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## Full Length Research Paper

# Applications Of Montmorillonite from the Tagan Deposit, Kazakhstan

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**Polluted environment creates stress for biosphere including human beings and often requires the uptake of natural minerals which help adapting to an ecologically challenging world. The natural clay mineral of montmorillonite is one of such substances, which is a natural sorbent that at the same time can also add the necessary nutrients to the human body. In this article we show that montmorillonite from the Tagan clay deposit in Kazakhstan is highly effective for protection and prevention of humans and animals against diseases.**

**Keywords:** Montmorillonite, Tagan Deposit, Kazakhstan

## INTRODUCTION

During the last decades naturally-occurring minerals have been increasingly used as medicines and biologically active food supplements. Among them are sorbents of the smectite mineral group, represented by montmorillonites, including its alkaline and alkaline earth varieties. Smectites or montmorillonites, together with other clay minerals, form a group of bentonite clays, where pure bentonite consists predominantly of monomontmorillonite.

Montmorillonite is formed as a result of alteration of volcanic rocks, mainly of tuffs and volcanic ash (Deer et al., 1966). The chemical formula of montmorillonite is  $(\text{Na,Ca})_{0.33}(\text{Al,Mg})_2(\text{Si}_4\text{O}_{10})(\text{OH})_2 \cdot n\text{H}_2\text{O}$ . Bentonite deposits in eastern Kazakhstan contain layers of high-

quality montmorillonites. They occur as cluster within the Zaysan depression of East Kazakhstan and are a part of the Manrak group of deposits. The Tagan deposit belongs to this group and is represented by high-quality montmorillonites and bentonite clays. The deposit is located in the Zhana-Tagan fold of the Zaysan depression, which underwent complex geological evolution in various paleo-geographical environments in the Mesozoic and Cenozoic. We believe that pure bentonite clays mainly consisting of montmorillonite were formed within lacustrine-marsh environments with the subsequent influence of weathering processes (Yerofeev, 1964 ; Kravchenko, 1974 ; Sapargaliyev and Kravchenko, 2007 ; Sapargaliyev, 2008 ; Brown, 1965).

**Table 1.** Exchange capacity of montmorillonites (bentonites) from the Tagan deposit.

Natural types	Composition of the exchange cations in clays, mg /100 g of dry matter				
	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	Sum
Alkaline	35.4-43.0	4.0-5.2	26.2-28.3	20.1-24.3	85.7-101.8
Transient	14.5-18.8	2.1-2.5	36.3-45.3	27.1-30.3	80.0-96.9
Alkaline earth	4.0-14.5	2.1-2.5	45.0-55.3	30.0-35.3	81.1-107.6

**Table 2.** X-ray analysis of montmorillonites (made on DRON-3M device using CuK $\alpha$  radiation, shooting mode J = 30ma, V = 30kV, shooting speed - 1°/min).

No	Sample Name	Main phase	Impurities
1	Alkaline montmorillonite	dioctahedral smectite $d_{001} = 13.3 \text{ \AA}$	Traces of quartz and plagioclase
2	Alkaline earth montmorillonite	dioctahedral smectite $d_{001} = 14.6 \text{ \AA}$	Traces of quartz and chlorine

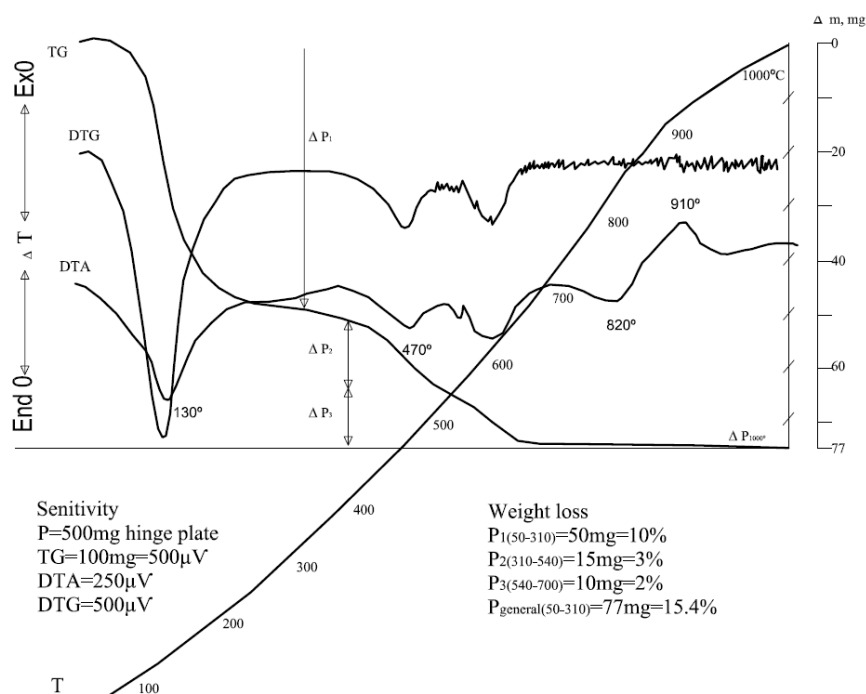
**Table 3.** Sorption properties of montmorillonites of the Tagan deposit and Change of interplanar distance indicators ( $d_{001}$ ,  $\text{\AA}$ ) of intensity peak half-width (H/W, mm) at introduction of radionuclide simulators ( $\text{UO}_2^{+2}$ ,  $\text{Sr}^{+2}$ ,  $\text{Cs}^+$ ) in the structure of montmorillonites.

