International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 13-08-2025, Accepted: 12-09-2025, Published: 27-09-2025
Volume 10, Issue 9, 2025, Page No. 58-63

Physico-chemical analysis of water collected from different dams of Karauli district, Rajasthan

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Abstract
The current study shows comparative water quality analysis of six different regions of Karauli, including Panchana dam (Site 1), Rangwana ka talab (Site 2), Needar Dam (Site 3), Jaggar dam (Site 4), Sagar (Site 5) and Kalisil dam (Site 6) during 3 seasons. For this, thirteen different physico-chemical parameters were analysed, including Temperature, pH, EC, TDS, Alkalinity, Hardness, BOD, COD, DO, Nitrate, Phosphate, Chloride and Sulphate. The results of the study showed highest values of all the analysed parameters in water from site 5 (Sagar) while water from site 2 (Rangwana ka talab) had the lowest values of all the analysed parameters. Furthermore, the study showed that water during the summer season showed highest pH, electrical conductivity, TDS, hardness, COD, Nitrate and Chloride. In the monsoon season, water from all the sites showed highest temperature, alkalinity, Dissolved oxygen and sulphate. However, winter season was marked by increased BOD for all the sites. These findings strongly emphasize the critical need for integrated water management strategies that are both site-specific and seasonally adaptive.

Keywords: Water quality, biological oxygen demand, chemical oxygen demand, electrical conductivity

Introduction

The last few years have witnessed increased industrialization in several areas of Rajasthan, in an attempt to increase revenue and provide employment to local people. This has led to a sudden boom in both small-scale as well as large scale industries in this area. While on one hand, this has provided employment to several youth and trained them to earn their livelihood, on the other hand, it has been extremely disastrous for the environment. In the name of advancement, the environmental impact has been neglected, taking a heavy toll on the ecosystem as well as its different components, be it the aquatic life, the plants that inhabit the land, animals or humans for that matter. The last couple of decades has seen advent of several industries in Karauli region of Rajasthan region, including, mining industry, stone processing industry, agro-processing industry, textile industry, and cottage industries:

- Mining industry releases fine particulate matter, silica dust, and slurry into water bodies, which contaminate them and seep into groundwater. Also, heavy metal leaching and increased turbidity degrade aquatic ecosystems along with reduction in ground water table due to stone extraction.
- Agro-processing industry releases organic waste, fertilizer residues, and pesticide-laden runoff into water bodies, leading to eutrophication. This causes increased BOD and COD, suffocating aquatic life.
- Textile industries release toxic dyes, alkalinity, and chemical effluents that alter the pH and color of water (Jaiman *et al.*, 2023; Renu *et al.*, 2023; Tiwari *et al.*, 2024; Arif *et al.*, 2021; Mobar *et al.*, 2021) [3, 10, 15, 19, 21].

All these toxicants persist and accumulate, making water unfit for human and animal consumption. Cottage industries cause improper disposal of soap, wax, paint, and solvents contaminates nearby ponds and streams. Considering all these factors with a focus on improvement of environment health, the current study has been drafted to focus on comparative analysis of water from six different regions of Karauli, including Panchana dam (Site 1), Rangwana ka talab (Site 2), Needar Dam (Site 3), Jaggar dam (Site 4), Sagar (Site 5) and Kalisil dam (Site 6) during summer, monsoon and winter season. The findings of the current study will contribute to amelioration of environmental health in several important ways by conducting a comparative seasonal analysis of water quality. The results will provide critical insights into how industrial, agricultural, as well as domestic activities cast a profound impact on aquatic ecosystems throughout the year. Identifying temporal trends—such as increased toxicant levels in summer or nutrient surges in monsoon—helps pinpoint peak pollution periods as well as high risk sites. Ultimately, such research empowers local authorities, environmental agencies, as well as the citizens to take informed actions that contribute towards protection of water quality, safeguard public health, as well as restore ecological balance in the Karauli region.

Materials and Methods

Survey and collection of water samples

The water samples were collected in sterilized sampling bottles of 250 ml capacity marked with stickers. The samples were collected from six different regions of Karauli, including Panchana dam (Site 1), Rangwana ka talab (Site 2), Needar Dam (Site 3), Jaggar dam (Site 4), Sagar (Site 5) and Kalisil dam (Site 6) during summer season (March-June), Monsoon (July-October) and winter (November-February). These samples were brought to the laboratory under cold conditions and stored at 40C till further use.

