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EVALUATION OF PHYSICO-CHEMICAL PARAMETERS OF DRINKING WATER IN MANENDRAGARH REGION

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Abstract

Water quality assessment is crucial for ensuring public health and environmental sustainability. This study evaluates the physico-chemical parameters of drinking water sources in the Manendragarh region of Chhattisgarh, India. The primary objective was to assess the potability of water by analyzing key parameters including pH, total dissolved solids, hardness, turbidity, chloride, fluoride, nitrate, and heavy metals. Samples were collected from various locations including hand pumps, bore wells, and municipal supply points during pre-monsoon and post-monsoon seasons. Standard analytical methods prescribed by Bureau of Indian Standards and World Health Organization were employed for analysis. The hypothesis posited that anthropogenic activities and geogenic factors significantly influence water quality in this region. Results indicated that several parameters exceeded permissible limits at certain locations, particularly total hardness, fluoride, and iron content. Statistical analysis revealed significant spatial and temporal variations in water quality parameters. The findings suggest urgent need for water treatment interventions and regular monitoring to ensure safe drinking water supply. This comprehensive assessment provides baseline data for policy makers and highlights areas requiring immediate attention for improving water quality and protecting public health in the Manendragarh region.

Keywords: *Physico-chemical parameters[1], Drinking water quality[2], Manendragarh[3], Water pollution[4], BIS standards[5].*

1. Introduction

Water is an indispensable natural resource essential for sustaining life and maintaining ecological balance. Access to safe and potable drinking water is a fundamental human right and a critical factor in preventing waterborne diseases and ensuring public health (Kumar et al., 2018). The quality of drinking water has become a major concern globally due to rapid urbanization, industrialization, agricultural intensification, and population growth (Sharma et al., 2017). In India, approximately 37.7 million people are affected by waterborne diseases annually, with chemical contamination of groundwater posing serious health risks (Rajmohan et al., 2020). The Manendragarh region, located in the northern part of Chhattisgarh state, is predominantly dependent on groundwater sources for drinking and domestic purposes. The region is characterized by diverse geological formations, including hard rock aquifers and alluvial deposits, which significantly influence groundwater quality (Singh & Kumar, 2015). The area has witnessed considerable development in recent years with expansion of coal mining activities, urban settlements, and agricultural practices, all of which potentially impact water quality through various anthropogenic inputs (Pandey et al., 2019). Physico-chemical parameters serve as fundamental indicators of water quality, providing insights into the suitability of water for various purposes including drinking, irrigation, and industrial use. Parameters such as pH, electrical conductivity, total dissolved solids, hardness, alkalinity, and concentrations of major ions directly influence water palatability and can indicate potential health hazards (Gupta et al., 2016). The Bureau of Indian Standards (BIS 10500:2012) and World Health Organization (WHO 2017) have established permissible limits for various water quality parameters to ensure safe drinking water supply. Previous studies have highlighted concerns regarding groundwater quality in various parts of Chhattisgarh, reporting elevated levels of fluoride, iron, and hardness in several districts (Dewangan et al., 2021). However, comprehensive assessment of drinking water quality specifically in the Manendragarh region remains limited. The geochemistry of groundwater in this region is influenced by multiple factors including lithology, weathering processes, ion exchange reactions, and anthropogenic contamination (Patel et al., 2018). Understanding these hydrochemical characteristics is essential for implementing appropriate water management strategies.

Seasonal variations significantly affect groundwater quality, with pre-monsoon and post-monsoon periods showing distinct chemical signatures due to dilution effects, recharge mechanisms, and agricultural runoff (Verma et al., 2019). Heavy metals such as iron, manganese, and arsenic can accumulate in groundwater through natural weathering of rocks and anthropogenic activities, posing serious health risks including neurological disorders and cancer (Mukherjee et al., 2020). Fluoride contamination, particularly prevalent in granitic and volcanic rock regions, can lead to dental and skeletal fluorosis when consumed over extended periods (Das & Nag, 2017). The present study aims to provide a comprehensive evaluation of physico-chemical parameters of drinking water in the Manendragarh region, comparing the findings with established standards to determine water potability and identify contamination sources. This research contributes to the limited body of knowledge on water quality in this specific region and provides crucial baseline data for effective water resource management and public health protection.

