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Mineral Pumice Efficiency in Wastewater Treatment in Dairy Industries

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Abstract. In this study, the effectiveness of mineral pumice application in sewage treatment in the dairy industries was investigated, with various factors such as adsorbent dose, mixing speed, pH and contact time being studied in detail. The results obtained showed that mineral pumice in a granular form, with a contact time of 20 hours and a volume fraction of one third and pH of 8 has the ability to COD (Chemical Oxygen Demand) decreasing up to 56.9%. However, by using mineral pumice in powder form, in three cases considered, higher efficiency than for pumice granules has been observed. It seems that acidity conditions do not have a positive effect on this efficiency. As the contact time increased, the adsorption rate increased, mostly due to increased probability of collision with the adsorbent surface. With an increasing adsorbent dose, the absorption rate also increased, especially in the range of 15 g/l. Regarding the mixing speed, no definite conclusion can be drawn, because in some cases, with increasing mixing speed, the COD reduction efficiency decreased. Considering the use of mineral pumice in reducing COD, in accordance with to the obtained results, it is better to use mineral pumice in granular, rather than in powder, form.

Key words: Mineral Pumice; Sewage of the Dairy Industries; COD; Sewage Treatment

Abbreviations

BOD: Biochemical Oxygen Demand
COD: Chemical Oxygen Demand
pH: Potential of Hydrogen Ion
SBR: Sequential Batch Reactor
TSS: Total Suspended Solids
UASB: Upstream Anaerobic Sludge Blanket

1. Introduction

Among all water treatment methods, adsorption is considered as the best method due to its cheapness and ease of operation. Mineral pumice has high porosity. So, its low weight and special composition increase the process of absorption and ion exchange. Factories and industrial units, depending on their type of activities, produce a large amount of sanitary and industrial sewage on daily. Among these industries, whose sewage has a high level of organic load, is the sewage of the dairy industry. Dairy industry has emerged as one of the most rapidly developing industries on both small as well as large scale, the volume of effluent generated is also very high. One of the industries that produces large volumes of sewage on a small and large scale is the dairy industry (Akansha et al 2020). Due to the biodegradability of these wastes, various biological methods such as stabilization pond, activated sludge, upstream anaerobic reactor (UASB) and sequential discontinuous reactor (SBR) have been used to treat them. As the main problems of conventional sewage treatment systems one can mention high construction costs, high energy consumption, the need for complex operation and the need for sludge treatment and disposal with the use of mechanized systems, which mainly employ high-level technology (Naddafi et al 2005, Imran et al 2012). The sorption method has advantages over other methods applied to remove various contaminants, such as cost-effectiveness, selective sorption, metal recovery, relatively high process speed and no sludge production (Naddafi et al 2005). Pumice may prove a material which can be potentially utilized as an adsorbent to expel natural matter, suspended solids, supplements, and coliform. For adsorption or expelling of a few materials like hanging solids, supplements and coliforms, the mineral pumice is used for the most part. Pumice is light due to its high porosity. So, its uncommon composition increases its efficiency as an absorbent in ion trade. Pumice may be a sort of volcanic shake that is commonly found in most parts of the world, including Iran. Pumice, as a rule, floats on the water surface due to its high porosity and small density (de Rozari et al 2021). This mineral is composed of aluminum oxide (AlO_2) and silica (SiO_2), and a small percentage of this mineral contains oxides of sodium, potassium, iron and magnesium (Yavuz et al 2008, Akbal et al 2000). The special composition of mineral pumice increases the efficiency of this adsorbent in the process of adsorption and ion exchange, because materials with a high percentage of silica can be converted to zeolite. Zeolites are widely used as natural exchangers in environmental engineering and belong to the natural converters that are used in environmental engineering (de Rozari et al 2021, Tong et al 2021). In this study, the effectiveness of mineral pumice in reducing the amount of COD, BOD and TSS in the sewages generated by dairy industries was investigated. The effect of various factors such as adsorbent dose, mixing speed, pH and contact time were studied. The effect of various factors such as sorption dose, mixing speed, pH and contact time were also investigated. The absorption of heavy metal from aqueous solutions was investigated by applying volcanic ash (pumice). Results showed that each ionic species in a solution can be removed only within its own range of optimal pH values (Toscano et al 2008). One type of mineral pumice (LECA) was used as an adsorbent to decrease three types of PAHs (Phenanthrene, Fluoranthene and Pyrene) in sewage. The contact time, the amount of adsorbent and the adsorption isotherms have been studied. The results showed that the amount of adsorption increases with increasing amount of an adsorbent. The results were consistent with the two isotherms of Langmuir and Friendlich (Nkansah et al 2012). They examined the uptake of ammonium by light expanded clay aggregate (LECA). They studied the effect of some factors affecting ion absorption such as initial pH, initial ammonium ion concentration, temperature and contact time. The results has showed that the equilibrium constant in all the considered temperature ranges also follows the Langmuir and Friendlich model (Sharifnia et al 2012). Eikebrokk and Saltnes (2002) examined the a method of NOM removal from drinking water by chitosan coagulation and filtration through lightweight expanded clay aggregate filters, and they proved that the method is able to eliminate a high percentage of NOM. Mineral dust was used to measure the sludge of the municipal sewage treatment plant, and many heavy and toxic metals were decreased. The results of their research gave rise to a new innovative method for the removal of heavy and toxic metals from municipal sewage sludge (Cusido and Soriano 2011). The main goal of the presented research was to investigate the ability of mineral pumice, in both granular and powder forms, to treat dairy industry wastewater and effectively remove its pollutants, including COD, BOD, and TSS. For this purpose, the considered wastewater was put in contact with mineral pumice at different pH and at different speeds, and the output wastewater of this experiment was examined in terms of quality.

