Comparative Study of Hydrothermally Synthesized $\text{AlPO}_4\text{-5}$, Activated Carbon, and the Combination of Activated Carbon and $\text{AlPO}_4\text{-5}$ Filters in the Treatment of Wastewater and Industrial Effluent

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Abstract Wastewater and industrial effluent are among the major polluted water, which is disposed without proper treatment. This polluted water requires an efficient and low-cost method of treatment such that its effect on the environment is minimized. The conventional method is easy and cheaper, but its efficiency is not up to the mark. In such case, we need an efficient method of treatment which yields good results. New technologies are emerging to improve the existing operations. One such technology is the use of zeolite. The present article aims at the development of a method which involves filtration using synthesized $\text{AlPO}_4\text{-5}$ and commercial activated carbon (AC) separately and also with their combination. The hydrothermal technique was employed for the synthesis of $\text{AlPO}_4\text{-5}$. The synthesized compound was characterized using XRD, FTIR, SEM, and positron annihilation lifetime measurements. The efficiency of the filters was testified based on the parameters such as pH, electrical conductivity, carbonate and bicarbonate, calcium, magnesium, chloride, and test for heavy metal. It was observed that AC, $\text{AlPO}_4\text{-5}$, and the combination of $\text{AlPO}_4\text{-5}$ and AC serve effectively when used as filters in the treatment of wastewater and industrial effluent. The reduction of chemical oxygen demand in a wastewater sample of 176 to 56 mg/L using the combination of $\text{AlPO}_4\text{-5}$ and AC confirms the destruction of organics present in the sample. Pearson

correlation coefficient analyses of the obtained results infer that most of the parameters are significantly correlated at 1 % level. The solutions received are encouraging, and further study is being posted out using different varieties of zeolite of different thickness and their combinations.

Keywords Hydrothermal · $\text{AlPO}_4\text{-5}$ zeolite · Activated carbon · Filters

Introduction

Municipal and industrial wastewater treatment operations have many concerns. Some include strategies which are becoming more stringent in order to protect our environment and human health. Existing operations are increasingly challenged to match these new objectives. Wastewater treatment amenities are getting hard and expensive, as it requires new infrastructure and state development. Along with these, for the better management of wastewater, it should include basic steps like reduction of waste volume, waste strength, and by-product recovery [1–3].

Activated carbon (AC) has long been acknowledged as one of the most versatile and effective adsorbents used in the removal of organic substances from wastewater [4–7]. AC is a chemically stable material and is known to take up metal complexes from solutions and hence they can be used for waste purification in certain chemical environments for the removal of metal complexes [8]. The procedure of developing modern commercial AC using vegetable materials was reported by Ostrejka 1974 [9]. AC with developed transitional porosity in the range of 2 to 50 nm has been proven to be significant adsorbent for the removal of coloring impurities from liquid phase systems [10].

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Zeolites are beautiful assemblages of well-formed crystals up to several inches in size and are prized by mineral collectors and adorn the mineral museum of every nation. They are thermally stable and resistant against radiation [11]. Natural zeolites have also been applied to get rid of heavy metals from wastewater [12–14]. In malice of the increasing commercial use of zeolites for binary and multicomponent ion exchange, understanding the basic batch-transport processes associated with multicomponent zeolite systems is rather limited [15, 16]. Zeolite provides dramatic results for wastewater handling. It removes and carries heavy metals by ion exchange. An effective removal of heavy metal ions is achieved through ion exchange in a pH range of 3.5–8.0 and even in the presence of alkali or alkaline earth cations. These materials possess a high internal surface area available for adsorption due to the canals and pores. The outside surfaces of the adsorbent particles contribute only a modest quantity of the total usable surface area. The framework contains channels and interconnected voids, which are absorbed by the cations and other water molecules. The cations are quite mobile and may usually be exchanged, to varying degrees, by other cations. The aluminophosphate zeolites have interesting properties for potential use in adsorption and catalytic applications, owing to their unique surface chemistry characteristics and molecular structures [17, 18]. Nevertheless, increasing research activities in molecular sieve science and technology is aiming towards the growth of innovative materials based on aluminophosphate molecular sieve zeolites. The uncovering of this new family opens the doorway to a new era in molecular sieve materials. The utilization of these materials in the treatment of wastewater is more efficient, especially in the removal of many chemical elements, major and minor anions, cations and heavy metals, and so on. The present article mainly focuses on the synthesis of AlPO_4 -5 zeolite using hydrothermal technique and their importance as compared to sand gravity filter when used in sequential order in the treatment of wastewater and industrial effluent.

Materials and Methods

Pseudo-bohemite (AlOOH) was used as the source material in the synthesis of AlPO_4 -5 which was supplied from Loba Chemicals Co. Ltd. Orthophosphoric acid (H_3PO_4) and dipropylamine used in the synthesis of AlPO_4 -5 were supplied from Sigma Aldrich Co. Ltd. Activated charcoal/activated carbon used in filtration process was supplied from Sigma Aldrich Co. Ltd. All these reagents were of analytical grade

and were used without further refining. Distilled water was used throughout the experiment.

Synthesis of Aluminophosphate Zeolite

The synthesis of zeolites involves crystallization from a gel in which a controlled co-polymerization and co-precipitation of all the component oxides i.e., aluminate and phosphate are in homogeneous gel phase. The crystallization of zeolites from this gel was carried out using hydrothermal technique at temperature 150°C , 24 h duration. Initially, the reactive aluminophosphate gel was prepared by neutralizing pseudo-bohemite (98.35 mmol) in water (50 ml) with an equimolar amount of dilute orthophosphoric acid (175 mmol) with rigorous stirring for 2 h. The as-prepared aluminophosphate reactive gel was aged for a desired period i.e., 3 h over a hot water bath at 50°C . Dipropylamine (36.4 mmol) was added to the reactive aluminophosphate gel to form precursor gel followed by aging again for 3 h over a hot water bath at 50°C . A known volume of precursor gel, maintaining percent fill of 40 %, was transferred into a Teflon-lined autoclave and was hydrothermally treated. Figure 1 represents the flowchart for the preparation of AlPO_4 -5 zeolite. The experimental run was held out in PTFE (polytetrafluoroethylene) Teflon-lined autoclaves are made of SS316. After the experimental run, the autoclave was quenched initially using an air jet and then with water to arrest the temperature at which the crystals are formed. The product was washed thoroughly using double distilled water and ultrasonicated to remove the excess organic templates.

Fig. 1 Schematic diagram for the synthesis of AlPO_4 -5 zeolite

Fig. 2 Filters used in the present work

Filtration Methods

The treatment of wastewater and effluent was carried out by filtration method using different filters such as sand filters (where sand beds of various thickness and grain sizes [19] were used), $\text{AlPO}_4\text{-5}$, AC, and the combination of $\text{AlPO}_4\text{-5}$ and AC. The principle behind this filtration technique is similar to that of rapid gravity filters. In designing of sand filter, PVC pipe of 2 in. diameter covered with thin muslin cloth at one end was used, in which beds of sand of known size and known thickness were arranged in descending order. At the bottom, gravels of 5 cm thickness were placed, upon which sand of 40, 24 and 4 μm size of 5 cm thickness each was placed sequentially. Similarly, filters of AlPO_4 , AC, and their combination were prepared. The layer thickness of AlPO_4 and AC filters were 0.75 and 1 cm, and their combined thickness was 1.75 cm. Pictorial representation of the different filters used in the present study is presented in Fig. 2. The effluent and wastewater were allowed to pass through all the above-mentioned

filters. The flow rate of all the filters was set as 2 L/h. The filtrate obtained was collected in separate beakers and then used for further chemical analysis.