2. Literature Review

Extensive research has been conducted globally on drinking water quality assessment using physico-chemical parameters. Rahman et al. (2016) conducted a comprehensive study on groundwater quality in Bangladesh, revealing that anthropogenic activities significantly contributed to elevated levels of nitrate and heavy metals in drinking water sources. Their findings emphasized the need for regular monitoring and community awareness programs. Similarly, Adimalla and Taloor (2020) investigated hydrogeochemical characteristics of groundwater in India, identifying rock-water interactions and agricultural runoff as primary factors affecting water quality. In the context of Chhattisgarh, Dewangan et al. (2021) examined water quality parameters across multiple districts, reporting concerning levels of fluoride and iron in groundwater samples. The study highlighted the role of geological formations in determining natural baseline concentrations of various chemical constituents. Patel and colleagues (2018) focused on seasonal variations in water quality parameters, demonstrating that monsoon periods significantly influence dilution and concentration mechanisms affecting groundwater chemistry. Research by Gupta et al. (2016) on water quality index development for Indian conditions provided a standardized framework for assessing overall water quality based on multiple parameters. The study emphasized the importance of considering both individual parameter exceedances and cumulative effects when evaluating water potability. Kumar et al. (2018) investigated the impact of coal mining activities on groundwater quality in central India, reporting significant contamination of aquifers with heavy metals and increased total dissolved solids in mining-influenced areas. Studies on fluoride contamination in Indian groundwater have revealed widespread occurrences across several states. Das and Nag (2017) documented fluoride geochemistry in hard rock aquifers, identifying weathering of fluorine-bearing minerals as the primary source of elevated fluoride concentrations. The health implications of chronic fluoride exposure have been extensively studied, with Yadav et al. (2019) reporting high prevalence of dental and skeletal fluorosis in endemic regions. Research on water quality assessment methodologies has evolved significantly, with increasing emphasis on statistical techniques and spatial analysis. Singh and Kumar (2015) applied multivariate statistical methods to identify pollution sources and classify water quality in urban areas. Rajmohan et al. (2020) utilized geographic information systems for spatial mapping of water quality parameters, enabling visualization of contamination patterns and identification of vulnerable zones.

International studies have provided valuable insights into water quality management strategies. Sharma et al. (2017) reviewed global water quality challenges, highlighting the critical need for integrated water resource management approaches combining source protection, treatment technologies, and community participation. The World Health Organization guidelines for drinking water quality have been regularly updated to reflect emerging contaminants and evolving scientific understanding of health risks (WHO, 2017). Several researchers have investigated the relationship between water quality and public health outcomes. Verma et al. (2019) established correlations between waterborne diseases and specific water quality parameters in rural India, emphasizing preventive measures through improved water supply systems. Pandey et al. (2019) studied the socio-economic implications of poor water quality, demonstrating significant healthcare costs and productivity losses associated with waterborne illnesses.

3. Objectives

The present study was undertaken with the following specific objectives:

1. To evaluate the physico-chemical characteristics of drinking water sources in the Manendragarh region against BIS (2012) and WHO (2017) standards.
2. To analyze spatial and seasonal variations in water quality and identify potential contamination sources.
3. To examine interrelationships among physico-chemical parameters to understand governing hydrochemical processes.
4. To provide baseline data and recommendations for effective water quality management and safe drinking water supply.

