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Comparison of Physicochemical Characteristics of Pond Water and Ground Water in the Industrial Zone of Paradeep Area, Odisha - Seasonal Analysis

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ABSTRACT:

This paper presents a comparative analysis of pond water and ground water quality in the industrial zone of Paradeep, a port city in Odisha. Water samples from four different locations were collected during different seasons and analyzed for various physicochemical characteristics. The findings reveal high concentrations of certain parameters in both water samples, indicating significant pollution. The study recommends extending the research to cover more years for a comprehensive assessment of water quality.

Key words: Pond water quality, Ground water quality, WQI, Physicochemical characteristics.

1 INTRODUCTION

1.1 Importance of Water Quality for Life and Civilization

Water is often referred to as the elixir of life due to its indispensable role in the sustenance of all living organisms. It is a fundamental resource for human survival, agriculture, industry, and ecosystem health. Good water quality is essential for drinking, cooking, sanitation, and hygiene. The availability of clean water is directly linked to public health, economic development, and social well-being. As civilization has advanced, the demand for high-quality water has increased, highlighting the importance of preserving and managing this vital resource.

1.2 Historical Significance and Modern Necessity of Water Quality

Historically, water has been revered in various cultures and civilizations. In Vedic times, water was worshipped as a life-giving and sustaining element. Ancient texts like the Rig-Veda emphasized the importance of water for health and prosperity. Today, the necessity for good water quality is more pronounced than ever. With the growing global population, urbanization, and industrialization, the stress on water resources has intensified. Ensuring access to safe and clean water is a critical challenge that modern societies must address to prevent waterborne diseases and support sustainable development.

1.3 Overview of Pond Water and Ground Water as Essential Resources

Pond water and ground water are crucial components of the hydrological cycle, serving as primary sources of freshwater in many regions. Ponds, often found in rural and urban settings, play a vital role in local ecosystems by supporting biodiversity and providing water for agricultural and domestic use. They also contribute to groundwater recharge, which is essential for maintaining the water table and ensuring a steady supply of groundwater. Groundwater, stored in aquifers, is a major source of drinking water and irrigation. It is generally more protected from surface pollution but is susceptible to contamination from various sources, making its quality equally important.

1.4 Pollution Sources Affecting Water Bodies

Water bodies, including ponds and groundwater, are increasingly threatened by pollution from multiple sources. Industrial discharge, agricultural runoff, and domestic sewage are significant contributors to water contamination. In industrial zones, untreated wastewater from factories and chemical plants can introduce hazardous substances into water bodies, posing severe health risks. Agricultural activities often lead to the runoff of pesticides, fertilizers, and other chemicals into ponds and aquifers. Domestic sewage, containing organic and inorganic pollutants, further exacerbates water quality issues. The indiscriminate disposal of waste and improper land management practices also contribute to the degradation of water quality, necessitating comprehensive measures to mitigate pollution and protect these vital resources.

2 STUDY AREA

Description of the Paradeep Industrial Zone and Sampling Locations

The Paradeep industrial zone, located in the port city of Paradeep in Odisha, India, is a region characterized by significant industrial activity. Paradeep is a major port on the east coast of India, serving as a crucial hub for maritime trade and industrial operations. The industrial zone houses various factories, chemical plants, and processing units, contributing to the local economy but also posing potential environmental challenges.

This study focuses on the comparison of pond water (surface water) and groundwater quality within this industrial zone. Four sampling locations were strategically chosen to cover the entire industrial zone, ensuring a comprehensive assessment of water quality across different areas. Water samples from these locations were collected during different seasons to capture the seasonal variations in water quality parameters.

The selected sampling points include areas near residential communities, schools, factories, and transportation hubs, reflecting the diverse sources of potential contamination and the varying uses of water in the region. The following table provides detailed descriptions of each sampling location.

Table 1: Locations and Descriptions of Sampling Points

Sl. No.	Sampling No.	Sampling Location	Description of the sample location's surroundings
1	PW1	Village Bagadia of Jhimani Gram Panchayat	People of Bagadia village are depends in this pond for their daily uses.
2	PW2	Village Siju of Kothi Gram Panchayat	People of Siju village are depends in this pond for their daily uses.
3	PW3	At Udayabata, near Goa Carban Factory	Number of people of Udayabata village, school children and workers of Goa Carbon Factory use the water in their daily uses purpose.
4	PW4	At Bauriapalanta, near IFFCO railway siding	People of Bauriapalanta, workers of IFFCO railway siding, truck drivers & helpers of BPCL, HPCL & IOCL Marketing division are depends in this pond for their daily uses.
5	GW1	Village Bagadia of Jhimani Gram Panchayat	People of Bagadia village are depends in this tube well for their daily uses.
6	GW2	Village Siju of Kothi Gram Panchayat	People of Siju village are depends in this tube well for their daily uses.
7	GW3	At Udayabata, near Goa Carban Factory	Number of people of Udayabata village, school children and workers of Goa Carbon Factory use the water in their daily uses purpose.
8	GW4	At Bauriapalanta, near IFFCO railway siding	People of Bauriapalanta, workers of IFFCO railway siding, truck drivers & helpers of BPCL, HPCL & IOCL Marketing division are depends in this pond for their daily uses.

3 MATERIALS AND METHODS

3.1 Sample Collection and Analysis Procedures

Water samples were collected from both pond water (surface water) and groundwater sources across the Paradeep industrial zone. The collection process was standardized to ensure consistency and reliability of the data.

- **Sample Collection:**
  - Water samples were collected using pre-cleaned polyethylene bottles with a capacity of 1 liter.
  - For groundwater, samples were taken from tube wells after thoroughly rinsing the bottles with the respective water.
  - For pond water, samples were collected at a depth of 1 meter from the surface, typically between 9:00 to 10:00 AM to maintain consistency in sampling time.

- Samples were collected during four different seasons: winter, summer, monsoon, and post-monsoon, to capture seasonal variations in water quality.
- All collected samples were transported to the Environmental Laboratory at PPL, Paradeep, within 12 hours of collection for analysis.

- **Sample Analysis:**
  - Physicochemical parameters of the water samples were analyzed using standard methods and procedures.
  - Parameters such as pH, temperature, conductivity, total hardness, alkalinity, salinity, turbidity, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), fluoride, chloride, phosphate, sodium, potassium, iron, zinc, and lead were measured.
  - The analysis was conducted according to the guidelines provided by the Bureau of Indian Standards (BIS).

3.2 Physicochemical Parameters Analyzed

The physicochemical parameters were selected based on their importance in assessing water quality and potential health impacts. The parameters and their respective standards are outlined in the following table.

Table 2: Water Quality Parameters and Standards Used in the Study

Sl. No.	Parameters	BIS Standards (Si)	Weight (wi)	Relative Weight (Wi)
1.	pH	6.5-8.5	4	0.08
2.	Temperature	40	2	0.04
3.	Conductivity	2000 $ohm^{-1}cm^{-1}$	3	0.06
4.	Total hardness	300-600	3	0.06
5.	Alkalinity	200-600	3	0.06
6.	Salinity	100 PPT	3	0.06
7.	Turbidity	5-25 NTU	1	0.02
8.	TDS	500-2000	3	0.06
9.	TSS	500	3	0.06
10.	DO	5-7	2	0.04
11.	BOD	5	2	0.04
12.	COD	20	2	0.04

13.	Fluoride	1.0-1.5	3	0.06
14.	Chloride	250-1000	3	0.06
15.	Phosphate	5	2	0.04
16.	Sodium	20	3	0.06
17.	Potassium	10-50	2	0.04
18.	Iron	0.1-1.0	2	0.04
19.	Zinc	5.0-15.0	3	0.06
20.	Lead	0.05	1	0.02

RESULTS AND DISCUSSION

Table: 3:- Calculation of q_n and WQI of PW1 in different seasons.

