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Implementation of Project-Based Learning: Utilizing Natural Rocks as Waste Absorbents

Oktaffi Arinna Manasikana, Nur Hayati, Noer Af'idah, Mulia Rasyidi

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Implementation of Project-Based Learning: Utilizing Natural Rocks as Waste Absorbents

Oktaffi Arinna Manasikana[1*], Nur Hayati[1], Noer Af'idah[1], Mulia Rasyidi[2]

[1] Department of Natural Science Education, Science Education Faculty, Hasyim Asy'ari Tebuireng Jombang University, Jl. Irian Jaya No. 55, Tebuireng,Jombang Indonesia 61471

[2] Program Studi Pendidikan Ilmu Pengetahuan Alam Institut Pendidikan Nusantara Global

[*] Corresponding Author e-mail: changemaker.salatiga@gmail.com

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Abstract

The current study explores the advantages of project-based learning, which involves using real-world problems as a basis for gathering and integrating new knowledge. Specifically, the study investigates the implementation of project-based learning in the Solid Interface course within the Natural Science Education program. Through direct practice, students are required to master the course material, making it more applicable to real-world situations. To assess the effectiveness of this approach, an experimental method was used, which involved students conducting experiments, observing and experiencing the process, and presenting their results to the class for evaluation. This method provides students with the opportunity to learn independently, follow a process, analyze objects, draw evidence, and draw their own conclusions from the process being carried out. The objective of this research is to apply the project-based learning model and explore the utilization of natural zeolite rocks as an absorbent for heavy metal ions, specifically Plumbum and cadmium waste. The study successfully implemented the project-based learning approach, and the stages were carried out successfully. The results showed that cadmium is a silvery white metal that can be forged, and exposure to this metal can cause paralysis and even death. The study investigated the adsorption of metal ions by chelate Zeolite-EDTA on variations of particle size, including 212 µm, 125 µm, and 90 µm, with an adsorbate/adsorbent ratio of 20 mL/g, 30 mL/g, 40 mL/g, and 50 mL/g. The results indicated that the best adsorption of lead waste occurred with Zeolite-EDTA chelate at a particle size of 212 µm, with an adsorbate/adsorbent ratio of 30 mL/g. For cadmium wastewater, the best adsorption was achieved with Zeolite-EDTA chelate at a particle size of 212 µm, with an adsorbate/adsorbent ratio of 20 mL/g. These findings contribute to the growing body of literature on project-based learning and the use of natural zeolite rocks as an absorbent for heavy metal ions.

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INTRODUCTION

The project-based learning model is chosen because it requires students to think creatively and act actively. The teacher's role is as a motivator, facilitator by directing and guiding students in completing the assigned project (O. A. Manasikana, Wijayadi, et al., 2022). The initial step in the project-based learning model is to collect and integrate new knowledge based on experiences in actual activities. Students will be given an initial problem, then create a project design, develop a schedule, monitor project progress, assess results, and conduct experience evaluation. Students not only learn theory but also learn practically in real life (Widiyanti & Dyah, 2021). The advantage of the project is students will discover new information and gain experiences that will always be remembered (Manasikana et al., 2023).

In project-based learning, students can create good interaction processes with their social environment, where they can develop new ideas from the information they receive to enhance their intellectual abilities and think more creatively and actively. This is in line with Vygotsky's learning theory that social interaction with people around us can develop new ideas and accelerate intellectual development (Manasikana, et al., 2022). Vygotsky focuses on the dialectical relationship between individuals and their surrounding community, where social interaction will have an impact on learning outcomes. According to Vygotsky, during classroom interactions, students can develop their scientific concepts through the learning process itself. Meanwhile, spontaneous concepts are acquired from their daily lives. Learning is done collaboratively through group assignments and project-based learning that is theoretically sourced from social constructivism Vygotsky, which provides a cognitive foundation through the increase in intensity of interpersonal interactions (Widiyanti et al, 2021). Through opportunities to express their ideas, listen to others' ideas, and reflect on their own ideas with others, students can learn to become more active and enhance their creative thinking skills.