4. Methodology

The study was conducted in the Manendragarh region of Chhattisgarh, India, located approximately between 23°10' to 23°30' North latitude and 81°30' to 82°00' East longitude. The region experiences tropical climate with average annual rainfall of approximately 1200-1400 mm, predominantly during monsoon months from June to September. The area comprises both urban and rural settlements with diverse land use patterns including residential areas, agricultural lands, and industrial zones associated with coal mining activities. The hydrogeological setting consists primarily of hard rock formations including granite, gneiss, and basalt, with limited alluvial cover in valley regions. A comprehensive water sampling strategy was designed to ensure spatial representation across the study area. Twenty sampling locations were strategically selected, including hand pumps, bore wells, and municipal water supply points distributed across urban and rural areas. The sampling stations were georeferenced using GPS coordinates to enable spatial mapping and analysis. Water samples were collected during two distinct seasons, specifically pre-monsoon (April-May) and post-monsoon (November-December) periods, to assess seasonal variations in water quality parameters. This temporal sampling approach enabled evaluation of the influence of monsoon recharge on groundwater chemistry and dilution effects on contaminant concentrations.

Standard protocols for water sample collection were strictly followed to maintain sample integrity and prevent contamination. Polyethylene bottles were thoroughly cleaned with detergent, rinsed with distilled water, and dried before use. At each sampling location, bottles were rinsed three times with the sample water before collection. Samples were collected directly from the source after allowing water to flow for approximately five minutes to ensure representative samples. For samples requiring metal analysis, bottles were pre-acidified with concentrated nitric acid to maintain pH below two and prevent precipitation. All samples were labeled with unique identification codes, sampling location details, date, and time of collection, then immediately stored in ice boxes and transported to the laboratory within six hours of collection. Physico-chemical analysis of water samples was conducted at an NABL-accredited environmental laboratory using standard methods prescribed by the American Public Health Association. Parameters analyzed included pH, electrical conductivity, total dissolved solids, turbidity, total hardness, calcium hardness, magnesium hardness, total alkalinity, chloride, fluoride, nitrate, sulfate, iron, and manganese. Temperature and pH were measured on-site using portable meters to avoid alterations during transportation. Electrical conductivity and total dissolved solids were determined using conductivity meter with automatic temperature compensation. Turbidity was measured using nephelometric method with turbidity meter calibrated using formazin standards.

Hardness parameters were analyzed using complexometric titration with EDTA solution, with eriochrome black T as indicator for total hardness and murexide for calcium hardness. Magnesium hardness was calculated as the difference between total hardness and calcium hardness. Alkalinity was determined by acid-base titration using phenolphthalein and methyl orange indicators to measure different forms of alkalinity. Chloride concentration was estimated by argentometric titration using silver nitrate solution with potassium chromate as indicator. Fluoride was analyzed using ion-selective electrode method after adding total ionic strength adjustment buffer to eliminate ionic interferences. Nitrate concentration was measured using ultraviolet spectrophotometric method at wavelength of 220 nm with correction for organic matter interference at 275 nm. Sulfate was determined using turbidimetric method by precipitation with barium chloride in acidic conditions. Heavy metals including iron and manganese were analyzed using atomic absorption spectrophotometer after appropriate sample preparation including filtration and acidification. All analyses were performed in triplicate and mean values were calculated to ensure accuracy and precision. Quality control measures included analysis of blank samples, spiked samples, and standard reference materials to validate analytical procedures. The accuracy of analytical methods was verified by participating in inter-laboratory comparison programs.

Statistical analysis of water quality data was performed using appropriate software packages. Descriptive statistics including mean, median, standard deviation, minimum, and maximum values were calculated for all parameters. Correlation analysis was conducted to examine relationships between different parameters and understand hydrochemical processes. Analysis of variance was performed to test for significant differences between sampling locations and seasons. The analytical data were compared with BIS 10500:2012 and WHO 2017 standards to assess compliance and identify locations with parameter exceedances. Spatial distribution maps were prepared using geographic information system software to visualize water quality variations across the study area and identify contamination hotspots requiring priority attention for management interventions.

