Investigation of the Application of Zeolites in the Adsorption Mechanism

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ABSTRACT

Zeolites are a group of hydrated aluminosilicates crystallized with fine pores that contain equilibrium cations of alkaline and alkaline earth metals (Na+, K+, Mg2+ and Ca2+) and reversibly absorb and release water. One of their characteristics is that they are able to reabsorb and re-release water and exchange some of their own building cations without major changes in their building. The presence of metals in the water of rivers and seawater poses a serious threat to the health of the aquatic community, the most common of which is damage to the gills of fish. Metals such as lead, cadmium, copper, arsenic, nickel, chromium, zinc, mercury, iron are known as heavy metals. These metals tend to accumulate in environmental systems and seriously contaminate soil and water, which can be harmful to humans, animals and plants even in low concentrations. Unlike biodegradable organic matter, metal ions are not removed from aquatic ecosystems by natural processes, which encourages scientists to develop new methods for removing heavy metal ions from water. As a result, in many countries, laws have been introduced to control water pollution. Various regulatory bodies have set maximum limits for the discharge of toxic heavy metals into aquatic systems. However, metal ions with a much higher concentration than usual are discharged into the water by industrial activities, leading to health hazards and environmental degradation.

1. Introduction

The human body and many other living organisms need small amounts of these heavy metals, but mainly consuming small amounts of them for humans and other living organisms can be pathogenic and cause many problems for the consumer. Heavy metals in the field of bio absorption are divided into three groups, the first category of toxic metals including: nickel-cobalt-zinc-lead and mercury. The second category includes: precious metals such as palladium-platinum-silver-gold and finally the third category includes: radionuclides Such as radium-uranium-ammerium, which typically weigh more than 5 grams per cubic centimeter. Biologists use the term heavy metal for metals that cause a variety of diseases and are harmful to humans [1, 2].

If the amount of these essential metals entering the body is too much, they can cause poisoning. In addition to carbohydrates, lipids, amino acids, and vitamins, some heavy metals are essential for the biological activity of cells, some metals, such as chromium and iron, are vital to life, and others, such as copper, zinc, and lead, are

essential for activity enzymes are essential. Maleki et al. studied the uptake of cadmium and copper by wheat straw modified with sodium bicarbonate from the aqueous medium. The adsorption process was intermittently studied in vitro with emphasis on the effects of various parameters such as PH, contact time, arsenic concentration and the amount of adsorbent on the adsorption efficiency. In order to better understand the adsorption process, equilibrium isotherms were determined [3-5].

The results showed that the adsorption of cadmium and copper is affected by factors such as initial concentration, amount of adsorbent and pH of the aqueous medium. The amount of adsorbed metal ions increased with increasing PH. Among the three isotherm models studied, including Langmuir, Freundlich and Dubinin-Radushkovich, two models, Langmuir and Freundlich, described the adsorption of cadmium and copper well. The average free adsorption energy (11.1 kJ/mol for cadmium and 11.4 kJ/mol for copper) indicates the mechanism of chemical adsorption of both metals on the adsorbent. Based on the results of this study, it can be stated that the adsorption

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method using modified wheat straw is an efficient and reliable method for removing cadmium and copper from aqueous solutions. Hamid Raftari et al. used tea leaf and wheat straw waste to absorb lead and sawdust and rice paddy husk adsorbents were used to absorb copper from contaminated water by discontinuous and continuous experiments. According to the results of discontinuous experiments, the equilibrium time was 2 hours, which was consistent with the Langmuir and Freundlich isotherms. Based on the results, the maximum adsorption of lead metal for adsorption of tea leaf wastes and wheat straw in continuous experiments was 99.5% and the adsorption of copper metal by sawdust and rice paddy husk was 95% and 63%, respectively [6-9].

The permissible limits for toxic heavy metals in industrial effluents as well as in drinking water for different standards are given in Table (1).

