FABRICATION OF METAL IONS EMBEDDED ZEOLITEFOR THE REMOVAL OF DISEASE CAUSING ELEMENTS FROM DRINKING WATER

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Abstract:
The creation of an adsorbent with a high adsorption capacity and low cost for removing different pollutants from polluted waters has proven particularly intriguing. Natural zeolites, which are crystalline hydrated aluminosilicates with pores filled with water, alkali, and alkaline earth cations, are plentiful and inexpensive supplies. In order to provide an alternative to activated carbon in the treatment of surface and groundwater as well as industrial effluents, inorganic chemical adsorbents have been extensively explored. Natural zeolites have been extensively employed as adsorbents in separation and purification procedures over the past few decades due to their excellent cation-exchange ability and molecular sieve characteristics. The current advancement of natural zeolites as adsorbents in water treatment is reviewed in this research.. We talk about the characteristics and modifications of natural zeolite. Around the world, different natural zeolites have demonstrated variable ion-exchange capacities for cations such as ammonium and heavy metal ions. Adsorption of anions and organics from aqueous solutions is another property of some zeolites. In order to remove aqueous contaminants, including heavy metals, organic matter (both natural and manmade), and anion contaminants, modified clays, zeolites, and layered double hydroxide-based sorbents have recently been developed. The adsorption capacity of modified zeolites for organics and anions is increased using a variety of processes, including acid treatment, ion exchange, and surfactant fictionalization. This paper reviews these developments and offers new insights. In order to handle rising organic micro-pollutants, metal-organic frameworks (MOFs), a novel type of sorbent-metal ions embossed zeolite with extraordinarily high surface areas, are also introduced.

Keywords: Adsorption. Sorbent. Adsorbents, ion-exchange, cation-exchange, acid treatment, surfactant fictionalization, metal organic framework,
DOI Number:10.48047/NQ.2022.20.21.NQ99136 **Neuroquantology 2022; 20(21):1304-1315**

1. Introduction

Despite being one of the primary sources of freshwater on Earth, groundwater has consistently been under stress due to contamination from both anthropogenic and natural causes. Pollution is often caused by insufficient industrial, agricultural, or building practises, as well as improper waste management.[1] As a result of the presence of a minute and unwanted element, contaminant, or impurity in groundwater, pollution might occur naturally; in this situation, the term contamination is more appropriate. On the other hand, on-site contaminants may cause groundwater contamination.[2]

Leachate from landfills, effluent from wastewater treatment facilities, dripping sewers, petrol stations, hydraulic fracturing, or an overabundance of fertiliser in agriculture Using tainted groundwater puts people at risk of getting sick or being poisoned.[3] Additionally, total hardness, calcium, chlorides, manganese, fluorides, sulphates, and nitrates, as well as nitrites, are among the contaminants compromising the quality of groundwater. [3]

Fluoride concentrations in groundwater are primarily influenced by two factors: Water resources and human activity. Fluoride can permeate into the soil and groundwater aquifers as well as be carried to rivers through the weathering of fluoride-containing rocks.[4] Fluoride concentrations can also be increased by human activities such as excessive fertilizer use and poor irrigation management. On the other side, the main sources of nitrate include fuel combustion, fertilizer, animal waste, and atmospheric deposition. [5]

Nitrate can be detrimental to people's health and ecosystems, despite being less hazardous than nitrite. Chronic nitrate exposure may result in nausea, vomiting, headaches, and an accelerated heart rate.[6] It's also crucial to remember that pollution typically causes an aquifer to create a contaminated plume.On the other side, excessive fertiliser usage in agriculture, leaking sewers, landfill leachate, wastewater treatment plant effluents, on-site sanitation systems, and hydraulic fracturing can all lead to groundwater contamination.[7]

Using tainted groundwater puts people at risk of getting sick or being poisoned. Additionally, total hardness, calcium, chlorides, manganese, fluorides, sulphates, and nitrates, as well as nitrites, are among the contaminants compromising the quality of groundwater.[8]Hydrogeology and human activities are the two main causes of a high fluoride concentration in groundwater .[9]

Fluoride can permeate into the soil and groundwater aquifers as well as be carried to rivers through the weathering of fluoride-containing rocks.[7] Furthermore, human activities like excessive fertilizer use and poor irrigation management can increase the fluoride content.On the other hand, the primary sources of nitrate include air deposition, fertilisers, animal waste, and fuel burning.[10] Despite being less dangerous than nitrite, nitrate can still be harmful to people's health and the environment. Chronic nitrate exposure may cause headaches, nausea, vomiting, or a faster heartbeat. It's also important to keep in mind that an aquifer frequently generates a pollution plume as a result of contamination.[11]

