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Seasonal Variation in Physico-chemical Characteristics of Domestic Wastewater in Himachal Pradesh: a Case Study

Smily Vishwakarma*, Dharmendra, and Deven Singh

Civil Engineering Department, National Institute of Technology, Hamirpur, India

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Abstract

The present study is based on data collection from some of the WWTPs (wastewater treatment plants) of the Himachal Pradesh region, and to investigate the range of physico-chemical characteristics of conventional WWTPs, which receive wastewater from different zones in different cities in Himachal Pradesh. Five parameters are measured and analyzed in this research work. They are pH, suspended solids (mg/L), biological oxygen demand (mg/L), chemical oxygen demand (mg/L), and oil and grease (mg/L). The parameters are compared seasonally to help improve the performance, and operational conditions of WWTPs are with the standard parameters range according to APHA (American Public Health Association), standard examination methods of water, and wastewater seasonal in parameters. Seasonal variations in physico-chemical properties are noticeable. The study analyzes the physico-chemical parameters of wastewater from various Sewage Treatment Plants (STPs) across six districts in Himachal Pradesh, India, revealing variations in water quality across different seasons and locations. The study highlights the need for proper treatment and management of wastewater to prevent environmental pollution and protect public health. The findings could be useful for the policy-makers and authorities responsible for wastewater management in the region.

1. Introduction

Water is used as a natural resource for a wide range of purposes including the domestic, commercial, and agricultural ones. Major challenges in urban and rural settlements in today's world are water scarcity, nutrient-depleted soils, and pollution. This will worsen as the worldwide population is growing, especially in nations where urbanization is occurring more quickly [1]. Urbanization growth has accelerated the rapid disintegration of water supply resources', and concurrently, increased the percentage of wastewater production. As a result, there is an urgent requirement for urban water planning and management to satisfy the demands of the growing population and to investigate the possibilities of using the wastewater generated for other uses by treating it to conserve the water supply from freshwater sources [2]. Water is necessary for all lifeforms and is crucial to their survival. Numerous aquatic species including both huge aquatic animals and microscopic planktons, live in water. No one can survive without water, even though there is a lot of it on the planet yet relatively little of it is useable. The Prominent factors responsible for water pollution include domestic sewage, industrialization, population growth, the use of pesticides and fertilizers, plastic and polythene bags, urbanization, and a shoddy government management system [4].

Wastewater is stated as the water that has been employed for domestic, industrial, commercial or agricultural runoff after it has served its intended function and is supplied to a society. Particularly, the domestic wastewater generated contains a lot of organic material that could be harmful if released into a surface stream, endangering both human health and the environment. Furthermore, inappropriate treatment of the generated residential wastewater can result in several water-borne diseases; as a result, one of the potentials offered

✉ *Corresponding author: Smily@nith.ac.in, djha@nith.ac.in (S. Vishwakarma)*

remedies is effective wastewater treatment and making it suitable for reuse [2].

Generally, the wastewater generated from domestic facilities such as homes, institutions, and commercial establishments is known as "Sewage or community wastewater". It is organic because it contains carbon compounds like human waste, paper, vegetable matter, etc. It is composed of 99.9% water and 0.1% solids [3]. Wastewater that exits a treatment facility, sewer or industrial outlet, whether it has been treated or not, is referred to as effluent [5]. In addition to domestic wastewater, it's a universal practice throughout the world to utilize wastewater and effluents from distilleries, agro-industrial units, and domestic or municipal effluents in agriculture. Wastewater irrigation has both positive and negative effects on crops, especially on vegetables [6]. A WHO report states that by 2030, some developing nations may have water shortages of over 50%, leading to 80% of individuals experiencing water-borne or water-related diseases [7].

Moreover, innovative decentralized systems are being designed and put into effect for present and future urban development, either separately or in combination with the use of a centralized system.

When using a range of basic technologies, a decentralized wastewater system simply treats raw wastewater near to the source (point of generation). Decentralized wastewater systems are those that process domestic and commercial sewage using a variety of onsite and cluster treatment technologies, according to the Office of Water United States Environmental Protection Agency (USEPA) [9]. There have been reported several emergent contaminants in WWTPs during the SARS-CoV-2 epidemic that are resistant to conventional biological treatment, particularly those of pharmaceutical source [10].

The relationship between the inflow and outflow of water across a certain area is known as the water budget. It provides a comparison of the water supply and demand, allowing for the detection of precipitation surpluses and deficits. The equilibrium between the country's available water and the water is being used. In India, there are 1,122 km^3 of utilizable water resources available annually. In addition, by the year 2050, increased use for irrigation, household, and industrial uses will make 123 km^3 to 169 km^3 greater return flow available. 3,000 m^3 of utilizable water per person were accessible in 1951, whereas only 1,100 m^3 were available per person in 1998 and estimate of about 687 m^3 by the year 2050 will be available [11].

Therefore, the primary goal of this study is based on data collection from some of the WWTPs of Himachal Pradesh region and to investigate the range of physico-chemical characteristics of conventional WWTPs, which receive wastewater from different zones in different cities in Himachal Pradesh.

The case study was conducted to analyze the physico-chemical characteristics of wastewater from various WWTPs in Himachal Pradesh, India. The aim was to investigate the range of parameters like pH, suspended solids, biological and chemical oxygen demand, and Oil and grease in wastewater received from treatment plants in the chosen study area cities in Himachal Pradesh. This study aimed to assess the seasonal variations in parameters of wastewater to help improve the performance and operational conditions of WWTPs to meet the standard parameters range. The study also aimed to highlight the need for proper treatment and management of wastewater to prevent environmental pollution and protect public health. The findings could be useful for policymakers and authorities responsible for wastewater management in the region.

2. Materials and methods

The analysis of physico-chemical parameters required for the assessment of seasonal variation of wastewater quality in some districts in Himachal Pradesh. The data of all three season (monsoon, winter, and summer) analyzed from January 2019 to December 2021. Samples were collected and preserved as per standard methods of APHA (2012). A.R grade chemicals were used for the assessment of wastewater quality. For identification of physico-chemical parameters-BOD incubator, UV spectroscopy, conductivity-meter, turbidity-meter, mercury thermometer, digital pH-meter, and titrations were used. The data obtained by the analysis of physico-chemical parameters of sewage treatment plant (STPs) in the study area, was further compared with the limits prescribed by Bureau of Indian Standards (BIS: IS: 10500,2012). The Indian standard's acceptable and permitted limits are shown in Table 8.

2.1. Area under investigation

The study was conducted in the regions of Mandi, Bilaspur, Chamba, Kangra, Hamirpur, Solan, and Kinnaur. These areas experience three seasons - a mild and dry winter from November to March, a hot and humid summer from mid-April to June, and a rainy season from July to mid-

September. Surrounded by the Shivalik range, the areas are hilly, with an altitude range of 450 meters to 1,100 meters, and experience temperatures ranging from 20 °C to 43 °C. The slopes of the hills are covered with Pinus roxburghii forest. The socio-economic conditions of the area are highly variable, with unique customs, languages, and cultural histories. The region offers an opportunity to explore indigenous traditional knowledge. The study was conducted, which utilized various methods including survey questionnaires, site visits, and participant observations. The study aimed to gather data and insights regarding the subject of interest by gathering information from individuals directly involved in the topic being studied. This involved visiting sites where the subject matter was present and conducting surveys with the people involved. In addition, participant observations were carried out to provide further insight into the topic being studied. Overall, the study utilized a comprehensive approach to gather data and insights about interest. The specimens were identified using monographic publications and regional floras [13].

"The studied area was chosen due to its proximity to the research institution and ease of access for data collection.