Table 1. Limit of metals in effluents from drinking water sources

Metals	Limit for industrial effluent discharge (mg / l)				Limit for drinking water (mg / l)			
	Indian standard			WHO				
	Internal surface water	General sewage	Sea coastal areas	Internal surface water	Indian Standard IS 10,500	WHO	USEPA	EU standard
Nickel	3/0	3/0	5/0	-	0/02	0/02	0/1	0/02
Zinc	5/0	15/0	15/0	5-15	5/0	3/0	5/0	-
copper	3/0	3/0	3/0	1/5-0/05	1/5	2/0	1/3	2/0
Cadmium	2/0	1/0	2/0	0/1	0/01	0/003	0/005	0/005
Lead	0/10	1/0	2/0	0/1	0/05	0/01	0/015	0/01
Chrome	2/0	2/0	2/0	-	0/05	0/05	0/1	0/05
Arsenic	0/2	0/2	0/2	-	0/01	0/01	0/01	0/01
Mercury	0/01	0/01	0/01	-	0/001	0/001	0/002	0/001
Iron	3/0	3/0	3/0	0/1	0/3	0/2	0/3	0/2
Manganese	2/0	2/0	2/0	0/5-0/05	0/1	0/5	0/05	0/05
Vanadium	0/2	0/2	0/2	-	-	1/4	-	-

2. Adsorption

Adsorption is the process by which liquid or gas particles, as adsorbents, settle on the surface of a liquid or solid adsorbent and form a layer of adsorbed atoms or molecules. Adsorption generally takes place at the solid-liquid interface and is therefore different from the adsorption process in which a substance penetrates into a solid or liquid to form a solution. The term surface adsorption was first coined in the late nineteenth century, but the process itself had little industrial application until activated carbon was first used to treat the city's water in the 1940s and 1950s. The adsorption process can be considered as a simple and effective process for removing heavy metals and dyes from water. In adsorption, various low-cost adsorbents with high availability and high efficiency can be used to replace inexpensive adsorbents with expensive commercial adsorbents. The use of adsorption method includes other advantages such as: reuse of water after treatment, flexibility and simplicity of design, ease of use, lack of sensitivity to toxic contaminants, no production of harmful and toxic substances, cost-effectiveness, ability to reduce and recover metals, no sludge production, selective adsorption and relatively high process speed [10-14].

2-1. Absorption mechanism

Each adsorbent has an inner surface and an outer surface, the inner surface of the adsorbent creates significant pores and surfaces. In the first stage, the molecule that wants to be absorbed reaches the adsorbent surface from the fluid mass. In the second stage, the molecule enters the ducts specified in the figure. In the last step, a layer of the adsorbed molecule

is placed on the pores. This completes the adsorption operation. In general, adsorption is mostly done in a reciprocating reaction, so that both adsorption and excretion are performed simultaneously to finally reach equilibrium [12-15].

2-2. Introduction to zeolite

Zeolites were first discovered in 1756 by a Swedish miner named Baron Axel Frederick, who took his name from the Greek word (Zein) (boiling) and (Lithos) (stone) meaning boiling stones, which indicates this unique property. The person is theirs. When heated, zeolites foam and roll in a certain way when they reach the melting point, which is due to the release of water molecules from the cavities of natural zeolites. The first zeolite discovered was stilbite, discovered in 1756, and the most famous and abundant natural zeolite was clinoptilolite, discovered in 1980. So far, more than 85 types of natural zeolites have been discovered and hundreds of synthetic zeolites have been synthesized. Of the natural zeolites, only 9 are found in large quantities in nature. The physical and chemical properties of different zeolites (pore size, crystal size, ion exchange capacity and absorption capacity, and chemical composition) are very different. Uses artificial and natural zeolites are derived from their physical and chemical properties, which in turn is a function of the crystal structure and chemical composition of zeolites. Zeolites are usually white or colorless, but they can also be red or yellow. Zeolytic channels (or pores) are microscopic and actually have molecular dimensions, often referred to as "molecular sieves." The size and shape of the channels have tremendous effects on the properties of these materials for adsorption processes, and this feature leads to their use in separation processes. Molecules can be separated by the effects of shape and size on their possible orientation in the pores, or by differences in adsorption power. Zeolites have a porous structure that can replace a wide range of cations such as Na^+, K^+, Ca^{2+}, Mg^{2+} and others [16-19].