Sorption properties of montmorillonites							
№	Sorbent	Sorbed ion, meq/100 g					
		$\text{UO}_2^{+2}$	$\text{Sr}^{+2}$	$\text{Cs}^+$			
1	Na-montmorillonite	78	338	682			
2	Ca-montmorillonite	92.5	283	625			
Change of interplanar distance indicators ( $d_{001}$ , $\text{\AA}$ ) of intensity peak half-width (H/W, mm) at introduction of radionuclide simulators ( $\text{UO}_2^{+2}$ , $\text{Sr}^{+2}$ , $\text{Cs}^+$ ) in the structure of montmorillonites.							
Introduced radionuclide ion	Tagan montmorillonite						
	alkaline		alkaline earth				
	$d$ , $\text{\AA}_{001}$	H/W, mm	$d_{001}$ , $\text{\AA}$	H/W, mm			
Outcome	13.4	15.5	14.4	11.0			
$\text{UO}_2^{+2}$	13.6	17.0	14.4	12.0			
$\text{Cs}^+$	13.5	13.8	14.4	11.0			
$\text{Sr}^{+2}$	13.8	14.2	14.4	12.5			
The structure and concentration of exchange cations of montmorillonite.							
Name	The concentration of exchangeable cations meq/100 g					Indicators of sorption, mg/g	PH
	Ca <sup>2+</sup>	Mg <sup>2+</sup>	K <sup>+</sup>	Na <sup>+</sup>	Sum		
"Tagansorbent" (Na- Ca- Mg montmorillonite)	31.98	28.0	0.45	42.37	102.8	790.0	7.8

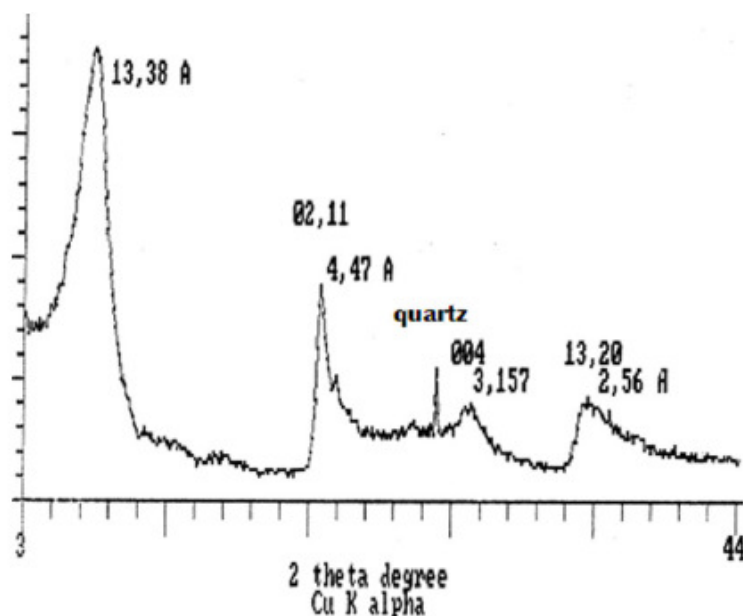
In this paper we present the analysed properties of montmorillonite from the Tagan deposit and its suitability for medical purposes.