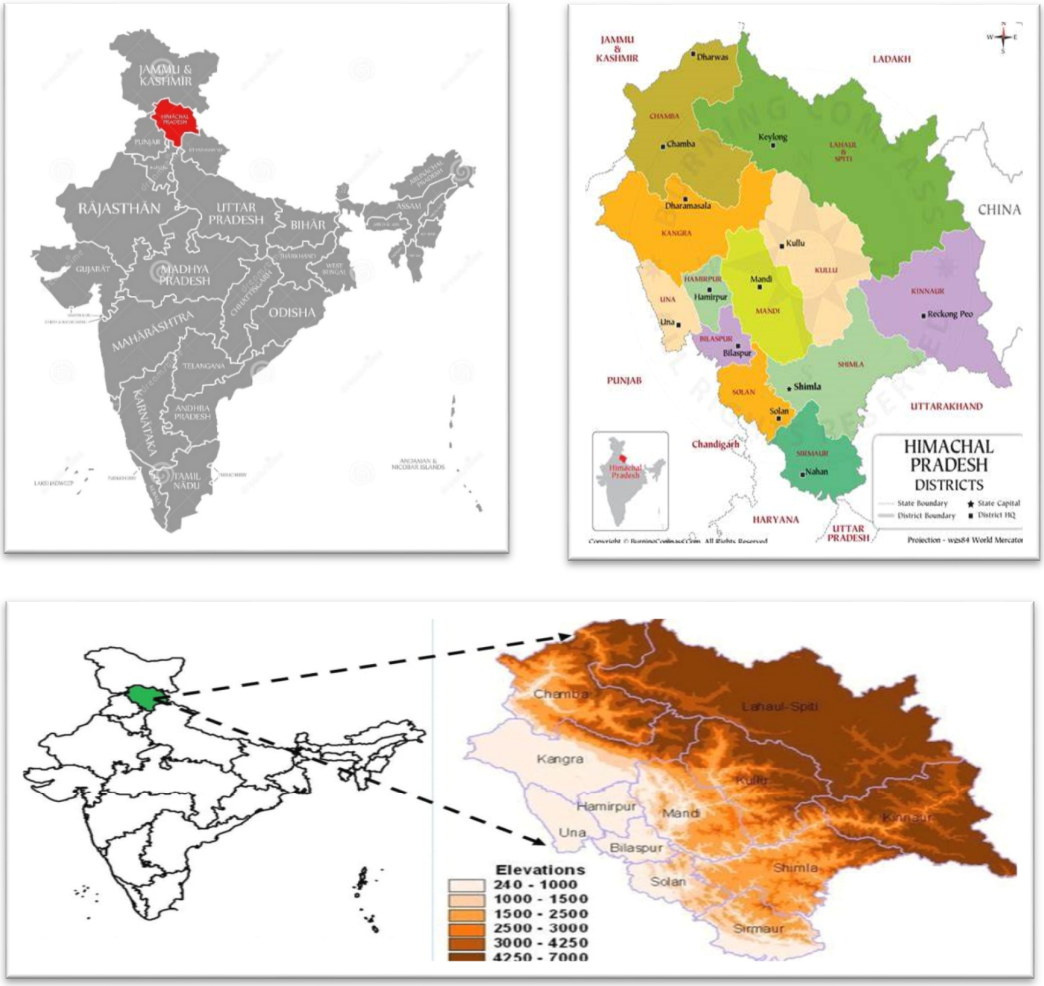


Figure 1. Studied area [22].

2.2. Sampling methodology

Wastewater treatment is the process of removing contaminants from wastewater including household sewage and industrial effluent before it is released into the environment. The treatment process typically involves several stages that are designed to remove different types of contaminants.

2.3. Sampling

Visit and collection of samples at wastewater treatment plants in seven districts of Himachal Pradesh, i.e., Mandi, Bilaspur, Chamba, Kangra, Hamirpur, Solan, and Kinnaur was done. The data from five treatment plants from mandi was STP khaliar, STP Raghunath ka Padhar, STP Sundernagar, STP Jogindernagar, and STP Sarkaghat zone-B. The data from Bilaspur District was taken from STP Ghumarwin and STP Naina Devi Ji. In Chamba, data was taken from STP Silta Bridge, STP Bhagot, and STP Barga. From Kangra, samples were taken from Palampur, Jawalamukhi, Dharmshala, Nagrota, Old kangra zone 3, and Tanda Medical College. From Hamirpur, data was taken from Zone-1, Zone 2, Zone-3, NIT Hamirpur, and Sujanpur. Data was taken from Solan – Zone B, Arki, and Kunihar. From Kinnaur- sample from Reckongpeo and Paonta zone-1 were taken. Following steps were taken while sample collection:

- Careful sampling of wastewater was done to obtain accurate and reliable results as the quality of the sample collected will determine the accuracy of the results obtained.
- Proper sampling techniques including the use of appropriate equipment and sampling locations was carried out for accurate analysis.
- Wastewater samples were collected at regular intervals.
- Sampling protocols were developed and followed consistently to ensure that data is comparable over time and between different locations.
- Analysis of the parameters, i.e. pH, suspended solids (mg/L), biological oxygen demand (mg /L), chemical oxygen demand (mg/L), and oil and grease (mg/ L) was done.

2.4. Data Analysis

The study included the values of five parameters obtained from seven Districts of Himachal Pradesh WWTP. Their daily performance was analyzed to examine variations seasonally in the wastewater quality parameters, identify the interrelationships between parameters, for example, BOD, COD and TSS of the plant. The data analysis period was divided into three seasons for each year: winter (November, December, January, and February, march), summer (April, and May, June, July), and rainy (August, September, October, and November) based on climatic conditions. The data was analyzed and interpreted using the standard method for the examination of water and wastewater (22^{nd} edition) used for each parameter along with the technique applied for the measurement. The physical-chemical parameter analysis was done according to the American Public Health Association methods (APHA 22nd Edn. 2012) for TSS, for pH IS: 3025, for Biological Oxygen Demand (BOD) IS 3025 (Pt44):1993, for Chemical Oxygen Demand (COD) IS 3025 Part (58)2006, for oil and grease [15]. For the monthly agenda, sewage samples were collected and studied monthly. Physical-chemical parameters are important in this study to determine the water quality and compare the results to standard values.

3. Results and Discussion

3.1. STP Mandi

The average pH of the wastewater for Mandi-At STP Khaliar was 7.57, 7.41, and 7.55 for winter, summer, and rainy seasons. At STP Raghunath ka Padhar was 6.99, 6.79, and 7.60 for winter, summer, and rainy season. At STP, Sundernagar was 7.4, 7.3, and 7.6 for winter, summer, and rainy season. For STP, Jogindernagar winter, summer, rainy pH were 7.53, 7.29 and 7.55, and for STP, Sarkaghat zone-B pH value were 7.81, 7.71, and 7.50 for winter, summer, rainy season. The average value for STP khaliar for winter, summer, and rainy seasons the parameters, Suspended solids- 75.56, 52.38, 46.83, BOD - 23.29, 6.05 ,13.61, COD - 89.87, 45.75, 64.67, oil and grease - 1.78, 2.00 and 1.33. For STP, Raghunath Ka Padhar value for winter, summer, and rainy seasons SS- 114.86, 76.38, 461.50, BOD- 69.64, 16.64, 41.43, COD - 142.54, 107, 199.33, O and G- 3.42, 1.72, 2.69. For Sunder Nagar, parameter value for winter, summer, and rainy seasons SS- 116.9, 141.1, 9.2, BOD - 55.4, 33.6, 3.1, COD- 191.6, 135.8, 28.6, O and G- 7.4, 2.1, 0.4.

