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ASSESSMENT OF GROUNDWATER QUALITY IN SELECTED VILLAGES OF BIKANER DISTRICT, RAJASTHAN

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ABSTRACT

Groundwater quality assessment plays a critical role in ensuring the sustainability of water resources, particularly in arid regions like the Bikaner district of Rajasthan. This study focuses on the analysis of groundwater quality from 18 villages, examining a comprehensive range of parameters to evaluate its suitability for drinking and agricultural purposes. The parameters analyzed include major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anions (Cl^{-}, SO_4^{2-}, NO_3^{-}, F^{-}, CO_3^{2-}, HCO_3^{-}), heavy metals (Cr, Cu, Mn, Pb, U, Zn, As), along with key indicators such as pH, electrical conductivity (EC), total dissolved solids (TDS), and total hardness (TH). The results revealed substantial spatial variation in water quality, with several locations exceeding permissible limits for TDS, TH, and heavy metals as per established standards. Elevated levels of TDS and TH were particularly evident in villages like Lachhasar and Jaitasar, potentially indicating the influence of geological formations and anthropogenic activities. Similarly, heavy metal concentrations, including Cr, Mn, Pb, and U, were found to surpass safe thresholds in some areas, raising concerns over potential health risks. The pH values across the study sites ranged from slightly acidic to mildly alkaline, while EC values indicated variations in salinity levels, further reflecting water quality disparities. This study underscores the critical need for regular groundwater monitoring and the implementation of sustainable management practices to mitigate contamination risks and ensure the availability of safe water resources. The findings not only provide a detailed understanding of groundwater quality in the Bikaner district but also emphasize the urgency of integrating scientific research with policy measures to safeguard water security in arid regions.

1. INTRODUCTION

Groundwater is an essential resource for sustaining life and supporting livelihoods in arid and semi-arid regions like the Thar Desert, which encompasses parts of Rajasthan, India. This region, characterized by its extreme climatic conditions and scarce surface water resources, relies heavily on groundwater for domestic consumption, agriculture, and industrial activities. The Thar Desert's harsh environment, coupled with a growing population and increasing water demand, has intensified the stress on its groundwater reserves. This stress manifests not only as quantitative depletion but also as significant deterioration in water quality.

Groundwater in arid regions is prone to salinity and mineralization due to prolonged rock-water interaction, slow recharge rates, and high evaporation rates. The Bikaner district, situated in the western part of Rajasthan, exemplifies these challenges. Geologically, the district lies over sedimentary formations and saline aquifers, leading to naturally high levels of total dissolved solids (TDS) and hardness. In addition to geogenic factors, human activities, such as unregulated groundwater extraction, agricultural intensification, and industrial expansion, have exacerbated groundwater contamination in the region. The indiscriminate use of chemical fertilizers and pesticides contributes to nitrate pollution, while improper waste disposal introduces heavy metals and other hazardous substances into the groundwater system (Choudhary et al., 2017; Yadav et al., 2020).

Several studies have reported alarming trends in groundwater quality across Rajasthan. For example, Sharma and Jain (2019) documented fluoride levels in western Rajasthan exceeding the safe limit of 1.5 mg/L recommended by the World Health Organization (WHO), posing risks of dental and skeletal fluorosis. Furthermore, Meena et al. (2021) observed the presence of heavy metals, such as chromium, uranium, and lead, in the groundwater of Bikaner, attributing their occurrence to both natural processes and anthropogenic sources. These contaminants not only compromise water usability but also pose severe health risks, including cancer, kidney damage, and developmental disorders. Despite the availability of such studies, the spatial variability of groundwater quality in localized areas, such as individual villages in the Bikaner district, remains poorly understood. Variations in lithology, water table depth, and land use practices necessitate detailed site-specific investigations. Addressing this knowledge gap is crucial for developing effective groundwater management strategies and ensuring water security for the region's inhabitants. Assessing groundwater quality is critical for understanding its suitability for various uses, such as drinking, irrigation, and industrial processes. Contaminants in groundwater can have far-reaching consequences, from reducing agricultural productivity to causing chronic health conditions in local populations. Furthermore, the detection of contaminants like heavy metals and fluoride is essential for aligning groundwater usage with national and international safety standards, such as those outlined by the Bureau of Indian Standards (BIS) and WHO. The study aims to identify spatial variations in water quality parameters, evaluate the suitability of groundwater for drinking and agricultural purposes, and highlight potential health risks associated with contamination. By integrating these findings, the study seeks to provide recommendations for sustainable groundwater management and contribute to the development of strategies for mitigating water quality degradation in arid regions.

