Comparative Analysis of Groundwater Quality in Jaisamand Lake and Adjacent Regions

Vinod KumarTak[1], Jai Singh Jodha[2]

[1,2]Department Of Chemistry, Faculty of Science, Janardan Rai Nagar Rajasthan Vidyapeeth (Deemed To Be University), Udaipur, Rajasthan, India.

Abstract
This study examines the physicochemical properties of ground and surface water in and around Jaisamand Lake, situated in District Salumber, Rajasthan, and evaluates their ecological effects on the local flora and fauna. A thorough examination was performed on factors such as pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total dissolved solids, main ions, heavy metals, and microbiological markers. The results revealed significant spatial variability in water quality, with certain locations exhibiting elevated concentrations of pollutants such as fluoride, nitrates, and fecal coliforms. The data were evaluated through statistical tools such as ANOVA to establish the significance of variations across different sampling sites. The study further explores the link between water quality degradation and the health and distribution of aquatic plants, fish populations, and avian diversity. It was found that eutrophication, bioaccumulation of heavy metals, and decreased oxygen levels have negatively impacted biodiversity. This research underlines the urgent need for integrated watershed management and pollution control measures to restore and conserve the ecological balance of this vital freshwater system.

Keywords: Jaisamand Lake; ANOVA; Physicochemical Analysis.

Introduction
Jaisamand Lake, recognized as Asia's second-largest man-made lake, plays a crucial part in the ecological and hydrological systems of Rajasthan located in Salumber district, it supports both anthropogenic activities and a rich diversity of flora and fauna. However, increasing agricultural runoff, domestic waste discharge, and industrial pollutants have begun to threaten the integrity of the water system. This study focuses on assessing the current status of ground and surface water quality in and around the lake and investigates how variations in these characteristics affect the lake's biodiversity. It accounts for nearly 40% of water used across various sectors, excluding hydropower generation and cooling processes in thermal power plants. As a widely accessed resource, groundwater significantly influences both public health and the national economy. It serves as a valuable natural reservoir, holding an estimated volume of around 210 billion cubic meters, accounting for both the recharge and evaporation cycles. Approximately 1/3 of this water is allocated to irrigation, the remaining two-thirds serve home and industrial purposes. A large portion eventually returns to rivers through recirculation. Currently, the growing demands of development, industrial expansion, and population increase have intensified the strain on water resources. Unlike surface water, groundwater pollution is subtle and difficult to detect and reverse due to current technological limitations. In line with global efforts to

understand the critical zone (CZ) and its dynamics, numerous studies have provided insights into groundwater flow and its evolution[2,10]. Pollutants in groundwater are often invisible and odourless, making contamination hard to identify. Moreover, the health impacts of such pollution tend to be chronic and are not easily diagnosed. About one-third of the world's population relies on groundwater for drinking water. The global organization dedicated to the study and management of groundwater resources. Global experts in groundwater science vigorously advocates for research and awareness on water-related issues. Groundwater holds significant importance in dry and semi-arid areas, the locations of base water and rain are scarce[7].

Materials & Methods

Dhebar Lake consists of three islands, all of which are inhabited by the Bhil Minas tribe, as mentioned in the People of Rajasthan. Baba ka Magra refers to the two larger islands, whereas Piari is the name given to the smallest island. A notable feature of the lake is its massive embankment, which stretches 1,202 feet (366 meters) in length, stands 116 feet (35 meters) high, and spans 70 feet (21 meters) in width at its base. The marble dam hosts six intricately designed cenotaphs and a central Shiva temple.
Sampling was conducted at five locations:

1. Near Water Works (HP)
2. Near Jaisamand Gate (HP)
3. Bus Stand Road (HP)
4. Jaisamand Market (HP)
5. Central Lake Area

Physicochemical Analysis

Water samples were analyzed for 30^+ factors such as pH, dissolved oxygen, biological oxygen demand, and chemical oxygen demand, ammonia nitrogen, calcium, cl^-, magnesium, nitrate, phosphate, fluoride, sodium, potassium, sulphate, and heavy metals (Fe, Cd, Pb, Cr, Zn, etc.).

