Challenges and Solutions in Groundwater Management: An Overview

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Abstract: Groundwater is a vital natural resource that is necessary for both human life and the global maintenance of ecosystems. This article provides an overview of the issues of groundwater management and its remedies. It highlights the complex interrelationships between groundwater quality degradation, pollution, depletion, and recharge. Agriculture, urbanization, industry, and other anthropogenic activities have all had a significant impact on groundwater resources. We require efficient management strategies in order to get beyond these challenges. It has been shown that integrating hydrological modelling, remote sensing technology, and stakeholder involvement in integrated systems can be used to assess groundwater dynamics and create sustainable management plans. Furthermore, it is crucial to implement legal frameworks, promote water-saving practices, and enhance monitoring networks.

Keywords: Ground water; Water resources; Sustainable management

1. INTRODUCTION

In order to ensure the long-term survival of groundwater resources, it is also crucial to implement regulatory frameworks, promote water-saving practices, and enhance monitoring networks. However, there are still many unanswered questions concerning groundwater systems, particularly in the areas of stakeholder participation, data accessibility, and monitoring infrastructure. To bridge these gaps, interdisciplinary cooperation, robust data collection techniques, and creative technical solutions are required. Furthermore, the advancement of sustainable water management strategies depends on encouraging groundwater conservation (Abonia and Laali, 2019) among legislators, corporations, and communities. Because of this, safeguarding groundwater resources necessitates a multifaceted approach that includes scientific research, policy creation, and community involvement.

2. WATER SOURCES IN RAJASTHAN

Rajasthan, known for its arid climate and limited surface water resources, heavily relies on groundwater for various socio-economic activities. This abstract provides an overview of the underground water sources in Rajasthan, highlighting their significance, challenges, and management strategies. The state of Rajasthan is predominantly dependent on groundwater, with over 75% of its rural and urban population relying on it for domestic, agricultural, and industrial purposes. The primary sources of groundwater in Rajasthan (Agrawal et al., 2021). include alluvial aquifers, fractured rock aquifers, and confined aquifers found in sedimentary basins. However, unsustainable groundwater extraction coupled with erratic rainfall patterns and increasing water demands pose significant challenges to groundwater sustainability in Rajasthan. Overexploitation has led to declining water tables, land subsidence, and deterioration of water quality, exacerbating water scarcity issues in the region. To address these challenges, various groundwater management strategies have been implemented, including rainwater harvesting, artificial recharge, and community-based water management initiatives. Government policies such as the Rajasthan Ground Water Act and the Jal Swavlamban Abhiyan aim to regulate groundwater extraction and promote sustainable water use practices.

Despite these efforts, effective groundwater management in Rajasthan requires integrated approaches that combine technological innovations, community participation, and policy interventions. Public awareness campaigns, capacity building programs, and stakeholder collaborations are essential for promoting water conservation and sustainable groundwater management practices in the region. The

Department of water resources, and Department of agriculture of the Rajasthan government provides information on water management plans and programs in arid areas, such as the construction and upkeep of water wells. In order to address the lack of water, traditional wells in arid regions can be revived (figure 1.). This is an environmentally friendly strategy that leverages local expertise and effectively uses available resources.

Fig. 1. Traditional Wells to be Revived in Desert Areas of Rajasthan

3. ISSUES FOR QUALITY ANALYSIS OF GROUND WATER

(i) High Fluoride Levels in Groundwater

Background: Rajasthan is known for its high fluoride content in groundwater, which exceeds the permissible limits set by regulatory standards (Bureau of Indian Standards, 1991). Prolonged consumption of water with elevated fluoride levels can lead to dental and skeletal fluorosis, a debilitating health condition.

(ii) Water Quality Monitoring

Establish a comprehensive water quality monitoring program to regularly assess fluoride levels in groundwater sources across Rajasthan. This monitoring should cover both rural and urban areas to identify areas with high fluoride contamination river (Biswas,et al., 2018). Numerous hydrogeological parameters, such as pH, redox conditions, the mineralogy of the aquifer's minerals, and groundwater flow patterns, can affect the presence and mobility of uranium in groundwater Brindha et al., 2011. In general, maintaining the sustainability of groundwater resources and safeguarding public health depend on an awareness of the prevalence, origins, health hazards, and available management strategies related to uranium in groundwater.