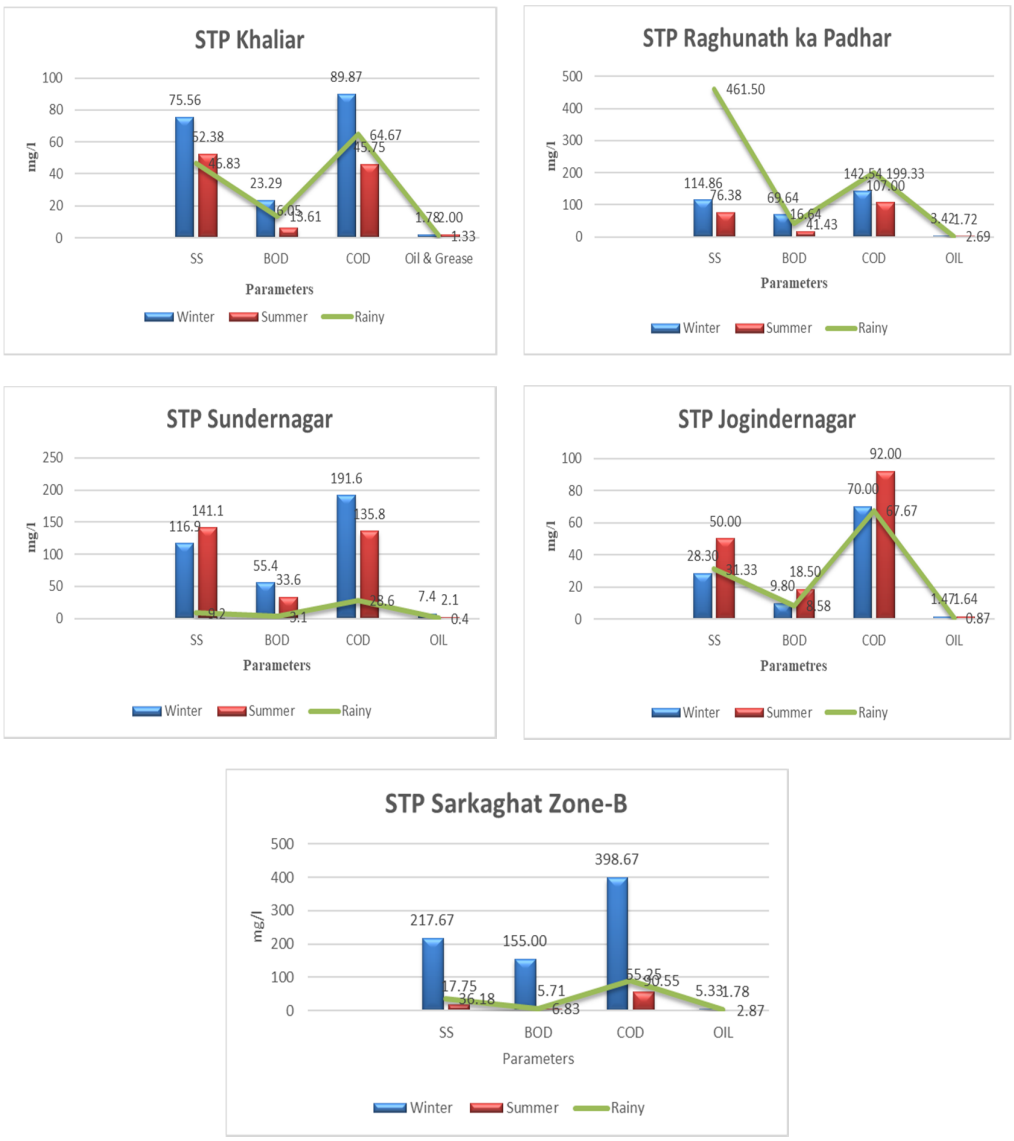


Figure 2. Seasonal variation of pH, SS, BOD, COD, and O and G at STP Mandi.

3.2. Plants in Mandi.

Based on the data, we can observe the following seasonal variations in the wastewater parameters for the different STPs:

pH: The pH values for all STPs were within the permissible range of 6.5-8.5 according to APHA. However, there were some variations in the pH values across different seasons for each STP, which could be due to changes in the characteristics of the wastewater.

Suspended Solids (SS): The concentration of SS varied across different seasons for each STP. Generally, the concentration of SS was higher in the winter season compared to summer and rainy seasons. This could be due to increased runoff in hilly areas, increased erosion, and lower water temperature.

Biochemical Oxygen Demand (BOD): The BOD values were highest during winter and rainy seasons compared to summers. This might be due to the colder temperature which tends to slower breakdown of organic matter and runoff during rainy season which will carry more organic matter leading to increase in BOD levels.

Chemical Oxygen Demand (COD): The COD levels also showed seasonal variations. However, the values were within the permissible limits according to APHA for all seasons and STPs.

Oil and Grease (O and G): The concentration of O and G also showed some seasonal variations across different STPs. However, the values were

within the permissible limits according to APHA for all seasons and STPs.

Overall, the data suggests that there are seasonal variations in the wastewater parameters for different STPs. These variations could be due to changes in the characteristics of the wastewater during different seasons.

Table 1. Data of treatment

KHALIAR					
Seasons	SS	BOD	COD	O and G	pH
Winter	75.56	23.29	89.87	1.78	7.57
Summer	52.38	6.05	45.75	2.00	7.41
Rainy	46.83	13.61	64.67	1.33	7.55
RAGHUNATH KA PADHAR					
Seasons	SS	BOD	COD	O and G	pH
Winter	114.86	69.64	142.54	3.42	6.99
Summer	76.38	16.64	107.00	1.72	6.79
Rainy	461.50	41.43	199.33	2.69	7.60
SUNDERNAGAR					
Seasons	SS	BOD	COD	O&G	pH
Winter	116.9	55.4	191.6	7.4	7.4
Summer	141.1	33.6	135.8	2.1	7.3
Rainy	9.2	3.1	28.6	0.4	7.6
JOGINDERNAGAR					
Sseasons	SS	BOD	COD	O&G	pH
Winter	28.30	9.80	70.00	1.47	7.53
Summer	50.00	18.50	92.00	1.64	7.29
Rainy	31.33	8.58	67.67	0.87	7.55
SARKAGHAT ZONE-B					
Seasons	SS	BOD	COD	O&G	pH
Winter	217.67	155.00	398.67	5.33	7.81
Summer	17.75	5.71	55.25	1.78	7.71
Rainy	36.18	6.83	90.55	2.87	7.50

3.3. Bilaspur

The average pH of the wastewater for Bilaspur- At STP Ghumarwin was 8, 8, and 7 for winter, summer, and rainy seasons. At STP, NIT Naina devi Ji was 8, 8, and 7 for winter, summer, and rainy season. The average value for STP Ghumarwin for winter, summer and rainy seasons the parameters, Suspended solids- 91, 172, 25, BOD – 14, 21 ,3, COD – 98, 108, 35, oil and grease – 2, 2, and 0. For STP, Naina Devi Ji value for winter, summer and rainy seasons SS- 308, 40, 125, BOD- 315, 5, 38, COD – 855, 46, 143, O and G- 11, 1, 3.