These positive ions are relatively freely held and can be easily exchanged for others in a way of contact with others. Zeolites are crystalline solids with small pores that have holes and channels with dimensions of 3 to 8 angstroms (1 nm = 10 Angstrom). Structurally, zeolite has an aluminosilicate frame or skeleton that is made of quadrilaterals with four oxygen atoms around a silicon or aluminum atom as the first structural unit. These quadrilaterals are abbreviated as TO_4, where T represents the Si or AL atom. The vertices of these quadrilaterals are joined together by an oxygen atom to form small secondary structural units. From the connection of these secondary units, a wide range of structural polygons are formed (Table 2).

Table 2. The most famous natural zeolites with chemical formula, year of their discovery and application

Application	Year of discovery	chemical formula	Name of zeolite mineral
Absorption of hydrocarbons	1758	$Na_2Al_2Si_3O_{10}.2H_2O$	Natrolite
Absorption of hydrocarbons	1801	$NaCl_2Al_5H_{20}.6H_2O$	Thomsonite
Recycle	1824	$(K_2, Na_2, Ca) (Al_2Si_6) O_{16}.6H_2O$	Philips
Absorption of heavy metals	1756	$(Na_2, Ca)(Al_2Si_7)O_{18}.7H_2O$	Steelebit
Absorption of mercury and silver - separation of the composition of alcohols	1772	$(Na_2,Ca)(Al_2Si_4)O_{12}.6H_2O$	Shabazit
Absorption of paraffin and alcohol	1785	$Ca (Al_2Si_4)O_{12}.4H_2O$	Lamontite
Lithium concentrate	1864	$(K_2,Na_2,Ca)(Al_2Si_{10})O_{24}.7H_2O$	Mordenite
Rehabilitation of contaminated soils - nitrogen uptake	1890	$Na_6 [(AlO_2)_6(SiO_2)_{30}].24H_2O$	Clinoptilolitis

3. Classification of zeolites

Several types of classifications have been performed for zeolites. An old classification is based on the shape of the crystal. In this classification, zeolites are divided into filamentous, columnar and mixed crystals. Another type of classification is based on the origin of their

formation. In this regard, zeolites are divided into two types of sedimentary and volcanic. In sedimentary zeolites, the ratio of silicon to aluminum is higher than in volcanic zeolites. Zeolites in Iran are sedimentary, while most natural species of zeolites in the world are volcanic[20-22]. The third type of bonding is based on the acidic or alkaline properties of zeolites. In this classification, zeolites in which the ratio of aluminum to silicon (Al to Si) in the range of 0.8 and above are acidic zeolites and zeolites in which the ratio is between 0.5 to 0.6 and less are zeolites are classified as alkaline.

3-1. Properties of zeolites

In general, the density of natural zeolites is in the range of 1.9 to 2.2 mg per cubic meter. Despite this density, zeolites with large amounts of barium and strontium may be around 2.5 to 2.8 mg/m3.
Most zeolite materials are colorless or white. However, some of them, which contain small or low amounts of iron, appear pale yellow or reddish brown. Suspended zeolites produce PHs of 9.5 to 10.5, resulting in complete or partial decomposition to higher PHs. Although most low or medium Si zeolites decompose in acidic solutions at PHs below 3, some high Si species, such as clinoptilolite and mordenite, are stable at PH around 2 and are stable for shorter periods, even at PH less than 2. In general, the sediment type of a particular zeolite is more stable to acid than its volcanic type. Because they usually contain more Si [23-26].
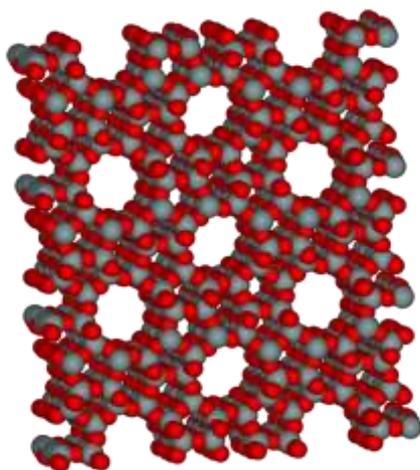