(iii) Public Awareness and Education

Launch public awareness campaigns to educate communities about the health risks associated with fluoride contamination and promote alternative sources of drinking water such as rainwater harvesting, treated surface water, or fluoride-removal technologies (Mohapatra and Anand, 2019).

(iv) Fluoride Removal Technologies

Implement fluoride removal technologies (Srimurali, et al. 2018, Noubactep, 2018) such as activated alumina, bone char, ion exchange, or reverse osmosis at community-level water treatment plants and household-level filtration units to mitigate fluoride contamination in drinking water (Brindha et al., 2011).

(v) Managed Aquifer Recharge (MAR)

Explore the feasibility of managed aquifer recharge techniques (Declan et al. 2018) to dilute fluoride concentrations in groundwater by artificially recharging aquifers with treated surface water or rainwater, thereby reducing the impact of fluoride contamination.

(vi) Policy and Regulation

Strengthen regulatory frameworks to enforce compliance with permissible fluoride levels in drinking water, establish guidelines for water quality testing and treatment, and provide support for implementing fluoride mitigation measures at the local level (Abonia et al., 2019)

(vii) Capacity Building

Build the capacity of local communities, water utility operators, and healthcare providers to effectively manage fluoride contamination, including training on water quality monitoring, treatment technologies, and health education initiatives.

(viii) Research and Innovation

Invest in research and innovation to develop cost-effective and sustainable fluoride removal technologies tailored to the specific conditions and needs of Rajasthan, considering factors such as affordability, scalability, and ease of maintenance.

(ix) Stakeholder Collaboration

Foster collaboration among government agencies (Government of India, 2017, CGWBWR, 2017), non-governmental organizations, academic institutions, community leaders, and industry stakeholders to coordinate efforts, share resources, and mobilize support for addressing fluoride contamination in groundwater effectively. By implementing a holistic approach encompassing monitoring, public education, treatment, policy reform, capacity building, research, and collaboration, Rajasthan can mitigate the problem of high fluoride levels in groundwater and ensure access to safe and potable drinking water for its population.

4. IMPORTANCE OF WATER QUALITY

Water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for various uses, including drinking, recreation, agriculture, industry, and ecosystem support. Maintaining high water quality (Kumari, et al. 2016) is essential for protecting human health, supporting aquatic life, and preserving ecosystem integrity.

1. Human Health: Access to safe and clean drinking water (Gupta, and Deshpande, 2012, Kumar et al. 2015, Punia & Siddaiah, 2017) is essential for preventing waterborne diseases and promoting public health. Contaminants such as bacteria, viruses, chemicals, and heavy metals can pose significant health risks if present in drinking water (Saxena, and Meena, 2016).
2. Ecosystem Health: Aquatic ecosystems rely on clean water for biodiversity, habitat preservation, and ecosystem services such as water purification, nutrient cycling, and flood regulation. Poor water quality can disrupt ecosystem functioning and lead to declines in species diversity and abundance.
3. Economic Activities: Water quality directly influences various economic sectors, including agriculture, fisheries, tourism, and industry. Contaminated water can impact agricultural productivity, fishery yields, and tourism revenues, leading to economic losses and livelihood challenges.
4. Environmental Sustainability: Maintaining high water quality is essential for achieving environmental sustainability and mitigating human impacts on natural ecosystems. Clean water supports healthy habitats, sustains wildlife populations, and preserves ecosystem resilience in the face of environmental stressors.