Samples were collected from at least 2 to 3 meters away from the boundaries of water body. For this purpose, a pre-sterilized bottle was tied at one end of a long bamboo pole and collect the sample after displaying surface water which might contain organic floating over it. After filling, the bottle the cap was placed tightly. Information regarding to samples was tagged on the bottle.

Determination of physicochemical parameters

Water samples from the selected sites were collected through the same procedure and analysed for various physical and chemical parameters. Analysis of the selected physico-chemical parameters were determined by following methods-

Temperature (◦C): Temperature was measured by using a mercury centigrade thermometer with an accuracy of 0.1C °C. It was measured at a depth of 10 to 20 cm at the collection site.

pH: pH is measurement of potential of Hydrogen atoms present in the solution, it indicates the acidic or basic nature of the solution. It was taken with the help of an Aquasol digital pH meter on the sampling site.

EC (µmhos): It is a measure of a water's ability to conduct an electrical current. EC was taken with the help of an Aquasol digital EC meter on the sampling site.

TDS (mg/L): TDS is the total amount of solids dissolved in the water, including soluble hydrogen carbonate ions, chloride salts, sulphates, calcium, magnesium, sodium, potassium, volatile solids, and non-volatile solids. Its concentration will affect the taste of drinking water. TDS was taken with the help of an Aquasol digital TDS meter on the sampling site.

Alkalinity (mg/L): Alkalinity was determined by a titrated water sample with a strong acid such as chlorine and sulphuric acid. To measure the alkalinity, took 100 ml water sample in a pipette and then added 2 drops of phenolphthalein indicator. Put sulphuric acid in the burette and titrate the sulfuric acid content. Continue titrating until colour changes in the sample are made. Added 2 drops of the combined indicator and proceed with sulphuric acid titration. Continue the titration till the colour of water sample will be changes in to red colour then calculate the alkalinity of water sample.

Hardness (mg/L): The sum of the concentrations of calcium and magnesium, defined as Total Hardness, expressed in terms of mg $CaCO_3$/L. Total hardness was estimated by the EDTA (Ethyl diamine tetra-acetic acid) titrimetric method (Clesceri *et al*., 1998) [5] and Aquasol total hardness testing kit (AE211).

BOD (mg/L): The BOD test, being a bioassay procedure, requires the addition of nutrients and maintaining the standard conditions of pH and temperature and the absence of microbial growth-inhibiting substances. For determination of BOD, the dilution method, and five days of incubation at a specified temperature (20°C) were followed. The difference in the dissolved oxygen measured initially and after incubation gave the BOD values of the samples (Clesceri *et al*., 1998) [5].

COD (mg/L): It is chemical demand of oxygen to oxidize organic metrical and inorganic nutrient, which represents the degree of organic contamination of the lake water. The COD determines the amount of oxygen required for chemical oxidation of organic matter using a strong chemical oxidant such as potassium dichromate under reflux conditions (Clesceri *et al*., 1998) [5].

DO (mg/L): DissThe dissolved oxygen values indicate the degree of pollution in water bodies. The azide modification of Winkler's method was used for dissolved oxygen determination (Clesceri *et al*., 1998) [5].

Nitrate (mg/L): It is a naturally occurring chemical that mixes nitrogen with oxygen or ozone. Nitrate was estimated by phenol disulphonic acid method. 50 ml sample was taken and same quantity of silver sulphate was heated and filtered the AgCl. Filtrate was evaporated in a porcelain basin to dryness. Residue was cooled and dissolved in 2 ml phenol disulphonic acid and volume was diluted to 50 ml. 6 ml liquid ammonia was added and reading was taken by using the filter at 410 nm and from standard curve nitrate value were calculated (APHA, 1992).