Statistical Analysis

Descriptive statistics were computed along with ANOVA (Analysis of Variance) to discern substantial spatial differences about water quality parameters.

Laboratory analysis

This study aims to evaluate groundwater quality in selected areas surrounding Jaisamand Lake, with an emphasis on pollution-related parameters. It addresses several aspects not previously examined, notably the physicochemical profiling of heavy metals, enumeration of aggregate coliforms (MPN), and measurements of fluoride, dissolved oxygen and biological oxygen demand (BOD). Specimens gathered on a monthly basis from January to December 2021. At each location, 2.5 L polyethylene containers—pre-rinsed to eliminate contamination—were filled on a seasonal schedule, and analyses were performed promptly to maintain result accuracy.

Result:

As per the Bureau of Indian Standards for potable water , The permissible pH range is between 6.5 and 8.5. In the first year of analysis (2021), pH levels in water samples from Jaisamand Lake and its surrounding regions ranged from 7.1 to 8.5, staying within the permissible limits. Out of 48 samples 100% samples were in the range of pH 6.5 to 8.5 and none touched the undesirable level. The presence of turbidity in water results from suspended and colloidal materials, including clay, till, and finely dispersed particles. According to the drinking water standards The acceptable turbidity level for water is 5 NTU. However, the standards also permit a maximum limit of turbidity up 10 NTU beyond this limit water is considered as non-potable. During the same period, hardness levels in the water ranged between 0.58 and 7, indicating variability in water quality. Hard water, when consumed, can pose health risks such as urolithiasis (kidney stones), cardiovascular diseases, renal issues, and even cancer. The potable water quality guideline stipulates that the acceptable limit of total alkalinity in water should not exceed 200 mg/l. Nevertheless, the regulations allow a maximum alkalinity level of 600 mg/l; water over this threshold is deemed inappropriate for consumption. The current investigation reveals significant variability in the total alkalinity values of the water samples. During the first year of our study (2021) analysis water samples and level of 32 mg/l to 760 mg/l in its immediate vicinity, respectively . During first year of our study (2021) analysis water samples and In the surrounding areas, the concentration levels varied from 44 mg/L and 450 mg/L. Water hardness is a critical measure of water quality, particularly when the water is intended for consumption. Water with TDS is unsuitable for both drinking and industrial use. During the first year of our study (2021) analysis water samples varied from minimum 195 mg/l to maximum 594 mg/l in respectively. This is a crucial parameter in drinking water. The term "total dissolved solids" (TDS) refers to some of the several types of minerals that are found in water. High concentrations of dissolved solids make the water unfit for drinking and industrial purposes. In industrial applications, the utilization of water containing high levels of dissolved solids can result in scaling within boilers, corrosion, and a decline in product quality. A high concentration of soluble solids , specifically 3000 mg/L, may cause distress in cattle and livestock. The Bureau of Indian Standards has advised a desirable limit of 500 mg/l for drinking water and total dissolved solids (TDS) content, with a maximum permitted level of 2000 mg/l. During the study year (2021) analysis water samples varied from minimum 415 mg/l to maximum 1460 mg/l in respectively. It is an important constituent of hardness with calcium and magnesium ions. More than 250 mg/l of sulphate concentration in ground water is objectionable. Beyond this limit the sulphate concentration may cause gastro-intestinal irritation. The Indian standard specification for drinking water has recommended the preferred threshold of 200 mg/l regarding sulfate concentration . The water samples from Jaisamand Lake and its surrounding areas does not have the sulphate as a concentration is either below the desirable limit