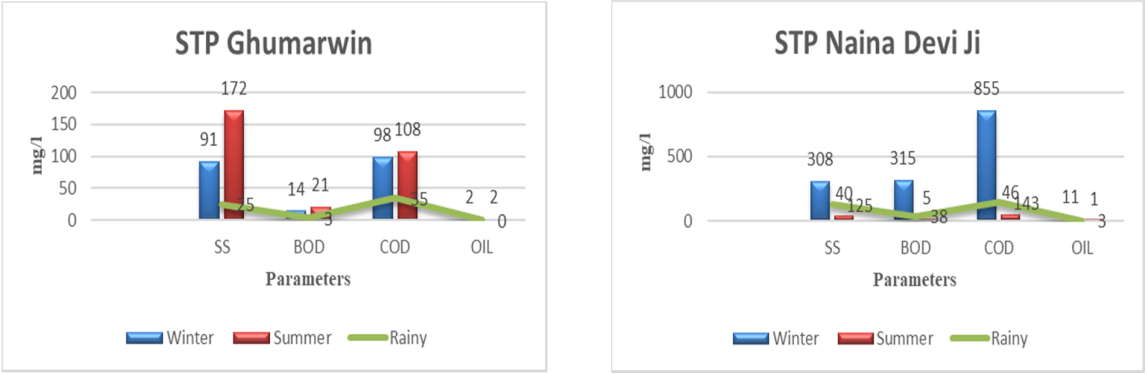


Figure 3. Seasonal variation of pH, SS, BOD, COD, and O and G at Bilaspur.

Table 2. Data of treatment plants in Bilaspur.

GHUMARWIN					
Seasons	SS	BOD	COD	Oil	pH
Winter	91	14	98	2	8
Summer	172	21	108	2	8
Rainy	25	3	35	0	7
NAINA DEVI JI					
Seasons	SS	BOD	COD	Oil	pH
Winter	308	315	855	11	8
Summer	40	5	46	1	8
Rainy	125	38	143	3	7

Based on the information provided, it appears that the pH levels of the wastewater from the STPs in Mandi and Bilaspur are within the acceptable range of 6.5-8.5 for discharge into the environment. However, there are some variations in the levels of other parameters such as suspended solids, BOD, COD, and oil and grease, which are important indicators of the quality of wastewater.

It is important to note that the permissible limits for these parameters vary depending on the intended use of the treated wastewater. For example, if the treated wastewater is intended for agricultural use, the permissible limits for BOD and COD are lower compared to if it is being discharged into a river or stream.

Therefore, it is important to conduct a thorough analysis of the treated wastewater to ensure that it meets the required quality standards before discharging it into the environment or using it for other purposes.

3.4. STP Chamba

The average pH of the wastewater for Chamba-At STP Sitla Bridge was 7.4, 7.7, and 7.3 for winter, summer, and rainy seasons. At STP, Bhagot was 7.3, 7.0, and 7.3 for winter, summer, and rainy season. At STP, Barga was 7.9, 7.8, and 7.6 for winter, summer, and rainy season. The average value for STP Sitla Bridge for winter, summer, and rainy seasons the parameters, suspended solids- 62.3, 108.9, 32.1, BOD - 30.9, 79.0, 8.5, COD - 121.6, 228.0, 62.9 Oil and Grease - 1.7, 2.4, 0.7. For STP Bhagot, value for winter, summer, and rainy seasons SS- 19.8, 22.0, 14.2, BOD- 9.2, 11.3, 4.5, COD - 56.0, 73.0, 43.6, O and G- 1.0, 1.0, and 0.4. For STP Barga, parameter value for winter, summer, and rainy seasons SS- 159.5, 92.0 and 27.1 BOD - 24.9, 36.4 and 7.4, COD- 117.5, 135.1 and 59.3 O and G- 1.4, 2.1, and 0.6.

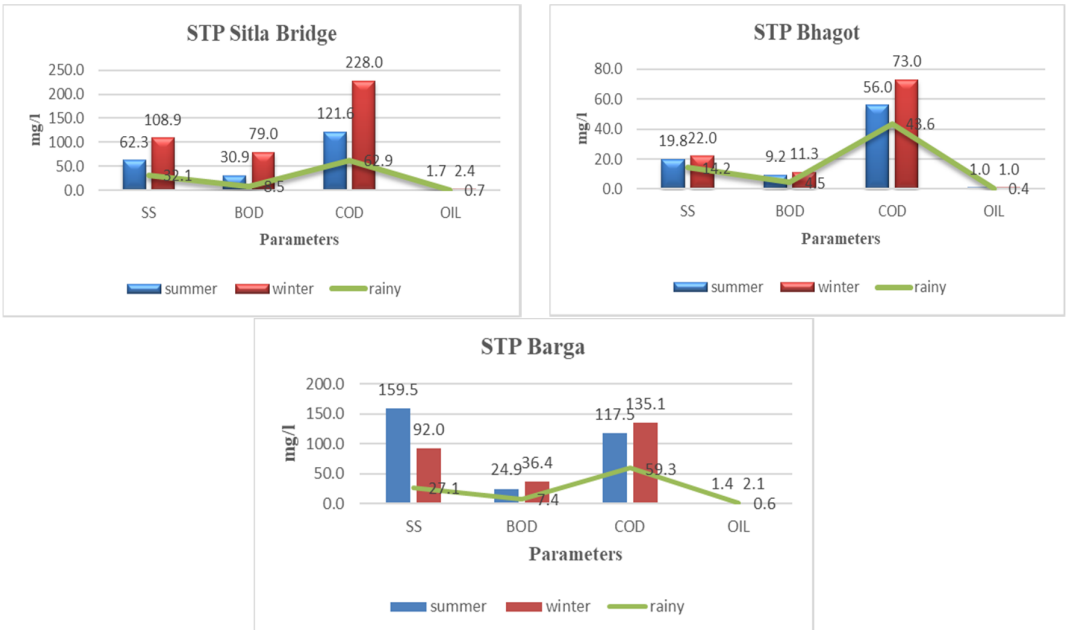


Figure 4. Seasonal variation of pH, SS, BOD, COD, and O and G at Chamba.

It seems like there is significant variation in the parameters across different locations and seasons. Some STPs have higher levels of suspended solids, BOD, COD, and oil and grease compared to others, which suggests that there may be differences in the quality of wastewater being treated and/or the efficiency of the treatment processes.

Overall, it is important to continue monitoring and improving the performance of these STPs to ensure that they are effectively treating the wastewater and protecting the environment and public health.

Table 3. Data of treatment plants in Chamba.

Sitla bridge	**Column 5**				
Seasons	SS	BOD	COD	OIL	PH
Summer	62.3	30.9	121.6	1.7	7.4
Winter	108.9	79.0	228.0	2.4	7.7
Rainy	32.1	8.5	62.9	0.7	7.3
Bhagot					
Seasons	SS	BOD	COD	OIL	PH
Summer	19.8	9.2	56.0	1.0	7.3
Winter	22.0	11.3	73.0	1.0	7.0
Rainy	14.2	4.5	43.6	0.4	7.3
Barga					
Seasons	SS	BOD	COD	OIL	PH
Summer	159.5	24.9	117.5	1.4	7.9
Winter	92.0	36.4	135.1	2.1	7.8
Rainy	27.1	7.4	59.3	0.6	7.6