Instrumentation

The X-ray powder diffraction pattern of the synthesized compound was recorded using Rigaku, Ultima III Series, TSX System, Japan. The 2θ range was set between 10° and 60° . The identification of the crystalline phase was accomplished by comparing with JCPDS using PCPDF Win version 2.01. The FTIR results were obtained using JASCO-460 Plus, Japan. The infrared spectrum of the compound synthesized was recorded in the range of $4400\text{--}400\text{ cm}^{-1}$. The ground measurements of blank (KBr) were put down before measuring the sample. The obtained spectrum was analyzed using JASCO spectra analysis program and JASCO file find

Fig. 3 XRD pattern of $\text{AlPO}_4\text{-5}$ and AC

Fig. 4 FTIR pattern of a $\text{AlPO}_4\text{-5}$ and b AC

Fig. 5 **a** SEM image of $\text{AlPO}_4\text{-5}$ zeolite. **b** Pictorial representation $\text{AlPO}_4\text{-5}$ molecular sieves

program. The morphology of the samples extracted was characterized using a high-resolution SEM, model HITACHI S-4200. The pore size analysis of the sample was done by positron annihilation lifetime measurements (PALS).

Chemical Analysis

In order to know the efficiency of the filter designed, few analyses were taken out for the filtrate extracted. In the present case, some of the analytical techniques used to measure the quality of water are pH; electrical conductivity (EC); total dissolved solids (TDS); percentage transmission (%T); chemical oxygen demand (COD); and test for carbonate and bicarbonate, calcium, magnesium, and chloride. Test for heavy metals was also carried out using atomic absorption spectroscopy (AAS).

The test for pH was carried out to recognize the acidic or basic nature of wastewater and industrial effluent samples. pH was measured using a pH meter, Salvin Process Instruments Co. SP 3079B, India. The pH meter was standardized using a standard buffer solution before each measurement. A standard reference and the sample were maintained at the ambient temperature. The electrical conductivity measurement was done to quantify the amount of soluble ions present in the samples using a conductivity meter (Salvin Process Instruments C., Model SP 1000A, India). The instrument was calibrated using 0.01 N KCl solution kept at different conductivity range (1468–2000 α Siemens) at room temperature. The %T of the filtrate was done to ensure the removal of suspended particles and to know the efficiency of filters in decolorizing wastewater and effluent. Spectrophotometer (Elico, India) was used to know the %T of the filtrate. The chemical oxygen demand test is widely used as an effective technique to measure the organic

strength of wastewater. The test allows measurement of waste in terms of the entire amount of oxygen needed for oxidation of organic matter to CO_2 and water. The dichromate reflux method was adopted to estimate COD. Titration method was used to measure the amount of carbonate, bicarbonate, calcium, magnesium, and chloride present in the filtrate as mentioned by Baruah TC, Barthakur HP [25]. Estimation of heavy metals like iron, nickel, cadmium, and lead was done using AAS.

Statistical Analysis

Statistical analysis of water quality parameters was carried out using Origin 8 and SPSS 19 version software. The magnitude and direction of the relationship between the water quality parameters were revealed by the Pearson correlation coefficient analysis.

Results and Discussion

Powder X-ray Diffraction Studies of $\text{AlPO}_4\text{-5}$ Zeolite and AC

The powder X-ray diffraction patterns of $\text{AlPO}_4\text{-5}$ zeolite and AC are given in Fig. 3. The identification of crystalline phase of these samples was done by comparison with JCPDS file (PCPDFWIN-2.01). The X-ray patterns of the synthesized compound match well with PDF: 500054, indicating the formation of $\text{AlPO}_4\text{-5}$ in the purest form. Furthermore, to know the grain size of the compound, profile analysis of the XRD pattern was done. The grain size analysis revealed that the grain size of $\text{AlPO}_4\text{-5}$ zeolites is approximately 48.864 nm. In the XRD pattern of AC, no strong peaks were observed

Table 1 Positron annihilation lifetime measurements (PALS) of AlPO_4 zeolite

Sample	τ_3 (ns); I_3 (%)	τ_4 (ns); I_4 (%)	Pore size ($V_p \pm 0.3$) ($\text{\AA}$) ³
$\text{AlPO}_4\text{-5}$	0.792; 17.33	2.10; 7.48	107.2

ns nanosecond

Table 2 PALS of AC

Sample	τ_2 (± 6) (ps)	$I_2 \pm 0.3$ (%)	Pore size ($V_p \pm 0.3$) ($\text{\AA}$) ³
AC (commercial)	320	86.6	2.94

Table 3 General water quality standards for industrial effluents and drinking water

Parameters	Tolerance limits for industrial effluents (IS: 2490, Part-I-1981)				Drinking water standards of BIS (IS: 10,500: 1991)	
	Into inland surface water sewersOn land for irrigation	Into inland surface water public sewersOn land for irrigation	Into inland surface water sewersOn land for irrigation	Into inland surface water public sewersOn land for irrigation	Desirable limits mg/L	Permissible limits mg/L
pH	5.5 to 9.0	5.5 to 9.0		5.5 to 9.0	6.5–8.5	No relaxation
TDS (ppm)	2100	2100		2100	500	2000
COD (mg/L)	250	–		–		
Calcium (mg/L)	–	–		–	75	200
Magnesium (mg/L)	–	–		–	30	100
Carbonate (mg/L)	–	–		–	300	600
Chloride (mg/L)	–	–		–	250	1000
Fe (mg/L)					0.3	1.0
Ni (mg/L)	3.0	3.0		–	–	–
Cd (mg/L)	2	1.0		–	0.01	No relaxation
Pb (mg/L)	0.1	1.0		–	0.05	No relaxation

confirming the amorphous nature of the substance used in the present study which is given in Fig. 3.

FTIR Studies

Figure 4 shows the FTIR spectra of $\text{AlPO}_4\text{-5}$ and AC. The sharp peak around $1100\text{--}1350\text{ cm}^{-1}$ is a special feature of ($\text{AlPO}_4\text{-5}$) zeolites that contains the hydrated triple crankshaft chains. The strongest vibration in this region refers to a P–O stretching mode, which is primarily associated with the movement of oxygen atoms [20]. The broadband in the spectral region around 1100 cm^{-1} is assigned to be the asymmetric stretching of PO_4 tetrahedra [21]. In Fig. 4, the spectrum of $\text{AlPO}_4\text{-5}$ shows evidence of typical characteristic peak at 470 and 630 cm^{-1} which are assigned to double ring and the O–P–O bending vibration [22]. The strong broad bands in the regions 3437 and 1645 cm^{-1} , corresponding to the OH groups, originated due to the adsorption of water molecules, amines, and by bending vibrations formed by the surface-adsorbed water molecules [23]. The band in the regions 703 , 685 , 668 , 650 , and 564 cm^{-1} corresponds to Al vibration. In the FTIR spectrum of AC, the band in the region $3600\text{--}3200\text{ cm}^{-1}$ range corresponds to the band of O–H stretching vibrations, formed by the existence of surface hydroxyl groups due to absorption of water molecules from the environment. The presence of bands at 1710 cm^{-1} is attributed to the stretching vibrations of C=O .