The aquifer's water flow and dispersion disperse contaminants over a larger area. Its expanding boundary, sometimes referred to as a plume edge, has the potential to collide with surface water sources like seeps and springs and render the water unfit for human and animal use.[12] An analysis of groundwater contamination may concentrate on the geology, hydrology, hydrogeology, and hydrology of the region as well as the types of contaminants. Pollutants can be transported by a variety of mechanisms, including diffusion, adsorption, precipitation, and degradation.[8]

The groundwater quality index (GWQI), which measures how potable groundwater is, is the most precise approach for doing so, according to Sabino et al. Horton created the water quality index (WQI) model in 1965 to distinguish between different types of water. The sum of all relevant factors influencing water quality yields a single, dimensionless number.[7]

Surface water and groundwater are intertwined in complex ways. For instance, a lot of lakes and rivers get their water from the ground. This implies that harm to groundwater aquifers—such as that caused by fracking or excessive extraction—might have an impact on the rivers and lakes that depend on them. One illustration of these interactions is the addition of saltwater to coastal aquifers.[10]

Using the precautionary principle, monitoring groundwater quality, designating areas for groundwater preservation, strategically positioning on-site sanitation systems, and maintaining the law are some prevention techniques. In areas where contamination has occurred, management options include point-of-use water treatment, groundwater remediation, and, as a last resort, abandonment. Making quality indicators is one such technique for keeping an eye on the quality of groundwater.[13]

When volcanic rock or ash combines with alkaline fluids, zeolite can be produced. The material zeolite can produce a wide range of aluminosilicates, which are assemblages of oxygen, silica, and aluminium. They are particularly susceptible to cation exchange abilities because of their structure and composition, and they are microporous.[14] Due to potential impurities, the intensity of these exchange capabilities varies from type to type and is noticeably weaker in naturally occurring zeolites.[11] Technologies are always developing and improving to meet human needs, including the need for clean water. In order to treat wastewater and drinking water in ways that are efficient and environmentally friendly, the water treatment industry is always researching, testing, and developing new and improved methods.[15]

For the treatment of waste water, grey water, and drinking water, zeolite water filtration medium offers a natural, eco-friendly option. Zeolites can be created synthetically, though, by boiling a mixture of sodium hydroxide, alumina, and silica. It is meant to catch particles that are too large to pass through by utilising the spaces between the grains. In the system described above, everything is caught at the top, and the lowest layers offer support and space for drainage.[16]

To improve filtering effectiveness, more holes can be added to the treatment medium using zeolite filters. Because zeolite media have many pores, they can absorb particles before trapping them. They consequently both adsorb and collect particles that are confined between grains.[17] This is made possible by the mineral zeolite's ability to do cation exchange, which requires soaking up positive ions from water and exchanging them for other ions. Zeolite's high pore density and vast surface area may enable it to catch a sizable amount of pollutants without the need for backwashing.[2]

Zeolite does not clog up as rapidly, so there is less pressure loss during therapy. Because it can reduce or remove some hard minerals and is more chemically resistant than some other media, this medium can serve as a water softener. During this process, particles adhere to the medium's surface, which is an active effect as opposed to passing through grains and becoming trapped.[17]

Additionally, it should be noted that the characteristics of the water to be treated, the source of natural zeolites, the level of modification required to produce synthesised zeolites, and other elements can have a big impact on how effective zeolite-based filters are.[18] Zeolite can be classified as natural or synthetic; the only distinction between the two is that the latter is created by processing natural ore bodies, whereas the former is created using chemical processes that need a lot of energy. Clinoptilolite zeolites have a ratio of 5 to 1 in comparison to a ratio of 1 to 1 in synthetic zeolites. Important considerations include the sort and amount of zeolites employed, the distribution of zeolite particle sizes, the initial concentration of impurities (cations and anions), and other elements.[3]

The efficiency of natural and modified zeolites to treat water depends on a variety of factors, including the pH value of the solution, the ionic strength of the solution, the temperature, the pressure, the contact time of the zeolite/solution system, and the presence of other organic compounds and anions.[19] The usefulness of natural zeolite (especially that from Central Asia) and synthetic zeolite in the rehabilitation of groundwater is currently not well established, which is unfortunate.[20]