Figure 1. Atomic structure of zeolite

3-2. Cation exchange property

The exchangeable cations of one zeolite are cations that are loosely bonded and preserved by a quadrilateral

framework and can be easily removed and exchanged by washing the zeolite with a strong solution of another cation. However, crystalline zeolites are among the most effective and well-known cation exchangers and their capacity is typically 3-4 mEq/g. The cation exchange capacity of a zeolite is essentially a function of the degree of substitution of $Al3+$ and $Fe3+$ instead of $Si4+$ in the polyhedral of that zeolite framework, and the higher the degree of substitution, the more alkaline and alkaline earth cations are required to be electrically neutralized. And the higher the ratio of silicon to aluminum, the lower the cation exchange capacity and vice versa. In practice, the ion exchange behavior of a zeolite depends on other factors, including:

- Roughness of the frame (shape and dimensions of the channels)
- Size and shape of ions (polarity)
- Density of electric charge in channels and cavities
- Negative load capacity and density
- Composition and concentration of electrolyte in foreign solution.

The number of channels and their arrangement determine the cationic displacement property of a particular zeolite. Cations are transported through zeolites with a three-dimensional channel system faster than zeolites with a one- or two-dimensional channel system. Whether or not a particular cation is placed within the cage frame, such as zeolites, depends on the size of the ions and the size of the zeolite channels. Unlike most non-crystalline ion exchangers, such as organic resins and inorganic aluminosilicate genes (incorrectly called zeolites in the trade), crystalline zeolites exhibit high selectivity for competing ions. The water molecules surrounding the cations with a strong field of action prevent them from approaching the charge field close to the zeolite, so zeolite shows less selectivity for these ions. Conversely, weakly acting cations are selectively removed from solution by most zeolites and stored more tightly, and zeolites selectively exchange this cation with other cations. Zeolites with a high ratio of silicon to aluminum (for example 3 to 5) in which there is little charge field in the frame, show significant selectivity to monovalent cations compared to divalent. While zeolites with a lower ratio of silicon to aluminum and with a higher charge field and closer

to each other, have a very high selectivity for divalent cations compared to monovalent. In general, zeolites have no anion exchange power at all. Natural zeolites of clinoptilolite due to the low number of Al (Si to Al ratio about 4.5 to 5) in its structure has an ion exchange capacity of about 2.3 mill equivalents per gram and its selection order for the displacement of different cations is as follows:

$$Cs > Rb > NH4 > Ba > Sr > Ca > Fe > Al > Mg > Li$$

The selectivity of clinoptilolite for Cs+ and NH4+ has been used in the development of processes for the removal of radioactive Cs from nuclear wastewater and the removal of NH4+ from municipal wastewater.

The stench of Saei Park in Tehran has been purified twice by means of a 10 cm column of clinoptilolite produced from domestic mines. About 95% of the NH4+ in the water has been removed. It is also similar to clinoptilolite. On the other hand, synthetic zeolite A with equal ratio of Si to Al has a very different cation selection property than natural zeolites and its selectivity for monovalent and divalent cations is as follows.

$$Ag > Tl > K > NH_4 > Rb > Li > Cs > Zn > Sr > Ba > Ca > Ni > Cd > Hg > Mg$$
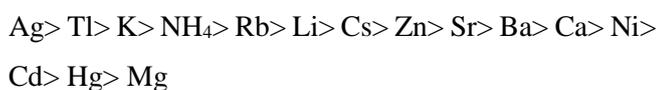
Cation exchange capacity is a measure of the number of charges per unit weight or volume of zeolite available for exchange [27-31].