Indonesia is known as a country that has abundant of natural resources, including mineral resources (Georgiev et al., 2009). Zeolite is the most widely mineral in Indonesia. One of the areas with zeolite deposits is in Bayat, Klaten, Central Java. Zeolite is an inorganic material that has a porous structure with a three-dimensional framework. Zeolites are composed of tetrahedral aluminous silicates that have a negative charge on the surface. In zeolite cavity is filled by a balance cations such as Na+ and K+. The crystal form is relatively regular with an interconnected cavity. This causes the zeolite surface area to be very large, so it is very good when used as an adsorbent (Allabad, 2021).

In its effectiveness as a natural zeolite adsorbent can be added with ligands. Research on the addition of ligands in natural zeolite has been done by (Salima et al., 2023). (Sambasevam et al., 2020) did the addition of natural zeolite with ligand ditizon to know its selectivity in adsorbing metal. It was found that the ditizon ligand which has 1-S and 4-N donor atoms is more selectively to form complexes with metals which have large complex (Kf) stability prices such as lead (Pb2+) and Cadmium (Cd2+). Another study was conducted by (Fitriana, 2019) by adding EDTA ligands to Na-Y zeolites at 293 K and 393 K using a socket. (Karepesina & Manuhutu, 2023) states that the addition of EDTA ligands attract aluminum from the aluminosilicate structure. Ethylendiamintetraacetic acid (EDTA) is a ligand having more than one donor atoms of 2N and 4-COOH. EDTA ligands as electron donors can form complex reactions with metal ions as electron acceptor, those metal ions are residue of (Pb2+) and cadmium residue (Cd2+). Studies and research on EDTA complex with Pb2+ and Cd2+ metal ions have been done by (Mardhatillah et al., 2023). The purpose of this research is to apply the project-based learning model and to determine the utilization of natural zeolite rocks as an absorbent for heavy metal ions plumbum and cadmium waste. According him the complex Pb-EDTA has greater stability constants than complex Cd-EDTA. The purpose of this research is to apply the project-based learning model and to determine the utilization of natural zeolite rocks as an absorbent for heavy metal ions plumbum and cadmium waste.

METHOD

The research was conducted using an experimental approach and data collection techniques through observation and questionnaires (Karepesina & Manuhutu, 2023). The experimental design was chosen to test the effect of treatment on the results by controlling all other factors that may affect the results (Salima et al., 2023). One control was randomly assigning individuals to groups (Mardhatillah et al., 2023). The research was conducted on students of the Natural Science Education program at Hasyim Asy'ari University in the Solid State Interface course. As for the preparation of equipment and materials for the utilization of zeolite as a waste absorber, they are as follows:

Zeolite sieve on 212 µm, 125 µm and 90 µm, glass apparatus, pH indicator, hotplate, magnetic stirrer, IR-Shimadzhu FTIR-8201PC spectrophotometer, atomic absorption spectrophotometer (SSA), Mettler AT200 analytical balance, and TIT TS-330 shaker orbitals, and universal pH.

Material

Natural zeolite from Bayat-Klaten, Na-EDTA (Na-Ethylenediaminetetraacetic Acid), aquadest, lead nitrate ($Pb(NO3)_2$) p.a and cadmium chloride ($CdCl_2.H_2O$) p.a.

Preparation

Sample Preparation

The natural zeolite that passes through a 212 µm sieve is sieved into a particle size that passes 125 µm and 90 µm sieve.

Process of Making Na-EDTA Solution 0.10 M

Preparation of Na-EDTA solution starting with a concentration of 0.20 M solution, was carried out by dissolving 15.775 grams of Na-EDTA solids in a 250 mL plume to atera mark with aquadest. From concentration 0.20 M dilution was done to a concentration of 0.10 M.

Process of Making Pb^{2+} and Cd^{2+} 500 ppm Solution

A total of 0.199 grams of Pb $(NO_3)_2$ solids were dissolved in a 250 mL plum flask until the tera mark with aquadest. Preparation of a solution containing cadmium (II) is by dissolving 0.224 grams of $CdCl_2.H_2O$ solids in aquadest on a 250 mL flask to a tar mark.