Sl. No.	**PW1**	**WINTER**			**SUMMER**			**MONSOON**			**POST MONSOON**		
	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.1	30	**2.4**	7.4	45	**3.6**	7.0	25	**2.0**	7.7	60	**4.8**
2.	Temperature	27.0	67.5	**1.35**	27.2	68	**2.72**	27.5	68.75	**1.37**	27.0	67.5	**1.37**
3.	Conductivity	255	12.75	**0.76**	260	13	**0.78**	361	18.05	**1.08**	240	12.0	**0.72**
4.	Total hardness	58	9.66	**0.58**	56	9.33	**0.56**	68	11.33	**0.68**	43	7.16	**0.43**
5.	Alkalinity	104	17.33	**1.04**	106	17.66	**1.06**	126	21	**1.26**	98	16.33	**0.98**
6.	Salinity	0.20	0.00002	**0**	0.19	0.00019	**0**	0.22	0.00022	**0**	0.20	0.00002	**0**
7.	Turbidity	5.6	22.4	**0.44**	8.2	32.8	**0.65**	12.4	49.6	**0.99**	5.4	21.6	**0.43**
8.	TDS	149.9	7.49	**0.45**	188.9	9.44	**0.57**	243	12.15	**0.73**	208.9	10.44	**0.63**
9.	TSS	15.1	3.02	**0.18**	9.4	1.88	**0.11**	16.1	3.22	**0.19**	11.8	2.36	**0.14**
10.	DO	5.1	98.95	**3.95**	5.4	95.83	**3.83**	5.4	95.83	**3.83**	5.5	94.79	**3.79**
11.	BOD	1.9	38	**1.5**	0.9	18	**0.7**	1.0	20	**0.8**	1.8	36	**1.4**

				2			**2**						**4**
12.	COD	21.8	109	**4.36**	18	90	**3.6**	19.4	97	**3.88**	24.2	121	**4.84**
13.	Fluoride	0.16	10.66	**0.64**	0.41	27.33	**1.64**	0.23	15.33	**0.92**	0.18	12	**0.72**
14.	Chloride	69.8	6.98	**0.42**	67.4	6.74	**0.40**	69.4	6.94	**0.41**	52.0	5.2	**0.31**
15.	Phosphate	5.2	104	**4.16**	4.1	82	**3.28**	5.4	108	**4.32**	4.7	94	**3.76**
16.	Sodium	38.6	193	**11.58**	39.4	197	**11.82**	44.6	223	**13.38**	47.2	236	**14.16**
17.	Potassium	2.9	5.8	**0.23**	3.4	6.8	**0.27**	3.0	6.0	**0.24**	2.71	5.42	**0.21**
18.	Iron	0.003	0.3	**0.01**	0.004	0.4	**0.01**	0.004	0.4	**0.01**	0.004	0.4	**0.01**
19.	Zinc	0.005	0.03	**0**	0.006	0.04	**0**	0.004	0.02	**0**	0.005	0.03	**0**
20.	Lead	ND	0	**0**	ND	**0**	**0**	ND	0	**0**	ND	0	**0**
		WQI=34.07			**WQI=35.62**			**WQI=36.09**			**WQI=38.74**		

Table: 4:- Calculation of q_n and WQI of PW2 in different seasons.

Sl. No.	**PW2**	**WINTER**			**SUMMER**			**MONSOON**			**POST MONSOON**		
	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.7	60	**4.8**	8.0	75	**6.0**	8.4	95	**7.6**	8.3	90	**7.2**
2.	Temperature	27.6	69	**1.38**	27.0	67.5	**1.35**	27.6	69	**1.38**	27.1	67.75	**1.35**
3.	Conductivity	359	17.95	**1.07**	302	15.1	**0.90**	244	12.2	**0.73**	247	12.35	**0.74**
4.	Total hardness	76	12.66	**0.76**	73	12.16	**0.73**	78	13	**0.78**	97	16.16	**0.97**
5.	Alkalinity	141	23.5	**1.41**	114	19	**1.14**	140	23.33	**1.40**	116	19.33	**1.16**
6.	Salinity	0.4	0.0004	**0**	0.3	0.0003	**0**	0.29	0.00029	**0**	0.28	0.00028	**0**
7.	Turbidity	11.9	47.6	**0.95**	10.6	42.4	**0.84**	6.6	26.4	**0.52**	6.8	27.2	**0.54**
8.	TDS	288.6	14.43	**0.86**	253.8	12.69	**0.79**	276.7	13.83	**0.83**	268.6	13.43	**0.80**

9.	TSS	13.4	2.68	**0.16**	11.2	2.24	**0.13**	8.8	1.76	**0.10**	7.0	1.4	**0.08**
10.	DO	5.7	92.70	**3.70**	6.2	87.5	**3.5**	5.8	91.66	**3.66**	6.3	86.45	**3.45**
11.	BOD	0.86	17.2	**0.68**	1.3	26	**1.04**	1.0	20	**0.8**	0.76	15.2	**0.60**
12.	COD	16.8	84	**3.36**	19.6	98	**3.92**	19.8	99	**3.96**	26.4	132	**5.28**
13.	Fluoride	0.07	4.66	**0.28**	0.11	7.33	**0.44**	0.07	4.66	**0.28**	0.09	6	**0.36**
14.	Chloride	94.7	9.47	**0.56**	100.7	10.07	**0.60**	117.7	11.77	**0.70**	107.2	10.72	**0.64**
15.	Phosphate	3.9	78	**3.12**	2.9	58	**2.32**	3.3	66	**2.64**	2.9	58	**2.32**
16.	Sodium	49.8	249	**14.94**	57.9	289.5	**17.37**	65.5	327.5	**19.65**	68.8	344	**20.64**
17.	Potassium	0.8	1.6	**0.06**	1.1	2.2	**0.08**	0.7	1.4	**0.05**	1.2	2.4	**0.09**
18.	Iron	0.004	0.4	**0.01**	0.003	0.3	**0.01**	0.004	0.4	**0.01**	0.004	0.4	**0.01**
19.	Zinc	0.004	0.02	**0**	0.005	0.03	**0**	0.005	0.03	**0**	0.005	0.03	**0**
20.	Lead	ND	0	**0**	ND	0	**0**	ND	0	**0**	ND	0	**0**
		WQI=38.1			**WQI=41.16**			**WQI=45.09**			**WQI=46.23**		

Table: 5:- Calculation of q_n and WQI of PW3 in different seasons.

Sl. No.	**PW3**	**WINTER**			**SUMMER**			**MONSOON**			**POST MONSOON**		
	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.31	40.3	**3.24**	7.4	45	**3.6**	7.9	70	**5.6**	7.7	60	**4.8**
2.	Temperature	29	72.5	**1.45**	31.4	78.5	**1.57**	28.6	71.5	**1.43**	27.1	67.75	**1.35**
3.	Conductivity	3230	161.5	**9.69**	3000	150	**9.0**	3500	175	**10.5**	2800	140	**8.4**
4.	Total hardness	370	61.66	**3.70**	348	58	**3.48**	392	65.33	**3.92**	375	62.5	**3.75**
5.	Alkalini	155	25.8	**1.5**	175	29.1	**1.7**	172	28.6	**1.7**	158	26.3	**1.5**