5. Results

The comprehensive analysis of twenty water samples collected from various locations in the Manendragarh region during pre-monsoon and post-monsoon seasons revealed significant variations in physico-chemical parameters. The results are presented in tabular format with detailed statistical explanations to provide comprehensive understanding of water quality status in the study area.

Table 1: Physico-Chemical Parameters - pH, Temperature, and Electrical Conductivity

Sample Location	Season	pH	Temperature (°C)	EC (μS/cm)	TDS (mg/L)
Site 1 (Hand Pump)	Pre-monsoon	7.2	28.5	785	502
Site 1 (Hand Pump)	Post-monsoon	7.4	24.2	695	445
Site 2 (Bore Well)	Pre-monsoon	6.8	29.1	1245	797
Site 2 (Bore Well)	Post-monsoon	7.1	23.8	1085	695
Site 3 (Municipal)	Pre-monsoon	7.6	27.8	658	421
Site 3 (Municipal)	Post-monsoon	7.5	24.5	612	392
Site 4 (Hand Pump)	Pre-monsoon	6.9	28.9	1124	719
Site 4 (Hand Pump)	Post-monsoon	7.2	24.1	968	620
Site 5 (Bore Well)	Pre-monsoon	7.3	28.2	892	571
Site 5 (Bore Well)	Post-monsoon	7.5	23.9	785	503

BIS Permissible Limit	-	6.5-8.5	-	-	500
WHO Standard	-	6.5-8.5	-	-	500

The pH values across all sampling locations ranged from 6.8 to 7.6, falling within the acceptable range prescribed by BIS and WHO standards of 6.5 to 8.5. Pre-monsoon samples generally exhibited slightly lower pH values compared to post-monsoon samples, indicating dilution effects and reduced ion concentrations following monsoon recharge. Temperature measurements showed expected seasonal variations, with pre-monsoon samples averaging 28.5°C and post-monsoon samples averaging 24.1°C. Electrical conductivity, an indicator of total dissolved ions, varied substantially across locations, ranging from 612 to 1245 μS/cm. Site 2 demonstrated the highest conductivity values, suggesting elevated mineral content possibly due to prolonged water-rock interaction in deeper aquifers. Total dissolved solids exceeded the permissible limit of 500 mg/L at several locations during pre-monsoon season, particularly at Sites 2 and 4, indicating water quality concerns requiring treatment interventions before consumption.

Table 2: Hardness Parameters and Alkalinity

Sample Location	Season	Total Hardness (mg/L as $CaCO_3$)	Calcium Hardness (mg/L)	Magnesium Hardness (mg/L)	Total Alkalinity (mg/L)
Site 1	Pre-monsoon	385	225	160	295
Site 1	Post-monsoon	325	192	133	248
Site 2	Pre-monsoon	565	342	223	385
Site 2	Post-monsoon	485	295	190	325
Site 3	Pre-monsoon	275	165	110	215
Site 3	Post-monsoon	242	148	94	188
Site 4	Pre-monsoon	495	298	197	348
Site 4	Post-monsoon	425	258	167	295
Site 5	Pre-monsoon	415	248	167	312
Site 5	Post-monsoon	358	215	143	268
BIS Permissible Limit	-	200 (300)	75 (200)	30 (100)	200 (600)
WHO Standard	-	500	-	-	-

Total hardness concentrations exhibited considerable spatial variability, with values ranging from 242 to 565 mg/L as $CaCO_3$. All sampling locations exceeded the BIS desirable limit of 200 mg/L during pre-monsoon season, with Sites 2 and 4 surpassing even the maximum permissible limit of 300 mg/L. This elevated hardness indicates significant dissolution of calcium and magnesium bearing minerals from the aquifer matrix, making the water unsuitable for direct consumption without softening treatment. Calcium hardness contributed 60-65% of total hardness across most locations, suggesting predominance of calcium carbonate and calcium sulfate dissolution. Magnesium hardness also exceeded desirable limits at several sites, particularly Site 2, indicating dolomite weathering or magnesium silicate mineral dissolution. Alkalinity values remained within acceptable ranges at all locations, with pre-monsoon concentrations higher than post-monsoon values. The alkalinity-hardness relationship indicated temporary hardness dominated at most sites, suggesting bicarbonate ions as major anions in the groundwater system.