Adding some EDTA to Natural Zeolit

First Method

Mixing natural Zeolit with Na-EDTA

Natural zeolite mixing with Na-EDTA was done based on Mudasir et al (2006) method. Natural zeolite was mixed with Na-EDTA solution in several concentration variations is 0.20 M, 0.15 M, 0.10 M and 0.05 M, then stir it for 24 hours. The mixture is filtered and the zeolite is washed with distilled water until the pH is close to neutral, then the zeolite is dried at room temperature.

Particle form of ZA-EDTA

Particle size ZA-EDTA Solutions containing Pb2 ions were adsorbed by 0.5 grams of natural zeolite and zeolite after addition of Na-EDTA in each particle size of 212 µm, 125 µm and 90 µm and 40 mL/g of Pb^{2+}.The mix was shaked for 24 hours in a room temperature 150 rpm speed. the mix solution are filtered then analized then the result of filtration are analized using AAS. The threatment is done also toion Cd^{2+}.

Adsorbat/ adsorben Ration

Solution containing ion $Pb^{2+}$to each adsororban ratio, they are 20/1 mL/g, 30/1 mL/g, 40/1 mL/g dan 50/1 mL/g adsorbened bynatural zeolit after adding Na-EDTA. The mixture was shaeken for 24 hours in a room temperature by 150 rpm speed.the mixture were filtered then the filtration were analizedusing ASS. The threatment is done also to ion Cd^{2+}.

The Second Method

2.5 mL Na-EDTA solution was added to each solution containing Cd^{2+} dan Pb^{2+} ions with the adsorbate ratio to Pb^{2+} 30/1 mL/g ion, in some temperature Na-EDTA solution 2,5 mL was added to each solution which contained adsorbant/adsorbant ratio to the ion, in particle temperature 212 µm. Afterward, it was shaked for 24 hours 150 rpm speed. The mixture was filtered then zeolit was dried and characterised using FT-IR, while the filtration was analized using AAS.

Tabel 1 Zeolite Sample Code Determination.

Sampel zeolite	**Kode**
Natural Zeolit	ZA
The first method zeolite (before metal adsorption)	ZA-EDTA
The first method zeolite (after metal adsorption)	ZA-EDTA-M
The second (after complex metal adsoption)	ZA-Kompleks EDTA

RESULTS AND DISCUSSION

The Implementation of Project-Based Learning

The implementation of project-based learning involves several stages and tasks. First, the teacher presents a real-world problem or challenge to the students. The students then brainstorm and develop a plan for how to solve the problem, including identifying the necessary resources, budget, and timeline.Next, the students begin to work on their project, gathering data, conducting experiments, and developing solutions. The teacher serves as a facilitator, offering guidance and support as needed, but allowing the students to take ownership of the project and make decisions about how to proceed (O. Manasikana et al., 2023). Throughout the project, the students are responsible for keeping track of their progress, documenting their findings, and presenting their results to the class. The final step is a reflection on the project, during which the students evaluate their work, identify what they learned, and suggest ways to improve their approach in the future. Overall, project-based learning encourages students to be creative and take ownership of their learning. It provides opportunities for them to work collaboratively, think critically, and apply their knowledge and skills to real-world situations (Widiyanti & Dyah, 2021). The project-based learning model has stages in the learning process. The stages can be seen in the following diagram (figure 1.).

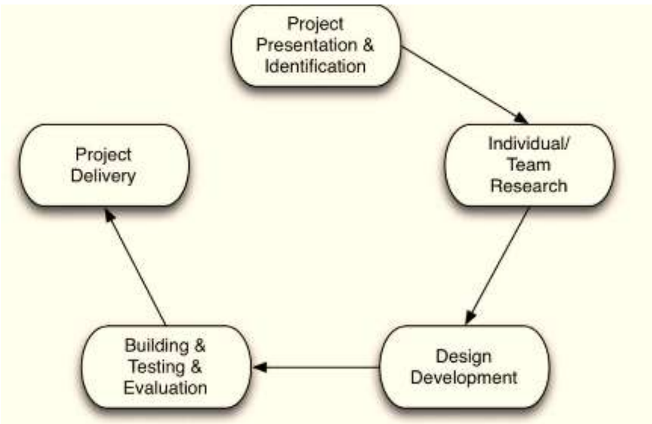


Figure 1. Stages of Project-Based Learning

Stage 1. Project Presentation & Identification.