SEM Image of AlPO_4 Zeolite

The SEM image of synthesized $\text{AlPO}_4\text{-5}$ zeolite is given in Fig. 5a. Figure 5a clearly indicates that the synthesized compound is in a range of $70\text{--}80\text{ }\mu\text{m}$ and the as-prepared samples

are spherical in shape and well crystalline. Figure 5b shows representative $\text{AlPO}_4\text{-5}$ molecular sieves having 12 rings.

Positron Annihilation Lifetime Measurements of AlPO_4 Zeolite and AC

PALS of AlPO_4 zeolite and AC were carried out to know the pore size of the synthesized compound and AC. The result obtained is given in Tables 1 and 2. It was observed that the pore size of AlPO_4 zeolite is $107.2\text{ (}\text{\AA}\text{)}^3$ and that of AC is $2.94\text{ (}\text{\AA}\text{)}^3$. The presence of these pores helps in absorbing the organics present in wastewater and industrial effluent. The pore size of AlPO_4 zeolite is comparatively higher than that of AC which is helpful in absorbing/trapping bigger size particles whose sizes are in the micron range, which are present in effluent and industrial effluent, whereas the presence of smaller pores in AC is helpful in taking up those compounds whose sizes are lesser or equal to micrometer.

These characterized samples were further used in the filtration of wastewater and industrial effluent. Sewage water was collected as a source of wastewater from wastewater treatment plant, Mysore. Textile effluent was collected as a source of industrial effluent from Flair garments, Tandavpura industrial area, Mysore. These water samples were filtered using the filters as mentioned above, and chemical analyses were performed for the filtrate extracted as per standard methods mentioned for the examination of wastewater [24, 25]. The results obtained were compared with the general water quality standards recommended by the government of India given in Table 3 (The Environment (Protection) Rules in 1986).

pH is one of the most important factor in monitoring the quality of water. In the present work, the pH of the wastewater and effluent was reduced when passed through zeolite from

Table 4 Analytical and basic statistical results of treated wastewater and industrial effluent

Parameters	Sample	Untreated	Number of cycles	Treated using sand bed	Statistical values for samples treated	Treated using AlPO ₄ -5	Statistical values for samples treated using AlPO ₄ -5
Sand bed							
pH	Wastewater	7.62	1	8.10	Mean = 8.085	5.69	Mean = 5.62
			2	8.14	Variance = 0.016	5.72	Variance = 0.009
			3	8.2	SD = 0.13	5.54	SD = 0.09
			4	7.9		5.54	
	Effluent	9.2	1	8.88	Mean = 8.32	8.45	Mean = 8.45
			2	8.8	Variance = 0.38	8.38	Variance = 0.003
			3	8	SD = 0.62	8.47	SD = 0.13
			4	7.6		8.53	
EC (μS)	Wastewater	1694	1	1670	Mean = 1661	1639	Mean = 1621
			2	1665	Variance = 62	1626	Variance = 197.5
			3	1653	SD = 7.87	1609	SD = 14.05
			4	1656		1611	
	Effluent	3530	1	3600	Mean = 3523	3510	Mean = 3500
			2	3512	Variance = 2701	3503	Variance = 58.2
			3	3489	SD = 51.9	3492	SD = 7.63
			4	3493		3498	
TDS (ppm)	Wastewater	1084	1	1068	Mean = 1055	1048	Mean = 1028
			2	1057	Variance = 93.6	1032	Variance = 251
			3	1052	SD = 9.67	1021	SD = 15.8
			4	1045		1011	
	Effluent	2259	1	1664	Mean = 1659	1606	Mean = 1590
			2	1657	Variance = 24.6	1589	Variance = 109
			3	1662	SD = 4.9	1583	SD = 10.4
			4	1653		1585	
%T	Wastewater	72	1	89.3	Mean = 88.6	92.8	Mean = 92.4
			2	87.2	Variance = 1.1	93	Variance = 0.3
			3	88.4	SD = 1.04	92.1	SD = 0.6
			4	89.5		91.7	
	Effluent	27.2	1	28.5	Mean = 28.4	41.6	Mean = 41.1
			2	28.7	Variance = 0.04	40.7	Variance = 0.14
			3	28.2	SD = 0.2	41.2	SD = 0.37
			4	28.5		41	
COD (mg/L)	Wastewater	176	1	176	Mean = 174	104	Mean = 99.7
			2	172	Variance = 2.9	101	Variance = 12.2
			3	174	SD = 1.70	96	SD = 3.5
			4	175		98	
	Effluent	704	1	592	Mean = 584	536	Mean = 525
			2	586	Variance = 34.2	524	Variance = 68.2
			3	578	SD = 5.85	516	SD = 8.26
			4	583		527	
Calcium (mg/L)	Wastewater	360	1	380	Mean = 358	300	Mean = 295
			2	354	Variance = 223	294	Variance = 22
			3	347	SD = 14	289	SD = 4.6
			4	351		297	
	Effluent	120	1	120	Mean = 116	100	Mean = 96
			2	118	Variance = 9.6	97	Variance = 11.3
			3	113	SD = 3.1	92	SD = 3.3
			4	115		95	
Magnesium (mg/L)	Wastewater	144	1	336	Mean = 328	144	Mean = 136
			2	328	Variance = 74	136	Variance = 42
			3	332	SD = 8.6	128	SD = 6.5
			4	316		136	
	Effluent	138	1	156	Mean = 148	132	Mean = 125
			2	145	Variance = 34	122	Variance = 24
			3	151	SD = 5.9	126	SD = 4.9
			4	143		121	
Carbonate (mg/L)	Wastewater	40	1	46	Mean = 44.5	0	Mean = 0
			2	46	Variance = 3.6	0	Variance = 0
			3	42	SD = 1.9	0	SD = 0

Table 4 (continued)