4. Physical and chemical properties of zeolites

Zeolites usually have a density between 2 and 2.3 grams per cubic centimeter. But barium-rich zeolites are an exception and their density may be between 2.5 and 2.8 grams per cubic centimeter. Zeolites are generally open in structure and thus have a special surface similar to silicate minerals [32].

Water uptake is relatively high per cell unit of zeolite. Of course, the amount of water absorption depends on the type of zeolite as well as the type of cations in its channels. In general, the width of the channels, the size of the cations and the hydration energy determine the amount of water absorbed by these minerals. The cation exchange capacity of zeolites is reported to be from 100 to 300 mEq/100 g.

In general, the width of the channels, ionic or molecular diffusion, the amount of water and hydration are important factors that determine their cation exchange capacity. Zeolites can act as sieves. For example, the analyst can freely exchange sodium with Ti, Ag, NH4, K, and Rb, but the rate of exchange of Rb with Cs is negligible [33].

Selective adsorption of Ag and Ti heavy metal ions on all very common clinoptilolite zeolites is widely used to separate and immobilize radioactive ions from wastewater [34].

Wafahkhah et al. investigated the effect of the initial PH parameter of the solution, the size of the adsorbent particles and the contact time of the adsorbent on the adsorption of copper metal ions from the copper sulfate solution by natural corn wood powder. The morphology of the adsorbent surface was studied before and after adsorption by vegetative electron microscope (SEM).

The porous and tubular surface of corn wood indicates its ability to absorb metal ions in solution. Langmuir model and Freundlich model were used to evaluate the equilibrium absorption. The obtained q max showed that with increasing the initial PH of the solution and decreasing the size of adsorbent particles, copper ion adsorption occurs to a greater extent. Also, the results showed that another parameter affecting the adsorption rate is the contact time of the solution including copper metal ions with corn wood powder particles. So, that the maximum amount of absorption is in the first twenty minutes and after that the absorption process does not increase much [35].

4-1. Equilibrium isotherms of adsorption

Adsorption isotherm is a mathematical relationship between the amount of metal adsorbed on the adsorbent and the amount of metal remaining in solution at a given temperature. These equilibrium relationships are one of the important and essential requirements for the design of absorption systems. There are different adsorption isotherm models to express the adsorption equilibrium behavior, each of which is based on specific assumptions [36].

4-2. Langmuir isotherm

Langmuir 1918 was the first to propose a coherent theory with a traditional approach to surface absorption on a flat surface. In this theory, a continuous process of bombardment of molecules on the surface and repulsion of molecules from the surface occurs in such

a way that the rate of accumulation of molecules on the equilibrium surface remains zero. The hypotheses of Langmuir model are:

1. The surface is homogeneous, i.e. the adsorption energy is constant and the same at all sites.
2. Adsorption on the surface should be done in certain places, that is, atoms or molecules adsorbed at specific and defined sites should be adsorbed.
3. Each site can only accommodate one molecule or atom; the adsorbent molecules are not able to move on the adsorbent surface.
4. Langmuir's theory is based on synthetic principles and states that the rate of surface adsorption is equal to the rate of repulsion from the surface.

The Langmuir isotherm model is as follows:

$$q_e = \frac{q_{max} k_l c_e}{1 + k_l c_e} \qquad (1)$$

The linear form of the above equation is as follows:

$$\frac{1}{q_e} = \frac{1}{q_{max} k_l c_e} + \frac{1}{q_{max}} \qquad (2)$$

Where (mg/g) q_m is the amount of adsorption corresponding to a complete monolayer or in other words the maximum adsorption capacity. Any adsorbent that has a higher adsorption capacity (q_m), i.e. for a certain amount of adsorption is It has less adsorbent and this is an advantage. q_e (mg/g) is the amount of metal ions adsorbed per unit mass of adsorbent (the amount of adsorbed material at equilibrium). C_e (mg/L) is the equilibrium concentration of the solute (concentration of solute in equilibrium) and the Langmuir constant K_L parameter and is a measure of how strongly the adsorbed molecules are adsorbed on a surface. **KL:** Langmuir constant in (mg/L) The larger the Langmuir constant, the more surface is covered with adsorbed molecules, and this is the result of the stronger tendency of adsorbed molecules to surface.