Determining a beneficial project by providing the necessary information. To enrich the information, the teacher seeks sources in reference books, websites, or other sources that can help students complete the project. In this stage, the teacher provides material in the form of theory, case studies, or problems related to the material being taught. The teacher provides a problem in the form of utilizing natural solids as adsorbents for waste. The project task given to students is to practice the utilization of zeolite as an absorbent for heavy metal ion waste.

Stage 2. Individual/ Team research

In this stage, the teacher gives freedom to students to create and choose topics according to the material. Students enrich information and references other than those given by the teacher. This is intended to see the activity and creativity of students in choosing and developing topics. In this stage, students will learn independently through their experience by finding appropriate references. In this stage, the teacher also sets a deadline and some rules for project implementation to ensure it runs effectively and efficiently. In this stage, students are divided into observation groups consisting of particle size variations, variations with leaching, and waste variations.

Stage 3. Design Development

In this stage, students arrange the project schedule to be made by creating a flowchart. The teacher monitors each stage and becomes a facilitator for students to consult.

Stage 4. Building, Testing & Evaluation

In this stage, the teacher monitors the progress of the project in each weekly meeting so that any field obstacles are resolved. Students prepare reports according to the rules and conduct project presentations.

Stage 5. Project delivery

In this stage, the teacher and students together evaluate the project work from start to finish. Through this stage, the teacher can see feedback from students in the form of conclusions and questions asked. This stage will show students who have done the project well or just adequately. The activity and creativity of students also become evaluation material for teachers so that students can upgrade their abilities well.

Utilizing Natural Rocks As Waste Absorbents

In this study conducted a study on the effect of adding Na-EDTA ligand in natural zeolite. Na-EDTA added zeolite was applied to adsorb Pb2+ and Cd2+ ions with variation of particle size and adsorb ate ratio. Then the study compared the ability of its absorbance with natural zeolite absorbance to Pb-EDTA and Cd-EDTA.

The Effect of Adding EDTA to Natural Zeolite

The effect of Na-EDTA addition on natural zeolite structure in this study was observed using FTIR spectra. Interpretation of FTIR spectra was observed from natural zeolite (ZA), natural zeolite by first method treatment before adsorbing metal (ZA-EDTA), natural zeolite with first method treatment after adsorbing metals (ZA-EDTA-M) and zeolite with second method treatment after adsorption metal complex (ZA-EDTA complex) can be in Figure 4.1 as follows.