	ty		3	**5**		6	**5**		6	**2**		3	**8**
6.	Salinity	1.09	0.00109	**0**	1.15	0.00115	**0**	1.20	0.0012	**0**	1.08	0.00108	**0**
7.	Turbidity	11.0	44	**0.88**	10.68	42.72	**0.85**	10.55	42.2	**0.84**	10.24	40.96	**0.81**
8.	TDS	845	42.25	**2.53**	865	43.25	**2.59**	945	47.25	**2.83**	985	49.25	**2.95**
9.	TSS	10.2	2.04	**0.12**	10.80	2.16	**0.13**	10.6	2.12	**0.12**	11.8	2.36	**0.14**
10.	DO	6.4	85.41	**3.41**	6.4	85.41	**3.41**	6.55	83.85	**3.35**	6.7	82.29	**3.29**
11.	BOD	1.39	27.8	**1.11**	1.46	29.2	**1.16**	1.54	30.8	**1.23**	1.50	30	**1.2**
12.	COD	112	560	**22.4**	120	600	**24**	90	450	**18**	105	525	**21**
13.	Fluoride	0.42	28	**1.68**	0.48	32	**1.92**	0.61	40.66	**2.44**	0.65	43.33	**2.63**
14.	Chloride	270	27	**1.62**	295	29.5	**1.77**	278	27.8	**1.66**	275	27.5	**1.65**
15.	Phosphate	1.6	32	**1.28**	1.8	36	**1.44**	2.4	48	**1.92**	1.92	38.4	**1.53**
16.	Sodium	148	740	**44.4**	149	745	**44.7**	156	780	**46.8**	162	810	**48.6**
17.	Potassium	1.44	2.88	**0.11**	1.40	2.8	**0.11**	1.4	2.8	**0.11**	1.94	3.88	**0.15**
18.	Iron	0.004	0.4	**0.01**	0.005	0.5	**0.02**	0.004	0.4	**0.01**	0.004	0.4	**0.01**
19.	Zinc	0.004	0.02	**0**	0.004	0.02	**0**	0.005	0.03	**0**	0.004	0.02	**0**
20.	Lead	ND	0	**0**	ND	0	**0**	ND	0	**0**	ND	0	**0**
		WQI=99.18			**WQI=101.5**			**WQI=102.48**			**WQI=103.81**		

Table: 6:- Calculation of q_n and WQI of PW4 in different seasons.

Sl. No.	**PW4**	**WINTER**			**SUMMER**			**MONSOON**			**POST MONSOON**		
	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.61	55.5	**4.44**	7.78	64	**5.12**	7.40	45	**3.6**	7.55	52.5	**4.2**
2.	Temper	27.1	67.7	**1.3**	27.4	68.5	**1.3**	28	70	**1.4**	27.4	68.5	**1.3**

	ature		5	**5**			**7**						**7**
3.	Conductivity	2780	139	**8.34**	3235	161.75	**9.70**	3640	182	**10.92**	3950	197.5	**11.85**
4.	Total hardness	210	35	**2.1**	278	46.33	**2.78**	232	38.66	**2.32**	257	42.83	**2.57**
5.	Alkalinity	161	26.83	**1.60**	169	28.16	**1.69**	159	26.5	**1.59**	154	25.66	**1.54**
6.	Salinity	1.14	0.00114	**0**	1.96	0.00196	**0**	1.26	0.00126	**0**	1.42	0.00142	**0**
7.	Turbidity	15.8	63.2	**1.26**	15.1	60.4	**1.20**	17.1	68.4	**1.36**	18.6	74.4	**1.48**
8.	TDS	1168	58.4	**3.50**	1876	93.8	**5.63**	1276	63.8	**3.83**	1845	92.25	**5.53**
9.	TSS	14.84	2.96	**0.18**	14.9	2.98	**0.18**	12.8	2.56	**0.15**	16.85	3.37	**0.20**
10.	DO	5.8	85.41	**3.41**	6.64	82.91	**3.31**	6.2	87.5	**3.5**	5.4	95.83	**3.83**
11.	BOD	1.5	30	**1.2**	1.37	27.4	**1.09**	1.00	20	**0.8**	1.64	32.8	**1.31**
12.	COD	153	765	**30.6**	157	785	**31.4**	163	815	**32.6**	170	850	**34**
13.	Fluoride	0.19	12.66	**0.76**	0.76	50.66	**3.04**	0.16	1066	**0.64**	0.93	62	**3.72**
14.	Chloride	876	87.6	**5.25**	898	89.8	**5.38**	876	87.6	**5.25**	1068	106.8	**6.40**
15.	Phosphate	148	2960	**118.4**	147	2940	**117.6**	160	3200	**128**	178	3560	**142.4**
16.	Sodium	1340	6700	**402**	1378	6890	**413.4**	1641	8205	**492.3**	1597	7985	**479.1**
17.	Potassium	34	68	**2.72**	54	108	**4.32**	53	106	**4.24**	64	128	**5.12**
18.	Iron	0.002	0.2	**0**	0.001	0.1	**0**	0.001	0.1	**0**	0.002	0.2	**0**
19.	Zinc	0.002	0.01	**0**	0.001	0	**0**	0.001	0	**0**	0.001	0	**0**
20.	Lea	ND	0	**0**	ND	0	**0**	ND	0	**0**	ND	0	**0**
		WQI=587.11			**WQI=607.21**			**WQI=692.5**			**WQI=704.62**		

Table: 7:- Calculation of q_n and WQI of GW1 in different seasons.

Sl. No.	**GW1**	**WINTER**	**SUMMER**	**MONSOON**	**POST MONSOON**

	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.3	40	**3.2**	8.3	90	**7.2**	7.3	40	**3.2**	8.0	75	**6.0**
2.	Temperature	27	67.5	**1.35**	27	67.5	**1.35**	26	65	**1.3**	28	70	**1.4**
3.	Conductivity	1888	94.4	**5.66**	1900	95	**5.7**	1940	97	**5.82**	1830	91.5	**5.49**
4.	Total hardness	160	26.66	**1.6**	185	30.83	**1.85**	185	30.83	**1.85**	182	30.33	**1.82**
5.	Alkalinity	278	46.33	**2.78**	288	48	**2.88**	300	50	**3.0**	288	48	**2.88**
6.	Salinity	0.80	0.00 08	**0**	0.82	0.00 082	**0**	0.90	0.00 09	**0**	0.75	0.00 075	**0**
7.	Turbidity	0.16	0.64	**0.01**	0.17	0.68	**0.01**	0.15	0.6	**0.01**	0.12	0.48	**0**
8.	TDS	879.6	43.98	**2.64**	888.6	44.43	**2.66**	880.8	44.04	**2.64**	879.4	43.97	**2.64**
9.	TSS	0.14	0.02	**0**	0.11	0.02	**0**	0.14	0.028	**0**	0.18	0.03	**0**
10.	DO	5.9	90.62	**3.62**	6.4	85.41	**3.41**	5.76	92.08	**3.68**	5.8	91.66	**3.66**
11.	BOD	1.2	24	**0.96**	1.6	32	**1.28**	1.3	26	**1.04**	1.6	32	**1.28**
12.	COD	26	130	**5.2**	30	150	**6.0**	32	160	**6.4**	28	140	**5.6**
13.	Fluoride	0.15	10	**0.6**	0.20	13.33	**0.8**	0.50	33.33	**1.2**	0.80	53.33	**3.2**
14.	Chloride	405	40.5	**2.43**	400	40.0	**2.40**	408	40.8	**2.44**	420	42.0	**2.52**
15.	Phosphate	0.61	12.2	**0.48**	0.64	12.8	**0.51**	0.68	13.6	**0.54**	0.52	10.4	**0.41**
16.	Sodium	194	970	**58.2**	188	940	**56.4**	230	1150	**69.0**	240	1200	**72.0**
17.	Potassium	17.8	35.6	**1.42**	19.8	39.6	**1.58**	18.4	36.8	**1.47**	19.9	39.8	**1.59**
18.	Iron	0.002	0.2	**0**	0.003	0.3	**0.01**	0.003	0.3	**0.01**	0.004	0.4	**0.01**
19.	Zinc	0.004	0.02	**0**	0.004	0.02	**0**	0.006	0.04	**0**	0.006	0.04	**0**
20.	Lead	ND	0	**0**	ND	0	**0**	ND	0	**0**	ND	0	**0**
		WQI=90.15			**WQI=94.04**			**WQI=103.6**			**WQI=110.5**		

Table: 8:- Calculation of q_n and WQI of GW2 in different seasons.