or well within the maximum problem parameter, In the majority of samples, the permissible limit for sulfate is exceeded. During the first year of our study (2021) analysis water samples varied from minimum 51 mg/l to maximum 305 mg/l in respectively. "Electrical conductivity, which rises in direct relation to dissolved salt content, offers a fast estimate of total dissolved solids; groundwater conductance can vary widely—from just a few tens of µmhos/cm in precipitation-rich, chemically inert rock areas to upwards of 10,000 µmhos/cm in desert brines." An electrical conductivity (EC) value ranging from 750 to 1000 µmhos/cm is deemed the safe limit for drinking water, whereas a value of 2000 µmhos/cm is regarded as tolerable to a certain degree. The study also found considerable variation in Electrical Conductivity (EC) in groundwater, indicating fluctuating levels of dissolved salts. During the first year of our study (2021) analysis water samples varied from minimum 587 umhos/cm to maximum 654 umhos/cm in respectively. The Indian drinking water quality standards indicate that a nitrate concentration of 45 mg/l is deemed the safe limit. A higher concentration of nitrate may lead to methaemoglobinaemia and an increased risk of cancer. Nitrate concentrations in the groundwater during the study also varied widely. During the first year of our study (2021) analysis water samples ranged from a minimum of 1.5 mg/l to a maximum of 110.2 mg/l, respectively. The maximum contaminant level (MCL) for nitrite in water is 1 milligram per liter (mg/L). The EPA asserts that exposure beneath this threshold is unlikely to result in substantial health issues. The standard for nitrite in drinking water is 0.01 mg/L at the waterworks exit and 0.1 mg/L at the entry to private properties and at consumer taps. Nitrites can be ingested as nitrate, a vital ingredient for plant growth, and then transformed into nitrite, which impairs hemoglobin's capacity to transport oxygen in the bloodstream. During the first year of our study (2021) analysis water samples varied from minimum 0.012 mg/l to maximum 0.0121 mg/l in respectively. Phosphorus measurements are crucial for evaluating the potential biological productivity of surface water, and in numerous regions, regulations are being implemented to restrict the quantities of phosphorus that can be released into receiving water bodies, especially lakes and reservoirs. Phosphorus measurements are standard in the functioning of wastewater treatment facilities and in aquatic pollution research in many regions. As per Indian standards, phosphate levels up to 0.1 mg/L are deemed safe for drinking water, though the permissible limit has been extended to 2.0 mg/L under certain conditions. The maximum permitted limit for phosphate concentration was increased to 2.0 mg/l. In the initial year of our study (2021), the examination of water samples exhibited a range from a minimum of 0.12 mg/l to a maximum of 2.18 mg/l, respectively. Fluoride is a vital ion for the wellbeing of all living organisms. Insufficient intake (below 0.5 mg/l) can lead to health issues such as dental caries, poor dental enamel formation, and impaired bone mineralization, particularly in children. Conversely, excessive consumption or application of fluoride (exceeding 1.0 mg/l) can lead to various health issues that impact individuals of all ages. In the initial year of our study (2021), the analysis of water samples ranged from a minimum of 0.52 mg/l to a maximum of 0.73 mg/l, respectively. The dissolved oxygen content in water is influenced by various physicochemical and biological factors. Oxygen serves as a critical indicator of a lake's trophic status. It is essential for metabolism of aquatic organisms. Solubility of oxygen is affected by temperature and increase considerably as water temperature decreases. A low content of dissolved oxygen is a sign of organic pollution. The World Health Organization standards stipulate that the dissolved oxygen (DO) value must not fall below 6 mg/L. In the initial year of our study (2021), the analysis of water samples revealed concentrations ranging from a minimum of 5.8 mg/l to a maximum of 8.3 mg/l.