## MATERIALS AND METHODS

Analyses of the structure of exchange cations in



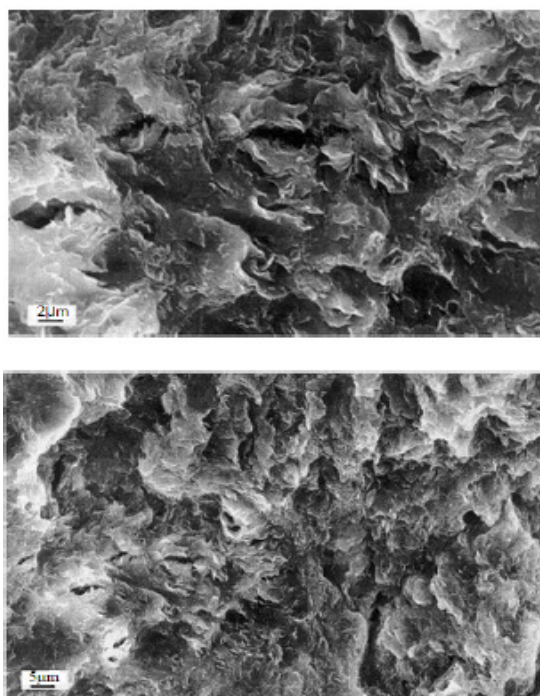
**Figure 1.** Diffraction pattern of sodium-calcium-magnesium montmorillonite. Adapted from (Sapargaliyev et al., 1997)



**Figure 2.** Derivatogram of a montmorillonite sample from the Tagan deposit.

montmorillonites from the Tagan ore field identified a natural change in montmorillonites, i.e. from alkaline varieties in the western flank to the alkaline earth ones in the eastern part of the field. This regularity in distribution of montmorillonites with different structure of exchange cations is shown in Table 1.

In alkaline montmorillonite of the Tagan deposit the exchange cation of sodium prevails over calcium and magnesium cations, but this is not reflected in the total sum. At the same time "pure" sodium montmorillonite, which would represent the end-member of typical alkaline montmorillonites, is not found in the deposit. Three



**Figure 3.** Surface of a montmorillonite particle under an electronic microscope (V.P. Kovalenko, Institute of Catalysis of the Siberian Branch of the Russian Academy of Science, Novosibirsk).

industrial types of bentonite clays were identified, including: alkaline, alkaline earth, and pharmaceutical ones, which allows their selective exploration that is being carried out at present.

The structure of montmorillonite was identified using X-ray diffraction analysis (XRD) (Brown, 1965) that showed the prevalence of montmorillonite of octahedral type with basal reflections of the first order in an air-dry state from 12.1 to 14.69–15.99 Å in all horizons (Table 2).

Montmorillonite of the Tagan deposit has a perfect crystal structure and the smallest amount of impurities (Fig. 1).

The change of interplanar distance in montmorillonite after physical and chemical processing of samples, i.e. from dehydration at 600°C to a state when it is saturated with glycerin, takes place during expansion of the crystal lattice from 9.7–9.8 Å to 18.2 Å. Air-dry montmorillonite samples (105°C) of 0.001 mm fraction with basal reflections of the first order (12.4–13.8 Å), are getting displaced to 16.9–17 Å at the saturation point with ethylene glycol. (Batalova, 1968) showed that the sodium montmorillonite of the Tagan deposit has the formula of  $\text{Na}_{0.84}\text{Ca}_{0.07}\text{Mg}_{0.11}(\text{Al Fe}^{3+}_{0.08}\text{Mg}_{0.68})[\text{Si}_{7.73}\text{Al}_{0.27}]\text{O}_{20}(\text{OH})_4$ .

Figure 2 shows kinetics of dehydration, values of weight change and speed of its loss in the alkaline montmorillonite, which were calculated using thermogravimetric curves (TG and DTG).

The first endothermic reaction is the most intensive one; it is caused by a loss of interlayer water at a temperature up to 300°C. Liberation of water (dehydration) from sodium-calcium-magnesium montmorillonite takes place during one stage; that confirms the existence of one layer of water in smectite, i.e. in the interval between packets 2:1 and octahedral, tetrahedral nets of the silicon-oxygen base.

Such distribution of water molecules in interlayered space provides monovalent exchange cations, represented by sodium and more rarely by potassium in smectite group of minerals.

