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Preparation and Characterization of Zinc Metal fabricated Zeolite Water Filters for the Removal of Perilous Ions from Drinking Water

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Abstract

In order to remove hazardous cations and anions from drinking water, we synthesized the zinc metal fabricated zeolite. For this synthesis the basic nature of zeolite as an adsorbent was employed. The waste water sample and drinking water samples collected from the different zones of Indore city were tested before and after filter treatment by this zinc zeolite. Natural zeolite is a type of porous substance with a significant specific surface area but a modest ability for adsorption. In recent years, focus has been placed on employing various techniques to prepare the surface-modified zeolite in order to increase the zeolite's adsorption capacity for contaminants. Zeolite modification treatments can significantly alter the pore structure and surface chemistry. The research report introduces the removal procedures for typical pollutants like fluoride ions and heavy metal ions and describes several zeolite modification techniques. This study also aims to demonstrate the viability of using modified zeolite to create inexpensive active zeolite embedded with zinc ions, which will help to achieve a larger removal impact and make drinking water safe for human consumption. This study's primary goal is to effectively resolve zeolite synthesis techniques and their potential applications. This paper provides an overview of zeolites studies that have used zeolites as adsorbents for the contaminants under consideration.

Keywords: Fabrication, Composite-zeolite, Surface Modification, faujasite framework, adsorption.

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1. Introduction:

Numerous studies are conducted to learn more about the synthesis and description of zeolite. According to the most recent review article from 2022 on the use of zeolite for waste water treatment, the adsorption technique is a highly versatile method for removing pollutants from effluents since it uses a variety of materials as adsorbents. Zeolites, which can be found in a wide range of materials, show promise as an adsorbent. Zeolites are minerals that can be found in nature or created from industrial waste and excel at treating contaminated effluents.

Zeolite's ability to remove contaminants can be up to 96% effective for heavy metals, 90% effective for phosphoric compounds, 96% effective for dyes, 80% effective for nitrogen compounds, and 89% effective for organics. A review of recent zeolites applications is required with the goal of identifying the more pertinent results and research gaps to promote the use of zeolites in the large-scale treatment of industrial effluents. This paper provides an overview of zeolites and reviews several recent studies that have used zeolites as adsorbents for the contaminants under consideration. It does so by highlighting the key features of the various adsorption systems, highlighting the unique aspects of each method, and highlighting areas that require additional research.

Different elements of the efficient synthesis of synthetic zeolites from a variety of raw materials have been rigorously studied in the review research on zeolite synthesis from low-cost resources and environmental applications. In addition, a summary of the potential benefits and drawbacks of various synthetic routes and raw materials has been provided. Although our discussion was limited to mainly environmental applications, it was discovered that zeolites have a wide range of applications. The findings of this review demonstrate that, in contrast to the use of rather expensive raw materials, it is possible to produce high-quality zeolites using generally available, inexpensive raw materials. These raw materials can maintain a consistent structure while also reducing cost and ageing time. Different approaches do, however, have some drawbacks that will need to be appropriately managed in the future. Furthermore, because synthetic zeolites have so many uses, there is a lot of promise for their use in environmental applications. Here are a few observations that must be addressed in the future before synthetic zeolites may be fully utilised on a commercial scale.

In the research paper on the preparation and use of modified zeolites as adsorbents in wastewater treatment, the article briefly described the modification of zeolite in terms of physical modification, chemical modification, and composite modification, all of which have been investigated to increase the adsorption potential of zeolite for various pollutants from wastewater. Chemical modification and composite modification were explored more extensively for removing many types of pollutants, while physical modification research was only focused on ammonium removal.

The majority of tests in the past have focused on eliminating certain pollutants, but in reality, there has never been a qualitative or quantitative analysis of the adsorption competition on the zeolite interface inside complicated wastewater. In order to deal with the complexity of the actual wastewater, it is advised that the study direction of modified zeolite be based on analysing the adsorption of modified zeolite concurrently.

In order to put the potential zeolites into context, this research work looks at the properties of zeolites and how the substance is made. Previous research work mainly was focused to remove contamination from waste water. Earlier the zeolite was studied, synthesized and characterized for adsorming the pollutants from the waster water mostly the removal of pollutants from the industrial effluents. In this research paper the synthesis of fabrication of zeolite by the zinc salts and natural zeolite is described. The new fabricated Zinc-Zeolite than was characterized by XRD and FTIR analysis. The main purpose of the research is to remove harmful metal cations and fluoride ions from the drinking water which are normally left even by the conventional filteration methods applied on drinking water. It is seen that the filteration methods which are used commercially not very effective even they are very expensive. By this research the prepared zinc-zeolite is not only found more effective for the removal of such unsafe metal cations and excessive fluorde ions from the drinking water this new customized zeolite is very cost effective also. Most of the previous research work has focused on the synthesis and characterization of zeolite material but in this research the latest synthesized zinc-zeolite could be made available on more commercial level as well as its regeneration can be done very easily and economically.