5. FACTORS AFFECTING WATER QUALITY

1. Natural Factors: Geological characteristics, climate patterns, and hydrological processes influence the composition and quality of water bodies. Factors such as soil erosion, sedimentation, and natural mineral deposits can affect water clarity and chemical composition (Charan et al 2015).
2. Anthropogenic Activities: Human activities such as agriculture, urbanization, industrialization, and waste disposal can introduce pollutants into water bodies. Contaminants such as nutrients, pesticides, heavy metals, pharmaceuticals, and pathogens can degrade water quality and pose risks to human and environmental health (Tressaud, A., 2006).
3. Land Use Practices: Land use practices such as deforestation, urban sprawl, and agricultural intensification can impact water quality by altering the flow of nutrients, sediments, and pollutants into water

bodies. Poor land management practices can exacerbate erosion, runoff, and pollution.

6. MONITORING AND MANAGEMENT

Effective water quality management involves monitoring, assessment, and mitigation of pollution sources (Babuji, et al., 2023) to protect and improve water quality. Strategies for water quality management include pollution prevention, watershed management, regulatory frameworks, wastewater treatment, ecosystem restoration, and public education and outreach. The contamination of soil, irrigation water and vegetables due to heavy metals in urban agricultural areas of Delhi also studied by Bhatia et al. (2015)

Maintaining high water quality is essential for supporting human health, sustaining ecosystems, and promoting socio-economic development. By understanding the factors influencing water quality and implementing effective management strategies, stakeholders can ensure the availability of clean and safe water for current and future generations.

The introduction to the study on metal concentrations in underground water in Rajasthan delves into the critical importance of water quality, particularly with regards to the presence of metals. As a region vital for agriculture and human habitation, understanding the levels of metals such as iron, manganese, and fluoride is paramount (Bhagwan and Abha, 2014). This introduction sets the stage for comprehending the potential impacts on public health and the environment, urging a focused examination of the intricate interplay between geological factors and metal concentrations in Rajasthan's underground water sources (Saxena et al. 2017).

7. INDIAN STANDARDS FOR WATER QUALITY

The Bureau of Indian Standards (BIS), under the Ministry of Consumer Affairs, Food, and Public Distribution, is responsible for establishing standards for water quality in India. The relevant standards for water quality (Sharma et al. 2018, 2019) are outlined in the Indian Standard IS 10500:2012, "Drinking Water - Specification."

Here are some key parameters and permissible limits outlined in the Indian Standard IS 10500:2012 for various physical, chemical, and microbiological parameters in drinking water:

1. Physical Parameters:
(i). Colour: ≤ 5 Hazen units
(ii). Odor: Threshold Odor number ≤ 3
(iii).Taste: Acceptable
(iii) Turbidity: ≤ 5 NTU (Nephelometric Turbidity Units)

2. Chemical Parameters:
(i). pH: 6.5 to 8.5
(ii). Total Dissolved Solids (TDS): ≤ 500 mg/L
(iii). Total Hardness (as $CaCO_3$): ≤ 300 mg/L
(iii). Chlorides (as Cl): ≤ 250 mg/L
(iv). Fluorides (as F): ≤ 1.0 mg/L
(v). Iron (as Fe): ≤ 0.3 mg/L
(vi). Nitrate (as NO_3): ≤ 45 mg/L

Heavy Metals:
(i). Arsenic (as As): ≤ 0.01 mg/L
(ii). Cadmium (as Cd): ≤ 0.01 mg/L
(iii). Chromium (as Cr): ≤ 0.05 mg/L
(iv). Lead (as Pb): ≤ 0.01 mg/L
(v). Mercury (as Hg): ≤ 0.001 mg/L

3. Microbiological Parameters:
(i) Total Coliforms: Absent in 100 mL sample
(ii) Escherichia coli: Absent in 100 mL sample

These standards are designed to ensure the quality and safety of drinking water provided to the public. Compliance with these standards helps prevent waterborne diseases and ensures the overall health and well-being of the population (Ceplecha et al.,2004).

It's important to note that in addition to IS 10500:2012, there are other relevant standards and guidelines issued by regulatory authorities at the central and state levels, depending on specific requirements and local conditions (Sharma and Verma, 2014). Additionally, standards may be periodically revised or updated based on scientific research and technological advancements (CPCB, 2018). Therefore, it's essential for stakeholders involved in water management to stay informed about any changes in water quality standards and regulations.