Relatively high intensity of dehydration and 10% of weight loss in this temperature range confirms good sorption ability of montmorillonite. Stoichiometric calculation of structural formula of smectite shows that in the ideal case scenario the quantity of  $\text{OH}^-$  groups included in the tops of octahedrons of an element grid makes no more than 3% from the total weight of a silicon-oxygen framework. In this case it reaches 5% for the two groups of hydroxides, with temperatures of system exit at 400–500°C (3%) and 530–650°C (2%).

The second endothermic reaction is related to a loss of hydroxide from the crystal lattice at maxima of less than 600°C; this is typical for ferrous montmorillonites, where aluminium is partially replaced by iron in

**Table 4.** Efficiency of the incorporated long-living radionuclides elimination and frequency of decrease in level of internal radiation during intake of alkaline montmorillonite (Tagansorbent).

Efficiency of the incorporated long-living radionuclides elimination.								
Name of the medicine	n	Cesium 137 (nku)		P	Potassium 40 (nku)		P	
		before	after		before	after		
Tagansorbent	20	16 ± 0.52	14.7±0.24	< 0.05	130.0±3.1	121.1±0.04	< 0.01	
Frequency of decrease in level of internal radiation during intake of alkaline montmorillonite (Tagansorbent), %.								
Persons observed	Positive effect, (%)		Level of a dose decrease				Effect of elimination	
	Cs <sup>137</sup>	K <sup>40</sup>	Cs <sup>137</sup>		K <sup>40</sup>		Cs <sup>137</sup>	K <sup>40</sup>
			min	max	min	max		
Liquidators at Chernobyl Nuclear Power Station, n = 20	52.6	57.9	79.3	80.4	58.6	98.0	70.8	82.8

octahedral layers. Doubling effect of the second endothermic reaction in montmorillonite is likely caused by impurities of kaolinite and halloysite.

The third endothermic reaction of the smallest intensity fixes losses of hydroxides bonded by the atoms of magnesium in octahedral coordination, by means of loss of hydroxides of silicon-oxygen layers in tetrahedral coordination and destruction of the dehydrated lattice of montmorillonite at a temperature of about 900°C.

Dehydration curves of montmorillonites have no sharp breaks between the loss of the last interlamellar water and the loss of hydroxyl from the crystal lattice. More than half of the interlamellar water is released at a temperature of up to 100°C and 60-63.5% in the range of 100-300°C. Full dehydration is reached at 800°C; that testifies to prevalence of particles of less than 0.001mm in montmorillonite. The majority of interlamellar water is released at a temperature of up to 180°C. Attached water is liberated slower at a temperature range of 800–900°C. Montmorillonite releases about 150 mg of water from 1g of the mineral during the dehydration, where more than half is the interlamellar water.

Fibrous, flaky-pelitic microstructures are observed in natural bentonites under a microscope. There is small debris of ductile material, usually 0.01-0.1mm in size, consisting of plagioclase and volcanic glass replaced by clay substance. Interference colors are usually light gray; flaky and clay aggregates are isotropic and appear to be transparent at the edges. SEM photos of montmorillonite show a very large surface of the mineral composed of thin flecks (Fig. 3).

In the coarsely-dispersed fraction (particles ≥ 0.5mm) quartz prevails, usually in aggregates with other minerals, and in the form of angular, not rounded fragments (60-88% of the total fraction).

0.0015-0.06 mm fraction is comprised of semi-rounded to rounded, usually transparent quartz grains. Neocrystallisation is frequent due to opal recrystallization. Feldspars, goethite-hydrogoethite, and aggregates of clay minerals are less widespread. Hydro-mica, amphibole, biotite, epidote, and carbonates were also noted in a few grains.

Contents of quartz and feldspars decrease in disperse fractions; there is a dominance of flaky, under the microscope poorly distinguishable aggregates of montmorillonite that are of 0.05-0.25 mm in size and have refraction indicators of  $N = 1.519$ ;  $N_p = 1.496$ .

Fractions with particle sizes of less than 0.001 mm are predominantly montmorillonite with impurities of kaolinite and halloysite in some horizons. Traces of hydromica, hydrogoethite, organic substances, cristobalite, and halite are also noted.

Montmorillonite is mainly of globular and less often of aggregate-flaky form.