3.5. STP Kangra

The average pH of the wastewater for Kangra- At STP, Palampur was 7.53, 7.94, and 7.33 for winter, summer, and rainy seasons. At STP, Jawalamukhi was 7.78, 7.78, and 7.58 for winter, summer, and rainy season. At STP, Dharamshala was 7.31, 7.27, and 7.51 for winter, summer, and rainy season. For STP, Nagrota winter, summer, and rainy pH were 7.31, 7.73, and 7.37, and for STP, Old Kangra Zone pH value were 8.06, 7.96, and 7.34 for winter, summer, and rainy season. For STP, Tanda medical College pH values were – 7.05, 7.31, and 7.05. The average value for STP Palampur for winter, summer, and rainy seasons the parameters, suspended solids- 47.28, 59.40, and 30.75, BOD - 27.28, 47.80, and 13.58, COD - 94.50, 100.89, and 118.67, oil and grease - 1.41, 2.45, and 0.86. For STP, Jawalamukhi value for winter, summer, and rainy seasons SS- 45.44, 79.11, and 50.33, BOD- 16.44, 20.22 and 27.22 COD - 142.54, 107, 199.33, O&G- 1.31, 1.49 and 1.31. For Dharamshala, parameter value for winter, summer, and rainy seasons SS- 21.67, 41.11 and 24. BOD - 6.39, 18.78 and 4.48 COD- 48.80, 95.11, and 43.60, O and G- 0.75, 1.36, and 0.34. For Nagrota, parameter value for winter, summer, and rainy seasons SS -26.11, 39.00 and 14.20. BOD - 4.97, 6.14 and 3.16. COD- 38, 38.40 and 33.20. Oil and grease 0.60, 0.62 and 0.33. For Old Kangra Zone 3, parameter value for winter, summer, and rainy seasons SS - 55.29, 53.78, and 25, BOD - 6.76, 29.89, and 6.70, COD- 56, 110.22, and 56.40, oil and grease- 0.76,1.7, and 0.65. For Tanda Medical College, parameter value for summer, winter and rainy seasons SS - 33.24, 34.50, and 36.80, BOD - 11.06, 25.50, and 9.60, COD - 65.88, 109.20, and 72.00, oil and grease - 0.87, 1.43, and 0.75.

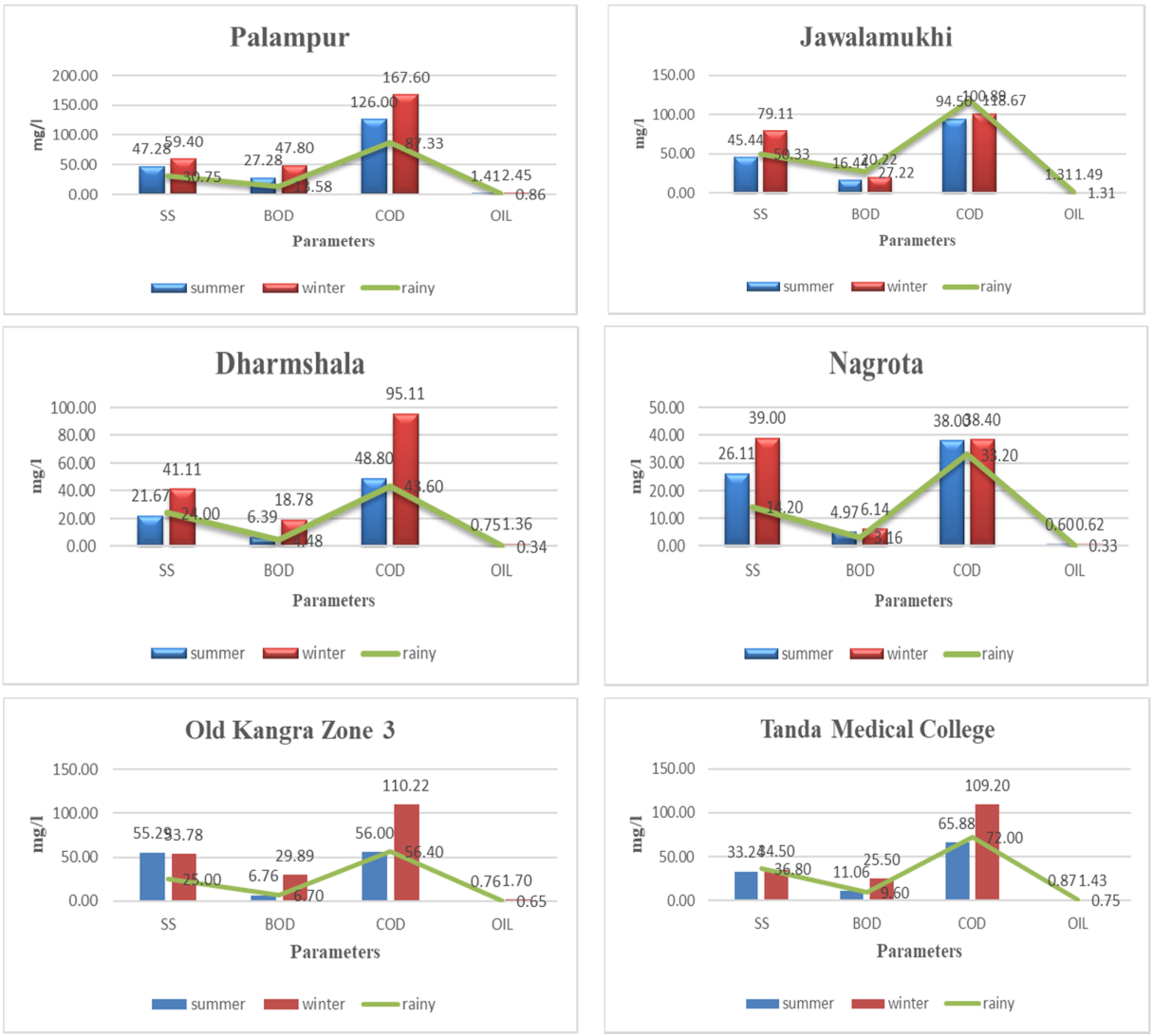


Figure 5. Seasonal variation of pH, SS, BOD, COD, and O and G at Kangra.

From the data for Kangra district, it seems that the average pH of wastewater in the five STPs (Palampur, Jawalamukhi, Dharamshala, Nagrota, and Old Kangra Zone) varied across the winter, summer, and rainy seasons, with some slight fluctuations.

The data also provides information on several parameters of water quality including Suspended Solids (SS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and oil and grease (O and G), for each STP across the three seasons. The values for these parameters varied across the seasons and the STPs, with some showing higher levels in certain seasons or STPs compared to others.

Overall, the data provides insight into the water quality of Kangra district and can be used to identify areas that may require improvement or further monitoring to ensure the safe disposal of wastewater.

3.6. Hamirpur

The average pH of the wastewater for Hamirpur- At STP Hamirpur Zone-3 was 7.46, 7.51, and 7.45 for winter, summer, and rainy seasons. At STP, NIT Hamirpur was 7.33, 7.36, and 7.32 for winter, summer, and rainy season. At STP, Sujanpur was 7.44, 7.47, and 7.79 for winter, summer, and rainy season. The average value for STP Hamirpur Zone-3 for winter, summer and rainy seasons the parameters, Suspended solids- 105.71, 79.87, 58.00, BOD – 62.06, 52.20, 16.38, COD – 196.47, 178.93, 90.33, oil and grease – 2.55, 1.91, and 1.03. For STP, NIT Hamirpur value for winter, summer and rainy seasons SS- 201.06, 107.31, 158.40, BOD- 157.22, 89.38, 144, COD –

378.67, 239.08, 324.80, O and G- 3.17, 2.38, 2.96. For Sujanpur, parameter value for winter, summer and rainy sasons SS- 10.86, 7.44, 6.00, BOD – 7.38, 5.31, 2.25, COD- 49, 41.33, 30.00, O and G- 0.65, 0.67, 0.25.

Table 4. Data of treatment plants in Kangra.