Sl. No.	**GW2**	**WINTER**			**SUMMER**			**MONSOON**			**POST MONSOON**		
	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.7	60	**4.8**	8.4	95	**7.6**	7.6	55	**4.4**	7.8	65	**5.2**
2.	Temperature	27	67.5	**1.35**	28	70	**1.4**	26	65	**1.3**	27	67.5	**1.35**
3.	Conductivity	1308	65.4	**3.92**	1336	66.8	**4.0**	1272	63.6	**3.81**	1329	66.45	**3.98**
4.	Total hardness	84	14	**0.84**	88	14.66	**0.88**	78	13	**0.78**	83	13.83	**0.83**
5.	Alkalinity	322	53.66	**3.22**	336	56	**3.36**	327	54.5	**3.27**	346	57.66	**3.46**
6.	Salinity	0.48	0.00048	**0**	0.51	0.00051	**0**	0.57	0.00057	**0**	0.55	0.00055	**0**
7.	Turbidity	0.72	2.88	**0.05**	0.78	3.12	**0.06**	0.76	3.04	**0.06**	0.79	3.16	**0.06**
8.	TDS	660.8	33.04	**1.98**	648.2	32.41	**1.94**	670.4	33.52	**2.01**	637.8	31.89	**1.91**
9.	TSS	0.72	0.14	**0**	0.78	0.15	**0**	0.76	0.15	**0**	0.74	0.14	**0**
10.	DO	5.46	95.20	**3.80**	5.49	94.89	**3.79**	5.34	96.45	**3.85**	5.95	90.10	**3.60**
11.	BOD	0.50	10	**0.4**	0.48	9.6	**0.38**	0.49	9.8	**0.39**	0.77	15.4	**0.61**
12.	COD	62	310	**12.4**	69	345	**13.8**	66	330	**13.2**	64	320	**12.8**
13.	Fluoride	0.76	50.66	**3.04**	0.91	60.66	**3.64**	0.88	58.66	**3.52**	0.79	52.66	**3.16**
14.	Chloride	153	15.3	**0.91**	149	14.9	**0.89**	141	14.1	**0.84**	167	16.7	**1.00**
15.	Phosphate	0.22	4.4	**0.17**	0.20	4.0	**0.16**	0.19	3.8	**0.15**	0.28	5.6	**0.22**
16.	Sodium	210	1050	**63.0**	198	990	**59.4**	217	1085	**65.1**	244	1220	**73.2**
17.	Potassium	5.8	11.6	**0.46**	5.9	11.8	**0.47**	5.6	11.2	**0.44**	6.3	12.6	**0.50**
18.	Iron	0.001	0.1	**0**	0.001	0.1	**0**	0.001	0.1	**0**	0.001	0.1	**0**

19.	Zinc	0.002	0.01	**0**	0.002	0.01	**0**	0.002	0.01	**0**	0.002	0.01	**0**
20.	Lead	ND	0	**0**	ND	0	**0**	ND	0	**0**	ND	0	**0**
		WQI=100.34			**WQI=101.77**			**WQI=103.12**			**WQI=111.88**		

Table:9:- Calculation of q_n and WQI of GW3 in different seasons.

Sl. No.	**GW3**	**WINTER**			**SUMMER**			**MONSOON**			**POST MONSOON**		
	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.8	65	**5.2**	7.4	45	**3.6**	7.9	70	**5.6**	7.8	65	**5.2**
2.	Temperature	27	67.5	**1.35**	28	70	**1.4**	26	65	**1.3**	27	67.5	**1.35**
3.	Conductivity	3234	161.7	**9.70**	3260	163	**9.78**	2846	142.3	**8.53**	2965	148.25	**8.89**
4.	Total hardness	216	36	**2.16**	267	44.5	**2.67**	198	33	**1.98**	248	41.33	**2.48**
5.	Alkalinity	256	42.66	**2.56**	246	41	**2.46**	234	39	**2.34**	238	39.66	**2.38**
6.	Salinity	1.8	0.0018	**0**	2.1	0.0021	**0**	2.0	0.002	**0**	1.8	0.0018	**0**
7.	Turbidity	0.60	2.4	**0.04**	0.7	2.8	**0.05**	0.85	3.4	**0.06**	0.65	2.6	**0.05**
8.	TDS	1326	66.3	**3.98**	1310	65.5	**3.93**	1346	67.3	**4.04**	1300	65	**3.9**
9.	TSS	0.55	0.11	**0**	0.58	0.11	**0**	0.62	0.12	**0**	0.52	0.10	**0**
10.	DO	5.92	90.41	**3.61**	5.69	92.81	**3.71**	5.22	97.70	**3.90**	5.28	97.08	**3.88**
11.	BOD	1.57	31.4	**1.25**	1.52	30.4	**1.21**	1.55	31	**1.24**	1.4	28	**1.12**
12.	COD	44	220	**8.8**	38	190	**7.6**	34	170	**6.8**	41	205	**8.2**
13.	Fluoride	0.24	16	**0.96**	0.09	6	**0.36**	0.28	18.66	**1.12**	0.15	10	**0.6**
14.	Chloride	672	67.2	**4.03**	634	63.4	**3.80**	567	56.7	**3.40**	648	64.8	**3.88**
15.	Phosphate	0.19	3.8	**0.15**	0.16	3.2	**0.12**	0.21	4.2	**0.16**	0.19	3.8	**0.15**
16.	Sodium	217	1085	**65.1**	234	1170	**70.2**	248	1240	**74.4**	246	1230	**73.8**

17.	Potassium	2.5	5.0	**0.2**	3.1	6.2	**0.24**	1.9	3.8	**0.15**	2.6	5.2	**0.20**
18.	Iron	0.001	0.1	**0**	0.001	0.1	**0**	0.001	0.1	**0**	0.001	0.1	**0**
19.	Zinc	0.001	0	**0**	0.001	0	**0**	0.001	0	**0**	0.002	0.01	**0**
20.	Lead	ND	0	**0**	ND	0	**0**	ND	0	**0**	ND	0	**0**
		WQI=109.09			**WQI=111.13**			**WQI=115.02**			**WQI=116.08**		

Table: 10:- Calculation of q_n and WQI of GW4 in different seasons.