	Effluent	360	4	44		0	
			1	240	Mean = 231	0	Mean = 2
			2	224	Variance = 46	0	Variance = 5.3
			3	232	SD = 6.8	4	SD = 2.3
Bicarbonate (mg/L)	Wastewater	3904	4	228		4	
			1	3904	Mean = 3829	854	Mean = 866
			2	3754	Variance = 5916	868	Variance = 82.6
			3	3886	SD = 76	876	SD = 9.0
	Effluent	4880	4	3772		866	
			1	3050	Mean = 3065	610	Mean = 630
			2	3067	Variance = 118	628	Variance = 250
			3	3074	SD = 10	648	SD = 15.8
Chloride (mg/L)	Wastewater	443.12	4	3072		635	
			1	248.15	Mean = 260	230.4	Mean = 247
			2	255	Variance = 126	242	Variance = 228
			3	274	SD = 11	254	SD = 15
	Effluent	230.42	4	264		265	
			1	212.7	Mean = 210	0	Mean = 2
			2	204	Variance = 26	0	Variance = 5.3
			3	208	SD = 5.1	4	SD = 2.3
Fe (mg/L)	Wastewater	0.309	4	216		4	
			1	0.261	Mean = 0.27	0.101	Mean = 0.11
			2	0.284	Variance = 0.000	0.118	Variance = 6.4
			3	0.257	SD = 0.013	0.112	SD = 0.008
	Effluent	0.247	4	0.280		0.118	
			1	0.218	Mean = 0.21	0.161	Mean = 0.16
			2	0.212	Variance = 3.3	0.168	Variance = 1.16
			3	0.224	SD = 0.005	0.168	SD = 0.003
Ni (mg/L)	Wastewater	0	4	0.224		0.164	
			1	0	Mean = 0	0	Mean = 0
			2	0	Variance = 0	0	Variance = 0
			3	0	SD = 0	0	SD = 0
	Effluent	0	4	0		0	
			1	0	Mean = 0	0	Mean = 0
			2	0	Variance = 0	0	Variance = 0
			3	0	SD = 0	0	SD = 0
Cd (mg/L)	Wastewater	0	4	0		0	
			1	0	Mean = 0	0	Mean = 0
			2	0	Variance = 0	0	Variance = 0
			3	0	SD = 0	0	SD = 0
	Effluent	0.573	4	0		0	
			1	0.135	Mean = 0.13	0.072	Mean = 0.07
			2	0.142	Variance = 2.2	0.076	Variance = 0.00
			3	0.135	SD = 0.004	0.082	SD = 0.004
Pb (mg/L)	Wastewater	0.036	4	0.144		0.076	
			1	0.033	Mean = 0.03	0.031	Mean = 0.029
			2	0.032	Variance = 9.17	0.024	Variance = 1.3
			3	0.033	SD = 0.0	0.032	SD = 0.003
	Effluent	0.065	4	0.031		0.031	
			1	0.056	Mean = 0.058	0.046	Mean = 0.04
			2	0.060	Variance = 5.33	0.036	Variance = 0.00
			3	0.060	SD = 0.002	0.042	SD = 0.004
AC			4	0.056		0.042	
	pH	7.62	1	7.20	Mean = 7.25	7.12	Mean = 7.13
			2	7.24	Variance = 0.002	7.16	Variance = 0.004
			3	7.32	SD = 0.05	7.12	SD = 0.02
	Effluent	9.2	4	7.26		7.12	
			1	8.60	Mean = 8.56	8.52	Mean = 8.48
			2	8.45	Variance = 0.006	8.45	Variance = 0.001
			3	8.58	SD = 0.08	8.52	SD = 0.04
EC (μS)	Wastewater	1694	4	8.64		8.45	
			1	1640	Mean = 1647	1628	Mean = 1625.5
			2	1652	Variance = 59.6	1632	Variance = 35.6

Table 4 (continued)

TDS (ppm)	Effluent	3530	3	1656	SD = 7.7	1624	SD = 5.9
			4	1642		1618	
			1	2490	Mean = 2509	2837	Mean = 2858
			2	2456	Variance = 2273	2852	Variance = 294
	Wastewater	1084	3	2526	SD = 47.68	2867	SD = 17.1
			4	2567		2876	
			1	1049	Mean = 1040	1035	Mean = 1013
			2	1036	Variance = 38.2	1024	Variance = 481
	Effluent	2259	3	1036	SD = 6.18	984	SD = 21.9
			4	1042		1012	
			1	1593	Mean = 1635	1580	Mean = 1587
			2	1645	Variance = 904	1598	Variance = 57
	Wastewater	72	3	1664	SD = 30	1586	SD = 7.5
			4	1638		1586	
			1	93.60	Mean = 92.5	93.10	Mean = 92.7
			2	92.80	Variance = 1.1	92.80	Variance = 0.05
%T	Effluent	27.2	3	92.60	SD = 1.08	92.60	SD = 0.23
			4	91.00		92.60	
			1	44.00	Mean = 45.2	42.80	Mean = 43.7
			2	46.40	Variance = 1.2	44.60	Variance = 0.7
	Wastewater	176	3	45.80	SD = 1.09	43.20	SD = 0.84
			4	44.60		44.20	
			1	40	Mean = 55	56	Mean = 61
			2	56	Variance = 110	60	Variance = 14.6
	Effluent	704	3	60	SD = 10.5	64	SD = 3.8
			4	64		64	
			1	240	Mean = 259	354	Mean = 363
			2	256	Variance = 206	356	Variance = 107
COD (mg/L)	Wastewater	360	3	268	SD = 14.3	368	SD = 10.3
			4	272		376	
			1	80	Mean = 98.5	199	Mean = 190
			2	96	Variance = 195	184	Variance = 48.9
	Effluent	120	3	112	SD = 13.9	186	SD = 6.99
			4	106		194	
			1	20	Mean = 27	72	Mean = 75
			2	24	Variance = 36	76	Variance = 4
Calcium (mg/L)	Wastewater	144	3	32	SD = 6	76	SD = 2
			4	32		76	
			1	72	Mean = 74	98	Mean = 92
			2	72	Variance = 5.3	86	Variance = 24
	Effluent	138	3	76	SD = 2.3	92	SD = 4.8
			4	76		92	
			1	48	Mean = 47.5	93	Mean = 86.7
			2	44	Variance = 11.6	84	Variance = 18.2
Magnesium (mg/L)	Wastewater	40	3	52	SD = 3.4	86	SD = 4.2
			4	46		84	
			1	24	Mean = 26	17	Mean = 20.5
			2	24	Variance = 16	17	Variance = 16.3
	Effluent	360	3	32	SD = 4	24	SD = 4.0
			4	24		24	
			1	120	Mean = 127	84	Mean = 89
			2	136	Variance = 46.6	96	Variance = 36
Carbonate (mg/L)	Wastewater	3904	3	124	SD = 6.8	92	SD = 6
			4	128		84	
			1	3050	Mean = 3056	1943	Mean = 1957
			2	3056	Variance = 24	1956	Variance = 110
	Effluent	4880	3	3062	SD = 4.89	1963	SD = 10.5
			4	3056		1967	
			1	732	Mean = 739	650	Mean = 662
			2	748	Variance = 49	666	Variance = 86
Bicarbonate (mg/L)	Wastewater	443.12	3	736	SD = 7	672	SD = 9
			4	742		662	
			1	212	Mean = 207	215	Mean = 211
			2	204	Variance = 14.6	212	Variance = 8.25

Table 4 (continued)