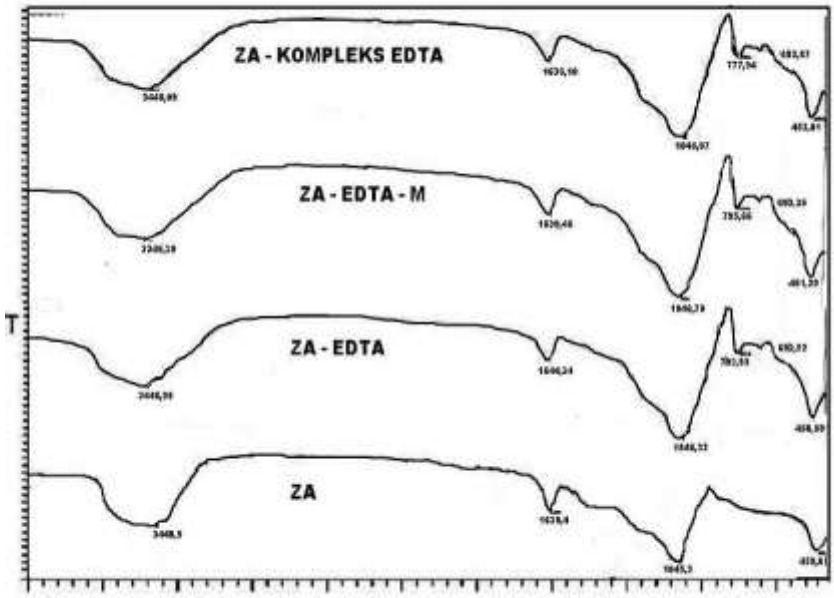


Figure 2. FT-IR Spectra From ZA, ZA-EDTA, ZA-EDTA-M and ZA- EDTA Complex

Figure 2 shows that the FT-IR spectra of the main constituent group of natural zeolite (ZA) has no significant difference to natural zeolite by the first treatment method before adsorbing the metal (ZA-EDTA), natural zeolite with the first method treatment after adsorbing the metal (ZA -EDTA-M) and zeolite with second method treatment after adsorbing complex metal (ZA-EDTA complex). This is the FTIR spectra of ZA-EDTA, ZA-EDTA-M and ZA-EDTA complexes there is no band shift at 3700-3100 cm-1 ie in the -OH group and the absence of an absorption shift in the internal vibration region in the 1250-950 range and 500-420 which marks the location of the TO4 cluster. Therefore, EDTA interaction in zeolite structure is possible because physical interaction does not show changes of zeolite structure in general (Sambasevam et al., 2020). FTIR spectral absorption areas in ZA, ZA-EDTA, ZA-EDTA-M and EDTA-ZA-complexes can be observed in Table 2.

Table 2. Absorption Area of FT-IR ZA, ZA-EDTA, ZA-EDTA-M and ZA- EDTA Complex

ZA absorption (cm^{-1})	**ZA-EDTA absorption (cm^{-1})**	**ZA-EDTA-M absorption (cm^{-1})**	**ZA-EDTA complex absorption (cm^{-1})**	**Additional information**
459,0	458,59	461,29	453,81	Si-O or Al-O tekuk
1045,3	1046,33	1046,76	1046,97	O-Si-O or O-Al-O asimetris
1639,4	1644,24	1639,46	1636,10	H-O-H bending
3448,5	3446,90	3445,20	3446,09	OH stretching
-	793,93	795,66	777,94	O-Si-O or O-Al-O Symetric
-	692,52	693,35	693,87	O-Si-O or O-Al-O symetric

Overall, FT-IR spectra of natural zeolite with first method treatment before adsorbing metal (ZA-EDTA), natural zeolite with first method treatment after adsorbing metal (ZA-EDTA-M) and zeolite with second method treatment after adsorbing metal complex (ZA - EDTA complexes) there is no significant difference in absorption with natural zeolite (ZA) spectra. This means natural zeolites with the first and second treatment methods do not alter the structure of natural zeolite.

Test of Absorbtion Ability

This study applied two different EDTA mixing methods are used, this is to compare the ability of adsorption.In the first method of natural zeolite, it was added EDTA first so that ZA-EDTA is then applied to adsorb Pb^{2+} and Cd^{2+} metal ions. In the second method of natural zeolite, EDTA and metal ions Pb^{2+} and Cd^{2+} are mixed together.

Particle Size

Adsorbent used are ZA and ZA-EDTA consist of sieved particle size 212 µm, 125 µm, and 90 µm. This particle size variation is used to know maximal particle size in adsorbing Pb^{2+} and Cd^{2+a} ion. Comparation if absorbtion ability from some of ZA and ZA-EDTA size explained on the figure 3.