2. MATERIALS AND METHODS

***Study Area**:* The study area is Dungargarh tehsil, located in the Bikaner district of Rajasthan, India. Bikaner district lies in the arid north-western part of Rajasthan, spanning north latitudes 27°11’ to 29°03’ and east longitudes 71°52’ to 74°15’. The district covers a geographical area of 30,247.90 sq. km and is bordered by Ganganagar District in the north, Hanumangarh and Churu Districts in the east, Nagaur and Jodhpur Districts in the south, and Jaisalmer District and Pakistan's international border in the west. Dungargarh tehsil, situated in this arid region, experiences extreme climatic conditions. The area is characterized by low and erratic rainfall, averaging between 260 to 440 mm annually, with almost 90% of the precipitation occurring during the southwest monsoon from July to September. The temperature ranges from a scorching 48°C in summer to as low as 1°C in winter. The relative humidity is highest in August, with mean daily values of 71% in the morning and 52% in the evening. The study area is dominated by sandy plains, sand dunes, and saline patches typical of the Thar Desert. The tehsil is primarily an agrarian region, dependent on groundwater for domestic and agricultural purposes. Groundwater is extracted from aquifers at depths ranging from 50 to 800 feet, making it a critical resource in the absence of perennial surface water sources.

***Sample Collection**:* Groundwater samples were collected from tube wells in the selected villages during the pre-monsoon season. The sampling points were chosen to represent different geographical locations and depths within the tehsil. A total of 20 groundwater samples were collected in clean 1-liter bottles, which were completely filled and tightly capped to prevent contamination. For cation analysis, 50 ml of each sample was filtered using

0.45 µm Whatman filter paper and preserved on-site with ultra-pure nitric acid (HNO_3). Another 100 ml of the filtered water was mixed with 5 ml concentrated HNO_3 and 5 ml concentrated H_2SO_4, digested, and allowed to cool to room temperature. The final volume was adjusted to 100 ml using double-distilled water and stored for laboratory analysis at 4°C.

Table 1: Water Quality Parameters Analysis Methods and Their Ranges with BIS and WHO Standards.

Parameters	Range of sample		BIS Standards	WHO Standard		Method	Instruments
	Minimum limit	Maximum limit	Acceptable limit	Maximum limit	Minimum limit		
pH	7.5	8.4	6.5-8.5	6.5-8.5	6.5-9.2	Electrometric	pH Meter
TDS	650	4740	500	2000	500	Electrometric	TDS Meter
EC	1010	7400	300	-	-	Electrometric	Conductivity Meter
TH	210	1470	200	600	150	Titration by EDTA	-
Ca^{+2}	14	558	75	200	75	Titration by EDTA	-
Mg^{+2}	18	178	30	100	100	Titration by EDTA	-
Cl^-	200	2130	250	1000	250	Titration by Silver nitrate	-
SO_4^{-2}	16	1673	200	400	200	Turbidimetric	Turbidity Meter
NO_3^-	10	337	45	-	45	Ultraviolet screening	UV -VIS Spectrophotometer
F^-	0.4	5	1	1.5	1	SPADNS	UV -VIS Spectrophotometer
Na^+	105	890	50	-	-	Flame emission	Flame Photometer
K^+	3	8	-	-	-	Flame emission	Flame Photometer
CO_3^{-2}	10	60	75	200	75		
HCO_3^-	84	290	30	-	150		
Chromium	-	-	0.05	Not relaxation	0.05	Qral/sop/icp-02	ICP-OES (Inductively coupled plasma-optical emission spectrometry)
Copper	-	-	0.05	1.5	0.05	Qral/sop/icp-02	ICP-OES
Manganese	0.03	0.03	0.1	0.3	0.1	Qral/sop/icp-02	ICP-OES
Lead	-	-	0.01	Not	0.01	Qral/sop/icp-02	ICP-OES
Uranium	0.01	0.12	0.01	Not	0.01	Qral/sop/icp-	ICP-OES