2. Materials and Methods

The necessary mineral pumice is prepared from Khajehabad mine located in the city of Neishabour in Iran. Pumice prepared using an X-ray fluorescence spectrometer was analyzed. Characteristics and weight percentages of the adsorbent are presented in Tables 1a, 1b and 1c. The experiments were performed in two different ways. In the first, mineral pumice in granular form was used, while in the second way it was used in powder form. The wastewater that was used came from the dairy industry in Neishabour. To reduce initial impurities, mineral pumice is washed several times in granular form with distilled water before grinding. It is then exposed to ambient air to dry completely. It is then ground and crushed using a sampler and granulated using an ASTM standard sieve with a mesh size of 60 to 80 (Figure 2). Two mesh sieves of 60 and 80 are placed on top of each other. So mesh 60 is on top and mesh 80 is below. Then, the pumice powder is passed through a 60 mesh sieve and the remaining portion on the 80 mesh sieve will be collected for testing (Figure 2). It is exposed to the sun to dry completely. The sampler was used for grinding and grading using an ASTM standard sieve with a mesh size of 60 to 80 (Figure 1). Two sieves 60 and 80 are placed on top of each other so that sieve 60 is placed on top of sieve 80. The pumice powder is then passed through sieve 60 and deposited on sieve 80 and collected for testing (Fig. 2).

Table 1a. Specifications and weight percentage (in %) of adsorbent (mineral pumice)

Sample	SiO_2	Al_2O_3	Na_2O	MgO	K_2O	TiO_2	MnO	CaO	P_2O_5	Fe_2O_3	SO_3	LOI
40281-H	50.74	16.35	3.04	3.31	0.67	1.11	0.12	9.46	0.40	11.73	0.00	3.08

Table 1b. Specifications and weight percentage of adsorbent (mineral pumice)

Sample	Ba ppm	Co ppm	Cr ppm	Cu ppm	Nb ppm	Ni ppm	U ppm	Th ppm	Ce ppm	CL ppm
40281-H	338	35	180	20	11	147	N	31	62	270

Table 1c. Specifications and weight percentage of adsorbent (mineral pumice)

Sample	Pb ppm	Rb ppm	Sr ppm	V ppm	Y ppm	Zr ppm	Zn ppm	TMo ppm
40281-H	48	24	862	180	15	225	67	12

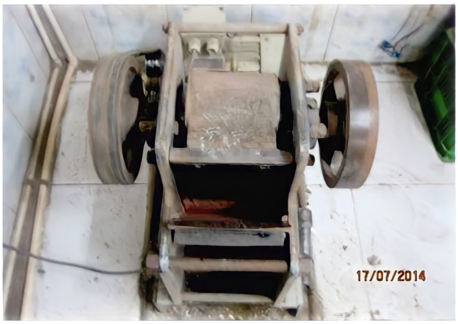

Fig. 1. The device used for crushing and grinding the pumice

At that point the pumice powder collected from the work 80 was washed with bubbling refined water a few times. By doing this, solvent mineral salts and staying to its surface are diminished and the turbidity of its sewage is diminished as much as conceivable. At that point, utilizing channel paper and a vacuum pump, the washed powder was washed from the sewage. Then the pumice powder was sifted and put in a stove at 120°C for 3 hours to dry totally. After drying totally, it was put in a desiccator and cooled to room temperature. Dissolvable mineral salts that followed to the surface