Metal Concentration in Ground Water

Rajasthan, a region characterized by arid climatic conditions and limited surface water resources, heavily relies on groundwater for various purposes. This abstract provides an overview of the concentrations of metals in groundwater sources across Rajasthan, highlighting the sources, distribution, and potential health implications (Adimalla and Quian, 2021). Groundwater in Rajasthan is susceptible to contamination from both natural geological sources and anthropogenic activities. The region's geological formations, including sedimentary basins and mineral-rich deposits, contribute to the presence of metals such as arsenic, fluoride, iron, manganese, and heavy metals in groundwater. Several studies have documented elevated concentrations of metals in groundwater across different parts of Rajasthan, posing potential health risks to the population. Arsenic and fluoride contamination, in particular, are widespread in certain areas, exceeding the permissible limits set by regulatory authorities and leading to adverse health effects such as dental fluorosis, skeletal fluorosis, and arsenicosis.

Anthropogenic activities such as mining, industrial discharge, agricultural runoff, and improper waste disposal also contribute to metal contamination in groundwater. Urbanization and industrialization have further exacerbated the problem, leading to increased pollution and degradation of groundwater quality (Arshad, 2020).. Addressing metal contamination in groundwater requires a multifaceted approach, including regular monitoring, groundwater quality assessment, source identification, and mitigation measures. Remediation techniques such as filtration, chemical treatment, and community-based interventions have been implemented to mitigate metal contamination and improve water quality in affected areas.

Furthermore, raising awareness among communities, promoting sustainable land use practices, and implementing stricter regulatory measures are essential for preventing further deterioration of groundwater quality in Rajasthan. Understanding the distribution and sources of metal concentrations in groundwater is crucial for ensuring water safety and public health in Rajasthan. By adopting integrated management strategies and collaborative efforts, stakeholders can mitigate metal contamination and safeguard groundwater resources for present and future generations.

8. HEALTH IMPACTS OF METAL CONTAMINANTS IN GROUNDWATER

Groundwater contamination by metals poses significant health risks to communities reliant on this vital resource, particularly in arid regions like Rajasthan, India. These abstract reviews the health effects associated with metal concentrations in groundwater in Rajasthan, highlighting the sources, exposure pathways, and adverse health outcomes. Arsenic, fluoride, iron, manganese, and heavy metals are among the primary contaminants found in groundwater across Rajasthan (Arun et al., 2015). Prolonged exposure to these metals through drinking water consumption can lead to various health complications, including dental and skeletal fluorosis, arsenicosis, anaemia, neurological disorders, and carcinogenic effects. Studies conducted in Rajasthan have reported elevated levels of arsenic and fluoride in groundwater, surpassing permissible limits set by regulatory standards. Chronic exposure to arsenic-contaminated water is associated with skin lesions, respiratory issues, cardiovascular diseases, and an increased risk of cancer. Fluoride contamination, prevalent in certain regions, contributes to dental and skeletal fluorosis, affecting the dental and skeletal health of the population. Additionally, high concentrations of iron and manganese in groundwater can lead to aesthetic issues such as discoloration, taste, and Odor problems, as well as health concerns such as gastrointestinal disturbances and neurological impairments. Heavy metals like lead, cadmium, uranium and chromium, originating from industrial activities and mining operations, pose significant health risks, including developmental delays, organ damage, and increased cancer risk (Babu et al.,2008, Borole et al.,1978).

Vulnerable populations, including children, pregnant women, and the elderly, are particularly susceptible to the adverse health effects of metal contamination in groundwater. Addressing these health impacts requires a comprehensive approach, including water quality monitoring, public health interventions, access to safe drinking water, and community education. Furthermore, collaboration between government agencies, healthcare providers, researchers, and community organizations is essential to develop targeted mitigation strategies and provide healthcare services to affected populations. Strengthening regulatory frameworks, implementing water treatment technologies, and promoting alternative water sources are crucial steps towards ensuring the health and well-being of communities reliant on groundwater in Rajasthan. Understanding the health effects of metal concentrations in groundwater is vital for implementing effective mitigation measures and safeguarding public health in Rajasthan and other regions facing similar challenges. Cities like Jaipur (Pareek et al., 2021a, 2021b), Udaipur, Jodhpur, Kota and Ajmer that are rapidly becoming more urbanized may see an increase in groundwater pollution (Sheikh, M. 2018, Singh, P., et al. 2017) as a result of poor garbage disposal, sewage leaks, and industrial discharge. Groundwater pollution can be avoided by implementing appropriate waste management systems and managing urban development responsibly.