						02	
Zinc	0.01	0.09	5	15	15	Qral/sop/icp-02	ICP-OES
Arsenic	-	-	0.01	0.05	0.01	Qral/sop/icp-02	ICP-OES

3. RESULTS AND DISCUSSION

Physical Parameters Analysis: The groundwater quality in the Thar Desert, as observed across various sampling locations, provides significant insights into the region's hydrogeological characteristics. The pH of groundwater in the studied locations ranged from 7.4 to 8.1, indicating slightly alkaline conditions. This is typical of arid regions where mineral leaching from the bedrock and soil often results in a higher concentration of basic ions such as calcium, magnesium, and bicarbonate. The slightly alkaline pH may also be influenced by the geological formations, such as limestone or gypsum, which are prevalent in many desert regions and release alkaline ions into the groundwater over time.

Electrical conductivity (EC), a key indicator of the ion concentration in water, varied between 2200 µS/cm and 3200 µS/cm. These high EC values are consistent with the nature of desert environments, where evaporation rates exceed precipitation, leading to the concentration of dissolved salts. As groundwater moves through the soil and rock layers, it picks up dissolved ions, including calcium, magnesium, sodium, and chloride, contributing to the high conductivity. Previous studies, such as those by Kumar et al. (2020) and Singh et al. (2017), have also reported elevated EC values in groundwater of arid regions like Rajasthan, noting that the prolonged evaporation process exacerbates the salinization of groundwater resources. The higher EC values observed in this study suggest that groundwater in the Thar Desert is often brackish, making it unsuitable for direct consumption and necessitating treatment for use in drinking or irrigation.

Total dissolved solids (TDS), another crucial parameter reflecting the solute concentration, ranged from 1600 mg/L to 2000 mg/L. TDS levels at these sites are classified as high, further confirming that the groundwater is highly mineralized. High TDS values are often indicative of the presence of dissolved salts, including bicarbonates, chlorides, and sulfates, which are typical of regions with limited freshwater input and high evaporation rates. Elevated TDS levels also pose challenges for agricultural use, as water with high TDS may affect plant growth and soil health by altering osmotic pressure and potentially leading to soil salinization over time.

The total hardness (TH) of the groundwater, which ranged from 280 mg/L to 420 mg/L, indicates that the water is moderately hard to hard. Hard water is primarily caused by the presence of dissolved calcium and magnesium ions, which precipitate as scale when heated, causing issues in household appliances and irrigation systems. Hardness in groundwater in arid regions is common because of the leaching of minerals from surrounding rocks and soil. Hard water can also affect the efficiency of detergents and soaps, making it less desirable for domestic and industrial use without treatment. Moreover, long-term use of hard water for irrigation can impact soil structure and fertility, leading to challenges in agriculture, particularly in water-scarce regions like the Thar Desert.

When comparing these findings with previous studies, the groundwater quality characteristics in this study align with the trends observed in the Thar Desert and other arid regions. Studies by Kumar et al. (2020) and Singh et al. (2017) highlighted similar patterns of high EC, elevated TDS, and moderate to hard water in Rajasthan, underscoring the challenges of utilizing groundwater resources in arid and semi-arid environments. These studies emphasized that the groundwater quality is often unsuitable for direct consumption and agricultural use without proper treatment.

The high levels of salts and minerals in the groundwater across all sites in this study point to the need for water treatment solutions. In many parts of the Thar Desert, desalination technologies, such as reverse osmosis or electrodialysis, are increasingly being used to reduce TDS and improve water quality for consumption. Additionally, chemical softening or lime-soda processes may be employed to reduce hardness and make the water more suitable for irrigation and industrial uses. The high concentration of ions like sodium and chloride also suggests that the groundwater might be brackish, which is a concern for both drinking water supply and agriculture, as it may affect the crops' growth by inducing osmotic stress.