The efficacy of natural and synthetic zeolites was examined in the current study to treat groundwater from Tselinograd District in Akmola Region, 70 km from Kazakhstan's capital. In Kazakhstan, the Chankanai mines produced natural zeolites.[17]Water quality indices were also developed based on the selected water quality criteria to evaluate the quality levels of groundwater and treated effluents.[2]

2. Nature of Zeolites

It has long been known that natural zeolite makes an effective adsorbent for the removal of cations from water. Natural zeolite is a type of porous substance having a significant specific surface area but a modest ability for adsorption.[12]

Natural zeolites, which are crystalline hydrated aluminosilicates with pores filled with water, alkali, and alkaline earth cations, are plentiful and inexpensive supplies. Natural zeolites have been extensively employed as adsorbents in separation and purification procedures over the past few decades due to their excellent cation-exchange ability and molecular sieve characteristics.[2]

The current advancement of natural zeolites as adsorbents in water treatment is reviewed in this research. We talk about the characteristics and modifications of natural zeolite. Around the world, different natural zeolites have demonstrated variable ion-exchange capacities for cations such as ammonium and heavy metal ions. Adsorption of anions and organics from aqueous solutions is another property of some zeolites.[3] The adsorption capacity of modified zeolites for organics and anions is increased using a variety of processes, including acid treatment, ion exchange, and surfactant functionalization.

3. Material and Methods

Alteration of natural zeolite:

Any zeolite's adsorption properties depend on the precise chemical and structural composition of the adsorbent. Adsorption is greatly influenced by the Si/Al ratio, cation type, number, and position. To increase the effectiveness of natural zeolite separation, these features can be altered chemically in a variety of ways.[17] It is usual practice to use acid-base treatment and surfactant impregnation via ion exchange to modify the hydrophilic and hydrophobic characteristics for the adsorption of various substances.

***Application of metalionsfabricatedzeoliteforwatertreatment*:**

Pollutants come in many different forms and can be found in effluent from industry or households, surface water, and ground water. These pollutants, which comprise both inorganic and organic substances, are rather dangerous for people, animals, and plants.[15] The removal of various contaminants from water using natural zeolites and their modified forms is covered in detail in the sections that follow.

Methods for the removal of toxic elements from the water:

Potable water is normally passed through many treatment processes to improve its aesthetic quality and safety.[11]The water from river i.e. fresh water is also treated with many of the treatment processes like granular media filtration, adsorption, membrane filtration, media filtration, ion exchange , sand filtration, water softening methods, adsorption, disinfection for the removal of pathogens and many more.[21] In the area where water crisis is there the high salt containing water or ocean water is also treated for the removal of minerals due to water demand and availability of new technology.[5]

The addition of minerals with water is critical to control its aggressiveness to piped distribution systems. Since the addition of minerals of desalinated to water is needed. It raises the question whether or not can water get extra edges by adding the salts on the value of nutrition or not.[10]

Due to various geographical origin and different treatment methods for Natural water.[4] It attains a wide diverse composition. As the rain water and the rain water covering the earth surfaces always are found low salinity and minerals. Whereas the ground water may contain high content of minerals may be excessively saline.[12]

When treated water is added with some required minerals for the benefits of health, it raises a question that other water sample may also be made more healthier by adding the beneficial minerals or not.[22]

The above methods have their own restriction. So the preparation of cost effective zeolite can be a better option for the purification of huge quantity of water.[20]

Experimental Methodology :

For the preparation of aluminium-zeolite the following steps of experiment were followed:

(i) Testing of various water sample

(ii) Preparation of aluminium embedded-zeolite

(i) Testing of water samples:

The water samples were collected from the different zones of Indore city of MP, India. Water samples collected and stored in plastic water bottles.

An essential test for determining the quality of water is turbidity. Water that is cloudy or hazy due to suspended particles like sediment, algae, or other substances is referred to as turbid. High turbidity levels may be a sign of environmental problems like pollution or sediment flow. Turbidity can be measured using a variety of techniques, including:

pH, turbidity, TSS, TDS, Alkalinity, hardness, methal cations like calsium, iron, and fluoride, sulphate anions. After analyzing these in the different water samples the aluminium zeolite was prepared as per the following method.With the help of turbiditimeter the turbidity of water samples was tested. Here a turbidity tube was used, it was filled with the water sample and lowered it into the liquid until the designated discs or increments were no longer visible. The depth as a turbidity estimate as NTUwas noted down.