Understanding the chemical makeup of groundwater and identifying any contamination requires routine monitoring. Groundwater quality assessments are often carried out by sampling and analysis by government agencies, environmental organizations, and research institutions.

Treating heavy metal concentrations in groundwater in Rajasthan requires a combination of remediation techniques tailored to the specific contaminants present. Here are several methods commonly used for treating heavy metal contamination in groundwater.

1. Activated Carbon Filtration: Activated carbon adsorbs heavy metals from water, effectively removing contaminants like lead, cadmium, and chromium. This method is relatively simple and can be implemented at the community level.
2. Ion Exchange: Ion exchange involves replacing heavy metal ions in water with less harmful ions, typically using ion exchange resins. This process effectively reduces the concentration of heavy metals in groundwater.
3. Reverse Osmosis (RO): RO systems utilize a semipermeable membrane to remove heavy metals, as well as other contaminants, from water by applying pressure to push water through the membrane while leaving behind contaminants.
4. Precipitation and Coagulation: Chemical agents such as lime, alum, or ferric chloride can be added to groundwater to precipitate heavy metal ions, forming insoluble compounds that can be removed through filtration (Arnold and Colford, 2007).
5. Electrocoagulation: This process involves applying an electric current to water containing heavy metals, which causes the formation of metal hydroxide flocs that can be easily separated from the water.
6. Phytoremediation: Certain plants have the ability to absorb heavy metals from the soil and groundwater through their roots. Constructed wetlands or specially designed plant-based systems can be used to treat contaminated groundwater.
7. In Situ Chemical Oxidation/Reduction: Injection of chemical agents such as hydrogen peroxide or sodium dithionite into the contaminated groundwater can promote chemical reactions that either oxidize or reduce heavy metal ions, making them less soluble and easier to remove.
8. Bioremediation: Microorganisms can be used to degrade or immobilize heavy metal contaminants in groundwater through biological processes. This method is often used in conjunction with other remediation techniques.
9. Managed Aquifer Recharge (MAR): MAR involves artificially recharging aquifers with treated surface water or rainwater, diluting the concentration of heavy metals in groundwater over time.
10. Community Awareness and Education: Educating communities about the sources and health effects of heavy metal contamination, as well as promoting water conservation and safe water practices, is essential for long-term mitigation efforts.

It’s important to note that the selection of the appropriate remediation method depends on factors such as the type and concentration of heavy metals present, hydrogeological conditions, available resources, and community preferences. Integrated approaches combining multiple treatment methods may be necessary for effective and sustainable remediation of heavy metal contamination in groundwater in Rajasthan. Atomic absorption spectroscopy (AAS) is a widely used analytical technique for determining the concentrations of various metals in groundwater samples. Here’s how AAS technology works and its application for analysing metal concentrations in underground water:

9.CONCLUSION

In conclusion, understanding and harnessing the underground water sources in Rajasthan are crucial for mitigating water scarcity and ensuring the resilience of communities in the face of climate change. By adopting holistic and participatory approaches, Rajasthan can achieve sustainable groundwater management and secure water access for its present and future generations. A prevalent problem regarding water quality in Rajasthan, India, is the high concentration of fluoride in groundwater.