Sl. No.	**GW4**	**WINTER**			**SUMMER**			**MONSOON**			**POST MONSOON**		
	Parameters	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**	**Values**	**(q_n)**	**WQI**
1.	pH	7.0	25	**2.0**	8.0	75	**6.0**	7.2	35	**2.8**	8.0	75	**6.0**
2.	Temperature	27	67.5	**1.35**	26	65	**1.3**	28	70	**1.4**	27	67.5	**1.35**
3.	Conductivity	3128	156.4	**9.38**	3800	190	**11.4**	3640	182	**10.92**	3940	197	**11.82**
4.	Total hardness	582	97	**5.82**	650	108.33	**6.50**	565	94.16	**5.65**	575	95.83	**5.75**
5.	Alkalinity	70	11.66	**0.70**	84	14	**0.84**	82	13.66	**0.82**	70	11.66	**0.70**
6.	Salinity	1.8	0.0018	**0**	2.2	0.0022	**0**	1.6	0.0016	**0**	1.2	0.0012	**0**
7.	Turbidity	0.4	1.6	**0.03**	0.5	2.0	**0.04**	0.7	2.8	**0.05**	0.2	0.8	**0.01**
8.	TDS	1864	93.2	**5.59**	1942	97.1	**5.83**	1896	94.8	**5.69**	1895	94.75	**5.68**
9.	TSS	0.36	0.07	**0**	0.40	0.08	**0**	0.30	0.06	**0**	0.44	0.08	**0**
10.	DO	5.1	98.95	**3.95**	6.2	87.5	**3.5**	4.9	101.04	**4.04**	5.2	97.91	**3.91**
11.	BOD	1.2	24	**0.96**	1.67	33.4	**1.33**	1.44	28.8	**1.15**	1.28	25.6	**1.02**
12.	COD	68	340	**13.6**	84	420	**16.8**	84	420	**16.8**	86	430	**17.2**
13.	Fluoride	0.08	5.33	**0.32**	0.06	4	**0.24**	0.08	5.33	**0.32**	0.08	5.33	**0.32**
14.	Chloride	810	81.0	**4.86**	756	75.6	**4.53**	778	77.8	**4.66**	816	81.6	**4.89**

15.	Phosphate	0.20	4.0	**0.16**	0.22	4.4	**0.17**	0.20	4.0	**0.16**	0.26	5.2	**0.20**
16.	Sodium	410	2050	**123.0**	400	2000	**120.0**	424	2120	**127.2**	412	2060	**123.6**
17.	Potassium	19.8	39.6	**1.58**	18.8	37.6	**1.50**	20.2	40.4	**1.61**	20.6	41.2	**1.64**
18.	Iron	0.002	0.2	**0**	0.001	0.1	**0**	0.001	0.1	**0**	0.002	0.2	**0**
19.	Zinc	0.003	0.02	**0**	0.003	0.02	**0**	0.003	0.02	**0**	0.003	0.02	**0**
20.	Lead	ND	0	**0**	ND	0	**0**	ND	0	**0**	ND	0	**0**
		WQI=173.3			**WQI=179.98**			**WQI=183.27**			**WQI=184.09**		

Table: 11:- Comparisons with average WQI values of PW & GW in different seasons.

Sl. No.	**WQI VALUES**				**AVERAGE WQI VALUE**
	WINTER	**SUMMER**	**MONSOON**	**POST-MONSOON**	
PW1	34.07	35.62	36.09	38.74	**36.13**
PW2	38.1	41.16	45.09	46.23	**42.645**
PW3	99.18	101.5	102.48	103.81	**101.742**
PW4	587.11	607.21	692.5	704.62	**647.86**
			MEAN WQI VALUES OF PW= 207.09		
GW1	90.15	94.04	103.6	110.5	**99.572**
GW2	100.34	101.77	103.12	111.88	**104.277**
GW3	109.09	111.13	115.02	116.08	**112.83**
GW4	173.3	179.98	183.27	184.09	**180.16**
			MEAN WQI VALUES OF GW=124.20		

Detailed Seasonal Analysis of Physicochemical Characteristics

This section presents a detailed analysis of the physicochemical characteristics of pond water and groundwater samples collected from the Paradeep industrial zone across different seasons. The parameters analyzed include pH, temperature, conductivity, total hardness, alkalinity, salinity, turbidity, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), fluoride, chloride, phosphate, sodium, potassium, iron, zinc, and lead. The seasonal variations of each parameter are discussed in detail.

pH- The pH values ranged from 7.0 (monsoon) to 7.7 (post-monsoon) in PW1, and from 7.3 (winter & monsoon) to 8.3 (summer) in GW1. Seasonal variations indicate a slight increase in pH during the post-monsoon period for both pond and groundwater samples.

Temperature -Temperature varied from 27.0°C (winter & post-monsoon) to 27.5°C (monsoon) in PW1, and from 26.0°C (monsoon) to 28.0°C (post-monsoon) in GW1. The

temperature showed minor fluctuations across seasons, with higher temperatures recorded in the monsoon and post-monsoon periods.

Conductivity- Conductivity ranged from 240.0 µS/cm (post-monsoon) to 361 µS/cm (monsoon) in PW1, and from 1830 µS/cm (post-monsoon) to 1940 µS/cm (monsoon) in GW1. Higher conductivity values were observed during the monsoon season, indicating increased dissolved salts.

Total Hardness- Total hardness values ranged from 43.0 mg/L (post-monsoon) to 68.0 mg/L (monsoon) in PW1, and from 160.0 mg/L (winter) to 185.0 mg/L (summer & monsoon) in GW1. Monsoon season showed higher hardness levels, likely due to increased mineral leaching.

Alkalinity-Alkalinity ranged from 98.0 mg/L (post-monsoon) to 126.0 mg/L (monsoon) in PW1, and from 278.0 mg/L (winter) to 300.0 mg/L (monsoon) in GW1. Seasonal variations were more pronounced in groundwater samples.

Salinity-Salinity ranged from 0.19 PPT (summer) to 0.22 PPT (monsoon) in PW1, and from 0.75 PPT (post-monsoon) to 0.9 PPT (monsoon) in GW1. Both pond and groundwater samples showed slight increases in salinity during the monsoon.

Turbidity-Turbidity varied from 5.4 NTU (post-monsoon) to 12.4 NTU (monsoon) in PW1, and from 0.12 NTU (post-monsoon) to 0.17 NTU (summer) in GW1. Higher turbidity in monsoon indicates more suspended particles in the water.

TDS-TDS values ranged from 149.9 mg/L (winter) to 243.0 mg/L (monsoon) in PW1, and from 879.4 mg/L (post-monsoon) to 888.6 mg/L (summer) in GW1. Increased TDS levels during monsoon indicate higher dissolved solids.

TSS-TSS ranged from 9.4 mg/L (summer) to 16.1 mg/L (monsoon) in PW1, and from 0.11 mg/L (summer) to 0.18 mg/L (post-monsoon) in GW1. Monsoon showed higher TSS levels due to increased runoff and erosion.

DO-DO values ranged from 5.1 mg/L (winter) to 5.5 mg/L (post-monsoon) in PW1, and from 5.76 mg/L (monsoon) to 6.4 mg/L (summer) in GW1. Higher DO levels in summer suggest better aeration.

BOD-BOD ranged from 0.9 mg/L (summer) to 1.9 mg/L (winter) in PW1, and from 1.2 mg/L (winter) to 1.6 mg/L (summer & post-monsoon) in GW1. Higher BOD in winter indicates more organic matter.

COD-COD values ranged from 18.0 mg/L (summer) to 24.2 mg/L (post-monsoon) in PW1, and from 26.0 mg/L (winter) to 32.0 mg/L (monsoon) in GW1. Increased COD in monsoon suggests higher organic pollutants.

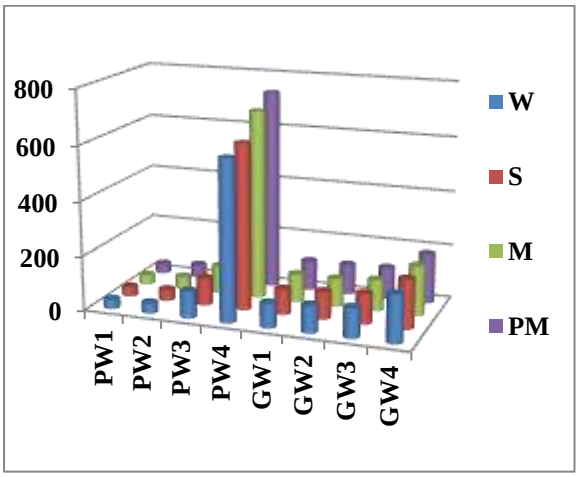
Fluoride-Fluoride ranged from 0.16 mg/L (winter) to 0.41 mg/L (summer) in PW1, and from 0.15 mg/L (winter) to 0.8 mg/L (post-monsoon) in GW1. Higher fluoride levels in summer and post-monsoon indicate more mineral dissolution.