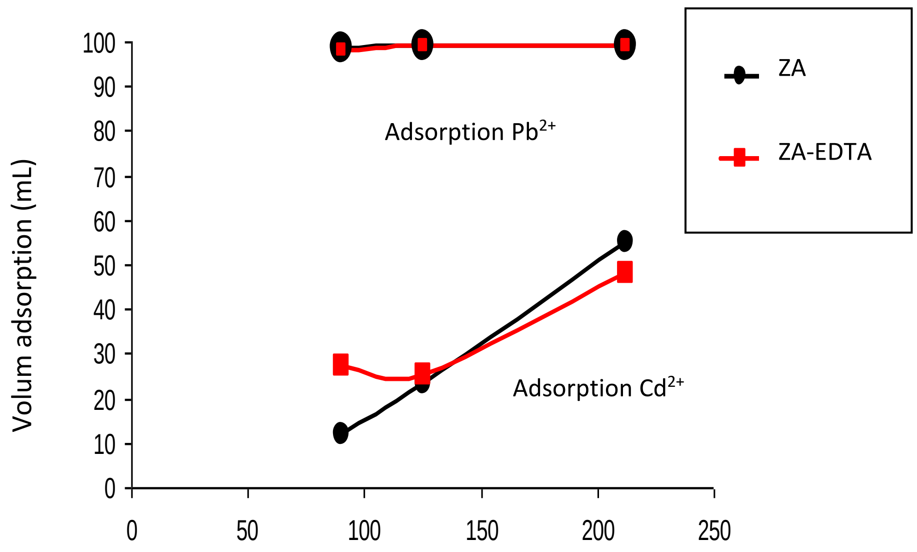


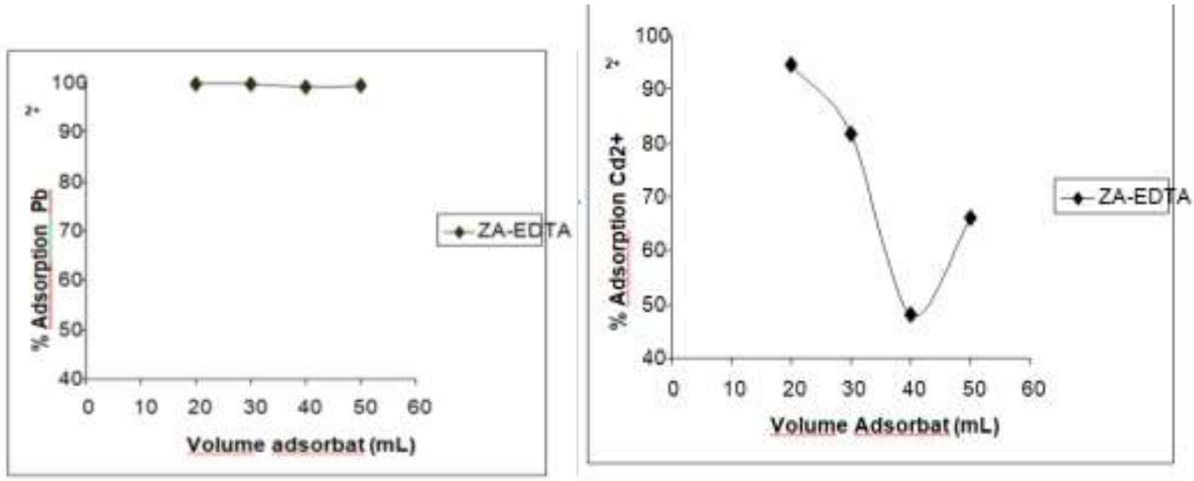
Figure 3. Adsorbtion Graphic ZA-EDTA Based on The Particle Size

In Figure 3 adsorption of Pb2+ ion and Cd2+ ions both ZA and ZA-EDTA give the best adsorption results on the largest particle size of 212 µm. On the smaller particle size of 212 µm, 125 µm and 90 µm, ZA and ZA-EDTA in the same mass will have a larger surface area, but this does not have an effect on adsorbing Pb2+ ion and Cd2+ ions. It means the large surface on zeolite does not affect process of adsorption (Mara et al., 2016).

Based on the adsorption result on the particle size variation, it can be seen that the addition of EDTA in natural zeolite is not able to give significant influence in adsorbing Pb2+and Cd2+ ions. This reinforces the results on the FTIR spectra that the interaction between EDTA and natural zeolite is a physical interaction.

Adsorbat/adsorben Ratio

Adsorbent used in this test is ZA-EDTA with the best particle size of 212 µm with variation of adsorbate / adsorbent used is 20 mL / g, 30 mL / g, 40 mL / g, and 50 mL / g. This variation is used to determine the maximum adsorption capacity of Pb2+dan Cd2+ ions.