Phosphate (mg/L): Phosphorus is usually essential nutrient which is present in natural water as phosphate. Total phosphorus was measured by spectrophotometric method. A pinch of activated charcoal added in a 100 ml sample was mixed thoroughly, followed by filtration through Whatman filter paper (No. l). This treatment removed colour and colloidal impurities. This digested (neutralized) sample for total kjeldahl nitrogen was used for total phosphorus estimation. Its phosphorus content was determined by stannous chloride ($SnCl_2$)-Ammonium molybdate method taking reading at 690 nm on Spectrophotometer using a distilled water blank with using same amount of chemicals. The pink colour of phenolphthalein disappears after addition of ammonium molybdate. The concentration of total phosphate was calculated using standard curve and multiplies it by the dilution factor.

Chloride (mg/): Chloride is present in both fresh and salty waters and is an essential element of life. High concentration of chloride can be harmful of aquatic organism. The presence of chloride increases the electrical conductivity of water and thus increases its corrosivity. Chloride ion is determined by Mohr's method, titration with standard silver nitrate solution in which silver chloride is precipitated first. The end of titration is indicated by formation of red silver chromate from excess $AgNO_3$ and potassium chromate used as an indicator in neutral to slightly alkaline solution.

Sulphate (mg/l)

Turbidity method was used to determine sulphate in the collected water samples (APHA, 2012). To 20 ml of a clear aliquot of the water sample, 1 mL of HCl (1+9) solution and 1 mL of conditioning reagent were added and mixed well for 30 seconds. After 10 minutes, the analysis was done at a wavelength of 420 nm by using UV-5100 Spectrophotometer. The calibration curve was prepared by using standard sulphate (10 ppm to 50 ppm) solution and a blank solution.

Results

1. **Comparative Analysis of Physico-Chemical Water Quality Parameters Across Six Sites in Karauli during Summer Season**

Table 1 and its corresponding graph show comparative water quality of six different regions of Karauli, including Panchana dam (Site 1), Rangwana ka talab (Site 2), Needar Dam (Site 3), Jaggar dam (Site 4), Sagar (Site 5) and Kalisil dam (Site 6) during summer season (March-June). Thirteen different physico-chemical parameters were analysed, including, Temperature, pH, EC, TDS, Alkalinity, Hardness, BOD, COD, DO, Nitrate, Phosphate, Chloride and Sulphate. The results show highest values of all the analysed parameters in water from site 5 (Sagar) while water from site 2 (Rangwana ka talab) had the lowest values of all the analysed parameters. The average values of the physico-chemical parameters across the six water sampling sites in Karauli during the summer season were found to be as follows: Temperature – 28.67, pH – 7.72, Electrical Conductivity (EC) – 280.83, Total Dissolved Solids (TDS) – 241.33, Alkalinity – 143.00, Hardness – 110.50, Biochemical Oxygen Demand (BOD) – 3.67, Chemical Oxygen Demand (COD) – 35.50, Dissolved Oxygen (DO) – 3.57, Nitrate – 9.02, Phosphate – 0.15, Chloride – 34.17, and Sulphate – 0.67. Comparing the water quality of all the sites across different seasons, water during the summer season showed highest pH, electrical conductivity, TDS, hardness, COD, Nitrate and Chloride.

2. Comparative Analysis of Physico-Chemical Water Quality Parameters Across Six Sites in Karauli during Monsoon Season

Table 2 and its corresponding graph show comparative water quality of six different regions of Karauli, including Panchana dam (Site 1), Rangwana ka talab (Site 2), Needar Dam (Site 3), Jaggar dam (Site 4), Sagar (Site 5) and Kalisil dam (Site 6) during monsoon/rainy season (July-October). Thirteen different physico-chemical parameters were analysed, including, Temperature, pH, EC, TDS, Alkalinity, Hardness, BOD, COD, DO, Nitrate, Phosphate, Chloride and Sulphate. Similar to the results in Table 1, the results show highest values of all the analysed parameters in water from site 5 (Sagar) while water from site 2 (Rangwana ka talab) had the lowest values of all the analysed parameters. The average values of the physico-chemical parameters across the six water sampling sites in Karauli during the summer season were found to be as follows: Temperature – 28.82, pH – 7.58, Electrical Conductivity (EC) – 139.67, Total Dissolved Solids (TDS) – 148.00, Alkalinity – 175.83, Hardness – 73.33, Biochemical Oxygen Demand (BOD) – 2.58, Chemical Oxygen Demand (COD) – 20.17, Dissolved Oxygen (DO) – 4.62, Nitrate – 4.32, Phosphate – 0.15, Chloride – 22.57, and Sulphate – 0.77. Comparing the water quality of all the sites across different seasons, water during the monsoon season showed highest temperature, alkalinity, Dissolved oxygen and sulphate.