Researchers are trying hard to understand how zeolite emerges from its antecedents because it is essential for industry. Since it is possible to engineer the process to produce a custom-made zeolite, science is now interested in the art of zeolite synthesis. Zeolite manufacturing must closely resemble natural geological processes. But since zeolite took millions of years to form and since zeolite must be synthesised for commercial usage in a matter of hours or days, it is not practical. The scientist must replicate the ideal zeolite synthesis circumstances in order to synthesise the desired zeolite with the desired properties more quickly.The use of this chemical technique to produce zeolite is one of the author's key areas of interest.

This research is aiming to filter drinking water by this customized zeolite filter. We know the huge population of India is actually not able to buy the expensive water filters available in the market and this population is only depending on the river water or any water resource for drinking water.

The purpose of this investigation was to investigate the composition and characteristics of zeolite synthesized from the Zinc salt solutions and gels. In order to do this, a study was conducted with the following goals:

i. Making zeolites using aqueous zinc salt solutions as a source of inexpensive material.

ii. To figure out how changing the content of the zinc salt solution and the order in which the solution is mixed affects the formation of zeolite crystals.

iii. To investigate the properties of the synthesised zeolite (including shape, physico-chemical composition, and phase identification) using XRD and FTIR.

iv. To assess the potential of the synthetic zeolite produced with regard to its ability to function as an ion exchanger by adsorbing the hazardous cation and anion of drinking water.

Lower production costs and ease of access are the key causes of this research work.

2. Experimental details with Material and Methodology:

This Research paper is showing not only the synthesis of zinc fabricated zeolite but also showing the analysis of different water samples before and after filteration with this zinc-zeolite. The results obtained have also shown the efficiency of fabrication and further modifications to it. This research has covered the following three experimental steps:

2.1 Synthesis of Zinc fabricated Zeolite

2.2 Analysis of drinking water samples before and and after filteration
2.3 Charaterization of Synthesized zeolite.

2.1 Synthesis of Fabricated Zeolite:

Synthesis of Zinc ions fabricated zeolite involves the three major ingredients: Zinc Oxide(ZnO), Zinc Acetate($CH_3COO)_2Zn$ and natural zeolite. A suspension was made by dispersing 5gram pf natural zeolite into 100ml of de-ionized water in around bottomed flask. In this suspension the equivalent amount 5%by weight of zinc oxide and zinc acetate were dissolved until a slurry was obtained. This slurry was stirred continuously under reflux reaction at 80% for about five hours. During this time the sodium ions of natural zeolite were exchanged and the zinc ions were embedded into it. This whole chemical change followed a good ion exchange reaction.

Further the obtained product was added with 0.1 molarity solution of sodium hydroxide(0.1M NaOH) until the pH was adjusted to 11. This was done for neutralizing the solution to prepare the desired substance. This whole mixture was kept for two hours in the thermostate set at 30^0C. After two hours the product was filtered and washed with distilled water extensively for the removal of acetate residual. The washed and filtered product was than dried in the hot air oven set at 60^0C overnight. After about 2 hours the product was calcined in the muffle furnace for next six hours at 450^0C. Finally the product obtained was cooled in the dessicator for keeping about two hours. The obtained product was zinc embedded zeolite. This was further made an adsorbent bed medium for filtering the standard solution of fluoride.

2.1.1 The experimental setup for the Zeolite Bed:

As an adsorption column, a pyrex glass column with an internal diameter of 2.1 cm and a height of 15 cm was employed. Glass wool was sandwiched between the zeolite adsorbent, and the bottom and top ends were filled with inert beads. The proper concentration of the fluoride ion-spiked solution was kept in a magnetically agitated container, and it was pumped vertically up the column. By periodically gathering 100 mL of the outgoing solution and timing how long it took to fill the volume, the flow velocity was monitored. Numerous factors, including bed mass, initial fluoride ion concentration, flow velocity, and intermittent operation, were tested to determine their effects. When the concentration of fluoride ions in the effluent was approximately equal to the beginning concentration, samples were obtained to measure the residual fluoride content at intervals of 10 to 30 minutes.Similary this process was repeated with the standard solution calcium hydroxide for the removal of calcium ions by the zeolite bed.