(a) (b)

Figure 4 Adsorption Chart of ZA-EDTA based on Adsorbate / Adsorbent Ratio, for (a) Pb2+ion, (b) Cd2+ion

From Figure 4 it can be seen that the graph of adsorbate / adsorbent ratio on Pb2+ ion did not experience a fluctuating change. This shows that ZA-EDTA is more selective in adsorbing Pb2+ ions, in order to compare adsorption with second method zeolite Pb2+ adsorption is best selected at adsorbent / adsorbent ratio of 30/1 mL / g. The best adsorbent / adsorbent ratio on Cd2+ ion is 20/1 mL / g. In the Cd2+ ion as a whole it appears that the larger the adsorbate / adsorbent ratio the smaller the adsorption ability. This is because the adsorbent mass remains but the volume of adsorbat always increases so that the adsorption process is not maximal (Salima et al., 2023).

Based on the adsorption of Pb2+dan Cd2+ ions on ZA-EDTA on particle size and adsorbate ratio, ZA-EDTA is effective when applied to adsorb metal cations such as Pb2+ ions rather than Cd2+ ions. This is because the Pb-EDTA complex has a complex stability constant (Kf) of 1.0 x 1018 greater than that of the Cd-EDTA complex of 3.2 x 1016 (Raspor et al, 1980). In addition, because the zeolite has a strongly acidic O negative charge, it is preferable to adsorb Pb2+ ions including borderline acid rather than Cd2+ ions which include soft acid based on HSAB Pearson principle(Georgiev et al., 2009).

Second Method

The second method was performed to compare its adsorption capability with the first method zeolite. In order to compare its adsorption ability, the second method of treatment was performed after the first method obtained the best adsorption data. In the second method using particle size from the best particle size data of 212 μm first method and the best adsorbate / adsorbent ratio on Pb2+ 30/1 mL / g ion and on Cd2+ + 20/1 mL / g ion. The adsorption ability of Pb2+ and Cd2+ ions can be seen in Table 3.

Table 3. Zeolite adsorption capability of first method. and second method

No.	Kind of Liquid	Percent absorbed	
		Zeolit first method	Zeolit second method
1.	Pb2+	99,82 %	88,86 %
2.	Cd2+	94,60 %	83,64 %

From table 3. it is known that the zeolite adsorption capability of the first method is better than the second method of zeolite. In the second method of natural zeolite, EDTA ligand and Pb2+ and Cd2+metal ions are mixed simultaneously, whereas the first method of EDTA ligand is not added directly in the adsorption process. Thus, it is possible in the second method of adsorption competition that is zeolite in adsorbing metal (without its interaction with EDTA) and zeolite in adsorbing EDTA-metal complex Pb-EDTA and Cd-EDTA. The adsorption competition in this second method causes the adsorption process is not maximal (Taufiq et al., 2022). This suggests that treatment differences in EDTA ligand mixing can give different results on the adsorption of natural zeolite to Pb2+ and Cd2+ ions.

CONCLUSION

In conclusion, the results of this research indicate that the implementation of project-based learning was successful and resulted in a final product that met the learning objectives. Furthermore, the addition of EDTA to natural zeolite did not alter the zeolite structure significantly, as evidenced by FTIR spectra. The best adsorption of Pb2+ and Cd2+ ions was observed for natural zeolites treated with EDTA addition at 212 μm particle size and adsorbate/adsorbent ratio of 30 mL/g and 20 mL/g, respectively. It was also found that the adsorption of Pb2+ and Cd2+ ions by natural zeolite with EDTA addition was more effective than that of natural zeolite adsorption on Pb-EDTA and Cd-EDTA complexes. Overall, the results suggest that natural zeolite with EDTA addition has potential as an absorbent material for heavy metal ions in wastewater treatment. Further research is recommended to explore the optimal conditions for adsorption and to investigate the mechanism of adsorption by natural zeolite with EDTA addition.

RECOMMENDATIONS

In light of the research findings, it is recommended that problem-based learning be considered as an alternative model to project-based learning. This would allow for the exploration of a wider range of problems and the development of a diverse set of skills in students. Additionally, it is suggested that further research be conducted to investigate the potential of EDTA zeolite chelate as an absorbent material for other heavy metals in wastewater treatment. This would expand the scope of the study and provide insights into the broader applicability of this approach.

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