There are globular forms of a diffuse, structure-less mass which are typical for Al-montmorillonite. Flaky grains (0.3-5 microns) have the irregular or rounded form with indistinct borders. During heating and ultrasonic processing the aggregates disintegrate and turn into globular forms (undoubtedly the flaky form is related to micro-aggregation of montmorillonite particles of a globular form).

**Table 5.** The content of heavy metals in mucosa after introduction of the sorbents and content of salts of heavy metals in urine of a person exposed to contamination with heavy metals.

Index	Metals content in mucosa			
	Cs	Co	Cu	Pb
Control	100±11	100±14	100±9	100±11
Prototype: SAC (0.1g)	27±3	32±4	50±6	26±2
SAC ( 0.1g twice)	28±3	24±3	39±4	30±4
SKN (0,1g)	34±3	29±3	46±5	27±3
Montmorillonite (0,1g)	25±3	31±3	17±2	26±3
0.1g twice	12±2	18±3	10±2	12±3
Clinoptilolite	34±4	29±3	38±3	29±3
0.1g twice	9±2	7±2	11±2	8±1
The content of salts of heavy metals in urine of a person exposed to contamination with heavy metals				
Type of poisoning	Group of comparison*	Sorption therapy**		
		Activated carbon	Montmorillonite	Clinoptilolite
Mercury salts ***	100±7	72±8	59±6	36±4
Salts of cesium 137 (C/l)	91±8*10 <sup>-10</sup>	37±3*10 <sup>-10</sup>	12±3*10 <sup>-10</sup>	9±2*10 <sup>-10</sup>

### **Sorption properties of montmorillonites of the Tagan deposit.**

Sorption properties were studied using uranyl, strontium and cesium ions from nitrate solutions, with initial concentration of strontium and cesium of 10-5 g/l, and uranium of 10-3 g/l (Sapargaliyev et al., 2004). Range of pH values 6.8-8.2 proved to be the optimum for the process. Sorption time was 1 hour with active agitating using magnetic mixers. Separation of solids from liquid was carried out by centrifugation on a centrifuge at 15 thousand turns per minute. Mineral sample size was one gram, the volume of a liquid phase was 100 ml. Change of ion concentration after sorption was defined using a Perkin-Elmer Inductively Coupled Plasma Mass Spectrometer (ICP-MS), as well as using atomic absorption on 3030 Perkin Elmer spectrometer. Calculation of concentration of the analysed elements by ICP-MS was carried out by an automatic semi-quantitative method of a multi-element standard solution, containing the elements of interest of 1 ng/g concentration. The accuracy varied between 1 and 5 %. Table 3 shows the results of sorption of  $UO_2^{+2}$ ,  $Sr^{+2}$  and  $Cs^+$  on minerals of various exchange complex.

Table 3 shows that the process of sorption is determined by the type of the exchange complex (presence of either  $Na^+$  or  $Ca^{+2}$  ions in the inter-packet levels). Na-montmorillonite is characterized by high degree of crystallinity and by crystal lattice order. Therefore it is dominated by the sorption mechanism due to occurrence of uncompensated electron states recorded by the Electron Paramagnetic Resonance

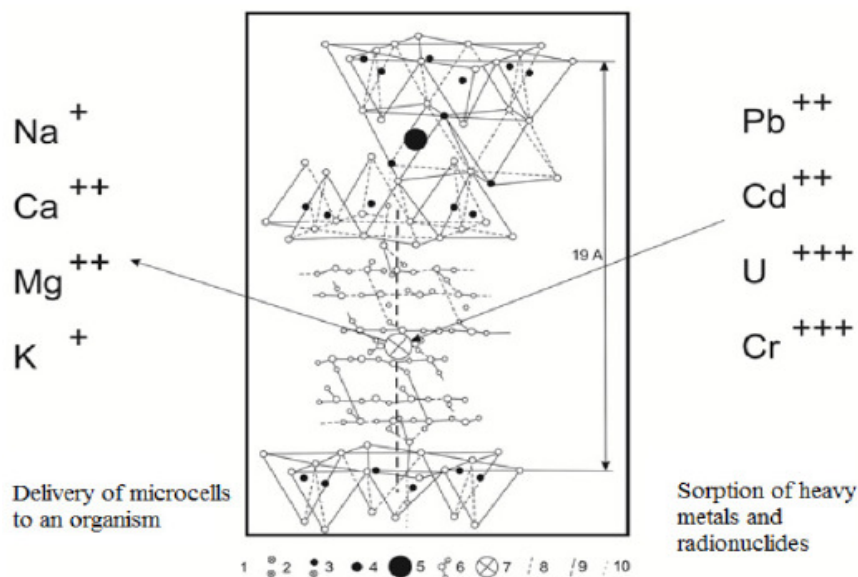
(EPR) method, whereas cationic exchange mechanism is dominant for Ca-montmorillonite.