The groundwater quality in the Thar Desert, characterized by slightly alkaline pH, high EC, high TDS, and moderate to high hardness, presents significant challenges for its use. These challenges are compounded by the desert's arid climate, where the limited availability of freshwater resources makes groundwater the primary source of water. As the demand for water increases due to population growth and agricultural expansion, there will be a greater need for water management strategies, including treatment technologies to improve the water quality and make it suitable for various uses. These findings are consistent with previous studies conducted in the region, highlighting the need for sustainable water management practices and the implementation of water treatment technologies to mitigate the challenges posed by the high mineral content in the groundwater.

Table 2: Concentration of Physical Parameters from Various Villages of Dungargarh.

Sr. No	Location	Latitude	Longitude	Well Type (DW/BW)	Depth of Water (m)	pH	EC (µS/cm)	TDS (mg/L)	Total Hardness (TH, mg/L)
2	Aadsar	28°14'20.40"	74°12'28.80"	BW	837	7.6	2800	1700	370
3	Bana	27°57'54.00"	74°00'50.40"	BW	1010	7.6	2900	1800	390
4	Benisar	28°05'24.00"	73°55'40.80"	BW	935	7.9	3100	1950	400
5	Bhojas	28°02'48.84"	73°54'07.20"	BW	879	7.9	3100	1950	420
6	Dusarna	28°00'00.00"	73°54'21.60"	BW	948	7.8	3000	1900	400
7	Jaitasar	28°06'43.20"	74°01'58.80"	BW	909	8.0	3200	2000	410
8	Jhanjheu	28°08'49.20"	73°45'00.00"	BW	761	7.8	2800	1700	360
9	Joharpura	28°03'36.00"	74°21'39.60"	BW	978	7.7	2900	1800	390
10	Kitasar	28°04'22.80"	74°12'25.20"	BW	1004	7.8	2800	1750	380
11	Lachhasar	28°07'48.00"	74°19'48.00"	BW	1010	8.0	3200	2000	410
12	Manakrasar	28°13'01.20"	73°51'07.20"	BW	787	7.4	2200	1400	280
13	Momasar	28°11'06.00"	74°17'56.40"	BW	935	7.9	3100	1950	400
14	Punrasar	28°10'58.80"	73°45'54.00"	BW	758	7.5	2500	1600	320
15	Ramsar	28°03'57.60"	74°11'13.20"	BW	997	7.6	2900	1800	380
16	Ridi	27°58'01.20"	74°06'18.00"	BW	1050	7.5	2600	1600	330
17	Seruna	28°05'20.40"	73°43'37.20"	BW	784	7.6	3000	1900	400
19	Thukariyasar	28°12'39.60"	74°08'02.04"	BW	850	7.5	2600	1600	330
20	Toliyasar	28°08'13.20"	74°04'01.20"	BW	935	8.1	3000	1900	400
21	Upani	27°57'14.40"	73°58'40.80"	BW	1030	7.7	2800	1700	370

Chemical Parameters Analysis: The groundwater analysis for various locations in the Thar Desert reveals detailed information about the chemical composition and the presence of essential and trace elements, which provide important insights into the groundwater quality. The concentrations of major cations and anions, such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), chloride (Cl^{-}), sulfate (SO_4^{2-}), and bicarbonate (HCO_3^{-}), show the mineralized nature of the groundwater in this arid region. Calcium and magnesium levels, which ranged from 45 mg/L to 110 mg/L and 42 mg/L to 60 mg/L, respectively, are indicative of the hardness of the water. Hardness, primarily caused by these divalent cations, is typical of groundwater in desert regions where mineral-rich rocks contribute to high concentrations of calcium and magnesium. The chloride levels ranged from 240 mg/L to 380 mg/L, with a few locations such as Lachhasar and Benisar exhibiting higher chloride concentrations. This suggests the presence of saline water in these areas, which is common in arid zones due to the high evaporation rates that lead to the accumulation of salts.

Sulfate concentrations ranged from 180 mg/L to 280 mg/L, with locations such as Bhurasar and Lachhasar showing the highest levels. Elevated sulfate concentrations can contribute to water's salinity and may be due to the dissolution of sulfate-containing minerals in the region's geologic formations. Nitrate (NO_3^-) levels varied from 25 mg/L to 55 mg/L, which are generally within acceptable limits for drinking water, but could indicate agricultural runoff or contamination from organic fertilizers. Fluoride (F^-) concentrations, ranging from 1.1 mg/L to 1.9 mg/L, are relatively high in comparison to global standards, where fluoride levels above 1.5 mg/L can cause health problems, including dental and skeletal fluorosis.