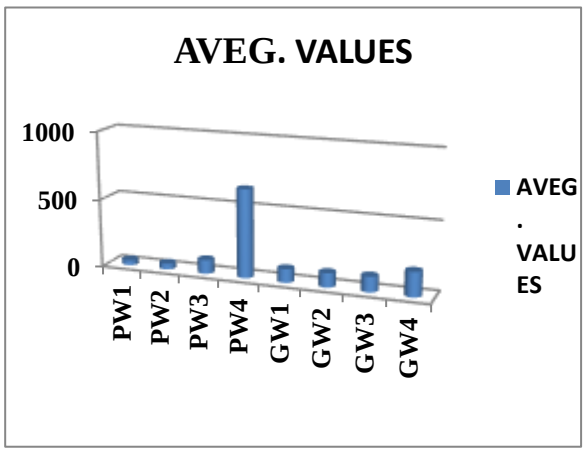
Chloride-Chloride ranged from 52.0 mg/L (post-monsoon) to 67.4 mg/L (summer) in PW1, and from 400.0 mg/L (summer) to 420.0 mg/L (post-monsoon) in GW1. Seasonal variations show higher chloride in post-monsoon.

Phosphate-Phosphate ranged from 4.1 mg/L (summer) to 5.4 mg/L (monsoon) in PW1, and from 0.52 mg/L (post-monsoon) to 0.68 mg/L (monsoon) in GW1. Increased phosphate in monsoon indicates more agricultural runoff.

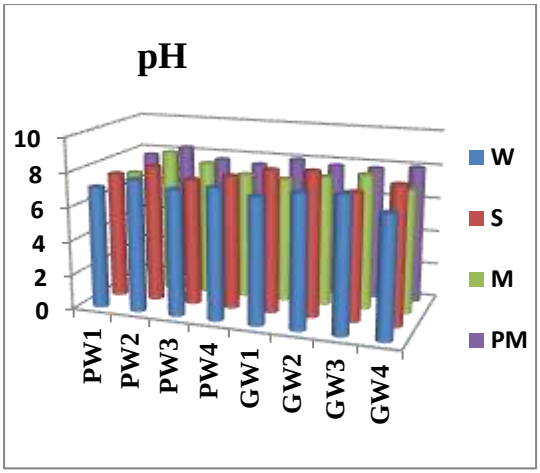
Sodium-Sodium ranged from 38.6 mg/L (winter) to 47.2 mg/L (post-monsoon) in PW1, and from 188.0 mg/L (summer) to 240.0 mg/L (post-monsoon) in GW1. Higher sodium levels in post-monsoon suggest increased salinity.
Potassium-Potassium ranged from 2.71 mg/L (post-monsoon) to 3.4 mg/L (summer) in PW1, and from 17.8 mg/L (winter) to 19.9 mg/L (post-monsoon) in GW1. Post-monsoon showed higher potassium levels.
Iron-Iron ranged from 0.003 mg/L (winter) to 0.004 mg/L (summer, monsoon & post-monsoon) in PW1, and from 0.002 mg/L (winter) to 0.004 mg/L (post-monsoon) in GW1. Seasonal variations were minimal.
Zinc-Zinc ranged from 0.004 mg/L (monsoon) to 0.006 mg/L (summer) in PW1, and from 0.004 mg/L (winter & summer) to 0.006 mg/L (monsoon & post-monsoon) in GW1. Higher zinc levels were observed in monsoon and post-monsoon.
Lead-Lead levels were below detectable limits in all samples, indicating minimal contamination.