By plotting $\frac{1}{q_e}$ in terms of $\frac{1}{c_e}$, k_L and q_m can be calculated [37-42].

$$R_L = \frac{1}{1 + K_L C_e} \qquad (3)$$

Depending on the value of R_L, the isotherm shape may be interpreted as follows:

$R_L > 1$: Adverse absorption,
$R_L = 1$: linear absorption,
$0 < R_L > 1$: Optimal absorption,
$R_L = 0$: Irreversible adsorption.

4-3. Dobbinin - Radushkovic (D-RK)

Dubinin-Radoshkovich adsorption isotherm is mainly used to describe the adsorption behavior of heavy metals on the surface of natural adsorbents. The isothermal equation of Dubinin-Radovskov surface adsorption is expressed as follows.

$$Ln\, q_e = Ln\, q_m - \beta\varepsilon^2 \qquad (4)$$

In this regard, qe is the amount of adsorbent per unit weight of adsorbent in terms of mg g-1, qm is the maximum adsorption capacity of the adsorbent in single layer in terms of mg g-1, β is the activity coefficient which depends on the average adsorption energy in terms of J2mol-2 and the planar potential in terms of Jmol-1 obtained from the following equation..

$$\varepsilon = RT\, Ln\, (\, 1 + 1/Ce) \qquad (5)$$

By plotting the linear curve of the Dubinin-Radoshkovic model based on $L_n\, q_e$, ε^2 the slope of the line is equal to -β and the width of the origin is equal to q_m. The adsorption potential depends on the temperature, but it should be noted that changes in the nature of the adsorbent and the adsorbent also cause changes in it. Accordingly, the absorption energy can be calculated according to the following equation [43].

$$E = \frac{1}{\sqrt{2\beta}} \qquad (6)$$

E is the average energy or apparent energy or in fact the free energy used to transfer an adsorbed molecule from inside the solution to the adsorbent surface (J/mol). Also, by measuring this energy, according to this type of single adsorption temperature, a suitable index can be obtained to determine the type of adsorption. So that if the absorption energy is less than 8 kJ/mole, the absorption can be considered as a physical type and a part of the van der Waals force. If the adsorption energy is between 16-18 kJ/mole, the type of adsorption can be considered by ion exchange mechanism, and if the

adsorption energy is more than 16 kJ/mole and 20 to 40, the adsorption mechanism of a chemical mechanism It is stronger than ion exchange [44-48].

5. Kinetic studies

The adsorption synthesis represents the changes in the amount of adsorption on the adsorbent over time, or in other words, an estimate of the adsorption capacity over time. As mentioned, adsorption kinetics are generally used to determine the control mechanism of adsorption processes. Adsorption kinetics depend on the physical and chemical properties of the adsorbent, which affects the adsorption mechanism [49-52].

5-1. Quasi-first-order kinetic model

$$\frac{dq_t}{dt} = (q_e - q_t) \tag{7}$$

In this constant section, we obtain the adsorption velocity of copper using the Lagrange quasi-first-order equation of velocity and the quasi-quadratic equation presented by Mckay.

The relation to the Lagrange quasi-first-order model is in the form of Equation (8).

$$\log(q_e - q_t) = log q_e - \frac{k_1}{2.303} t \tag{8}$$

Where q_t is the amount of copper adsorbed per unit mass of adsorbent (mg / g at time t and q_e is the amount of copper adsorbed at equilibrium. By plotting Log (q_e-q_t) in terms of t, the values of k_1 and q_e can be determined the slope and width from the origin [53-57].