The BOD result is contingent upon measurements of dissolved oxygen; hence, the accuracy of the results is significantly affected by the precision of these measurements.

During the first year of our study (2021) analysis water samples varied from minimum 0.0 mg/l to maximum 2.84 mg/l in respectively. The water temperatures and nutrient conditions in drinking water distribution networks are improbable to facilitate the proliferation of these organisms. In many aquatic environments, the main genus is Escherichia; however, certain species of Citrobacter, Klebsiella, and Enterobacter also exhibit thermotolerance. During first year of our study (2021) analysis water samples varied from minimum 3mg/l to maximum 114mg/l in respectively. During the first year of our study (2021) analysis of Total Coliform of water samples varied from minimum 3mg/l to maximum 131 mg/l in respectively. The maximum permissible limits of drinking limits of cadmium in drinking water was recommended as 0.01 mg/l by IS (1993) & WHO (1984). During the first year of our study (2021) analysis water samples varied from minimum 0.0 mg/l to maximum 0.0 mg/l in respectively. During the first year of our study (2021) analysis water samples varied from minimum 0.0 mg/l to maximum 0.0

mg/l in respectively. The lead and processing industries are the primary contributors of lead pollution. Causes hepatic and renal damage, decreases in hemoglobin, lead pollution formation, cognitive impairment, and reproductive and pregnancy problems. The symptoms usually develop slowly but high level of exposure produce severe neurological damage often manifested by encephalopathy and convulsion. In the first year of our study (2021), the analysis of water samples revealed concentrations ranging from a minimum of 0.004 mg/l to a maximum of 0.042 mg/l. Zn is a crucial growth element to both pflora and funna The FAO has established a standrad concentration of zinc in irrigation waters at 2 mg/l. The secondary drinking water standard established by the U.S. EPA is 5 mg/L. Zinc in water can originate from industrial effluents. During the first year of our study (2021) analysis water samples varied from minimum 0.0 mg/l to maximum 1.94 mg/l in respectively. Ammonia nitrogen is made up of ionized ammonia (ammonium, NH4+) and unionized ammonia (NH_3). Ammonia is a toxicant that can directly harm aquatic life. During the first year of our study (2021) analysis water samples varied from minimum 0.28 mg/l to maximum 0.75 mg/l in respectively. Boron is water soluble and occurs in nature as $B(OH)_3$ and $B(OH)_4$. In acidic and neutral aqueous solutions, boric acid is the dominant species of boron. Boric acid is a weak acid that can react with alcohols to produce borate esters. Boron salts are often highly soluble in water. H_3BO_3 demonstrates a solubility in water of 57 g/L, $Na_2[B_4O_5(OH)_4]\cdot 8H_2O$ 25.2 g/L, and B_2O_3 22 g/L. Boron trifluoride demonstrates the lowest solubility among boron compounds in water, with a solubility measurement of 2.4 g/L. Boron oxide in its amorphous form is also soluble in alcohol, glycerol, and acids. During the first year of our study (2021) analysis water samples varied from minimum 0.26 mg/l to maximum 0.64 mg/l in respectively. It's expressed in milligrams of oxygen per liter (mg/L). COD is a critical parameter for water quality because it indicates how much Oxidizable organic material is present in a sample, potentially resulting in diminished dissolved oxygen (DO) levels. A decrease in dissolved oxygen can induce anaerobic conditions detrimental to higher aquatic organisms. Chemical oxygen demand is utilized to confirm wastewater discharge, Quantify biodegradable fractions of wastewater effluent, and Indicate the size of a wastewater treatment plant needed. The sample is digested for two hours at 150°C, and the concentration of the oxidant is determined by redox titration. High Chemical Oxygen Demand (COD) values suggest a large presence of oxidizable organic substances, which can lower the Dissolved Oxygen (DO) levels, thereby affecting aquatic life. In the initial year of our study (2021), the analysis of water samples ranged from a minimum of 15 mg/l to a maximum of 46 mg/l, respectively. Magnesium in drinking water may help protect against cardiovascular disease, cancer, and cerebrovascular disease. Some evidence suggests that Elevated magnesium concentrations in drinking water may diminish the risk of mortality from coronary heart disease. Magnesium may also help protect against gastric, colon, rectal, pancreatic, esophageal, and ovarian cancer. Additionally, magnesium intake from drinking water may significantly protect against cerebrovascular disease. In the majority of aquatic environments, Mg content ranges from 1 mg/l to 40 mg/l. During the first year of our study (2021) analysis water samples varied from minimum 18 mg/l to maximum 196 mg/l in respectively. Phenolphthalein alkalinity is a type of alkalinity that measures the amount of standard acid needed to reduce the pH of a water sample to 8.3. It is sometimes referred to as p-alkalinity, partial alkalinity, or free alkalinity. Phenolphthalein alkalinity constitutes a subset of total alkalinity. During the first year of our study (2021) analysis water samples varied from minimum 4 mg/l to maximum 24 mg/l in respectively. The World Health Organization (WHO) stipulates that the acceptable concentration of potassium in drinking water is 12 mg/L.