			3	208	SD = 3.8	212	SD = 2.87
			4	204		208	
	Effluent	230.42	1	53	Mean = 56.5	34	Mean = 39
			2	60	Variance = 9.6	36	Variance = 38.6
			3	58	SD = 3.1	38	SD = 6.21
			4	55		48	
Fe (mg/L)	Wastewater	0.309	1	0.173	Mean = 0.181	0.138	Mean = 0.14
			2	0.184	Variance = 3.03	0.142	Variance = 5.33
			3	0.184	SD = 0.005	0.138	SD = 0.002
			4	0.184		0.142	
	Effluent	0.247	1	0.181	Mean = 0.191	0.172	Mean = 0.17
			2	0.198	Variance = 5.49	0.176	Variance = 2.23
			3	0.194	SD = 0.007	0.172	SD = 0.004
			4	0.194		0.182	
Ni (mg/L)	Wastewater	0	1	0	Mean = 0	0	Mean = 0
			2	0	Variance = 0	0	Variance = 0
			3	0	SD = 0	0	SD = 0
			4	0		0	
	Effluent	0	1	0	Mean = 0	0	Mean = 0
			2	0	Variance = 0	0	Variance = 0
			3	0	SD = 0	0	SD = 0
			4	0		0	
Cd (mg/L)	Wastewater	0	1	0	Mean = 0	0	Mean = 0
			2	0	Variance = 0	0	Variance = 0
			3	0	SD = 0	0	SD = 0
			4	0		0	
	Effluent	0.573	1	0.045	Mean = 0.05	0.058	Mean = 0.06
			2	0.054	Variance = 4.83	0.058	Variance = 5.33
			3	0.054	SD = 0.006	0.062	SD = 0.002
			4	0.062		0.062	
Pb (mg/L)	Wastewater	0.036	1	0.029	Mean = 0.029	0.027	Mean = 0.027
			2	0.031	Variance = 2.25	0.026	Variance = 1.58
			3	0.031	SD = 0.001	0.027	SD = 0.001
			4	0.028		0.029	
	Effluent	0.065	1	0.019	Mean = 0.023	0.030	Mean = 0.030
			2	0.023	Variance = 1.43	0.032	Variance = 3.67
			3	0.028	SD = 0.003	0.028	SD = 0.001
			4	0.025		0.032	

7.62 to 5.69 and 9.2 to 8.45, respectively. This is because zeolite is weakly acidic in nature leading to increase in pH when the solution/samples are passed through them. The pH

Fig. 6 Graphical representation of COD values for 4 cycles using the wastewater sample

of the filtrate dropped from 7.62 to 7.12 and 9.2 to 8.52 when passed through the combination filters of AC and $\text{AlPO}_4\cdot 5$. The EC of the wastewater and effluent was reduced when filtered through zeolite, sand bed, AC, and combination of filters. It was observed that the electrical conductivity was reduced to the greatest when filtered through the combination filter. The porous nature and the sorptive property of both zeolite and AC favor the removal of dissolved salts. It is well known that the value of TDS increases as the EC of the water increases. In the present study, it was observed that the TDS of the sample decreases effectively when passed through a combination filter indicating the absorption of dissolved solid and organics present in the samples. The literature survey reveals that as TDS of the water sample decreases as the %T increases. In the experiments conducted, the %T was the greatest for the samples filtered through AC. The pore size of the AC is less when compared to that of $\text{AlPO}_4\cdot 5$, which was confirmed from PALS. These microporous structures or channels present in AC play a major role in the removal of dissolved solid.

Table 5 Pearson correlation coefficients showing the relation between all parameters of water samples (wastewater and industrial effluent) treated using sand bed

		pH	EC (μ S)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
pH	Pearson correlation Sig. (2-tailed) N	1	0.312	0.296	-0.289	0.300	-0.275	-0.259	0.300	-0.287	-0.331	-0.407	. ^a	0.275	0.309
EC (μ S)	Pearson correlation Sig. (2-tailed) N	8	0.452	0.477	0.487	0.470	0.510	0.536	0.471	0.490	0.424	0.317	. ^a	0.510	0.456
TDS (ppm)	Pearson correlation Sig. (2-tailed) N	0.312	1	0.999**	-0.999**	1.000**	-0.996**	-0.996**	1.000**	-0.992**	-0.957**	-0.944**	. ^a	0.998**	0.991**
T (%)	Pearson correlation Sig. (2-tailed) N	0.452	8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	. ^a	0.000	0.000
COD (mg/L)	Pearson correlation Sig. (2-tailed) N	0.296	0.999**	1	-1.000**	1.000**	-0.995**	-0.996**	0.999**	-0.991**	-0.961**	-0.945**	. ^a	0.998**	0.994**
Calcium (mg/L)	Pearson correlation Sig. (2-tailed) N	0.477	0.000	8	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	. ^a	0.000	0.000
Magnesium (mg/L)	Pearson correlation Sig. (2-tailed) N	-0.289	8	-1.000**	1	-0.999**	0.997**	0.997**	-0.999**	0.993**	0.957**	0.940**	. ^a	-0.999**	-0.993**
Carbonate (mg/L)	Pearson correlation Sig. (2-tailed) N	0.487	0.000	0.000	8	0.000	0.000	0.000	0.000	0.000	0.000	0.001	. ^a	0.000	0.000
Bicarbonate (mg/L)	Pearson correlation Sig. (2-tailed) N	0.300	1.000**	1.000**	-0.999**	1	-0.996**	-0.997**	0.999**	-0.992**	-0.957**	-0.945**	. ^a	0.999**	0.992**
Chloride (mg/L)	Pearson correlation Sig. (2-tailed) N	0.470	0.000	0.000	0.000	8	0.000	0.000	0.000	0.000	0.000	0.000	. ^a	0.000	0.000
Fe (mg/L)	Pearson correlation Sig. (2-tailed) N	-0.275	-0.996**	-0.995**	0.997**	-0.996**	1	0.997**	-0.995**	0.994**	0.938**	0.932**	. ^a	-0.996**	-0.989**
Ni (mg/L)	Pearson correlation Sig. (2-tailed) N	0.510	0.000	0.000	0.000	0.000	8	0.000	0.000	0.000	0.001	0.001	. ^a	0.000	0.000
Cd (mg/L)	Pearson correlation Sig. (2-tailed) N	-0.259	-0.996**	-0.996**	0.997**	-0.997**	0.997**	1	-0.995**	0.995**	0.950**	0.928**	. ^a	-0.998**	-0.989**
	Pearson correlation Sig. (2-tailed) N	0.536	0.000	0.000	0.000	0.000	0.000	8	0.000	0.000	0.000	0.001	. ^a	0.000	0.000
	Pearson correlation Sig. (2-tailed) N	0.300	1.000**	0.999**	-0.999**	0.999**	-0.995**	-0.995**	1	-0.992**	-0.957**	-0.939**	. ^a	0.997**	0.989**
	Pearson correlation Sig. (2-tailed) N	0.471	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	. ^a	0.000	0.000
	Pearson correlation Sig. (2-tailed) N	-0.287	-0.992**	-0.991**	0.993**	-0.992**	0.994**	0.995**	-0.992**	1	0.950**	0.901**	. ^a	-0.991**	-0.980**
	Pearson correlation Sig. (2-tailed) N	0.490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8	0.000	0.002	. ^a	0.000	0.000
	Pearson correlation Sig. (2-tailed) N	-0.331	-0.957**	-0.961**	0.957**	-0.957**	0.938**	0.950**	-0.957**	0.950**	1	0.895**	. ^a	-0.956**	-0.963**
	Pearson correlation Sig. (2-tailed) N	0.424	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	8	0.003	. ^a	0.000	.000
	Pearson correlation Sig. (2-tailed) N	-0.407	-0.944**	-0.945**	0.940**	-0.945**	0.932**	0.928**	-0.939**	0.901**	0.895**	1	. ^a	-0.943**	-0.953**
	Pearson correlation Sig. (2-tailed) N	0.317	0.000	0.000	0.001	0.000	0.001	0.001	0.002	0.002	0.003	8	. ^a	0.000	0.000
	Pearson correlation Sig. (2-tailed) N	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a
	Pearson correlation Sig. (2-tailed) N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation Sig. (2-tailed) N	0.275	0.998**	0.998**	-0.999**	0.999**	-0.996**	-0.998**	0.997**	-0.991**	-0.956**	-0.943**	. ^a	1	0.992**
	Pearson correlation Sig. (2-tailed) N	0.510	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	. ^a	0.000	0.000