5-2. A quasi-quadratic synthetic model

$$\frac{dq_t}{dt} = (q_e - q_t)^2 \tag{9}$$

Where k_2 (g/ (mg min)) is a quasi-quadratic absorption rate constant. By integrating equation (8) and applying the conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$ we have:

$$\frac{1}{q_e - q_t} = \frac{1}{q_t} + K_2 t \tag{10}$$

The equation can be rearranged into the following linear form:

$$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{1}{q_e} t \tag{11}$$

By plotting the t / q_t diagram in terms of t, the values of q_e and k_2 can be determined from the slope and width from the origin [58-64].

5-3. Removal percentage and adsorption capacity of metal ions

Equation (13) is used to calculate the percentage of metal ions removed from aqueous solutions by adsorbent, and Equation (12) is used to calculate the adsorption capacity: Where C_0 (mg/L) is the initial concentration and C_e is the final concentration of the solution, V (L) is the volume of the solution and m (g) is the adsorbent mass [64-68]. The relationship used to determine the adsorption capacity

$$q = \frac{C_0 - C_e}{m} * v \tag{12}$$

In this regard:
q: Adsorption capacity ((mg adsorbed) / g adsorbent),
C_0: Initial concentration of copper solution (ppm),
C_e: final concentration of copper solution (ppm),
m: adsorbent mass (g),
V: solution volume (lit).
The relationship used to determine the percentage of copper adsorption is as follows:

$$Re \% = \frac{C_0 - C_e}{C_0} * 100 \tag{13}$$

6. Conclusion

Zeolites are minerals that are mainly composed of aminosilicate. These materials, which are crystalline and have fine porosity, have been widely used for adsorption of carbon dioxide. The most important reason for the interest in zeolites is that a number of their properties, such as porosity size and structure or chemical composition, affect their adsorption performance. The unique physical and chemical properties of their natural zeolites have made them useful in many agricultural and horticultural applications. Zeolite-related technologies in agriculture and horticulture include the gradual release of fertilizers, zooponics, and soil remediation. These applications increase the demand for zeolites in the technological spectrum (from their application in developing countries to their application on other planets). Research shows that the gradual release of fertilizers by zeolites can occur in natural and artificial soils through ion exchange reactions or a combination of ion exchange reactions or a combination of ion exchange reactions and the decomposition of minerals.

In the second method, zeolites are used in combination with low-solubility minerals such as apatite phosphate. Under the right conditions, zeolites will increase fertilizer application efficiency. The ability of clinoptilolite to reduce nitrification (up to 11%), reduce nitrate leaching (up to 30%), increase ammonium and potassium uptake, reduce ammonia evaporation and gradual release of NH4+ and K+ and other nutrients have been studied. Zooponics systems have been successfully developed in Cuba and Bulgaria, but such systems require periodic treatments with more chemical fertilizers or nutrient solutions than zeolites combined with minerals to provide nutrients. The most desirable zooponic systems are those with interesting zeolite properties (including hard and porous structure, medium volume density, good drainage, high cation exchange capability and chemical stability against PH changes) and balanced plant nutrition for non-additive production cycles. Provide fertilizers. Zooponic systems with these characteristics can be considered as plant growth mediators in large commercial sectors and consumer stores. Zeolites can increase the cation exchange capacity (CEC) of soil and moisture and improve water conductivity.

Also increase the amount of crops in acidic soils and reduce the amount of heavy and harmful elements such as copper, cadmium, lead and zinc absorbed by the plant in contaminated soils. The extent of the effect of these properties depends on the amount of zeolite added. If commercial zeolites are to be developed for agricultural and horticultural purposes, it is better to revise the technology of their use in relation to each crop, especially to meet the specific needs of the products. For those involved in research and development of natural zeolites in horticulture and agriculture, refining existing technologies and achieving market success are challenges that should be considered in research and development in the field of agriculture and horticulture in the use of zeolites.

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