The concentration of fluoride ions and calcium ions were checked before passing through zeolite bed and after receiving the filtered solution by this bed.

2.2 Analysis of drinking water samples before and after filtration:

2.2.1 Turbidity Analysis : When suspended particles that scatter or absorb light cause a liquid to become cloudy or hazy, this is referred to as turbidity. It is frequently used as a water quality indicator, notably for clarity and the presence of particulates. A water sample's turbidity can be examined to learn important details about any pollutants, silt, or other impurities that might be present. There are a variety of techniques that can be used, from straightforward visual observations to more complex equipment, to determine the turbidity of a water sample. In this research the turbidimeter was used to determine the turbidity of the water samples. In this the water samples were analyzed by Turbidimeter.

Turbidimeters: This instrument typically uses a light source and a detector that are positioned 90 degrees apart from each other. The detector gauges how much light is reflected or dispersed by the water sample's suspended particles. Additionally, turbidimeter has offered numerical outcomes in NTU (nephelometric turbidity unit) or FTU (Formazin Nephelometric Unit).

2.2.2 TSS Analysis: Total Suspended Solids, or TSS, is a measurement of the quantity of suspended solids in a sample of water. TSS analysis is a crucial component for assessing water quality and quantifying the amount of particle matter in the water. Sediment, organic matter, inorganic particles, and plankton are just a few examples7 of the items that can be found in TSS. In this research the TSS of the water samples was analyzed by Gravimetric Method using a pre-weighed filter paper or glass fiber filter, a specified volume of water was filtered. The mass of suspended solids retained on the filter was then calculated after drying and reweighing the filter. The TSS concentration was determined by the weight difference before and after filtering.

2.2.3 TDS (Total Dissolved Solids) Analysis: The entire concentration of inorganic salts, minerals, metals, and other dissolved compounds in a water sample is known as total dissolved solids (TDS). The total dissolved solids (TDS) analysis provides details on the total mineral content and can be used as a sign of the water's quality and suitability for different uses, including drinking water, irrigation, or industrial applications. TSS of different water samples was analyzed by the Gravimetric method. The gravimetric method is a widely used technique for measuring TDS. In this procedure, suspended particles were removed by filtering a pre weighed filter with a specified volume of water by filtering a pre weighed filter with a specified volume of water. The filter's pore size is typically 0.45 micrometers. The filtered water was subsequently dried in a pre-weighed dish via evaporation. The dried residue was placed in a dish and weighed again; the result showed the TDS concentration of water samples.

2.2.4 Hardness and Alkalinity Determination:

The hardness of water samples was determined by EDTA complexometric titration by using standard hard water, basic buffer solution (mixture of weak base and its salt NH_4OH+NH_4Cl) and Eriochrome Black-T indicator. and the alkalinity of water samples was determined by acid-base titration using N/50 H_2SO_4, phenolphthalein and methyl orange indicators

2.2.5 Fluoride, Chloride, calcium ions and Sulphate ions analysis: In this research the fluoride ions of water sample were analysed by using colorimeter and fluoride ion-specific electrode. Like wise the chloride ions of water samples were determined by argentometric titration using the standard solution of silver nitratrate and potassium chromate indicator. In this research the calcium and sulphate ions were determined by the inorganic salt analysis.

2.3 Characterization of Customized zeolite:

2.3.1 Characterization by XRD:

The prepared sample of zinc zeolite was subjected to instrumental characterization by Automated Multipurpose X-ray Diffractometer, with high accuracy of θ-θ Goiometer it enables omega scans, two-theta scans also two theta scans in the sample if oriented horizontally. It also contains the two axes equipped with encoders to control of each axis by a resolution of 0.0001. This automated XRD has standard powder attachment, threeKW sealed tube X-ray generator having max. voltage of 60kV. This XRD also has a cross beam optics and two detectors; one is 0D Scintillation Count detector (Point Detector) and the second one is one-D Semiconductor Detector.

XRD instrument- IIT Indore

2.3.2 Characterization by FTIR:

An analytical tool (with a MIR source, ZnSe beam splitter, and DLaTGS detector) called the Fourier Transform Infrared Spectrometer (FT-IR), Tensor 27, Bruker, was used to recognize sample, based on the relative amount of energy of important functionalities present in the sample. The instrument allows to analyse the sample in the 4000-400 cm-1 frequency band.