Fig. 2. Placement of the sieves on top of each other

were expelled. The turbidity of the gushing was decreased too. After that, channel paper was utilized beside the vacuum pump. This isolated the washed powder from the sewage. The pumices were cleaned at that point and then set in an stove at 120°C for 3 hours to dry totally.

In this study, the effects of 4 parameters: contact time (T), adsorbent measurement (M), pH and blending speed (V) were investigated. Based on the foundation of investigate and preparatory tests, 3 levels were considered for contact time, 4 levels for adsorbent measurements, 4 levels for pH and 2 levels for blending speed. The introductory pH of the sewage was 8. For this reason, pH = 7 and a digit higher or lower from pH = 7 were chosen. The length of 6 hours to reach harmony was chosen based on tests performed. Concurring to the number of components and levels considered, the number of test steps was 96. Taguchi test plan strategy was utilized. Taguchi method is a simple method to optimize an engineering process, which has unique features compared to other process optimization methods. Features such as simplifying the methods and evaluating the methods during product production in the process are among the special features of this method. In this way, engineers can produce higher quality products at a lower cost with the help of designing experiments. The focus of this method is more on removing the factors that lower the quality of the product. The parameters and levels considered are appeared in In this ponder, agreeing to past inquires about, 3 levels were considered for contact time, 4 levels for adsorbent dosage, 4 levels for pH and 2 levels for choice speed. The starting pH of the sewage was gotten. For this reason, an impartial number with a run of one more or less was moreover chosen. The length of 6 hours for harmony was chosen based on motor tests. Agreeing to the number of components and levels considered, the number of test steps is 96 steps. So, they utilized of the strategy of Taguchi test plan. The parameters and levels considered are appeared in Table 2. The plan of the tests was a table with 12 tests (L16) appeared in Table 3. In arrange to play down the impact of blunder sources, arrange of tests was arbitrarily chosen and performed with 2 replications. The normal of their comes about was utilized within the investigation. The cruel of the gotten comes about was utilized for investigation.

Table 2. Parameters and levels considered in the design of experiments

Parameter	Level 1	Level 2	Level 3	Level 4
Contact Time [h]	8	10	12	14
Adsorbent Dose [g/l]	1	5	10	15
pH	8	7	6	9
Mixing Speed [rpm]	100	150	200	250

Table 3. Experiments designed by Taguchi method

Number of experiment	Contact Time [h]	Adsorbent Dose [g/l]	pH	Mixing Speed [rpm]
1	8	1	8	100
2	8	15	6	200
3	10	5	8	150
4	10	10	6	200
5	10	15	9	250
6	12	1	8	150
7	12	5	6	100
8	12	10	9	250
9	12	15	7	100
10	20	10	9	200
11	20	10	8	250
12	20	15	7	200

COD measurement in this study is closed using reverse reflux method. For this purpose, a number of clean boiling stones were added to the Erlenmeyer volume of 250 or 500 ml and 20 cm^3 of the sample were pipetted to the Erlenmeyer flask. Then 20 cm^3 of 25.0 N dichromate was added and mixed. Then 5 cm^3 of sulfuric acid with density of 98% was added. Also, silver nitrate was added with the tip of a spatula. Then, Erlenmeyer was connected to the refrigerant and cold water flow was established inside the refrigerants. To ensure that no vapors escape, the upper part of the refrigerants was covered by a small beaker and the sample was refluxed for 2 hours. After 2 hours, the heat was turned off and the samples were allowed to cool without separating the refrigerants. Then 80 cm^3 of distilled water was added from the top of the refrigerants. The Erlenmeyers were separated from the refrigerants, and after complete cooling, 5 drops of ferrous reagent were added to each Erlenmeyer flask and titrated under a port containing ammonium ferrous sulfate until a reddish-brown color appeared (Fig. 3). The volume of ammonium ferrous sulfate consumed for each Erlenmeyer was recorded and equated to 1 as follow Eq. 1:

$$COD\frac{\text{mg}}{\text{L}}\text{O}_2 = \left(\frac{(A-B)\times N\times E_{o2}\times 1000}{V}\right)^6, \tag{1}$$

where:

A – volume of ferrous sulfate used for the control was 20 cm^3 in this study,
B – volume of ferrous sulfate consumed for the sample in cm^3,

N – modified normality of ferrous sulfate,
E_{o2} – equivalent is the gram of oxygen,
V – volume size in cm^3.