Palampur					
	SS	BOD	COD	Oil	PH
Summer	47.28	27.28	126.00	1.41	7.53
Winter	59.40	47.80	167.60	2.45	7.94
Rainy	30.75	13.58	87.33	0.86	7.33
Jawalamukhi					
	SS	BOD	COD	Oil	PH
Summer	45.44	16.44	94.50	1.31	7.78
Winter	79.11	20.22	100.89	1.49	7.78
Rainy	50.33	27.22	118.67	1.31	7.58
Dharmshala					
	SS	BOD	COD	Oil	PH
Summer	21.67	6.39	48.80	0.75	7.31
Winter	41.11	18.78	95.11	1.36	7.27
Rainy	24.00	4.48	43.60	0.34	7.51
Nagrota					
	SS	BOD	COD	Oil	PH
Summer	26.11	4.97	38.00	0.60	7.31
Winter	39.00	6.14	38.40	0.62	7.73
Rainy	14.20	3.16	33.20	0.33	7.37
Old Kangra Zone 3					
	SS	BOD	COD	Oil	PH
Summer	55.29	6.76	56.00	0.76	8.06
Winter	53.78	29.89	110.22	1.70	7.96
Rainy	25.00	6.70	56.40	0.65	7.34
Tanda Medical College					
	SS	BOD	COD	Oil	PH
Summer	33.24	11.06	65.88	0.87	7.05
Winter	34.50	25.50	109.20	1.43	7.31
Rainy	36.80	9.60	72.00	0.75	7.05

Based on the given data, we can understand the quality of wastewater in Hamirpur district during different seasons and in different sewage treatment plants (STPs). The pH values for STP Hamirpur Zone-3, STP NIT Hamirpur, and STP Sujanpur were recorded during winter, summer, and rainy seasons.

In addition to pH, the data provides information about the levels of suspended solids (SS), biological oxygen demand (BOD), chemical oxygen demand (COD), and oil and grease (O and G) for each STP during different seasons. These parameters are important indicators of the quality of wastewater and can help assess the effectiveness of the treatment processes in the STPs.

Overall, the data suggests that the quality of wastewater in Hamirpur district varies depending on the season and the STP. For example, the average pH values for STP Hamirpur Zone-3 and STP Sujanpur were relatively consistent across seasons, while the pH values for STP NIT Hamirpur were slightly lower during winter and rainy seasons. Similarly, the levels of SS, BOD, COD, and O and G also varied across seasons and STPs, indicating that the treatment processes may be more effective in some cases than others.

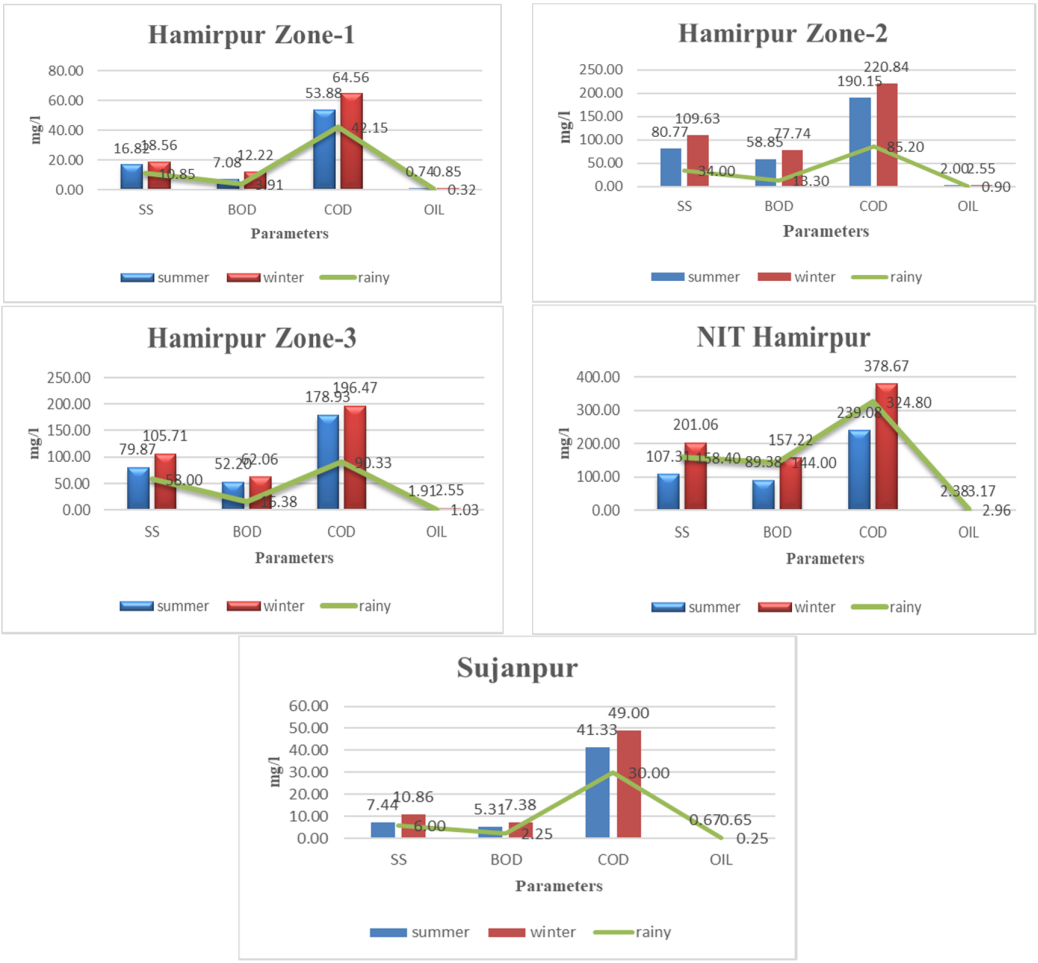


Figure 6. Seasonal variation of pH, SS, BOD, COD, and O and G at Hamirpur.

Table 5. Data of treatment plants in Hamirpur.

	SS	BOD	COD	Oil	PH
Hamirpur Zone-1					
Summer	16.82	7.08	53.88	0.74	7.39
Winter	18.56	12.22	64.56	0.85	7.37
Rainy	10.85	3.91	42.15	0.32	7.47
Hamirpur Zone-2					
Summer	80.77	58.85	190.15	2.00	7.61
Winter	109.63	77.74	220.84	2.55	7.51
Rainy	34.00	13.30	85.20	0.90	7.70
Hamirpur Zone-3					
Summer	79.87	52.20	178.93	1.91	7.51
Winter	105.71	62.06	196.47	2.55	7.46
Rainy	58.00	16.38	90.33	1.03	7.45
NIT Hamirpur					
Summer	107.31	89.38	239.08	2.38	7.36
Winter	201.06	157.22	378.67	3.17	7.33
Rainy	158.40	144.00	324.80	2.96	7.32
Sujanpur					
Summer	7.44	5.31	41.33	0.67	7.47
Winter	10.86	7.38	49.00	0.65	7.44
Rainy	6.00	2.25	30.00	0.25	7.79

3.7. Solan

The average pH of the wastewater for Solan- At STP Solan Zone-B was 8.25, 7.84, and 7.99 for winter, summer, and rainy seasons. At STP, Arki was 8.50, 8.02, and 7.32 for winter, summer, and rainy season. At STP, Kunihar was 8.11, 7.72, and 7.84 for winter, summer, and rainy season. The average value for STP Solan Zone-B for winter, summer, and rainy seasons the parameters, suspended solids- 85.18, 36.14, 18.80, BOD – 34.95, 29, 9.80, COD – 165.45, 115, 67.20, oil and grease – 1.01, 0.94, and 0.81. For STP, Arki value for winter, summer, and rainy seasons SS- 111.11, 23.82, 21.90, BOD- 39.97, 16.62, 12.78, COD – 172.89, 74.35, 63.20, O and G- 2.06, 0.64, 2.16. For Kunihar, parameter value for winter, summer, and rainy seasons SS- 30.11, 33.56, 23.08, BOD – 14.98, 19.99, 8.61, COD- 73.78, 91.78, 49, O and G- 0.58, 1.26, 0.50.