FTIR instrument- Analysis of Zn-Zeolite Sample image: IIT Indore

3. **Results & Discussions** :

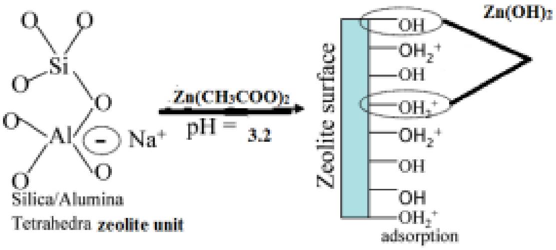
In this research work the experimental work was dived into three catagories:

3.1 Synthesis of Zinc-Zeolite

3.2 Characterization of Zinc-Zeolite

3.3 Water sample analysis

3.1 Synthesis of Zinc-Zeolite:



Availability of Zinc ions on the surface of zeolite as zinc hydroxide:

3.2 Characterization of Zinc-Zeolite:The characterization of the sample prepared has shown the following details

3.2.1 XRD Results Analysis:

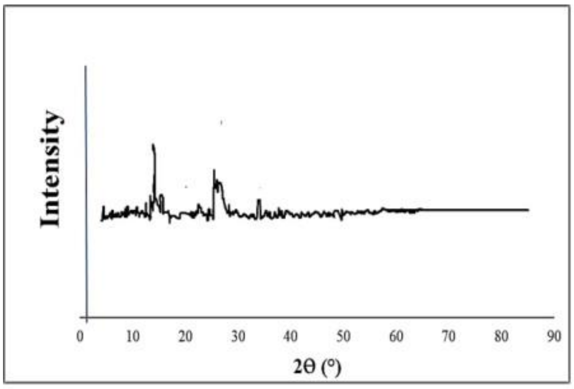


Figure 1: XRD graph of Zn-Zeolite

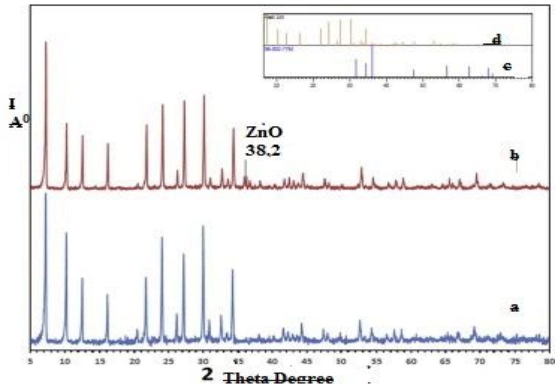


Figure 2: XRD graphto study the adsorption difference before and after zinc fabrication of Zeolite

In this research the synthesized zeolite was analysed by XRD instrument . The obtained result was analysed as:

Data Analysis: To ascertain the crystal structure and pinpoint the phases present in the zinc zeolite sample, the acquired diffraction pattern was processed and examined. This was accomplished by comparing the experimental diffraction pattern to a database of known diffraction patterns for various crystal structures.

Phase identification: To identify the crystalline phases present in the zinc zeolite sample, the diffraction pattern was compared to the database. This knowledge aided in comprehending the makeup of the substance and any modifications that might result from the adsorption of cations and anions.

Structure Analysis: The crystal structure, lattice parameters, and other structural characteristics of the indicated phases were also be ascertained from the diffraction pattern. This knowledge could shed light on the way that cations and anions adsorb within the zeolite framework.

3.2.2 FTIR Results Analysis:

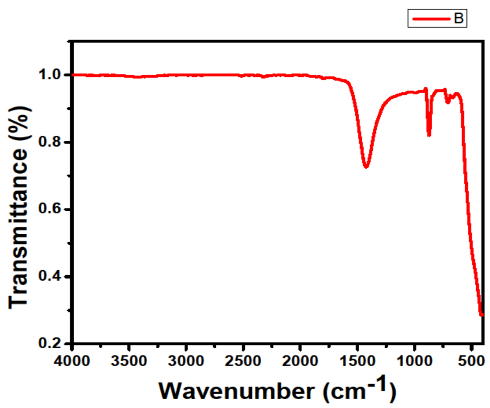


Figure 3: FTIR of Zinc-Zeolite

A potent method for determining the molecular make-up and functional groups contained in a sample is FTIR (Fourier Transform Infrared) spectroscopy. FTIR analysis can be used to learn important details about the chemical bonds, surface groups, and potential interactions with adsorbed species in a zinc zeolite. An overview of the FTIR analysis procedure for a zinc zeolite sample is given below:

Data analysis: To identify distinctive absorption bands and functional groups present in the zinc zeolite sample, the recorded absorption spectra was examined. In this analysis, specific vibrational modes and chemical bonds were assigned to the generated spectrum by comparing it to reference spectra or databases.