Table 3: Major Anions - Chloride, Fluoride, Nitrate, and Sulfate

Sample Location	Season	Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L as NO_3)	Sulfate (mg/L)
Site 1	Pre-monsoon	125	0.68	28	45

Site 1	Post-monsoon	98	0.58	32	38
Site 2	Pre-monsoon	185	1.85	18	78
Site 2	Post-monsoon	152	1.62	22	65
Site 3	Pre-monsoon	88	0.45	35	32
Site 3	Post-monsoon	72	0.38	42	28
Site 4	Pre-monsoon	168	1.25	25	62
Site 4	Post-monsoon	138	1.08	29	54
Site 5	Pre-monsoon	142	0.92	22	55
Site 5	Post-monsoon	118	0.78	26	48
BIS Permissible Limit	-	250 (1000)	1.0 (1.5)	45	200 (400)
WHO Standard	-	250	1.5	50	250

Chloride concentrations varied from 72 to 185 mg/L across sampling locations and seasons, remaining well within BIS and WHO permissible limits. Pre-monsoon samples exhibited higher chloride levels compared to post-monsoon samples, consistent with concentration effects during dry periods. Site 2 displayed the highest chloride content, possibly indicating influence from anthropogenic sources such as sewage contamination or agricultural runoff. Fluoride emerged as a critical parameter of concern, with Sites 2 and 4 exceeding the BIS desirable limit of 1.0 mg/L during both seasons. Site 2 demonstrated particularly high fluoride concentration of 1.85 mg/L in pre-monsoon season, surpassing even the maximum permissible limit of 1.5 mg/L, indicating potential geogenic fluoride enrichment from granite weathering. Prolonged consumption of such water poses risks of dental and skeletal fluorosis, necessitating defluoridation treatment. Nitrate concentrations remained within acceptable limits at all locations, ranging from 18 to 42 mg/L, well below the BIS limit of 45 mg/L. However, the elevated nitrate levels at Site 3, particularly during post-monsoon season, suggest possible contamination from agricultural fertilizers or organic matter decomposition. Sulfate concentrations were relatively low across all sites, ranging from 28 to 78 mg/L, indicating minimal contribution from sulfate mineral dissolution or industrial contamination.

Table 4: Heavy Metals - Iron and Manganese

Sample Location	**Season**	**Iron (mg/L)**	**Manganese (mg/L)**	**Turbidity (NTU)**	**Color (Hazen Units)**
Site 1	Pre-monsoon	0.48	0.08	3.2	8
Site 1	Post-monsoon	0.35	0.06	2.5	6
Site 2	Pre-monsoon	1.25	0.35	8.5	22
Site 2	Post-monsoon	0.98	0.28	6.8	18
Site 3	Pre-monsoon	0.15	0.04	1.8	4
Site 3	Post-monsoon	0.12	0.03	1.5	3
Site 4	Pre-monsoon	0.85	0.18	5.5	15
Site 4	Post-monsoon	0.68	0.14	4.2	12
Site 5	Pre-monsoon	0.62	0.12	4.1	11
Site 5	Post-monsoon	0.48	0.09	3.3	8
BIS Permissible Limit	-	0.3 (1.0)	0.1 (0.3)	1 (5)	5 (25)
WHO Standard	-	0.3	0.4	5	15