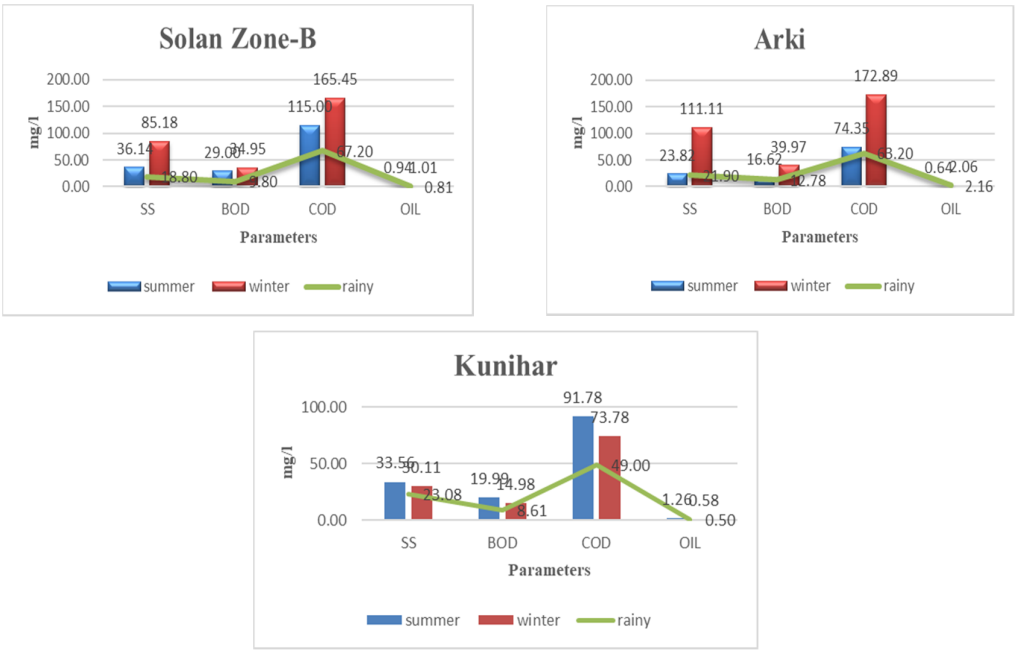


Figure 7. Seasonal variation of pH, SS, BOD, COD, and O and G at Solan.

Table 6. Data of treatment plants in Solan.

Solan Zone-B					
	SS	BOD	COD	Oil	PH
Summer	36.14	29.00	115.00	0.94	7.84
Winter	85.18	34.95	165.45	1.01	8.25
Rainy	18.80	9.80	67.20	0.81	7.99
Arki					
	SS	BOD	COD	Oil	PH
Summer	23.82	16.62	74.35	0.64	8.02
Winter	111.11	39.97	172.89	2.06	8.50
Rainy	21.90	12.78	63.20	2.16	7.32
Kunihar					
	SS	BOD	COD	Oil	PH
Summer	33.56	19.99	91.78	1.26	7.72
Winter	30.11	14.98	73.78	0.58	8.11
Rainy	23.08	8.61	49.00	0.50	7.84

Based on the given data, we can understand the water quality of Solan district in terms of pH and various parameters such as suspended solids (SS), biological oxygen demand (BOD), chemical oxygen demand (COD), and oil and grease (O and G) in the wastewater.

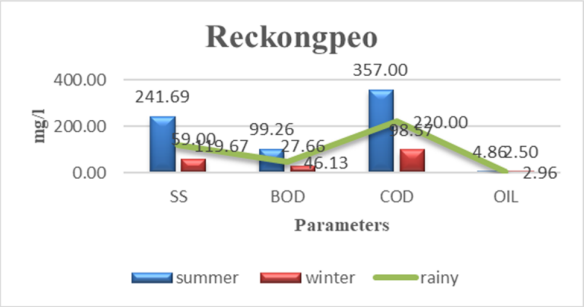
The average pH of wastewater at the three Sewage Treatment Plants (STPs) in Solan district varied between 7.32, and 8.50, with STP Arki having the highest pH values in all three seasons.

The levels of SS, BOD, COD, and O and G at the STPs varied across the three seasons, with higher values observed during the winter season

compared to summer and rainy seasons. Among the STPs, STP Solan Zone-B had the highest levels of SS, BOD, COD, and O and G, while STP Kunihar had the lowest levels of these parameters.

3.8. Kinnaur

The average pH of the wastewater for Kinnaur- At STP, Reckongpeo was 7.03, 7.77, and 7.01 for summer, winter, and rainy seasons. At STP, Paonta Zone-1 was 8.27, 7.90, and 7.70 for winter, summer, and rainy season. The average value for STP Reckongpeo for winter, summer, and rainy seasons the parameters, suspended solids- 59, 241.69, 119.67, BOD – 27.66, 99.26, 46.13, COD – 98.57, 357, 220, oil and grease – 2.50, 4.86, and 2.96. For STP Paonta Zone-1 value for winter, summer, and rainy seasons SS- 79.60, 27.46, 16.80, BOD- 51.98, 13.57, 10.44, COD – 239.60, 100, 77.60, O and G- 1.88, 1.10, 0.45.



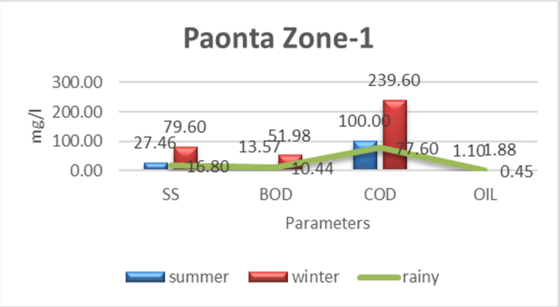


Figure 8. Seasonal variation of pH, SS, BOD, COD, and O and G at Kinnaur.

Table 7. Data of treatment plants at Kinnaur.

Reckongpeo	Column 1	Column 2	Column 3	Column 4	Column 5
	SS	BOD	COD	Oil	PH
Summer	241.69	99.26	357.00	4.86	7.03
Winter	59.00	27.66	98.57	2.50	7.77
Rainy	119.67	46.13	220.00	2.96	7.01
Paonta Zone-1					
	SS	BOD	COD	Oil	PH
Summer	27.46	13.57	100.00	1.10	7.90
Winter	79.60	51.98	239.60	1.88	8.27
Rainy	16.80	10.44	77.60	0.45	7.70

This data provides information about the quality of wastewater in Kinnaur district. The pH values for STP Reckongpeo were slightly acidic for summer and rainy seasons, while the value was slightly alkaline for winter season. For STP, Paonta Zone-1, the pH values were alkaline for all three seasons.

The data also provides information on various parameters used to measure the quality of wastewater. The values for suspended solids, BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), and oil and grease were measured for both STP Reckongpeo and STP Paonta Zone-1. These parameters give an indication of the organic and inorganic pollutants present in the wastewater. The values for these parameters were higher in STP Reckongpeo compared to STP Paonta Zone-1 for all seasons, indicating a higher level of pollutants in the wastewater in Reckongpeo.

Overall, this data suggests that there is a need for proper treatment of wastewater in both STP Reckongpeo and STP Paonta Zone-1 to ensure that the wastewater meets the required quality standards before it is discharged into the environment.

4. Standard limits

The WWTP's follows the guidelines of BIS standards code IS 3025, and the parameters analysis according to standard methods for examination of water and wastewater (APHA), and the final effluent satisfies the water quality standards for reuse in irrigation. The result in the Table shows that the physicochemical parameters in the effluent water at the WWTP's meet the water standard limits for irrigation use for parameters such as temperature, pH, BOD, COD, Oil and Grease, conductivity, and Suspended Solids. The Seasonal Variation of the parameters in respect to the standard limit according to APHA is shown below.