Peak Interpretation: Each peak in the FTIR spectrum represented a particular bond or vibration in the material. In the shown FTIR observed peaks between 500-4000cm^{-1} are showing the increased adsorption by the synthesized sample: zinc-zeolite.

3.3 Water Sample Analysis:

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:

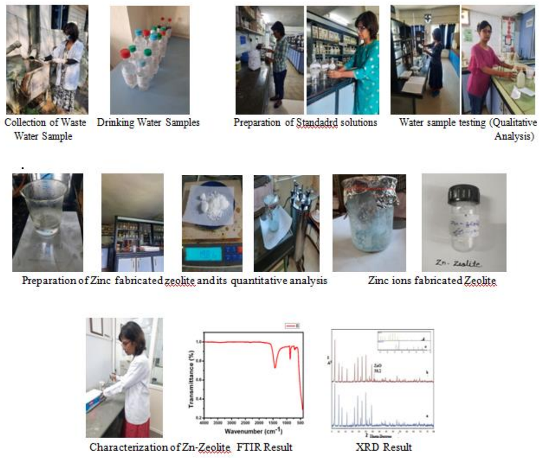
Table 1: Summary of Water analysis results for different areas of Indore city (Before Treatment by Zeolite)

S. No.	Parameters	Unit	Water Sample-1	Water Sample-2	Water Sample-3	Water Sample-4	Water Sample-5
		Locations	Kalindi Township	Baikund-dham Colony	Sudama Nagar	Nehru Nagar	Bangali Square
1	Turbidity	NTU	2.2	1.7	2.01	1.7	2.3
2	TSS	mg/L	9	8	4	11	7
3	TDS	mg/L	690	706	366	815	766
4	Total Hardness	mg/L	256	266	113	337	326
5	Alkalinity	mg/L	142	119	95	471	302
6	Fluoride	mg/L	0.74	1.54	0.57	1.14	1.02
7	Chloride	mg/L	192	179	158	249	262
8	Sulphate	mg/L	45	88	28	88	40
9	Calcium	mg/L	62	65	42	75	70

Table 2: Summary of Water analysis results for different areas of Indore city (AfterTreatment by Al-Na Zeolite)

S. No.	Parameters	Unit	Water Sample-1	Water Sample-2	Water Sample-3	Water Sample-4	Water Sample-5
		Locations	Kalindi Township	Baikund-dham Colony	Sudama Nagar	Nehru Nagar	Bangali Square
1	Turbidity	NTU	1.8	1.5	1.7	1.4	1.8
2	TSS	mg/L	7	7	3	10.4	6
3	TDS	mg/L	680	690	355	770	750
4	Total Hardness	mg/L	200	195	100	280	250
5	Alkalinity	mg/L	135	110	85	425	280
6	Fluoride	mg/L	0.72	1.5	0.51	1.01	1.01
7	Chloride	mg/L	190	170	150	230	250
8	Sulphate	mg/L	45	88	28	88	40
9	Calcium	mg/L	30	32	30	60	40

4. Graphical Presentation of the Experimental Work



5. CONCLUSION AND FUTURE PERSPECTIVES:

The natural zeolite which is available on low cost can be fabricated with the zinc like metal cations , which may be obtained by the economic metal salts. The research has also given a new direction for making the very cost effective water filters and this research has also shown the synthesis and characterization of such low cost water filter zinc zeolite. The research paper included a brief overview of the physical, chemical, and composite modifications of zeolite that have been researched to improve the material's ability to adsorb different cation and anion causing ill effects on human health from drinking water.

The majority of tests in the past have focused on eliminating specific contaminants, but in reality, there has never been a qualitative or quantitative analysis of the adsorption competition on the zeolite interface inside complicated wastewater. In order to deal with the complexity of the actual wastewater, it is suggested that in the future, the study of modified zeolite can be based on simultaneously analysing the adsorption of modified zeolite.

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The Pollution Control Board (PCB) Indore and the Anusandhan Analytical and Biochemical Research Laboratory, Rau-Rangwasa CAT Road Indore, where the water sample of different areas of Indore city were analysed. The zinc zeolite sample was prepared in Dr. APJ Kalam University Indore.

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