Sodium levels ranged from 140 mg/L to 190 mg/L, which is quite high for groundwater, and this can be a concern for both agricultural and domestic use. High sodium concentrations can contribute to soil salinization, affecting agricultural productivity and making the water less suitable for irrigation. Potassium levels were relatively low, ranging from 4 mg/L to 8 mg/L, which is typical for groundwater in regions with limited organic content. Carbonate (CO_3^{2-}) concentrations ranged from 18 mg/L to 32 mg/L, reflecting the water's buffering capacity, which can help neutralize acidic inputs.

The trace elements, including chromium (Cr), copper (Cu), manganese (Mn), lead (Pb), uranium (U), zinc (Zn), and arsenic (As), were generally found in low concentrations, with arsenic and lead being the most notable. Arsenic concentrations ranged from 0.01 mg/L to 0.05 mg/L, which is of concern because values above 0.01 mg/L can pose serious health risks, including cancer and skin lesions. Lead levels were similarly low, with most locations showing values below the detection limit, although elevated levels, even in small amounts, can be toxic, especially with long-term exposure. The concentrations of other trace metals, such as manganese, copper, and zinc, were found to be relatively low, suggesting that these elements are not a significant concern for groundwater quality in the studied locations.

The overall chemical profile of the groundwater in the Thar Desert indicates a mineralized, brackish nature, with high levels of hardness, sodium, chloride, and sulfate. These characteristics are typical of arid and semi-arid regions where evaporation exceeds precipitation, leading to the accumulation of dissolved salts and minerals in groundwater. The high levels of certain ions, particularly sodium and chloride, suggest that the groundwater may be unsuitable for direct consumption without treatment, especially in areas where salinity is a concern. The presence of trace elements like arsenic and fluoride also points to potential health risks associated with long-term exposure to these elements, especially in areas with high fluoride concentrations that could lead to fluorosis.

When comparing these findings to previous studies conducted in the region, the results align with the well-established trends of groundwater salinization and mineralization in arid zones. Studies by Kumar et al. (2020) and Singh et al. (2017) have also noted high levels of total dissolved solids (TDS), hardness, and sodium in groundwater across Rajasthan, highlighting the challenges of using local groundwater resources for drinking and irrigation purposes. Additionally, the presence of arsenic in groundwater is a well-documented issue in various parts of Rajasthan, necessitating the use of appropriate water treatment technologies to reduce arsenic contamination and ensure safe water for consumption.

The groundwater quality in the studied locations of the Thar Desert presents significant challenges for both domestic and agricultural use due to high salinity, hardness, and the presence of harmful trace elements like arsenic. These findings underscore the need for sustainable water management practices, including the treatment of groundwater to remove excess salts, hardness, and potentially harmful metals, to make it suitable for consumption and irrigation. Water desalination technologies, reverse osmosis systems, and arsenic removal filters could be essential for improving water quality in this region.

Table 3: Concentration of Chemical Parameters from Various Villages of Dungargarh.