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REFERENCE

[1] Abonia, R., & Laali, K. (2019). Ionic liquid-mediated synthesis and functionalization of heterocyclic compounds. *Advances in Heterocyclic Chemistry*, 131, 1-48. DOI: 10.1016/bs.aihch.2018.12.002

[2] Adimalla, N., & Qian, H. (2021). Groundwater chemistry, distribution and potential health risk appraisal of nitrate enriched groundwater: A case study from the semi-urban region of South India. *Ecotoxicology and Environmental Safety*, 207, 111277. DOI: 10.1016/j.ecoenv.2020.111277

[3] Agrawal, P., Singhal, S., & Sharma, R. (2021). Heavy Metal Contamination in Groundwater Sources. *In Water Quality Management*, 91-122. John Wiley & Sons. DOI: 10.1002/9781119709732.ch4

[4] Arnold, B. F., & Colford, Jr, J. M. (2007). Treating water with chlorine at point-of-use to improve water quality and reduce child diarrhea in developing countries: a systematic review and meta-analysis. *The American Journal of Tropical Medicine and Hygiene*, 76(2), 354-364.

[5] Arshad, M., (2020). Heterocyclic compounds bearing pyrimidine, oxazole and pyrazole moieties: design, computational, synthesis, characterization, antibacterial and molecular docking screening. *SN Applied Sciences*. 2. DOI:10.1007/s42452-020-2243-0.

[6] Arun, L., Rout, C., & Prakash, D. (2015). Assessment of Heavy Metals Contamination in Yamuna River in Rural and Semi-urban Settings of Agra, India. *International Journal of Earth Sciences and Engineering*, 08, 1627-1631.

[7] Babu, M. N. S., Somashekar, R. K., Kumar, S. A., Shivanna, K., Krishnamurthy, V., & Eappen, K. P. (2008). Concentration of uranium levels in groundwater. *International Journal of Environmental Science and Technology*, 5(2), 263–266.

[8] Babuji, Preethi, T, Subramani, Duraisamy, Karunanidhi, & P, Gopinathan. (2023). Human Health Risks due to Exposure to Water Pollution: A Review. *Water*, 15. DOI: 10.3390/w15142532.

[9] Bhagwan Y., & Abha G. (2014). Impact and Remedial Strategy of Fluoride in Groundwater: A Review. *International Journal of Engineering Research and Application*, 4(2), 570-577.

[10] Bhatia, A., Singh, S., & Kumar, A., (2015). Heavy Metal Contamination of Soil, Irrigation Water and Vegetables in Peri-Urban Agricultural Areas and Markets of Delhi. *Water Environment Research: A Research Publication of the Water Environment Federation*, 87, 2027-2034. DOI: 10.2175/106143015X14362865226833..

[11] BIS (Bureau of Indian Standards). (1991). Indian Standard Specification for Drinking Water. IS: 10500. *New Delhi: Bureau of Indian Standards*.

[12] Biswas, B., Jain, S., & Rawat, S. (2018). Spatio-temporal analysis of groundwater levels and projection of future trend of Agra city, Uttar Pradesh, India. *Arabian Journal of Geosciences*, 11, 278. DOI: 10.1007/s12517-018-3577-4.

[13] Borole, D. V., Gupta, S. K., Krishnaswami, S., Datta, P. S., & Desai, B. I. (1978). Uranium isotopic investigations and radiocarbon measurements of river-groundwater systems, Sabarmati Basin, Gujarat, India. Isotope Hydrology 1978. *IAEA Journal*, 1979, 181.

[14] Brindha, K., Elango, L., & Nair, R. N. (2011). Spatial and temporal variation of uranium in a shallow weathered rock aquifer in southern India. *Journal of Earth System Science*, 120(5), 911–920.

[15] Brindha, K., Rajesh, R., Murugan, R., & Elango, L. (2011). Fluoride contamination in groundwater in parts of Nalgonda District, Andhra Pradesh. *Environmental Monitoring and Assessment*, 172, 481-492.

[16] Central Pollution Control Board (CPCB),(2018). Ministry of Environment, Forest and Climate Change, Government of India. "Guidelines for Drinking Water Quality in India." *New Delhi: CPCB.*

[17] Central Ground Water, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India (2017), Report on Aquifer Mapping and Ground Water Management, Jaipur, District, Rajasthan.

[18] Central Groundwater Board CGWB. Report on aquifer mapping and ground water management Dausa District (Rajasthan. CGWBWR, 2017).