Alkaline montmorillonite (Table 3) is characterized by a noticeable increase of the interplanar distances that indicates intrusion of radionuclide ions from a solution into the interlayered space of the crystal lattice. On the contrary, samples of alkali montmorillonite show no change in interplanar distances. This is typical for montmorillonites containing ions of  $Mg^{+2}$  in the hydrated condition in inter-layer space. For these clays chemisorption mechanism predominates.

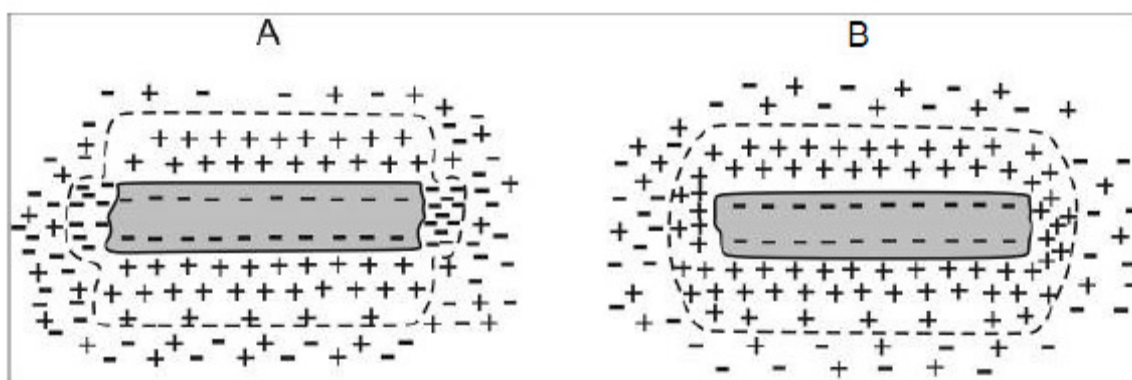
Sorption of strontium ions from a solution is a result of complexation, where ions bond with positions on external and internal borders of the mineral particles in two different ways. In the A-type (not depending on pH) a position of electro-nonsaturated sites of the clay is caused by defects of structure at the expense of isomorphic replacement of trivalent ions in an octahedral layer of the montmorillonite structure by bivalent ions, such as  $Fe^{+2}$  and  $Mg^{+2}$ .

In the B-type (pH dependent) at pH of 8 the superficial  $AlOH$  and  $SiOH$  groups are deprotonated and turn into  $SiO^-$  and  $AlO^-$ , respectively. As a result, during the radionuclide intrusion, the following complexes are formed:  $\equiv AlOSr^+ \equiv AlO^-Sr(OH)^+ \equiv SiOSr^+ \equiv SiO^-Sr(OH)^+$ . The EPR data show the existence of superficial complexes.

In the sample of alkaline montmorillonite, the emergence of wide lines ( $\Delta H = 60$  MT) with various g-factors is registered after a sorption of Sr, Cs and U. They are caused by complexes of  $Fe^{+3}$  ions in the neighboring cation site that lead to the superexchange



**Figure 4.** Scheme of exchange of montmorillonite mineral with external cations (crystal structure according to [18]): 1 – oxygen; 2 – hydroxyl; 3 – silicon; 4 – aluminum, Fe<sup>3+</sup>; 5 – magnesium; 6 – water molecules; 7 – boundary cations; 8-10 – communication: 8 – electrovalent one, 9 – hydrogen intermolecular one, 10 – hydrogen hydrocationic one.



**Figure 5.** Double electric layer of montmorillonite mineral particles in acid (A) and alkaline (B) environments.

effect.

Changes in the range of Mn<sup>2+</sup> ions in alkaline montmorillonite were not detected, which shows that they play no role in sorption processes.

It is difficult to track the role of A-centers in alkaline montmorillonites due to their concealment by significant amount of impurities that distorts an already weak intensity spectrum of the A-center. In the same montmorillonites, as shown in Table 3, the involvement of Fe<sup>3+</sup> ions in sorption processes is smaller (~20%), than in its alkaline variety (~46 %).