NOTE: PW1<PW2<PW3<PW4 AND GW1<GW2<GW3<GW4
WINTER<SUMMER<MONSOON<POST-MONSOON





Comparison with average WQI values of PW & GW in different seasons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PW2
PW3
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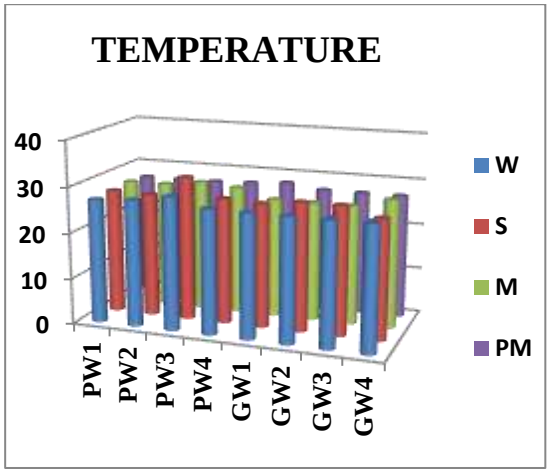
GW1
GW2
GW3
GW4
W
S
M
PM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W
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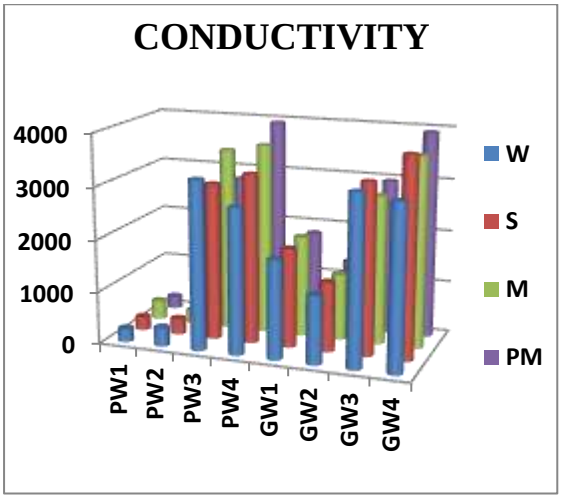
M
PM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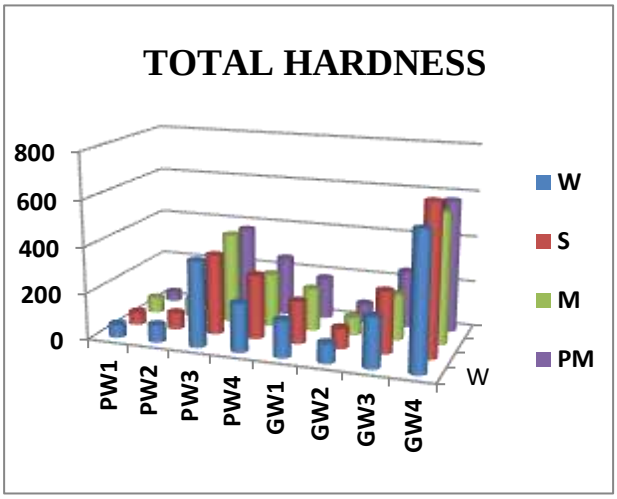
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PW4
GW1
GW2
GW3
GW4
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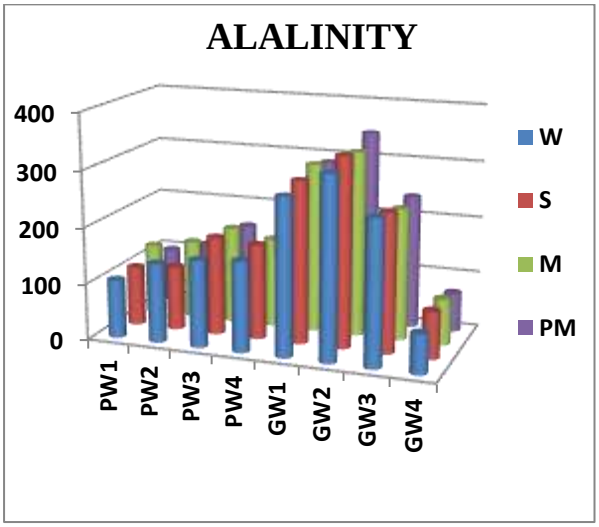
W
S
M
PM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PW4
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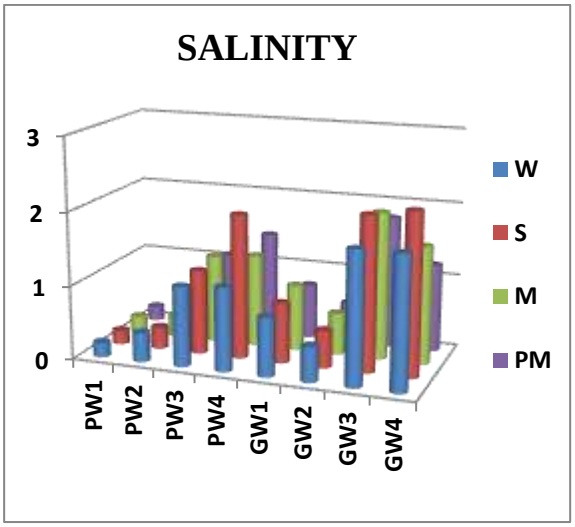
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PW3
PW4
GW1
GW2
GW3
GW4
W
S
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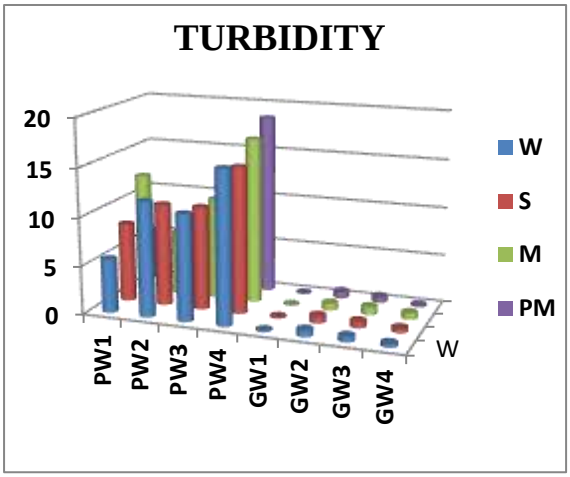
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PW4
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GW2
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GW4
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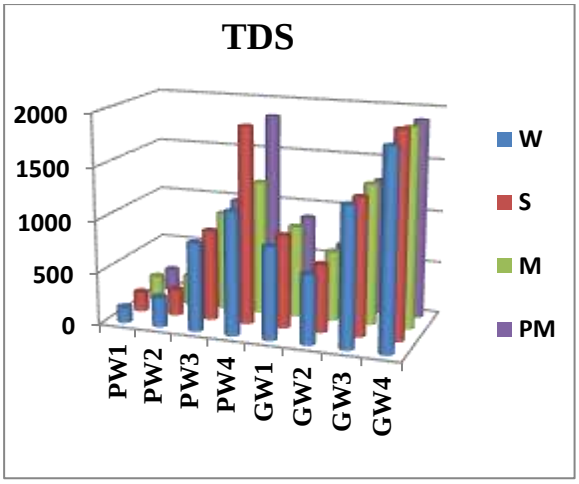
M
PM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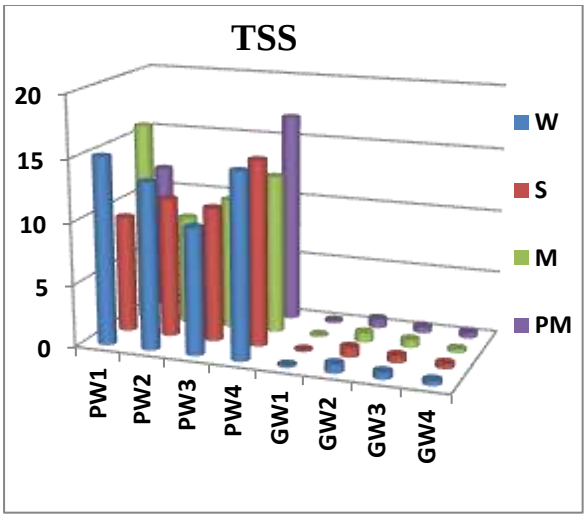
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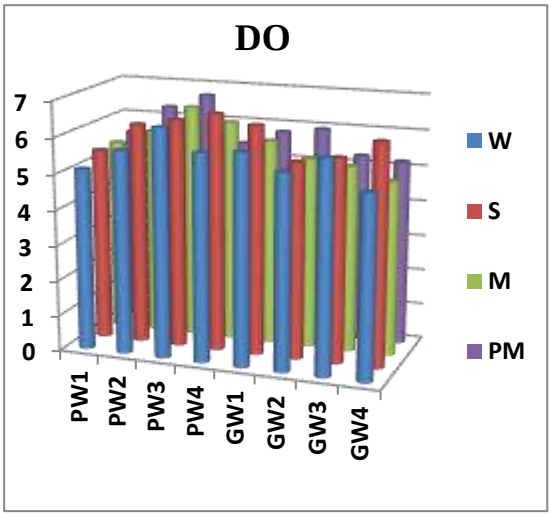
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6
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PW3
PW4
GW1
GW2
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M
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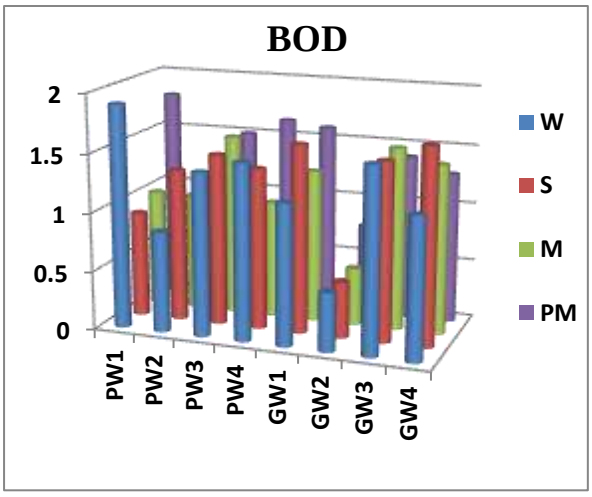
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S
M
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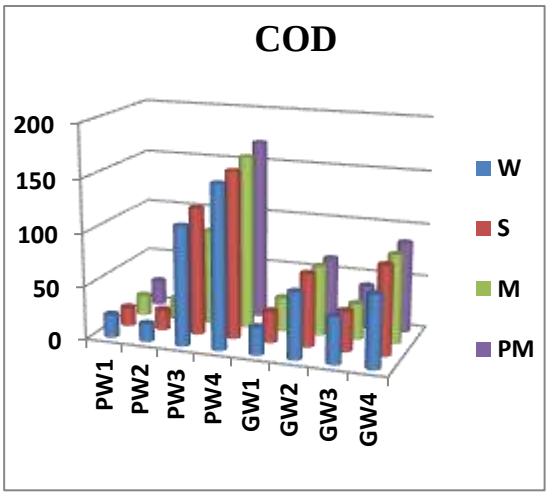
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GW1
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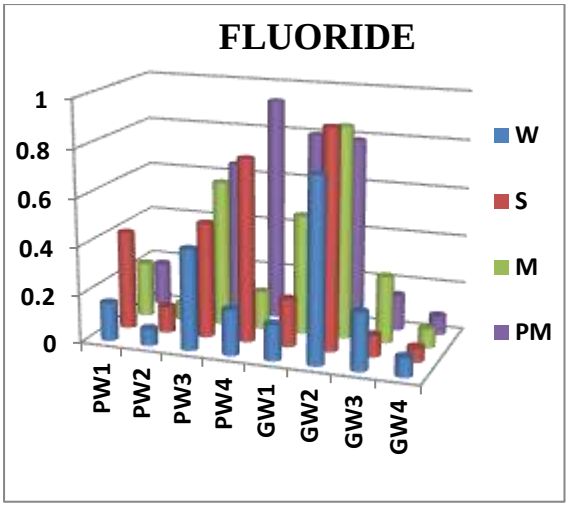
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PW2
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PW4
GW1
GW2
GW3
GW4
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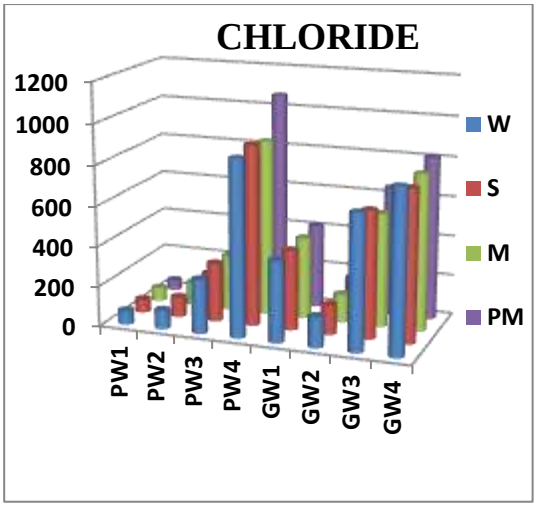
S
M
PM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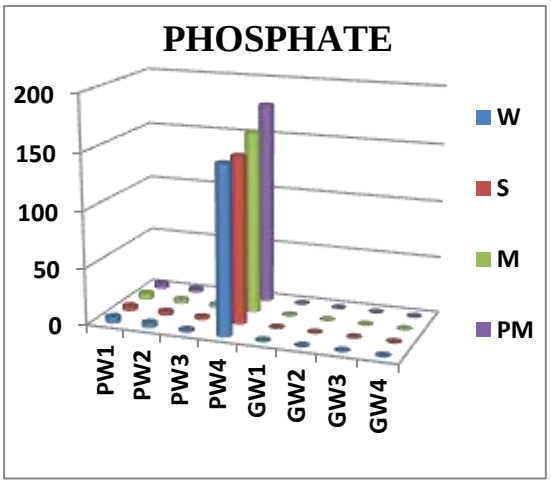