Table-1 Statistical analysis of data between chosen investigation areas and water quality's parameters of Jaisamand lake and its surrounding first year (2021) of study.

	Jai Samand Lake Near Water Works (HP)	Jai Samand Lake (Near Jaisamand Gate) (HP)	Jai Samand Lake (Bus Stand Road) (HP)	Jai Samand Lake (Jai Samand Market) (HP)	Lake Jaisamand	Total	
	Sum	**Sum**	**Sum**	**Sum**	**Sum**	**Sum**	**Mean**
Ammonia Nitrogen(mg/l)	0.00	0.00	0.00	0.00	4.99	4.99	1.00
B.O.D.(mg/l)	0.00	0.00	0.00	0.00	27.71	27.71	5.54
Boron Dissolved(mg/l)	4.92	4.94	4.95	4.54	7.29	26.64	5.33
C.O.D.(mg/l)	286.72	434.00	510.00	341.39	286.00	1858.11	371.62
Calcium as Ca(mg/l)	1171.00	1052.00	407.00	796.80	415.00	3841.80	768.36
Chloride(mg/l)	3632.80	3498.07	499.19	2577.80	704.00	10911.86	2182.37
Conductivity (µmho/cm)	15808.00	17849.00	15735.00	17473.00	7396.00	74261.00	14852.20
Dissolved Oxygen(mg/l)	60.10	88.70	55.80	83.00	84.40	372.00	74.40
Fecal Coliform (MPN/100ml)	57.00	85.00	102.00	54.00	1093.00	1391.00	278.20
Fluoride As F(mg/l)	11.78	20.14	8.88	5.90	7.28	53.98	10.80
Magnesium as Mg(mg/l)	683.54	985.00	1004.00	957.56	384.00	4014.10	802.82
Nitrate as N(mg/l)	19.60	997.69	424.40	312.30	27.90	1781.89	356.38
pH	89.70	89.20	89.80	90.30	96.93	455.93	91.19
Phenolphthalein Alkalinity	85.00	134.00	104.00	81.00	102.00	506.00	101.20
Phosphate As PO4(mg/l)	10.55	20.48	6.02	10.22	3.37	50.64	10.13
Potassium As K (mg/l)	78.00	69.80	65.80	66.00	53.20	332.80	66.56
Sodium(mg/l)	2033.00	530.00	482.00	2112.00	336.50	5493.50	1098.70
Sulphate(mg/l)	1882.20	2261.41	1403.00	1422.00	972.00	7940.61	1588.12
Temperature(0C)	305.00	314.00	318.00	316.00	316.00	1569.00	313.80
Total Alkalinity (mg/l)	1969.00	785.00	6815.00	8860.00	684.00	19113.00	3822.60
Total Coliform(MPN/100ml	72.00	284.00	47.00	390.00	1964.00	2757.00	551.40

)							
Total Dissolved Solids(mg/l)	9744.00	9227.00	13027.00	15215.00	5216.00	52429.00	10485.80
Total Hardness CaCO3(mg/l)	4851.00	6922.00	4544.00	3562.00	2362.00	22241.00	4448.20
Turbidity(JTU/NTU)	33.00	40.00	54.00	61.00	15.24	203.24	40.65
Iron as Fe(mg/l)	5.04	5.32	3.38	2.40	0.70	16.83	3.37
Cadmium as Cd(mg/l)	0.00	1.98	0.00	0.00	0.00	1.98	.40
Copper as Cu(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	.00
Lead as Pb(mg/l)	1.09	0.00	0.04	0.17	0.00	1.29	.26
Nickle as Ni(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	.00
Total Chromium as Cr(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	.00
Zinc as Zn(mg/l)	1.43	7.85	21.76	3.34	0.62	35.00	7.00
Total	42895.47	45706.59	45732.02	54797.71	22560.12	211691.91	
Mean	1383.72	1474.41	1475.23	1767.67	727.75	6828.77	

ANOVA					
	Type III Sum of Squares	df	Mean Square	F	P
Treatment	44869709.09	4	11217427.27	2.23	0.07
Error	604485477.2	120	5037378.98		

Table-2 Analysis of variance of data between chosen investigation areas and water qualities parameters of Jaisamand lake and its surrounding second year (2022) of study.