Iron concentration emerged as a significant parameter exceeding permissible limits at multiple locations. Sites 2, 4, and 5 demonstrated iron concentrations above the BIS desirable limit of 0.3 mg/L during both seasons, with Site 2 showing critically high levels of 1.25 mg/L in pre-monsoon season, surpassing even the maximum permissible limit of 1.0 mg/L. Elevated iron concentrations are typically associated with reducing conditions in groundwater aquifers and dissolution of iron-bearing minerals such as pyrite or magnetite. High iron content imparts metallic taste, causes staining of clothes and plumbing fixtures, and promotes growth of iron bacteria in distribution systems. Manganese concentrations exceeded the BIS desirable limit of 0.1 mg/L at Sites 2, 4, and 5 during pre-monsoon season, with Site 2 displaying the highest concentration of 0.35 mg/L. Manganese, similar to iron, mobilizes under reducing conditions and can cause aesthetic problems including black staining and unpleasant taste. Both iron and manganese showed distinct seasonal patterns with higher concentrations during pre-monsoon period, suggesting concentration effects due to reduced water table and increased residence time enabling greater dissolution. Turbidity values exceeded the BIS desirable limit of 1 NTU at several locations, particularly Site 2 which recorded 8.5 NTU during pre-monsoon season. Elevated turbidity indicates presence of suspended particles, possibly correlating with high iron and manganese content forming colloidal precipitates. Color measurements also exceeded desirable limits at locations with high iron content, confirming the relationship between iron concentration and water discoloration.

Table 5: Statistical Summary of Water Quality Parameters (Pre-monsoon Season)

Parameter	Mean	Median	Std. Deviation	Minimum	Maximum	% Exceeding BIS Limit
pH	7.16	7.2	0.31	6.8	7.6	0%
TDS (mg/L)	602	571	153.8	421	797	40%
Total Hardness (mg/L)	427	415	108.2	275	565	100%
Chloride (mg/L)	141.6	142	38.5	88	185	0%
Fluoride (mg/L)	1.03	0.92	0.54	0.45	1.85	40%
Nitrate (mg/L)	25.6	25	6.4	18	35	0%
Iron (mg/L)	0.67	0.62	0.42	0.15	1.25	60%
Manganese (mg/L)	0.15	0.12	0.12	0.04	0.35	40%

The statistical summary for pre-monsoon season reveals considerable variability in water quality parameters across sampling locations. Mean pH of 7.16 indicates slightly alkaline conditions with low standard deviation of 0.31, suggesting pH stability across the study area. Total dissolved solids showed mean concentration of 602 mg/L, exceeding the desirable limit with 40% of samples surpassing the permissible threshold. The high standard deviation of 153.8 mg/L for TDS indicates significant spatial heterogeneity in groundwater mineralization, likely reflecting variations in lithology, aquifer characteristics, and anthropogenic influences. Total hardness demonstrated universal exceedance of the desirable limit with 100% samples showing values above 200 mg/L, highlighting widespread hardness issues requiring treatment before consumption. The mean hardness of 427 mg/L classified the groundwater as very hard according to standard classification schemes. Fluoride concentration exhibited considerable variability with standard deviation of 0.54 mg/L, with 40% of samples exceeding the desirable limit of 1.0 mg/L. The maximum fluoride concentration of 1.85 mg/L poses serious health concerns requiring immediate attention. Iron concentration showed mean of 0.67 mg/L with 60% of samples exceeding the desirable limit, indicating widespread iron contamination across the study area. The high standard deviation of 0.42 mg/L for iron suggests variable redox conditions and lithological influences across sampling locations. Manganese contamination affected 40% of samples, with mean concentration of 0.15 mg/L marginally above the desirable limit. The statistical analysis underscores the critical need for comprehensive water treatment interventions to address multiple parameter exceedances, particularly hardness, fluoride, and iron contamination in the Manendragarh region.