Table 8. Limits prescribed by BIS standards, 2012 [8][12]

Parameters	Standard method	Acceptable value	Permissible limit	Instrument used for analysis
pH	APHA 4500 HB	6.5	8.5	pH-meter
Temperature	-	Alters with external factors	-	Thermometer
Alkalinity (as $CaCO_3$) mg/L		200	600	Titration
Biological Oxygen Demand (BOD), mg/L	APHA 5210B	30	No relaxation	5-day test BOD bottles and Incubator
Calcium hardness, mg/L		75	200	
Chemical Oxygen Demand (COD), mg/L	APHA 5220D	-	250	COD digestor Calorimetric method
Conductivity (µS/m)	APHA 2510B		400	Conductivity-meter
Total Hardness mg/L		200	600	
Total dissolved solids, mg/L	APHA 2540D	500	2000	TDS-meter Gravimetry
Turbidity		1	5	Spectrophotometer
Color (Hazen)		5	15	-
Odor		-	-	-
Ammonia, mg/L		0.5	No relaxation	
Chloride (as Cl^-), mg/L		250	1000	
Copper (as Cu), mg/L		0.05	1.5	Titration
Iron (as Fe), mg/L		0.3	1	Titration
Nitrate (asNO_3^-), mg/L		4.5	No relaxation	

4.1. Seasonal variations in pH of wastewater

All aquatic life, including plants and animals, depend on the pH to survive. The hydrogen ion (H) concentration in the solution is determined by the pH scale. By examining all biochemical processes and physico-chemical characteristics, the pH maintains the acidic or basic property and is an important factor of all aquatic ecosystems [16]. According to APHA, Standard methods for examination of water and wastewater, the recommended pH for wastewater should be between 6.5-8.5. The mean value of pH obtained lies between the permissible range according to the APHA.

4.2. Seasonal Variations in BOD in Wastewater

The amount of oxygen used by microorganisms during the aerobic decomposition of organic matter at a given temperature and time is known as BOD or Biochemical Oxygen Demand. Hence, BOD can be referred to as the biodegradable fraction of wastewater [17]. The value of BOD in the current study generally increases during winter and rainy seasons compared to summers which is quite common. This might be because of the geography of the area, the colder temperature which tends to slower breakdown of organic matter and runoff during rainy season which will carry more organic matter leading to increase in BOD levels.

4.3. Seasonal variations in COD levels in wastewater

COD also known as Chemical Oxygen Demand. When organic matter is chemically oxidized by a powerful oxidant, the number of oxygen equivalents consumed is known as COD. When organic matter is chemically oxidized by a powerful oxidant, the number of oxygen equivalents consumed is known as COD. COD is the measure of both biodegradable and non-biodegradable organic compounds [17]. The COD is always higher than the BOD_5 as the former includes substances that are chemically as well as biologically oxidized [18]. In this study, COD is under permissible limits according to APHA.

4.4. Seasonal variations in Oil and Grease in wastewater

Oil and grease is defined as a group of related materials rather than a specific chemical compound extractable by certain solvents, such as hexane. Common conventional techniques for treating oily wastewater include dissolved air flotation (DAF), gravity methods, chemical treatment, biological treatment, and the use of membranes [19]. The conventional techniques remove oil and grease using skimming tanks and oil and grease traps in treatment plants but the main disadvantage of these methods is their low efficiency of removal [20].

4.5. Seasonal variations in total suspended solids in wastewater

Total suspended solids (TSS) are one of the main pollutants that are thought to be responsible for the deterioration in water quality, increasing water treatment costs, dwindling fish populations, and general water aesthetics. TSS is a major element because too much of it reduces the amount of dissolved oxygen (DO) in the effluent water [21]. In this study level of suspended solids varies seasonally. The concentration of suspended solids is mostly higher in winter than in summer and rainy season which is not uncommon, particularly in regions that experience significant precipitation and snowmelt during winter month. This might occur because of increased runoff in hilly areas, Increased erosion, and lower water temperature.

5. Conclusions

From the data provided for different districts, we can conclude that the quality of wastewater varies across different regions and seasons. The pH values for wastewater range from acidic to slightly alkaline across the districts, with most values falling within the neutral range.

The levels of suspended solids (SS), biological oxygen demand (BOD), chemical oxygen demand (COD), and oil and grease (O and G) also vary significantly across different regions and seasons. In general, the highest values for SS, BOD, COD, and O and G were observed in the winter season, followed by summer and then the rainy season. This could be due to reduced dilution and slower biological activity in the colder winter months.

Overall, the data suggests that there is a need for improved wastewater treatment and management practices to ensure the protection of the environment and human health. Within the next few decades, water may overtake oil as the most important resource in many parts of the world. There are several chances to increase water sustainability in the future by identifying key control water quality indicators and their concentrations [14]. Based on the results and conclusions drawn from this study, some potential future directions for research could include comparative studies of the performance of different treatment technologies in different wastewater treatment plants, Studies to assess the impact of the discharge of treated wastewater on the environment, especially on soil and agricultural productivity, Development and implementation of advanced treatment technologies to improve the removal of nutrients and emerging contaminants from wastewater and studies to assess the economic feasibility of implementing advanced treatment technologies in different wastewater treatment plants.

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تغییرات فصلی در ویژگی‌های فیزیکی و شیمیایی فاضلاب خانگی هیماچال پرادش: مطالعه موردی

اسمایلی ویشواکارما*، دارمندرا و دیون سینگ

گروه مهندسی عمران، موسسه ملی فناوری، هامیرپور، هند

ارسال 2023/02/24، پذیرش 2023/05/10

* نویسنده مسئول مکاتبات: Smily@nith.ac.in, djha@nith.ac.in

چکیده:

مطالعه حاضر بر اساس جمع‌آوری داده‌ها از برخی از WWTPs (تصفیه‌خانه‌های فاضلاب) منطقه هیماچال پرادش، و به منظور بررسی طیف وسیعی از ویژگی‌های فیزیکی و شیمیایی WWTPهای معمولی است که فاضلاب را از مناطق مختلف در شهرهای مختلف هیماچال پرادش دریافت می‌کنند. در این کار پژوهشی پنج پارامتر اندازه‌گیری و تحلیل می‌شود. آنها pH، مواد جامد معلق (mg/L)، اکسیژن مورد نیاز بیولوژیکی (mg/L)، اکسیژن مورد نیاز شیمیایی (mg/L) و روغن و گریس (mg/L) هستند. پارامترها به صورت فصلی برای کمک به بهبود عملکرد مقایسه می‌شوند و شرایط عملیاتی WWTP ها با محدوده پارامترهای استاندارد مطابق با APHA (انجمن بهداشت عمومی آمریکا)، روش‌های استاندارد بررسی آب و فاضلاب از نظر پارامترهای فصلی است. تغییرات فصلی در خواص فیزیکی و شیمیایی قابل توجه است. این مطالعه پارامترهای فیزیکی و شیمیایی فاضلاب از کارخانه‌های مختلف تصفیه فاضلاب (STPs) را در شش منطقه در هیماچال پرادش، هند تجزیه و تحلیل می‌کند و تغییرات کیفیت آب را در فصول و مکان‌های مختلف نشان می‌دهد. این مطالعه نیاز به تصفیه و مدیریت مناسب فاضلاب را برای جلوگیری از آلودگی محیط زیست و حفظ سلامت عمومی نشان می‌دهد. این یافته‌ها می‌تواند برای سیاست گذاران و مقامات مسئول مدیریت فاضلاب در منطقه مفید باشد.

کلمات کلیدی: تصفیه فاضلاب، بازیافت، استفاده مجدد.