Table 5 (continued)

	pH	EC (μ S)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
Pb (mg/L)	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	0.309	0.991 ^{***}	0.994 ^{***}	-0.993 ^{***}	0.992 ^{***}	-0.989 ^{***}	-0.989 ^{***}	0.989 ^{***}	-0.980 ^{***}	-0.963 ^{***}	-0.953 ^{***}	.	0.992 ^{***}	1
N	Pearson correlation													
	0.456	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.	0.000	.
N	Sig. (2-tailed)													
	8	8	8	8	8	8	8	8	8	8	8	8	8	8

^a Cannot be computed because at least one of the variables is constant

***Correlation is significant at the 0.01 level (2-tailed)

Similarly, there was a greatest reduction in COD value when passed through AC as compared to other two filters, which infers the removal or the reduction of the organics present in the wastewater and effluent. Calcium and magnesium are among the major cations present in water. Carbonate and bicarbonate are those salts which cause hardness in water; these salts were completely removed when filtered through zeolite. This is due to the ion exchange property of zeolite. In general, chloride content normally increases as the mineral content increases. The removal of chloride was effective when passed through zeolite beds. Iron, cadmium, nickel, and lead are some of the heavy metals which are normally present in the wastewater and effluents. When the samples were tested, it was observed that Ni was absent in both wastewater and effluent, whereas Cd was absent in wastewater. Upon treatment, the heavy metals were reduced effectively using AC, zeolite, and a combination of both.

When $\text{AlPO}_4\text{-5}$ and AC are arranged in the form of beds of known thickness, two types of porous nature are formed within the beds. The voids present in between the crystals of $\text{AlPO}_4\text{-5}$ and AC behave as macropores when arranged as beds, whereas micropores are present within the crystals of $\text{AlPO}_4\text{-5}$ and AC. Removal of organics/dissolved solids/salts/heavy metals is governed by the diffusion of the effluent/wastewater when passed through the macropores of the beds as well as the micropores present in the crystals. When passed through $\text{AlPO}_4\text{-5}$, the ion exchange property of $\text{AlPO}_4\text{-5}$, which depends on the properties such as ion-sieve, steric, and electrostatic forces within the zeolite pores, plays a key role in trapping the impurities present in the sample. Sorption of heavy metals by $\text{AlPO}_4\text{-5}$ depends on the ion exchange or the chemisorption ability of the material. The ability of $\text{AlPO}_4\text{-5}$ to sorb heavy metal effectively depends on the charge of aluminum present in $\text{AlPO}_4\text{-5}$ framework, size of $\text{AlPO}_4\text{-5}$ particle, its porous nature, and thickness of $\text{AlPO}_4\text{-5}$ when used as a filter. Al with higher charges and small radii favors the sorption of heavy metals. Removal of heavy metal is ascribed to various mechanisms involved during ion exchange and sorption processes. The $\text{AlPO}_4\text{-5}$ consists of large channels containing negatively charged sites resulting from Al^{3+} . Ions of sodium, calcium, and potassium which are positively charged get accumulated into the channels of $\text{AlPO}_4\text{-5}$ which will further be replaced by heavy metals. During the ion exchange process, lead, iron, and cadmium ions pass through the macropores of the zeolite bed and through the microchannels of the crystals, and gets replaced by the exchangeable cation present within the channels. During ion exchange process, the OH^- groups present on $\text{AlPO}_4\text{-5}$ framework form strong chemical bonds with metal ions resulting in the formation of stable complexes. Similarly, the properties of AC, like adsorption, absorption, porosity, and aspect ratio, also play a major role in trapping/removal of impurities present in both wastewater and industrial effluent.

Table 6 Pearson correlation coefficients showing the relation between all parameters of water samples (wastewater and industrial effluent) treated using $\text{AlPO}_4\text{-5}$

		pH	EC (μS)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
pH	Pearson correlation	1	0.998**	0.992**	-0.997**	0.994**	-0.951**	-0.969**	0.989**	-0.996**	-0.997**	0.671	. ^a	0.986**	-0.758*
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.069	.	0.000	0.029
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
EC (μS)	Pearson correlation	0.998**	1	0.996**	-0.998**	0.996**	-0.959**	-0.976**	0.992**	-0.998**	-0.998**	0.684	. ^a	0.992**	-0.745*
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.062	.	0.000	0.034
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
TDS (ppm)	Pearson correlation	0.992**	0.996**	1	-0.996**	0.996**	-0.963**	-0.979**	0.996**	-0.998**	-0.996**	0.706	. ^a	0.992**	-0.736*
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	.	0.000	0.037
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
T (%)	Pearson correlation	-0.997**	-0.998**	-0.996**	1	-0.994**	0.963**	0.979**	-0.993**	0.999**	1.000**	-0.674	. ^a	-0.986**	0.781*
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.067	.	0.000	0.022
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
COD (mg/L)	Pearson correlation	0.994**	0.996**	0.996**	-0.994**	1	-0.940**	-0.970**	0.993**	-0.994**	-0.994**	0.740	. ^a	0.994**	-0.719*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.001	0.000	0.000	0.000	0.000	0.036	.	0.000	0.045
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Calcium (mg/L)	Pearson correlation	-0.951**	-0.959**	-0.963**	0.963**	-0.940**	1	0.977**	-0.955**	0.968**	0.963**	-0.535	. ^a	-0.943**	0.812*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.001		0.000	0.000	0.000	0.000	0.172	.	0.000	0.014
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Magnesium (mg/L)	Pearson correlation	-0.969**	-0.976**	-0.979**	0.979**	-0.970**	0.977**	1	-0.984**	0.982**	0.980**	-0.667	. ^a	-0.976**	0.793*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.001	0.000		0.000	0.000	0.000	0.071	.	0.000	0.019
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Carbonate (mg/L)	Pearson correlation	0.989**	0.992**	0.996**	-0.993**	0.993**	-0.955**	-0.984**	1	-0.995**	-0.993**	0.725	. ^a	0.990**	-0.750*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	.	0.000	0.032
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Bicarbonate (mg/L)	Pearson correlation	-0.996**	-0.998**	-0.998**	0.999**	-0.994**	0.968**	0.982**	-0.995**	1	0.999**	-0.678	. ^a	-0.987**	0.771*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.065	.	0.000	0.025
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Chloride (mg/L)	Pearson correlation	-0.997**	-0.998**	-0.996**	1.000**	-0.994**	0.963**	0.980**	-0.993**	0.999**	1	-0.679	. ^a	-0.986**	0.777*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.064	.	0.000	0.023
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Table 6 (continued)

