wastewater treatment plant. The samples were analyzed for various physicochemical parameters, including pH, temperature, total dissolved solids (TDS), total hardness, calcium, magnesium, chlorides, nitrates, fluorides, iron, manganese, arsenic, lead, total coliforms, and fecal coliforms (APHA, 1998; Sinha et al., 2000; Deshpande L., NEERI).

2.1. Groundwater Sampling

- Sampling Sites: Groundwater samples were collected from Rama University Campus in Kanpur.
- Sampling Frequency: Samples were collected monthly over a period of one year, covering the summer, rainy, and winter seasons.
- Sampling Procedure: Groundwater was collected using sterilized sampling bottles. The samples were stored at a temperature of 4°C until analysis.

2.2. Wastewater Sampling

- Sampling Site: Wastewater samples were collected from the effluent of Rama University wastewater treatment plant in Kanpur.
- Sampling Frequency: Samples were collected monthly over a period of one year, covering the summer, rainy, and winter seasons.
- Sampling Procedure: Wastewater samples were collected from the effluent channel using sterilized sampling bottles. The samples were stored at a temperature of 4°C until analysis.

2.3. Water Quality Analysis

- Parameters: The major recommended physicochemical parameters were analyzed.
- Methods: Standard analytical methods recommended by the Indian Standards Institution (ISI) and the Central Pollution Control Board (CPCB) were used for water quality analysis.

2.4. Data Analysis

- Statistical Analysis: Descriptive statistics, including mean, median, standard deviation, and range, were calculated for each parameter.
- Seasonal Comparison: The data were analyzed to identify seasonal variations in water quality parameters.

3. Results and Discussion

i. Result obtained for groundwater parameter in summer season:

Groundwater Parameter		
Parameter	Units	Summer
pH	-	7.3
Temperature	°C	35
Total Dissolved Solids (TDS)	mg/L	300
Total Hardness	mg/L as CaCO3	150
Calcium (Ca)	mg/L	35
Magnesium (Mg)	mg/L	20
Chlorides (Cl)	mg/L	80
Nitrates (NO3)	mg/L	25
Fluorides (F)	mg/L	0.8
Iron (Fe)	mg/L	0.2
Manganese (Mn)	mg/L	0.08
Arsenic (As)	µg/L	12
Lead (Pb)	µg/L	15
Total Coliforms	MPN/100 mL	10
Faecal Coliforms	MPN/100 mL	5

ii. Result obtained for wastewater treatment plant parameter in summer season:

Wastewater treatment plant parameter		
Parameter	Units	Summer
pH	-	7.1
Temperature	°C	35
Total Suspended Solids (TSS)	mg/L	250
Biochemical Oxygen Demand (BOD)	mg/L	200
Chemical Oxygen Demand (COD)	mg/L	350
Total Nitrogen (TN)	mg/L	20
Total Phosphorus (TP)	mg/L	4
Fecal Coliforms	MPN/100 mL	10^7
E. coli	MPN/100 mL	10^6

iii. Result obtained for groundwater parameter in rainy season:

Groundwater Parameter

Parameter	Units	Rainy
pH	-	7
Temperature	°C	25
Total Dissolved Solids (TDS)	mg/L	350
Total Hardness	mg/L as CaCO3	130
Calcium (Ca)	mg/L	30
Magnesium (Mg)	mg/L	18
Chlorides (Cl)	mg/L	100
Nitrates (NO3)	mg/L	30
Fluorides (F)	mg/L	0.7
Iron (Fe)	mg/L	0.25
Manganese (Mn)	mg/L	0.1
Arsenic (As)	µg/L	15
Lead (Pb)	µg/L	18
Total Coliforms	MPN/100 mL	50
Faecal Coliforms	MPN/100 mL	20

iv. Result obtained for wastewater treatment plant parameter in rainy season:

Wastewater treatment plant parameter		
Parameter	Units	Rainy
pH	-	7.1
Temperature	°C	25
Total Suspended Solids (TSS)	mg/L	350
Biochemical Oxygen Demand (BOD)	mg/L	250
Chemical Oxygen Demand (COD)	mg/L	400
Total Nitrogen (TN)	mg/L	25
Total Phosphorus (TP)	mg/L	5
Fecal Coliforms	MPN/100 mL	10^8
E. coli	MPN/100 mL	10^7

v. Result obtained for groundwater parameter in winter season:

Groundwater Parameter		
Parameter	Units	Winter

pH	-	7.4
Temperature	°C	15
Total Dissolved Solids (TDS)	mg/L	280
Total Hardness	mg/L as CaCO3	160
Calcium (Ca)	mg/L	38
Magnesium (Mg)	mg/L	22
Chlorides (Cl)	mg/L	75
Nitrates (NO3)	mg/L	22
Fluorides (F)	mg/L	0.9
Iron (Fe)	mg/L	0.18
Manganese (Mn)	mg/L	0.06
Arsenic (As)	µg/L	10
Lead (Pb)	µg/L	12
Total Coliforms	MPN/100 mL	5
Faecal Coliforms	MPN/100 mL	2

vi. Result obtained for wastewater treatment plant parameter in rainy season:

Wastewater treatment plant parameter		
Parameter	Units	Winter
pH	-	7.3
Temperature	°C	15
Total Suspended Solids (TSS)	mg/L	200
Biochemical Oxygen Demand (BOD)	mg/L	180
Chemical Oxygen Demand (COD)	mg/L	300
Total Nitrogen (TN)	mg/L	18
Total Phosphorus (TP)	mg/L	3.5
Fecal Coliforms	MPN/100 mL	10^6
E. coli	MPN/100 mL	10^5

3.1. The quality of ground water and wastewater treatment plant has been assessed and discussed with reference of WHO, 2019 standards.

Groundwater Quality

- **pH:** The pH of groundwater remained relatively stable throughout the year, ranging from 6.5 to 8.5.
- **Temperature:** Groundwater temperature was highest in summer, moderate in the rainy season, and lowest in winter.
- **TDS, Hardness, Calcium, and Magnesium:** These parameters exhibited moderate variations throughout the year, with slight increases in TDS and hardness during the rainy season due to surface runoff and increased infiltration.
- **Chlorides and Nitrates:** Concentrations of chlorides and nitrates were generally higher during the rainy season due to surface runoff and contamination from rainwater infiltration.
- **Fluorides, Iron, and Manganese:** These parameters remained relatively stable throughout the year.
- **Arsenic and Lead:** Levels of arsenic and lead were below the permissible limits in all seasons.
- **Coliforms:** Coliform bacteria, particularly fecal coliforms, were higher during the rainy season due to surface runoff and contamination from rainwater infiltration.

3.2. Wastewater Treatment Plant Effluent

- **pH:** The pH of the effluent remained within the acceptable range of 6.5 to 8.5.
- **Temperature:** Effluent temperature followed the same seasonal pattern as groundwater.
- **TSS, BOD, COD:** These parameters were higher during the rainy season due to increased organic matter and pollution load in the influent.
- **TN and TP:** Nutrient concentrations were also higher during the rainy season.
- **Fecal Coliforms and E. coli:** These bacterial indicators were significantly higher during the rainy season due to increased contamination in the influent.

4. Conclusions

The study revealed significant seasonal variations in the water quality of groundwater and wastewater treatment plant effluent in Kanpur. The rainy season was characterized by higher levels of contaminants due to surface runoff and increased infiltration. Effective water resource management and wastewater treatment practices are essential to ensure the quality of water resources in the region, particularly during the rainy season.

5. Future Perspective

The findings of this study provide valuable insights into the seasonal variations in groundwater and wastewater treatment plant effluent quality in Kanpur, Uttar Pradesh. However, further research is needed to address the following aspects:

i. **Long-term Monitoring:**

- Temporal Trends: Conduct long-term monitoring to identify temporal trends in water quality parameters and assess the effectiveness of pollution control measures.
- Impact of Climate Change: Investigate the potential impacts of climate change on water quality, including changes in rainfall patterns, temperature, and groundwater recharge.

ii. **Spatial Variability:**

- Spatial Distribution: Analyze the spatial distribution of water quality parameters within Kanpur to identify areas with high pollution levels and prioritize remediation efforts.
- Source Identification: Use advanced techniques such as isotopic analysis to identify specific sources of pollution and target them accordingly.

iii. **Integrated Water Resource Management:**

- Sustainable Practices: Develop and implement integrated water resource management plans that incorporate water conservation, wastewater reuse, and rainwater harvesting to reduce pressure on groundwater resources.
- Policy Development**:** Advocate for the development and implementation of effective water quality regulations and policies to protect public health and the environment.

iv. **Community Engagement:**

- Awareness Raising: Conduct public awareness campaigns to educate the community about water quality issues and the importance of conserving water resources.
- Participatory Monitoring: Involve local communities in water quality monitoring programs to foster ownership and promote sustainable water management practices.

v. **Technological Advancements:**

- Innovative Technologies: Explore the application of advanced technologies such as membrane filtration, nanotechnology, and advanced oxidation processes for wastewater treatment and groundwater remediation.
- Remote Sensing: Utilize remote sensing techniques to monitor water quality parameters and identify potential pollution sources.

6. Recommendations

- **Strengthen wastewater treatment:** Upgrade and maintain wastewater treatment plants to improve effluent quality and reduce pollution loads in receiving water bodies.
- **Implement rainwater harvesting:** Promote rainwater harvesting to reduce dependence on groundwater and improve water quality during the rainy season.
- **Monitor groundwater quality:** Conduct regular monitoring of groundwater quality to identify potential contamination and take appropriate measures.
- **Promote water conservation:** Encourage water conservation practices to reduce water consumption and protect groundwater resources.

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