Descriptive statistics			
	N	Mean	Std. Deviation
Jai Samand Lake Near Water Works (HP)	31	1730.48	4025.43
Jai Samand Lake (Near Jaisamand Gate) (HP)	31	1490.27	3723.39
Jai Samand Lake (Bus Stand Road) (HP)	31	1848.28	5407.56
Jai Samand Lake (Jai Samand Market) (HP)	31	2346.82	6108.01
Lake Jaisamand	31	704.53	1609.98

In water treatment, the concentration of added potassium from potassium permanganate may reach a maximum of 10 mg/l. In the initial year of our study (2021), the analysis of water samples ranged from a minimum of 3.8 mg/l to a maximum of 7.8 mg/l, respectively. The WHO advises that drinking water should not exceed 200 milligrams of sodium per liter (mg/L). This is predicated on aesthetic factors, such as preference. However, some countries have higher levels. During the first year of our study (2021) analysis water samples varied from minimum 21.7 mg/l to maximum 210 mg/l in respectively. The World Health Organization (WHO) stipulates that the secondary aesthetic water guideline for iron is 0.3 mg/L. This advice is predicated on flavor and aesthetics rather than any adverse health impact. Iron concentrations in water typically remain under 10 mg/L. Iron concentrations over 0.3 mg/L in water are typically considered unsuitable for drinking due to taste, discoloration, and health concerns. In the initial year of our study (2021), the analysis of water samples ranged from a minimum of 0.208 mg/l to a maximum of 0.489 mg/l, respectively.

Statistical Analysis -I

The results of the one-way ANOVA are presented below. The analysis was conducted to evaluate whether there were statistically significant differences among the treatment groups The treatment impact was statistically prominent, **$F(4, 120) = 2.23$, $p = 0.07$**, indicating that there are significant differences among the treatment group means.

Discussion:

Studies demonstrate that elevated levels of fluoride, nitrates, heavy metals, and persistent organic contaminants in groundwater can provide considerable health hazards to humans.

Anthropogenic activities, especially those related to agriculture and industry, have degraded groundwater quality, thereby impacting public health. This study investigates groundwater quality in an south Rajasthan, known for its intensive farming and industrial practices, to assess the range of defilement, and the associated health risks for local populations. The research employs a detailed water quality index for potable water, along with parameters such as the sodium adsorption ratio (SAR), sodium percentage (Na%), and residual sodium carbonate (RSC) to evaluate water suitability for irrigation. Key pollutants rendering the water unsafe include total hardness, nitrates (NO_3^-), nitrites (NO_2^-), total dissolved solids (TDS), sulfates (SO_4^{2-}), and fluoride (F^-) [13]. Furthermore, the study shows that approximately 60% of China's provinces or autonomous regions—around 20 in total—are affected by elevated arsenic levels in groundwater. These areas are predominantly situated in fluvial and alluvial-lacustrine plains and valleys inside arid to semi-arid climates, as well as in alluvial plains, basins, and river deltas in more humid environments climates[3]. Young children are especially susceptible to the detrimental impacts by these contaminants [12, 6, 9, 5, 11, 14]. This research offers significant insights for the management of water resou rces in Jaisamand Lake, particularly concerning the effects of anthropogenic pressures.

Conclusion

This study utilized a comprehensive Water Quality Index (WQI) to evaluate the appropriateness of water for potable use. . It underscores the need for treatment of wastewater—both liquid and solid—before discharge into the lake to avoid direct contamination of groundwater. There is an urgent call for collaborative action from local authorities, NGOs, and government bodies to curb and manage pollution effectively in the region.

Ecological Impact on Flora and Fauna

The degradation of water quality has resulted in:

- Reduced diversity and abundance of submerged aquatic vegetation.
- Occurrence of algal blooms due to phosphate enrichment.
- Decline in sensitive fish species and increased dominance of pollution-tolerant species.
- Reduced bird nesting and foraging in polluted zones.