	pH	EC (μS)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
<i>N</i>	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Pearson correlation	0.671	0.684	0.706	-0.674	0.740 [*]	-0.535	-0.667	0.725 [*]	-0.678	-0.679 [*]	1	. ^a	0.741 [*]	-0.245
Sig. (2-tailed)	0.069	0.062	0.050	0.067	0.036	0.172	0.071	0.042	0.065	0.064		.	0.036	0.558
<i>N</i>	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Pearson correlation	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a
Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>N</i>	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Pearson correlation	0.986 ^{***}	0.992 ^{***}	0.992 ^{***}	-0.986 ^{***}	0.994 ^{***}	-0.943 ^{***}	-0.976 ^{***}	0.990 ^{***}	-0.987 ^{***}	-0.986 ^{***}	0.741 [*]	. ^a	1	-0.698
Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	.		0.054
<i>N</i>	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Pearson correlation	-0.758 [*]	-0.745 [*]	-0.736 [*]	0.781 [*]	-0.719 [*]	0.812 [*]	0.793 [*]	-0.750 [*]	0.771 [*]	0.777 [*]	-0.245 [*]	. ^a	-0.698	1
Sig. (2-tailed)	0.029	0.034	0.037	0.022	0.045	0.014	0.019	0.032	0.025	0.023	0.558	.	0.054	
<i>N</i>	8	8	8	8	8	8	8	8	8	8	8	8	8	8

^a Cannot be computed because at least one of the variables is constant

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 7 Pearson correlation coefficients showing the relation between all parameters of water samples (wastewater and industrial effluent) treated using AC

		pH	EC (μS)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
pH	Pearson correlation	1	0.999**	0.998**	-1.000**	0.998**	-0.998**	-0.544	0.989**	-0.999**	-0.999**	0.979**	. ^a	0.998**	0.734*
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.163	0.000	0.000	0.000	0.000	.	0.000	0.038
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
EC (μS)	Pearson correlation	0.999**	1	0.999**	-0.999**	0.999**	-0.997**	-0.559	0.991**	-1.000**	-0.998**	0.985**	. ^a	0.999**	0.755*
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000	0.150	0.000	0.000	0.000	0.000	.	0.000	0.030
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
TDS (ppm)	Pearson correlation	0.998**	0.999**	1	-0.998**	0.997**	-0.994**	-0.550	0.989**	-0.999**	-0.997**	0.984**	. ^a	0.997**	0.757*
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.158	0.000	0.000	0.000	0.000	.	0.000	0.030
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
T (%)	Pearson correlation	-1.000**	-0.999**	-0.998**	1	-0.999**	0.997**	0.543	-0.991**	1.000**	0.999**	-0.981**	. ^a	-0.999**	-0.749*
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.165	0.000	0.000	0.000	0.000	.	0.000	0.033
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
COD (mg/L)	Pearson correlation	0.998**	0.999**	0.997**	-0.999**	1	-0.996**	-0.567	0.990**	-0.999**	-0.996**	0.988**	. ^a	1.000**	0.759*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000	0.142	0.000	0.000	0.000	0.000	.	0.000	0.029
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Calcium (mg/L)	Pearson correlation	-0.998**	-0.997**	-0.994**	0.997**	-0.996**	1	0.578	-0.988**	0.997**	0.997**	-0.981**	. ^a	-0.995**	-0.739*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000		0.133	0.000	0.000	0.000	0.000	.	0.000	0.036
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Magnesium (mg/L)	Pearson correlation	-0.544	-0.559	-0.550	0.543	-0.567	0.578	1	-0.576	0.544	0.541	-0.633	. ^a	-0.562	-0.459
	Sig. (2-tailed)	0.163	0.150	0.158	0.165	0.142	0.133		0.135	0.164	0.166	0.092	.	0.147	0.252
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Carbonate (mg/L)	Pearson correlation	0.989**	0.991**	0.989**	-0.991**	0.990**	-0.988**	-0.576	1	-0.990**	-0.993**	0.971**	. ^a	0.990**	0.765*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.135		0.000	0.000	0.000	.	0.000	0.027
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Bicarbonate (mg/L)	Pearson correlation	-0.999**	-1.000**	-0.999**	1.000**	-0.999**	0.997**	0.544	-0.990**	1	0.999**	-0.983**	. ^a	-0.999**	-0.756*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.135		0.000	0.000	0.000	.	0.000	0.030
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Chloride (mg/L)	Pearson correlation	-0.999**	-0.998**	-0.997**	0.999**	-0.996**	0.997**	0.541	-0.993**	0.999**	1	-0.978**	. ^a	-0.996**	-0.752*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.166	0.000	0.000	0.000	0.000	.	0.000	0.031
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Table 7 (continued)

		pH	EC (μS)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
Fe (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	0.979**	0.985**	0.984**	-0.981**	0.988**	-0.981**	-0.633	0.971**	-0.983**	-0.978**	1	. ^a	0.986**	0.819*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.092	0.000	0.000	0.000		.	0.000	0.013
Ni (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cd (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	0.998**	0.999**	0.997**	-0.999**	1.000**	-0.995**	-0.562	0.990**	-0.999**	-0.996**	0.986**	. ^a	1	0.748*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.147	0.000	0.000	0.000	0.000	.		0.033
Pb (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	0.734*	0.755*	0.757*	-0.749*	0.759*	-0.739*	-0.459	0.765*	-0.756*	-0.752*	0.819*	. ^a	0.748*	1
	Sig. (2-tailed)	0.038	0.030	0.030	0.033	0.029	0.036	0.252	0.027	0.030	0.031	0.013	.	0.033	
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8

^a Cannot be computed because at least one of the variables is constant

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 8 Pearson correlation coefficients showing the relation between all parameters of water samples (wastewater and industrial effluent) treated using combination of AC and AlPO_4 -5