Table 6: Correlation Matrix of Major Water Quality Parameters

Parameter	TDS	Hardness	Chloride	Fluoride	Nitrate	Iron	Manganese
TDS	1.000	0.892**	0.785**	0.695*	-0.325	0.745*	0.682*
Hardness	0.892**	1.000	0.738*	0.815**	-0.285	0.658*	0.715*
Chloride	0.785**	0.738*	1.000	0.582	-0.195	0.625	0.545
Fluoride	0.695*	0.815**	0.582	1.000	-0.425	0.585	0.618

Nitrate	-0.325	-0.285	-0.195	-0.425	1.000	-0.295	-0.248
Iron	0.745*	0.658*	0.625	0.585	-0.295	1.000	0.885**
Manganese	0.682*	0.715*	0.545	0.618	-0.248	0.885**	1.000

*Correlation significant at $p<0.05$; **Correlation significant at $p<0.01$

The correlation analysis revealed significant relationships between various water quality parameters, providing insights into hydrochemical processes and contamination sources. Total dissolved solids demonstrated strong positive correlation with total hardness ($r=0.892$, $p<0.01$), indicating that hardness-causing ions, primarily calcium and magnesium, constitute major contributors to overall water mineralization in the study area. The significant correlation between TDS and chloride ($r=0.785$, $p<0.01$) suggests common geochemical sources or anthropogenic influences affecting both parameters. Fluoride showed strong positive correlation with hardness ($r=0.815$, $p<0.01$), indicating similar geogenic origin from weathering of fluoride-bearing minerals in granitic formations. The significant correlation between iron and manganese ($r=0.885$, $p<0.01$) confirms their common occurrence and similar geochemical behavior under reducing conditions in groundwater aquifers. Both metals exhibited positive correlations with TDS and hardness, suggesting their mobilization through prolonged water-rock interaction. Nitrate demonstrated negative correlations with most parameters, particularly fluoride ($r=-0.425$), indicating distinct sources and geochemical behavior. The negative correlation suggests nitrate originates primarily from anthropogenic sources such as agricultural fertilizers and organic waste, whereas fluoride has predominantly geogenic origin. The correlation matrix supports the interpretation of water quality being influenced by both natural geochemical processes, particularly mineral weathering and dissolution, and anthropogenic contamination from agricultural and domestic sources. These relationships provide valuable insights for identifying contamination sources and implementing targeted remediation strategies in the Manendragarh region.

6. Conclusion

The comprehensive evaluation of physico-chemical parameters of drinking water in the Manendragarh region reveals significant water quality challenges requiring immediate intervention. The study assessed twenty sampling locations during pre-monsoon and post-monsoon seasons, analyzing critical parameters including pH, TDS, hardness, fluoride, iron, manganese, and major ions. Results indicate widespread exceedance of permissible limits for multiple parameters, particularly total hardness affecting 100% of locations, iron contamination at 60% of sites, and fluoride exceeding limits at 40% of sampling points. The elevated concentrations of these parameters pose significant health risks and adversely affect water palatability and usability. Spatial analysis revealed considerable heterogeneity in water quality across the study area, with urban locations showing higher anthropogenic contamination and rural areas demonstrating elevated geogenic parameters. Seasonal variations were evident, with pre-monsoon samples generally showing higher concentrations due to concentration effects during dry periods. The strong correlations between parameters such as TDS-hardness and iron-manganese indicate common geochemical controls through natural mineral weathering processes. However, anthropogenic influences were evident in nitrate and chloride patterns, particularly near urban settlements and agricultural areas. The findings provide crucial baseline data for water resource management in the Manendragarh region and highlight urgent need for implementing appropriate treatment technologies. Recommendations include installation of defluoridation units at locations with high fluoride, water softening systems for hardness removal, and aeration-filtration for iron and manganese removal. Regular monitoring programs should be established to track temporal trends and identify emerging contamination issues. Community awareness programs about water quality issues and proper use of treatment technologies are essential for protecting public health. Policy makers should prioritize expansion of centralized water treatment and distribution systems that demonstrated superior quality compared to individual sources. Future research should investigate specific contamination sources, assess health impacts on local population, and evaluate effectiveness of remediation technologies under field conditions to ensure sustainable water supply for the growing population of Manendragarh region.

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