(ii) ***Preparationofmetalzeolitefrom the natural zeolite:***

The aluminium metal zeolite were prepared by using natural zeolite. For this the following chemicals were required:Natural zeolite, aluminium sulphate salt, distilled water, NaOH, [19]

For preparing Aluminium zeolite, the natural zeolite is soaked in 1Molarity, NaOH solution for about 3 hours. Then the supended material was filtered and washed with distilled water until all the traces of NaOH were removed and the material was tested neutral. After this the filtered, washed material was then immersed for about 12 hours in different concentration solutions of aluminium sulphate [$(Al_2(SO_4)_3$]. The aluminium sulphate [$(Al_2(SO_4)_3$] solution were prepared in 0.05M, 0.1M, 0.2M and 0.3 M concentration. After 12 hrs. the residue was then dried in hot air oven at 100^0C for 1 hrs.[9]

This obtained material was converted in Al-Zeolite. This has a great adsorption ability.

The prepared aluminium-zeolite sample were used to prepare the zeolite bed and the collected water samples were filtered by passing through these zeolite bed. After filteration the water samples were tested again and the results werecompared.

4. **Results&Discussions**

The following parameters were tested in the Pollution Control Board (PCB) Indore and Anusandhan Analytical and Biochemical Research Laboratory, Indore:

The results are as shown in the below table:

Table 1: Summary of Water analysis results for different areas of Indore city (Before Treatment by Al-Na Zeolite)

S. No.	Parameters	Unit	Water Sample-1	Water Sample-2	Water Sample-3	Water Sample-4	Water Sample-5
		Locations	Bangali Square	Rajendra Nagar	Vijay Nagar-Sheme54	LIG	Saket
1	Colour	Pt. Co. Scale	1	1	1	1	1
2	Odour		Odourless	Odourless	Odourless	Odourless	Odourless
3	pH	pH Scale	8.13	8.1	7.3	7.9	8.2
4	Total Hardness	mg/L	326	325	290	340	450
5	TDS	mg/L	766	710	765	425	800
6	Alkalinity	mg/L	302	158	164	98	520
7	Fluoride	mg/L	1.02	1.32	1.2	1.4	1.38
8	Chloride	mg/L	262	340	290	250	400
9	Sulphate	mg/L	40	52	77	65	90

Table 1.1: Summary of Water analysis results for different areas of Indore city (AfterTreatment by Al-Na(0.05M) Zeolite)

S. No.	Parameters	Unit	Water Sample-1	Water Sample-2	Water Sample-3	Water Sample-4	Water Sample-5
		Locations	Bangali Square	Rajendra Nagar	Vijay Nagar-Sheme54	LIG	Saket
1	Colour	Pt. Co. Scale	1	1	1	1	1
2	Odour		Odourless	Odourless	Odourless	Odourless	Odourless
3	pH	pH Scale	8.01	7.9	7.1	7.3	7.2
4	Total Hardness	mg/L	320	275	260	300	310
5	TDS	mg/L	730	650	600	400	680
6	Alkalinity	mg/L	225	130	145	110	140
7	Fluoride	mg/L	0.9	1.1	1.1	1.01	0.9

8	Chloride	mg/L	250	320	240	255	240
9	Sulphate	mg/L	32	40	60	35	80

Table 1.2: Summary of Water analysis results for different areas of Indore city (AfterTreatment by Al-Na(0.1M) Zeolite)

S. No.	Parameters	Unit	Water Sample-1	Water Sample-2	Water Sample-3	Water Sample-4	Water Sample-5
		Locations	Bangali Square	Rajendra Nagar	Vijay Nagar-Sheme54	LIG	Saket
1	Colour	Pt. Co. Scale	1	1	1	1	1
2	Odour		Odourless	Odourless	Odourless	Odourless	Odourless
3	pH	pH Scale	7.9	6.8	7.0	6.9	6.8
4	Total Hardness	mg/L	280	220	200	250	280
5	TDS	mg/L	600	596	550	380	550
6	Alkalinity	mg/L	200	125	130	100	130
7	Fluoride	mg/L	0.5	1.0	0.9	0.5	0.5
8	Chloride	mg/L	200	250	200	230	210
9	Sulphate	mg/L	25	35	50	30	50

Table 1.3: Summary of Water analysis results for different areas of Indore city (AfterTreatment by Al-Na(0.2M) Zeolite)