GW4
W
S
M
PM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GW2
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S
M
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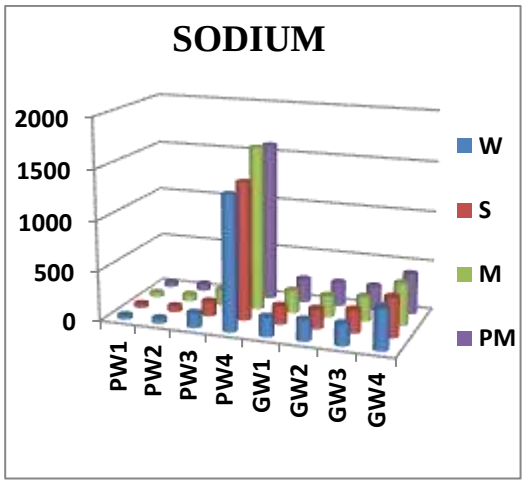
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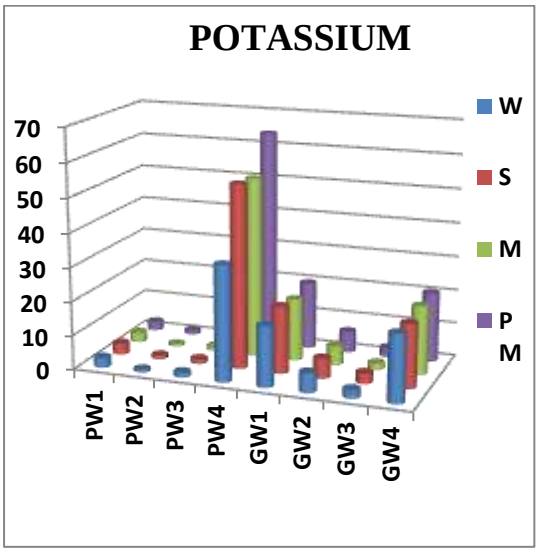
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50
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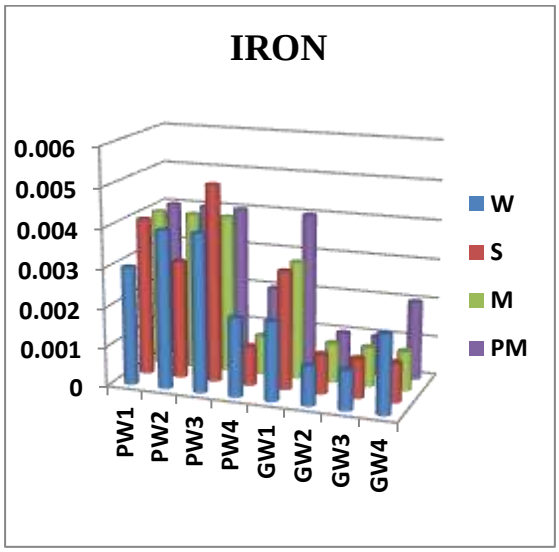
GW3
GW4
W
S
M
P
M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0.004
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PW4
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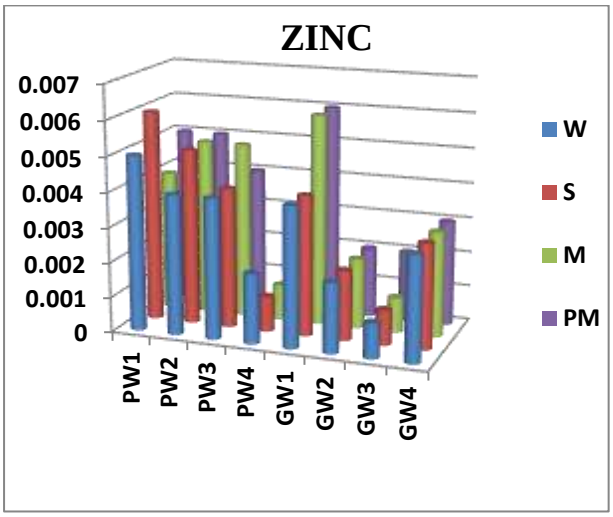
GW2
GW3
GW4
W
S
M
PM



CONCLUSION

Summary of Findings

The study reveals significant seasonal variations in the physicochemical characteristics of pond water and groundwater in the Paradeep industrial zone. Monsoon and post-monsoon seasons showed higher levels of most parameters, indicating increased pollution from runoff and industrial activities. Both pond water and groundwater samples exhibited values exceeding permissible limits for several parameters, suggesting that the water is not fit for drinking without proper treatment.

Implications for Water Quality Management

The findings underscore the need for stringent water quality monitoring and management practices in the industrial zone. Local authorities should implement regular water quality assessments and enforce regulations to control pollution sources. Public awareness campaigns are essential to educate the community on the importance of protecting water resources.

Recommendations for Further Study and Local Awareness

- **Extended Study Duration:** Conduct long-term studies to better understand the trends and variations in water quality.
- **Pollution Source Identification:** Investigate specific sources of pollution to implement targeted mitigation measures.
- **Community Engagement:** Increase local awareness about water conservation and pollution prevention.
- **Water Treatment Facilities:** Establish and maintain water treatment facilities to ensure safe water for drinking and other uses.
- **Policy Implementation:** Develop and enforce policies to regulate industrial discharge and agricultural runoff.

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