		pH	EC (μS)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
pH	Pearson correlation	1	0.999**	0.999**	-0.998**	0.999**	-0.998**	-0.716*	0.594	-0.995**	-0.998**	0.976**	. ^a	0.997**	0.865**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.046	0.121	0.000	0.000	0.000	.	0.000	0.006
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
EC (μS)	Pearson correlation	0.999**	1	0.999**	-1.000**	1.000**	-0.999**	-0.724*	0.574	-0.996**	-0.998**	0.979**	. ^a	0.997**	0.870**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000	0.042	0.137	0.000	0.000	0.000	.	0.000	0.005
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
TDS (ppm)	Pearson correlation	0.999**	0.999**	1	-0.998**	1.000**	-0.998**	-0.709*	0.563	-0.998**	-0.999**	0.973**	. ^a	0.996**	0.872**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.049	0.146	0.000	0.000	0.000	.	0.000	0.005
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
T (%)	Pearson correlation	-0.998**	-1.000**	-0.998**	1	-0.999**	0.999**	0.737*	-0.578	0.995**	0.996**	-0.982**	. ^a	-0.998**	-0.870**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.037	0.134	0.000	0.000	0.000	.	0.000	0.005
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
COD (mg/L)	Pearson correlation	0.999**	1.000**	1.000**	-0.999**	1	-0.998**	-0.720*	0.566	-0.997**	-0.998**	0.977**	. ^a	0.996**	0.874**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000	0.044	0.144	0.000	0.000	0.000	.	0.000	0.005
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Calcium (mg/L)	Pearson correlation	-0.998**	-0.999**	-0.998**	0.999**	-0.998**	1	0.749*	-0.591	0.992**	0.995**	-0.983**	. ^a	-0.999**	-0.868**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000		0.033	0.122	0.000	0.000	0.000	.	0.000	0.005
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Magnesium (mg/L)	Pearson correlation	-0.716*	-0.724*	-0.709*	0.737*	-0.720*	0.749*	1	-0.559	0.682	0.700	-0.790*	. ^a	-0.738*	-0.541
	Sig. (2-tailed)	0.046	0.042	0.049	0.037	0.044	0.033		0.150	0.063	0.053	0.020	.	0.036	0.167
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Carbonate (mg/L)	Pearson correlation	0.594	0.574	0.563	-0.578	0.566	-0.591	-0.559	1	-0.520	-0.566	0.582	. ^a	0.614	0.545
	Sig. (2-tailed)	0.121	0.137	0.146	0.134	0.144	0.122	0.150		0.187	0.143	0.130	.	0.106	0.163
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Bicarbonate (mg/L)	Pearson correlation	-0.995**	-0.996**	-0.998**	0.995**	-0.997**	0.992**	0.682	-0.520	1	0.996**	-0.966**	. ^a	-0.988**	-0.878**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.187		0.000	0.000	.	0.000	0.004
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Chloride (mg/L)	Pearson correlation	-0.998**	-0.998**	-0.999**	0.996**	-0.998**	0.995**	0.700	-0.566	0.996**	1	-0.968**	. ^a	-0.994**	-0.861**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.053	0.143	0.000		0.000	.	0.000	0.006
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Table 8 (continued)

		pH	EC (μS)	TDS (ppm)	T (%)	COD (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Fe (mg/L)	Ni (mg/L)	Cd (mg/L)	Pb (mg/L)
Fe (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	0.976 ^{***}	0.979 ^{***}	0.973 ^{***}	-0.982 ^{***}	0.977 ^{***}	-0.983 ^{***}	-0.790 [*]	0.582	-0.966 ^{***}	-0.968 ^{***}	1	. ^a	0.982 ^{***}	0.804 [*]
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.130	0.000	0.000		.	0.000	0.016
Ni (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cd (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	0.997 ^{***}	0.997 ^{***}	0.996 ^{***}	-0.998 ^{***}	0.996 ^{***}	-0.999 ^{***}	-0.738 [*]	0.614	-0.988 ^{***}	-0.994 ^{***}	0.982 ^{***}	. ^a	1	0.862 ^{***}
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.106	0.000	0.000		.		0.006
Pb (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Pearson correlation	0.865 ^{***}	0.870 ^{***}	0.872 ^{***}	-0.870 ^{***}	0.874 ^{***}	-0.868 ^{***}	-0.541	0.545	-0.878 ^{***}	-0.861 ^{***}	0.804 [*]	. ^a	0.862 ^{***}	1
	Sig. (2-tailed)	0.006	0.005	0.005	0.005	0.005	0.005	0.167	0.163	0.004	0.006	0.016	.	0.006	
	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8

^a Cannot be computed because at least one of the variables is constant

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Based on the results obtained (Table 4), we can conclude that $\text{AlPO}_4\text{-5}$ and the combination of AC and $\text{AlPO}_4\text{-5}$ serves effectively when compared to other filters. The results obtained were compared with the water quality standards, (Table 3) which clearly demonstrates that for most of the parameters, $\text{AlPO}_4\text{-5}$ alone and the combination of AC and $\text{AlPO}_4\text{-5}$ filters yield good results. After filtration, almost all the parameters lie within the tolerance limit as recommended by the Indian standards. Furthermore, to know the efficiency of all the filters, filtration was continued for 4 cycles using both wastewater and industrial effluent. After collecting the filtrate (for every 2 h), the filter was washed thoroughly with distilled water, and the whole assembly was kept for drying in oven maintaining temperature of 40 °C for 24–48 h. The dried filter was again used for filtration process. At every 2-h interval, samples were collected and subjected to chemical analysis. The results obtained for COD test using wastewater for 4 cycles are given in Fig. 6. It was observed that even after 4 cycles, the efficiency of the combined filter was almost the same, confirming that these filters can be used repeatedly. Similar results were obtained for almost all parameters which are given in Table 4.

Basic statistical analysis, such as mean, variance, and standard deviation were analyzed using Origin 8. The results obtained are given in Table 4. Correlation analyses were performed to know the linear relationship between water quality parameters. It is well known that correlation is a measure of degree of linear relationship between two variables. In correlation analysis, the value ranges from –1 to 1. If the values are closer to 1, there is a strong positive linear relationship between the variables being correlated, whereas if the values are closer to 0, it indicates that there is no linear relationship between two variables. The water quality parameter results of all the filtrate obtained using the above-mentioned filters for 4 cycles were subjected to Pearson correlation analysis. The results obtained are given in Tables 5–8. The overall statistical results infer that most of the water quality parameters show positive linear relationship, where as few parameters shows negative linear relationship which are significant at 1 and 5 % levels. Comparing Tables 5–8, we can say that there is a more positive correlation between the water quality parameters and are statistically significant at the 1 % level, when treated through sand bed filter. However, the strength of the positive correlation is less (Table 5). In case of $\text{AlPO}_4\text{-5}$ and AC filters, most of the water quality parameters show negative correlation and are statistically significant at 1 and 5 % levels which are given in Tables 6 and 7. The results of the combination filter ($\text{AlPO}_4\text{-5}$ and AC) were compared with the results of the above three filters. The results confirm that most of the water quality parameters show positive linear relationship with few parameters showing negative linear relationship and are statistically significant at 1 and 5 % levels (Table 8).

Conclusions

$\text{AlPO}_4\text{-5}$ was successfully synthesized using the hydrothermal technique. In hydrothermal technique, experiment is carried in a closed system and so the purity of the product can be expected which was confirmed by XRD studies. XRD, FTIR, and SEM confirm one of the possible conditions for the synthesis of $\text{AlPO}_4\text{-5}$. The use of AC, $\text{AlPO}_4\text{-5}$, and the combination of $\text{AlPO}_4\text{-5}$ and AC as filters for the treatment of wastewater and industrial effluent is more effective when compared to sand filters having beds of several thicknesses. Our experiment further confirms that the amount of material used to design the $\text{AlPO}_4\text{-5}$ filters or the combination of AC and $\text{AlPO}_4\text{-5}$ is comparatively less than sand gravity filters which occupy more space. Ion exchange, adsorption, absorption, porous nature, aspect ratio, and surface area are some of the important properties that have to be considered for the materials used in the treatment of wastewater and effluents. Both zeolite and AC possess all of the above-mentioned properties which make them great substances that can be used for the effective treatment wastewater/industrial effluent. For most of the parameters, the combination of $\text{AlPO}_4\text{-5}$ and AC yields favorable results which were confirmed by chemical and statistical analysis. The combined properties possessed by $\text{AlPO}_4\text{-5}$ and AC enhance the efficiency of the filter for handling of effluent and industrial effluent.

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