3. Comparative Analysis of Physico-Chemical Water Quality Parameters Across Six Sites in Karauli during Winter Season

Table 3 and its corresponding graph show comparative water quality of six different regions of Karauli, including Panchana dam (Site 1), Rangwana ka talab (Site 2), Needar Dam (Site 3), Jaggar dam (Site 4), Sagar (Site 5) and Kalisil dam (Site 6) during winter season (November-February). Thirteen different physico-chemical parameters were analysed, including, Temperature, pH, EC, TDS, Alkalinity, Hardness, BOD, COD, DO, Nitrate, Phosphate, Chloride and Sulphate. Similar to the results in Table 1 and Table 2, water sample from site 5 (Sagar) showed the highest values of all the analysed parameters while water from site 2 (Rangwana ka talab) had the lowest values of all the analysed parameters. The average values of the physico-chemical parameters during the winter season was found to be as follows: Temperature – 19.68, pH – 7.70, Electrical Conductivity (EC) – 172.83, Total Dissolved Solids (TDS) – 170.00, Alkalinity – 126.17, Hardness – 97.17, Biochemical Oxygen Demand (BOD) – 3.78, Chemical Oxygen Demand (COD) – 28.00, Dissolved Oxygen (DO) – 3.87, Nitrate – 5.73, Phosphate – 0.15, Chloride – 20.50, and Sulphate – 0.33. Comparing the water quality of all the sites across different seasons, water during the winter season showed the highest BOD.

Table 1: Physicochemical Analysis of selected aquatic sites/ sub areas of Karauli in summer season (March-June)

Sr. No.	Physicochemical parameters	Aquatic sites/ Sub areas					
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
1.	Temperature (◦C)	24.5	28.6	27	26.3	33.5	32.1
2.	pH	7.2	7.5	8.1	7.3	8.3	7.9
3.	EC (µmhos)	270	281	273	271	297	293
4.	TDS (mg/l)	157	201	175	167	398	350
5.	Alkalinity (mg/l)	130	144	138	132	160	154
6.	Hardness (mg/l)	97	115	110	101	121	119
7.	BOD (mg/l)	3	3	3	4	5	4
8.	COD (mg/l)	25	39	35	27	45	42
9.	DO (mg/l)	2.2	3.6	3.2	2.8	5.0	4.6
10.	Nitrate (mg/l)	7.6	9.0	8.8	8.0	10.6	10.1
11.	Phosphate (mg/l)	0.1	0.1	0.1	0.2	0.2	0.2
12.	Chloride (mg/l)	24	36	35	28	42	40
13.	Sulphate (mg/l)	0.50	0.64	0.53	0.50	1.03	0.80

Site 1- Panchana Dam, Site 2- Ranganwa Ka Talab, Site 3- Needar Dam, Site 4- Jaggar Dam, Site 5- Sagar, Site 6- Kalisil Dam

Table 2: Physicochemical Analysis of selected aquatic sites/ sub areas of Karauli in winter season (November- February)

Sr. No.	Physicochemical parameters	Aquatic sites/ Sub areas					
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
1.	Temperature (◦C)	16.8	20.0	18.0	18.0	24.2	21.1
2.	pH	7.1	7.8	7.8	7.5	8.0	8.0
3.	EC (µmhos)	154	178	179	158	185	183
4.	TDS (mg/l)	138	155	151	144	232	200

5.	Alkalinity (mg/l)	108	130	124	111	146	138
6.	Hardness (mg/l)	86	97	97	88	115	100
7.	BOD (mg/l)	2.8	4	3.4	3	5.0	4.5
8.	COD (mg/l)	20	30	25	25	36	32
9.	DO (mg/l)	3.1	4	3.5	3.1	5	4.5
10.	Nitrate (mg/l)	5.2	5.6	5.6	5.6	6.3	6.1
11.	Phosphate (mg/l)	0.1	0.1	0.1	0.2	0.2	0.2
12.	Chloride (mg/l)	18	21	20	20	22	22
13.	Sulphate (mg/l)	0.2	0.3	0.3	0.2	0.6	0.4