Researches have established that different composition of the exchange complex influences not only quantitative, but also qualitative parameters of montmorillonites that gives a chance for their targeted use during sorption.

The pre-clinical studies on rats poisoned with lead (Sapargaliyev, 1997) showed that alkaline montmorillonite actively and reliably sorbs the lead, reduces its toxic impact on blood and lymphatic systems of an organism and can successfully be used in patients with various degrees of lead poisoning by purifying the body (Table 3).



Influence of incorporated long-living radionuclides on the organism of people who are affected by ionizing radiation remains one of the main problems of radiation medicine in Kazakhstan and Russia. Scientists of the Scientific Center of Hygiene and Epidemiology (Laboratory of Ecological and Radiation Endocrinology, Almaty, Kazakhstan) carried out experiments on the removal of radioactive isotopes Cs<sup>137</sup> and K<sup>40</sup> from the organisms of personnel exposed to radiation after the accident at the Chernobyl Nuclear Power Station (CNPS) using the Tagansorbent product (Na-Ca-Mg montmorillonite). After intake of Tagansorbent the levels of both Cs<sup>137</sup> and K<sup>40</sup> decreased significantly ( $P < 0.05$  and  $P < 0.01$ , respectively) (Abylayula et al., 2001); compared to the initial radionuclide levels incorporated in the organisms of the CNPS liquidators before the treatment - in 70.8% of cases for Cs<sup>137</sup>, and in 82.8% of cases for K<sup>40</sup>.

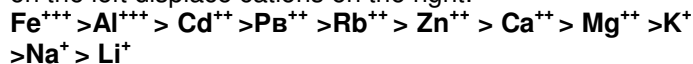
Table 4 shows the data on removal of incorporated long-living radionuclides from the organisms of people, who took part in liquidation of consequences of CNPS, treated at the hospital of veterans of the World War II.

Figure 4 shows a scheme of cation exchange between heavy metals, radionuclides and crystal structure of montmorillonite. Removal of heavy metals and radionuclides from a human body is based on the ability of the crystal structure of montmorillonite to exchange cations located in a diffusion layer. As shown in Figure 4, heavy elements having a big valency and ionic radius force out ions of sodium, potassium, calcium and magnesium, with their subsequent elimination from the human body, together with traces of the mineral.

## DISCUSSION

Obtained results allow recommending alkaline montmorillonite as one of effective remedies for removal of the long-living incorporated radionuclides from organisms of people who were exposed to ionized radiation, in addition to already known sorbents and medicine (Abylayula et al., 2001).

The mechanism of a cation exchange of the montmorillonite, represented by cations of Na<sup>+</sup>, Ca<sup>++</sup>, Mg<sup>++</sup> and K<sup>+</sup> is based on the ionic radius of these elements, where in the list of elements below the cations on the left displace cations on the right:



Among ions of the same valency, the largest energy of absorption belongs to those with larger radius and smaller hydration because electrostatic gravitation of such ions to the particle surface is much higher. Ions that have large valency and higher electric charge possess greater energy of absorption, therefore they displace other cations from the absorbed condition more vigorously, but themselves pass into solution with

difficulty because their electrostatic interaction with disperse particles is stronger.

Calculations for the sodium montmorillonite show the distribution of charges on tetrahedral layers of an elementary cell – 0.27 and on the octahedral one – 0.92 (Batalova, 1968). Ion charges on the lattice surface are partially compensated by ion charges inside of it, and remain partially free which allows forming active centers.

Montmorillonite dissolves in water and in other environments, accompanied by formation of flat particles with a greater thickness of layer on basal surfaces than on cleavage, making the latter less stabilized (Abylayula et al., 2001). As a result of hydration some cations leave particles of montmorillonite and distribute near the surface. These are mainly cations of sodium and less often calcium. Together with ions of the opposite charge, a colloidal particle forms a so-called micelle, which has a double electric layer. A surface of the basic plane of the particles has a positive charge and a cleavage has a negative charge. In order to characterize the double electric layer of the side cleavage of montmorillonite particles, it is necessary to consider pH values of the environment, which impacts their stability.

As the environment changes, side cleavage surfaces of particles get recharged as follows: positively-charged cations of aluminum determine the potential in the acid environment, whereas negatively-charged radicals of Al<sub>2</sub> – in the alkaline environment.