[19] Ceplecha, Z. L., Waskom, R. M., Bauder, T. A., Sharkoff, J. L., & Khosla, R. (2004). Vulnerability assessments of Colorado ground water to nitrate contamination. *Water, Air, & Soil Pollution*, 159, 373–394.

[20] Declan, P., Elise, B., Joanne, V., Jatinder, S., (2018). Managed Aquifer Recharge (MAR) in Sustainable Urban Water Management, *Water* 10(3):239. DOI:10.3390/w10030239

[21] Gupta, S., & Deshpande, R. D. (2012). Assessment of Groundwater Quality for Drinking and Irrigation Purposes in Nagaur District, Rajasthan, India. *Environmental Monitoring and Assessment*, 184(9), 5183-5192.

[22] Kumar, A., et al. (2015). Assessment of Groundwater Quality for Drinking and Irrigation Purposes: A Case Study from Jaipur District, Rajasthan, India. *Applied Water Science,* 5(4), 335-344.

[23] Kumari, S., et al. (2016). Groundwater Quality Assessment of Sikar City and Its Environs, Rajasthan, India. *Journal of Applied and Natural Science*, 8(1), 383-389.

[24] Mohapatra, M., & Anand, S. (2019). Review on fluoride removal from water by adsorption. *Journal of Environmental Management*, 250, 109557.

[25] Noubactep, C. (2018). Fluoride in drinking water: A review on the status and stress effects. *Critical Reviews in Environmental Science and Technology*, 48(6), 495-547.

[26] Pareek, A., Pareek, D., Bhimwal, M.K., (2021). To study the metal ion concentration in rural area ground water of Jaipur, Rajasthan, REX, *Renewable Research Journal*, 9(3), 461-468.ISSN 2321-1067.

[27] Pareek, A., Pareek, D., Bhimwal, M.K., (2021). Evaluation of metals in tap water "A case study in Chandpol a Banipark residential area in Jaipur. REX, *Renewable Research Journal*, 9(9), 384-389. ISSN 2321-1067.

[28] Punia, A., and Siva Siddaiah, N., (2017) Assessment of Heavy Metal Contamination in Groundwater of Khetri Copper Mine Region, India and Health Risk Assessment, *Asian Journal of Water, Environment and Pollution*, 14(4), 9-19. DOI: 10.3233/AJW-170032.

[29] Saxena, P., & Meena, M. K. (2016). Heavy Metal Contamination in Groundwater of Jaipur City, Rajasthan, India: A Case Study. *Environmental Monitoring and Assessment*, 188(2), 1-11.

[30] Saxena, R., Sharma, P., & Sharma, K. (2017). Groundwater Scenario in Rajasthan: Issues and Challenges. *International Journal of Current Microbiology and Applied Sciences*, 6(12), 1550-1556.

[31] Sharma, M. P., et al. (2019). Assessment of Groundwater Quality in Parts of Western Rajasthan, India Using Water Quality Index (WQI). *Applied Water Science*, 9(1), 12.

[32] Sharma, P., & Verma, H. L. (2014). Hydrogeochemical Assessment of Groundwater Quality in Parts of Jodhpur District, Western Rajasthan, India. *Applied Water Science*, 4(2), 183-198.

[33] Sharma, P., et al. (2018). Heavy Metal Contamination in Groundwater of Parts of Jodhpur District, Western Rajasthan, India. *Groundwater for Sustainable Development*, 7, 158-164.

[34] Sheikh, M.M. (2018) Smart City and Urban Issues: A case study of Jaipur City,Rajasthan, India, *Annals of Geographical Studies*, 1 (1),23-33.

[35] Singh, P., et al. (2017). Heavy Metal Contamination in Groundwater of Kota District, Rajasthan, India. *International Journal of Advanced Research in Science, Engineering, and Technology*, 4(3), 2575-2583.

[36] Srimurali, M., et al. (2018). Recent trends in fluoride removal techniques: A review. *Chemical Engineering Journal*, 333, 589-608.

[37] Tressaud, A. (2006).Advances in Fluorine Science, *Fluorine and the Environment*, first edition, 1, 244-257. ISBN: 9780444528117.