The findings demonstrate a clear deterioration in water quality in certain sectors of Jaisamand Lake due to anthropogenic pressures. Immediate interventions—such as community-based lake management, regulation of effluents, and ecological restoration—are essential for preserving this fragile aquatic ecosystem.

Recommendations

- Regular monitoring of water quality at multiple sites.
- Treatment of sewage before discharge into the lake.
- Public awareness programs to reduce local pollution.
- Promotion of sustainable agricultural practices to minimize runoff.
- Ecological restoration projects, including replantation of native aquatic vegetation.

References

sAmerican Public Health Association, (APHA), (1995). Standard Method for Examination of Water and Wastewater. 19th Edn., Published by E and FNSPON, Washington DC., pp: 2-56.

1. Goldhaber MB, Mills CT, Morrison JM, Stricker CA, Mushet DM, LaBaugh JW (2014) Hydrogeochemistry of prairie pothole region wetlands: role of long-term critical zone processes. Chem Geol 387:170–183.https://doi.org/10.1016/j.chemgeo.2014.08.023
2. He X, Li P, Ji Y, Wang Y, Su Z, Elumalai V (2020b) Groundwater arsenic and fuoride and associated arsenicosis and fuorosis in China: occurrence, distribution and management. Expo Health 12:355–368. https://doi.org/10.1007/s12403-020-00347-8.
3. International Association of Hydrogeologists (2020) Groundwater—more about the hidden resource. ttps://iah.org/education/ general-public/groundwater-hidden-resource. Accessed 13 Nov 2020n
4. Ji Y, Wu J, Wang Y, Elumalai V, Subramani T (2020) Seasonal variation of drinking water quality and human health risk assessment in Hancheng City of Guanzhong Plain, China. Expo Health, 12:469–485.
5. Karunanidhi D, Aravinthasamy P, Deepali M, Subramani T, Bellows BC, Li P (2020) Groundwater quality evolution based on geochemical modeling and aptness testing for ingestion using entropy water quality and total hazard indexes in an urbanindustrial area (Tiruppur) of Southern India. Environ Sci Pollut, Res. https://doi.org/10.1007/s11356-020-10724-0
6. Li P, Tian R, Xue C, Wu J (2017a) Progress, opportunities and key fields for groundwater quality research under the impacts of human activities in China with a special focus on western China. Environ Sci Pollut Res 24:13224–13234.
7. Manivasakam, N. (1996). Physicochemical examination of water sewage and industrial effluents.
8. Mthembu PP, Elumalai V, Brindha K, Li P (2020) Hydrogeochemical processes and trace metal contamination in groundwater: impact on human health in the Maputaland coastal aquifer, South Africa. Expo Health 12:403–426
9. Sawyer AH, Michael HA, Schroth AW (2016) From soil to sea: the role of groundwater in coastal critical zone processes. WIREs Water 3:706–726
10. Subba Rao N, Dinakar A, Kumari BK, Karunanidhi D, Kamalesh T (2021) Seasonal and spatial variation of groundwater quality vulnerable zones of Yellareddygudem watershed, Nalgonda district, Telangana State, India. Arch Environ Contam Toxicol https://doi.org/10.1007/s00244-020-00783-2.

11. Wu J, Sun Z (2016) Evaluation of shallow groundwater contamination and associated human health risk in an alluvial plain impacted by agricultural and industrial activities, mid-west China. Expo, Health 8:311–329
12. Wu J, Zhang Y, Zhou H (2020) Groundwater chemistry and groundwater quality index incorporating health risk weighting in Dingbian County, Ordos basin of northwest China. Geochemistry, 80(4):125607. https://doi.org/10.1016/j.chemer.2020.125607
13. Zhou Y, Li P, Chen M, Dong Z, Lu C (2020) Groundwater quality for potable and irrigation uses and associated health risk in southern part of Gu'an County, North China Plain. Environ Geochem Health. https://doi.org/10.1007/s10653-020-00553-y.