S. No.	Parameters	Unit	Water Sample-1	Water Sample-2	Water Sample-3	Water Sample-4	Water Sample-5
		Locations	Bangali Square	Rajendra Nagar	Vijay Nagar-Sheme54	LIG	Saket
1	Colour	Pt. Co. Scale	1	1	1	1	1
2	Odour		Odourless	Odourless	Odourless	Odourless	Odourless
3	pH	pH Scale	7.4	6.5	6.9	6.8	6.7
4	Total Hardness	mg/L	250	200	198	245	260
5	TDS	mg/L	595	580	530	375	520
6	Alkalinity	mg/L	195	120	125	100	125
7	Fluoride	mg/L	0.4	0.8	0.8	0.4	0.3
8	Chloride	mg/L	190	230	195	220	200
9	Sulphate	mg/L	22	32	47	29	45

Table 1.3: Summary of Water analysis results for different areas of Indore city (AfterTreatment by Al-Na(0.3M) Zeolite)

S. No.	Parameters	Unit	Water Sample-1	Water Sample-2	Water Sample-3	Water Sample-4	Water Sample-5
		Locations	Bangali Square	Rajendra Nagar	Vijay Nagar-Sheme54	LIG	Saket
1	Colour	Pt. Co. Scale	1	1	1	1	1
2	Odour		Odourless	Odourless	Odourless	Odourless	Odourless
3	pH	pH Scale	7.3	6.4	6.6	6.7	6.6
4	Total Hardness	mg/L	245	195	195	240	250
5	TDS	mg/L	580	570	520	370	510
6	Alkalinity	mg/L	190	115	120	98	120
7	Fluoride	mg/L	0.3	0.7	0.7	0.3	0.2
8	Chloride	mg/L	180	225	190	210	198
9	Sulphate	mg/L	20	30	45	25	40

The above data shown in the Table1 and Table 1.1, 1.2, 1.3 & 1.4 are showing the improved results in the drinking water. By the above data it is very evident that as the concentration of Aluminium cation(Al^{3+}) is increasing in e zeolite, its adsorption capacity is also increasing. That results the decreasing hardness, alkalinity, chloride ions, sulphate ions and mainly the fluoride ion concentration. The prepared zeolite added with aluminium ions in different concentration further was characterized by XRD and FTIR methods. The results are shown as:

FTIR Results of Al^{3+} metal ions fabricated Na-Zeolite:

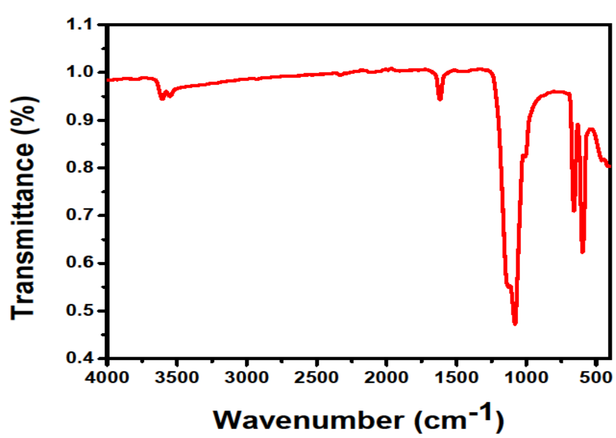

Figure1: Al-Ze Zeolite (0.1 M)

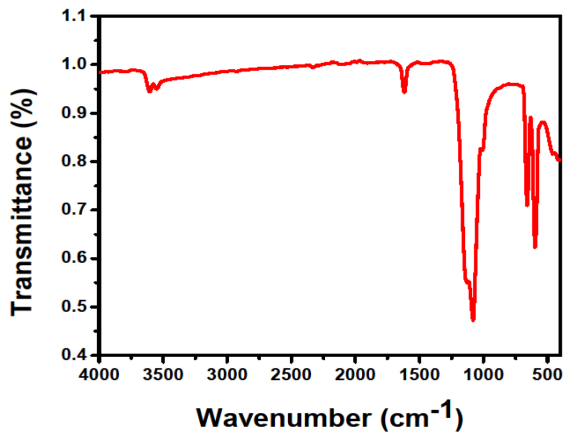

Figure2: Al-Ze Zeolite (0.2 M)