Three types of active centers at the side cleavage surfaces of montmorillonite were determined [12] and are as follows (Fig. 5):

1. Single (A) and twin (B) hydroxyl groups of silicon atoms, tetrahedral net;
2. Unsaturated atoms of oxygen at the border of tetrahedral and octahedral layers;
3. Unsaturated twin hydroxyl groups of aluminium atoms, octahedral net.

Figure 5. Double electric layer of montmorillonite mineral particles in acid (A) and alkaline (B) environments.

Many microorganisms have a negative charge, due to presence in their membranes and cellular walls of the following atomic groupings or ligands: phosphoric (PO<sub>4</sub><sup>3-</sup>), carboxyl (COO<sup>-</sup>), sulfhydryl (HS<sup>-</sup>), and hydroxyl (OH<sup>-</sup>). Such bacteria are used for production of some metals, i.e. during hydrometallurgical processing of mineral resources.

Montmorillonite offers a quick and effective treatment of dysentery symptoms; this is due to binding of clay charges with the charged surface of pathogenic microorganisms, leading to a rapid stopping of the illness. Mechanism of interaction of a pathogenic bacterium and a mineral particle is approximately the same as of antigen and antibody. It is known that these molecules differ from each other by the distribution of electric charges on their surfaces: their molecules are mutually attracted and form



a strong bond. Usually there are several of such places "sensitive" to attraction; therefore, several antigens and antibodies bind with each other simultaneously.

Surrounded by mineral particles with negative charges, positively loaded bacteria after enveloping are excreted out of a human body by a natural way. Along with negative charges, montmorillonite also has positive charges on the cleavage surfaces of the particles. Accordingly, pathogenic bacteria are not able to develop an own protection, thus developing on their surfaces another electric charge. Therefore, there is no addiction danger for pathogenic bacteria and it will not be able to develop a counteraction.

Intake of montmorillonite compensates organism with important cations of  $\text{Na}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Fe}^{3+}$  and  $\text{Si}^{4+}$ .

Russian and Ukrainian scientists studied sorption properties of the montmorillonite in detail with regards to elimination of salts of mercury and cesium from the human body (Rudichenko et al.). In their studies tests were conducted on animals by introduction of natural minerals of montmorillonite, clinoptilolite (zeolite) and well-known enterosorbents into an intestine lumen, including activated charcoal, synthetic sorbent and a sorbent based on methylpolysiloxane polymers (PMS). White outbred mice weighing 18-20g were injected with 0.5 ml of chloride solution of cesium, cobalt, copper or lead separately with concentration of 0.015 mol/kg of weight. After 30 minutes, 0.5ml of each sorbent listed in Table 5 were administered by a forced gastrointestinal tube, at the rate of 0.1g per introduction. After 14-18 hours the animals were decapitated, lower bowels were taken out and internal contents were washed away by 10ml of cooled saline solution, a piece of a bowel was dissected lengthways, mucous was scratched out by a pallet, then weighed and burned in the muffle furnace at 500°C. Obtained mineral residue was dissolved in hydrochloric acid followed by determination of metals using atomic absorption spectrophotometer (Table 5).

Double administration of montmorillonite and clinoptilolite resulted in even better extraction of toxic metals. Use of natural minerals is effective for both single and repeated administration of sorbents.

Experiments on removal of mercury and cesium salts from human bodies of volunteers showed that natural sorbents represented by sodium montmorillonite and clinoptilolite were more effective compared to other sorbents. Residual content of mercury and cesium salts in urine of a volunteer was much smaller when using sorbents from natural minerals as illustrated in Table 5.

## CONCLUSIONS

The clay mineral montmorillonite is a natural sorbent and can be used as a highly effective substance for protection and prevention of humans and animals against diseases

(Adeleye and Clay, 2008 ; Thomas, and Bohor, 1968 ; Dähn et al., 2001).

Alkaline montmorillonite from deposits in Kazakhstan was successfully used to develop the Tagansorbent medicine (Sapargaliyev, 1997). Tagansorbent is a natural sorbent that has no side effects. It is used for the removal of radionuclides and cations of heavy metals from the human body and for dysentery treatment. Use of the Tagansorbent allows: (1) to effectively cure infectious diseases like dysentery and diarrhea, (2) to remove cations of heavy metals and radionuclides from the human body, and (3) to supplement an organism with essential microelements such as  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{Fe}^{2+}$ , and  $\text{Si}^{4+}$ .

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