Site 1- Panchana Dam, Site 2- Ranganwa Ka Talab, Site 3- Needar Dam, Site 4- Jaggar Dam, Site 5- Sagar, Site 6- Kalisil Dam

Table 3: Physicochemical Analysis of selected aquatic sites/ sub areas of Karauli in monsoon/rainy season (July- October)

Sr. No.	Physicochemical parameters	Aquatic sites/ Sub areas					
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
1.	Temperature (◦C)	28.0	28.8	28.7	28.3	30	29.1
2.	pH	7.0	7.7	7.6	7.2	8.0	8.0
3.	EC (µmhos)	131	142	137	135	150	143
4.	TDS (mg/l)	117	145	133	121	192	180
5.	Alkalinity (mg/l)	168	175	178	175	180	179
6.	Hardness (mg/l)	64	68	72	68	89	79
7.	BOD (mg/l)	2	2.5	2	2	4	3
8.	COD (mg/l)	10	23	19	11	30	28
9.	DO (mg/l)	3.6	4.8	4.7	3.8	5.7	5.1
10.	Nitrate (mg/l)	2.8	4.1	4.8	3.0	6.0	5.2
11.	Phosphate (mg/l)	0.10	0.15	0.15	0.10	0.2	0.2
12.	Chloride (mg/l)	21.4	22.6	22.4	22	24	23
13.	Sulphate (mg/l)	0.6	0.8	0.7	0.7	1.0	0.8

Discussion

The current study presents a comprehensive seasonal analysis of water quality parameters across six major water bodies in Karauli, Rajasthan, including Panchana Dam, Rangwana ka Talab, Needar Dam, Jaggar Dam, Sagar, and Kalisil Dam during summer, monsoon, and winter seasons. The results highlight distinct seasonal variations in the different physico-chemical parameters, which are greatly affected by climatic factors, human activities, as well as hydrological dynamics. The results showed that water from Site 5 (Sagar) consistently showed the highest values for all the analysed parameters across different seasons, indicating heavy contamination or eutrophication potential in that site. On the contrary, water from Site 2 (Rangwana ka Talab) consistently showed the lowest values of all the analysed physico-chemical parameters, suggesting relatively unpolluted water. This may be attributed to several factors, such as:

- Sagar is world-renowned for black sandstone mining. While the black sandstone itself is not a water pollutant, however, its mining and exposure may exacerbate existing water pollution problems.
- Besides this, mining can result in deposition of sediments in water bodies, potentially damaging aquatic life.
- Also, mining activity causes haziness in surrounding water bodies and obstructs sunlight penetration in water, thereby affecting aquatic life.
- The black sandstone contains heavy metals such as iron sulfides, which may cause contamination of groundwater as well as surface water.
- Other factors such as discharge of domestic wastewater sewage and agriculture runoff may lead to elevated BOD, COD, EC, TDS, nitrates and phosphates in water.
- Stagnant or slow-moving water coupled with high evaporation rates may further cause elevated EC, TDS, chloride, and sulphate levels in water.

Thereafter, it was shown that pH values across seasons remained within the neutral to slightly alkaline range, with a peak in summer (7.72), followed by winter (7.70), and the lowest in monsoon (7.58). The slightly higher pH during summer season maybe attributed to increased photosynthetic activity by aquatic flora, which shift pH toward alkalinity (Bupaet *et al.*, 2013; Li *et al.*, 2023; Shen *et al.*, 2024; Ferreira *et al.*, 2025) [9, 12, 20]. Furthermore, lower pH in the monsoon occurs during surface runoff, introducing organic acids and acidic pollutants.

Next, Electrical conductivity of all the water bodies was analysed. The EC as well as TDS was significantly higher in the summer, moderately high in winter, and lowest during the monsoon. The highest EC and TDS in summer may occur owing to increased evaporation as well as lower dilution, concentrating dissolved salts. On the contrary, monsoon rainfall dilutes the ions in water bodies, leading to decreased EC and TDS. Winter values, on the other hand, fall in between owing to decreased evaporation and moderate water flow (Ahmed *et al.,* 2022; Rao *et al.,* 2022; Dharmapriya *et al.,* 2022; Natesan *et al.,* 2022) [1, 16, 18].