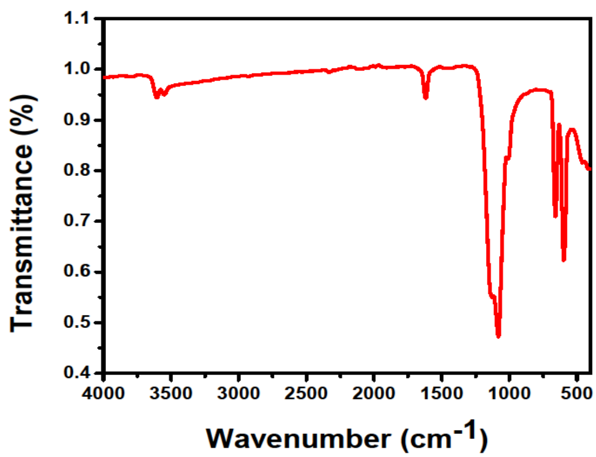

Figure3: Al-Ze Zeolite (0.3 M)

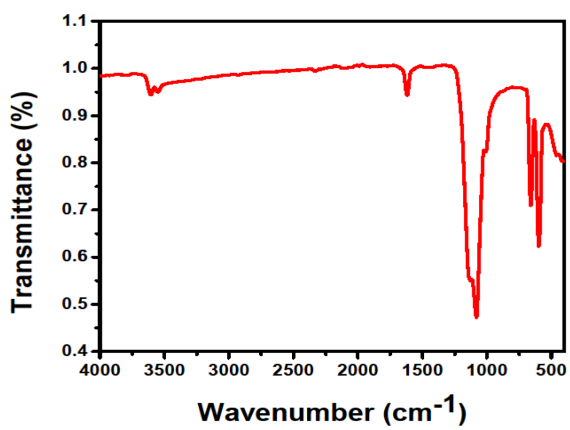

Figure4: Al-Ze Zeolite (0.05 M)

As per the following chemical reaction the ion exchange reaction takes place between the Al modified zeolite and water ions:

$Al_2(Ze)_3 + 6F^- = 2AlF_3$ (Removal of fluoride ions from water)

$Al_2(Ze)_3 + 6Cl^- = 2AlCl_3$ (Removal of chloride ions from water)

$Al_2(Ze)_3 + 2Co3+ = Co_2(Ze)_3$ (Removal of cobalt ions from water)

$Al_2(Ze)_3 + 3Ni2+ = 3NiZe$ (Removal of cobalt ions from water)

5. Conclusion

The article included a quick overview of the zeolite modification inIn terms of the three types of modification—physical, chemical, and composite—that have been researched toboost the zeolite's capacity to absorb numerous hazardous substances from drinking water. Chemical and composite modification were explored more extensively for the removal of many types of pollutants, while physical modification research was only focused on ammonium removal. The effects of the modification will be significantly influenced by the temperature, kind, and concentration of reagents.

The zeolites are having good adsorption n ability which can be improved by modifying it with aluminum ions. In summation the final aluminum zeolite becomes better adsorbent for the removal of toxic ions from water. The data examined in this study can be used to enhance the adsorption capacity of zeolite as the structure of natural zeolite is modified with other metal salts.

Zeolites can be modified using a variety of techniques, but the best modification should be selected based on particular contaminants. Future research on modified zeolite may, it is suggested, focus on examining the adsorption of modified zeolite concurrently in order to address the complexity of the actual drinking water.

6. Future Perspectives

Natural zeolites are crucial, low-cost components for the treatment of wastewater and water. Natural zeolites perform exceptionally well in the adsorption of cations in aqueous solutions, such as ammonium and heavy metals, due to the nature of cation exchange. But for a multi-component system, zeolites exhibit variable ion selectivity and competitive adsorption. Additionally, these substances are poor adsorbents for organics and anionic ions. Cationic surfactants can be used to modify surfaces. Monitoring and analysis should be conducted over a longer period of time in order to provide a thorough examination of the state's water quality. For this type of monitoring, a minimum of a year should pass in order to collect enough data or trends to verify the validity of the study. Making the gathered data more comparable to scientific conclusions would also benefit from the standardization of the sample sites.

Acknowledgements

The analysis of water properties were done in the Pollution Control Board (PCB) Indore and Anusandhan Analytical and BiochemicalResearch Laboratory, Rau-Rangwasa CAT Road Indore. The material i.e. aluminium zeolites were prepared in the Dr. APJ Kalam University indore.

Conflicts of Interest:

The co-author has reviewed the article and concurs with its contents; there are no competing financial interests to disclose. We attest that the submission is unique and is not already being considered by another publisher.

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