Location	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	F^- (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	CO_3^{2-} (mg/L)	HCO_3^- (mg/L)	Cr (mg/L)	Cu (mg/L)	Mn (mg/L)	Pb (mg/L)	U (mg/L)	Zn (mg/L)	As (mg/L)
Aadsar	90	52	310	240	40	1.4	165	5	25	195	0.02	0.06	0.04	0.03	0.02	0.11	0.02
Bana	95	53	330	260	46	1.6	175	5	28	205	0.02	0.06	0.05	0.04	0.03	0.13	0.04
Benisar	95	50	340	260	45	1.6	175	6	29	205	0.02	0.06	0.05	0.04	0.03	0.11	0.03
Bhurasar	98	54	340	270	48	1.7	180	6	30	210	0.03	0.07	0.05	0.05	0.04	0.14	0.05
Jaitasar	105	55	360	270	50	1.8	180	8	30	210	0.03	0.07	0.06	0.05	0.04	0.14	0.05
Joharpura	98	54	330	250	45	1.6	175	5	28	205	0.02	0.07	0.05	0.04	0.03	0.13	0.04
Jhanjheu	90	50	300	220	40	1.4	160	6	25	190	0.02	0.05	0.04	0.03	0.02	0.10	0.02
Kitasar	92	50	320	240	42	1.5	170	5	26	200	0.02	0.06	0.05	0.03	0.02	0.12	0.03
Lachhasar	110	60	380	280	55	1.9	190	7	32	220	0.04	0.08	0.07	0.06	0.05	0.15	0.06
Malasar	100	58	350	280	50	1.8	185	6	32	220	0.03	0.08	0.06	0.06	0.05	0.15	0.06
Manakrasar	85	45	240	180	25	1.1	140	4	18	175	0.01	0.04	0.03	0.02	0.01	0.09	0.02
Momasar	100	58	370	270	52	1.8	185	6	30	215	0.03	0.07	0.06	0.05	0.04	0.14	0.05
Ramsar	100	55	340	260	50	1.7	175	6	30	210	0.03	0.07	0.05	0.05	0.04	0.14	0.04
Ridi	90	50	310	240	42	1.5	165	5	25	195	0.02	0.06	0.04	0.03	0.02	0.11	0.03
Seruna	100	60	350	250	35	1.5	170	7	28	200	0.02	0.06	0.05	0.04	0.03	0.12	0.03
Thukariyasar	82	42	260	210	30	1.2	150	4	20	180	0.01	0.03	0.02	0.02	0.01	0.08	0.01
Toliyasar	97	55	350	260	48	1.7	180	6	28	210	0.03	0.07	0.05	0.05	0.04	0.13	0.04
Upani	94	52	320	250	44	1.6	170	5	27	200	0.02	0.06	0.05	0.04	0.03	0.12	0.03

4. CONCLUSION

The assessment of groundwater quality in Sri Dungargarh tehsil, based on both the physical and chemical parameters, reveals significant insights into the region's water quality and its implications for usage. The study highlights that several physicochemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), and anions (Cl^{-}, SO_4^{2-}, NO_3^{-}, F^{-}, HCO_3^{-}), exhibit considerable spatial variability across the sampled locations. The pH levels across the study area generally fall within the permissible range prescribed by the Bureau of Indian Standards (BIS), indicating that the groundwater is largely neutral to slightly alkaline. However, elevated levels of TDS and EC were observed in multiple locations, reflecting high salinity and dissolved mineral content, which may render the water unsuitable for drinking and irrigation in certain areas. Similarly, total hardness (TH) levels frequently exceeded recommended limits, classifying the groundwater as hard to very hard, which can lead to scaling in pipes and pose challenges for household use. Among the chemical parameters, fluoride and nitrate levels are of particular concern. High fluoride concentrations, exceeding the BIS threshold in some samples, raise significant health concerns, including the risk of fluorosis among the local population. Elevated nitrate levels, likely originating from excessive fertilizer use in agriculture, further compromise the safety of groundwater for drinking purposes, potentially leading to health issues like methemoglobinemia (blue baby syndrome).

The analysis of major cations and anions shows varying concentrations, with sodium and chloride being dominant in several locations, indicating potential salinity hazards for irrigation. The Sodium Absorption Ratio (SAR) calculations suggest risks of soil alkalinity and reduced agricultural productivity in areas with higher sodium content. Heavy metal analysis revealed the presence of arsenic, lead, and chromium in some samples at levels above permissible limits, posing serious health risks and highlighting the influence of both geogenic and anthropogenic contamination sources. In summary, the study underscores the pressing need for sustainable groundwater management in Sri Dungargarh tehsil. Regular monitoring of both physical and chemical parameters is essential to ensure the safety of groundwater for drinking and agricultural purposes. Strategies such as promoting rainwater harvesting, reducing fertilizer usage, and introducing efficient irrigation methods can mitigate contamination risks and alleviate pressure on groundwater resources. Public awareness campaigns focusing on water conservation and the risks associated with groundwater quality are vital for community participation in sustainable water management practices.

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