The elevated levels of pH, electrical conductivity (EC), total dissolved solids (TDS), hardness, chemical oxygen demand (COD), nitrate, and chloride observed during the summer season maybe attributed owing to intense evaporation as well as limited rainfall, which reduce water volume, leading to concentration of dissolved substances. Increased temperatures lead to the enhancement of microbial as well as chemical reactions, increasing pH and COD of water bodies. During the summer season, agricultural runoff, rich in fertilizers, contributes to increased nitrate levels. Accumulation of domestic and sewage discharges add to the organic and chemical load of the water bodies. Chloride as well as other ions accumulate in water bodies owing to decreased dilution as well as flushing, while hardness increases with an increase in calcium and magnesium concentrations of water bodies through evaporation. All

these seasonal dynamics occur owing to the combined effects of climatic conditions, anthropogenic inputs, and reduced hydrological flow, which makes summer the most polluted season in terms of water quality (Rahman *et al.*, 2021; Dey *et al.*, 2021; Ustaoğlu *et al.*, 2021; Maansi *et al.*, 2022) [6, 13, 17, 22].
Thereafter, the elevated values of temperature, alkalinity, dissolved oxygen (DO), and sulphate during the monsoon season was shown. The results showed that temperature was highest during the monsoon season (28.82°C), slightly lower during summer (28.67°C), and lowest in winter (19.68°C). This is in accordance with expected seasonal climatic patterns in Rajasthan, where solar radiation and ambient temperatures peak during the monsoon owing to cloud-covered humidity while they are lowest during winter. Also, high temperatures of water can further accelerate microbial activity as well as biochemical reactions, thereby influencing parameters such as BOD and DO (Knapp *et al.*, 2022; Mengqi *et al.*, 2023) [11, 14]. Alkalinity was found to be highest during monsoon season since rainwater interacts with soil and rocks, leading to the leaching of bicarbonates, carbonates, and hydroxides into the water bodies. This leads to increase in dissolved oxygen during monsoon owing to enhanced surface aeration caused by rainfall as well as turbulent inflow, along with dilution of organic pollutants, which lowers oxygen demand. Sulphate levels increased due to surface runoff carrying leached sulphate ions from agricultural fields, soil, and atmospheric deposition through acid rain.

Thereafter, out of all the seasons, the researchers showed that the highest Biological Oxygen Demand (BOD) was observed during the winter season across all sites. This maybe attributed to several interrelated factors, including:

- During winter, lower temperatures lead to decreased metabolic activity of aerobic microorganisms, which causes slowing down of the decomposition of organic matter, leading to its accumulation in water bodies. This accumulated organic load thereafter contributes to a higher BOD.
- Furthermore, winter season is marked by reduced water movement as well as lesser evaporation rates, leading to the establishment of stagnant conditions, which further limit the natural aeration as well as dilution of organic pollutants.
- In continuation of this, human activities such as washing, disposal of domestic waste, and agricultural runoff may also continue during winter, but, with lower biological degradation rates. This may contribute to increased oxygen demand (Alprol *et al.*, 2021; El-Rawy *et al.*, 2021) [2, 8].

Concluding the findings of the study in a nutshell, the current study provides a comprehensive seasonal assessment of physico-chemical water quality parameters across six major water bodies in Karauli, Rajasthan. The findings of the study unveil significant spatial as well as temporal variations in the water parameters, with Site 5 (Sagar) consistently showcasing the poorest water quality owing to likely effect of anthropogenic pressures such as domestic discharge, agricultural runoff, as well as stagnant conditions. Furthermore, the study shows seasonal comparisons, which indicate that during summer season, water showed the highest levels of pH, EC, TDS, hardness, COD, nitrate, and chloride, all of which probably occurred owing to intense evaporation and pollutant accumulation. On the contrary, monsoon waters displayed elevated temperature, alkalinity, DO, as well as sulphate, owing to increased runoff and rainfall-induced aeration. The water bodies during winter season recorded the highest BOD levels, likely occurring due to decreased microbial degradation coupled with organic matter accumulation. All these insights underscore the urgent requirement for site-specific as well as season-responsive water management strategies for alleviating and controlling pollution at highly impacted sites like Sagar.

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