Fig. 3. Picture of COD measurement in the chemistry laboratory of Shahrud University

In the first step, before crushing and grinding the pumice, with the idea of a drip filter in the discussion of sewage treatment, mineral pumice was tested in granular form in two stages. First, two samples of sewage were prepared from the factory. The first sample was prepared from the output of the degreasing pool and the other sample was prepared from the output of the balancing pool. In the next step, two containers with the same capacity and cross-section were prepared and the pumices were added into two containers. The cross sections of both containers were covered and then the sewage was poured on the pumice. The mixture was left in the laboratory and away from sunlight for 20 hours. After this period, the samples were placed in black and full containers and sent to the laboratory to measure the three parameters COD, BOD and TSS.

3. Discussion and Results

3.1. Evaluation of Results Obtained for Mineral Pumice in Granular Form

As mentioned, at the beginning of the experiments natural mineral pumice (granular) was used (with a volume percentage of one third), and the results obtained are presented in Table 4.

As can be seen, the efficiency of COD reducing of the sewage after contact with the pumice in the form of granules is 56.9%. However, the same experiment was performed on the sewage from the balancing pond, which at the time of 20 hours of contact, the rate of COD reduction was observed to be 60% (Fig. 4).

Table 4. Results from the using of granular mineral pumice on dairy sewage

Parameters	Sample after degreasing pond [mg/L]	Sample after contact with pumice for 20 hours	Reduction efficiency
COD	2200	750	56.9
BOD	1220	385	68.4
TSS	570	225	60.5

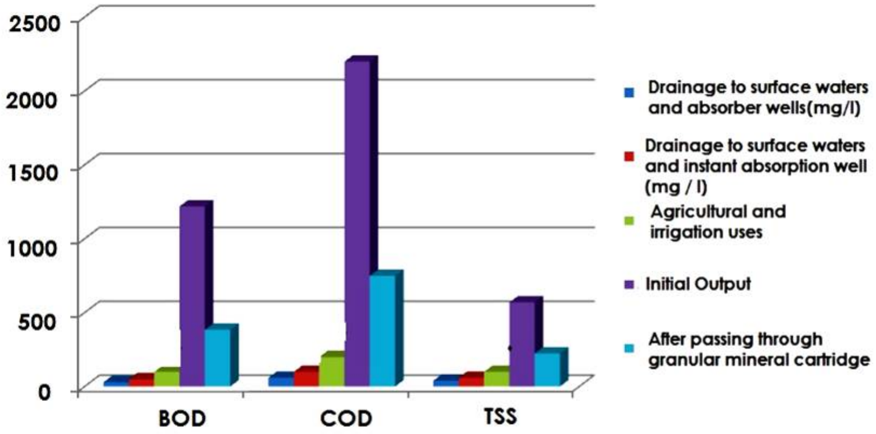

Fig. 4. Comparison of initial output and sewage passed through mineral pumice granules with approved domestic standards (DOE)

3.2. Evaluation of Results Obtained for Mineral Pumice in Powder Form

The results of the experiments are presented in the Table 5.

Table 5. Results of application of mineral pumice in powder form on dairy sewage

Number of experiment	Contact Time [h]	Adsorbent Dose [g/l]	pH	Mixing Speed [rpm]	COD Original Sample [mg/l]	COD after contact with pumice [mg/l]	COD Reduction %
1	8	1	8	100	2640	2000	24.25
2		10	6	200	2640	2240	15.16
3	10	5	8	150	2640	1060	59.85
4		10	6	200	2640	2340	11.37
5		15	9	250	2640	2280	13.64
6	12	1	8	150	2640	2100	20.46
7		5	6	100	2640	1890	25
8		10	9	250	2640	2100	20.46
9		**15**	**7**	**100**	**2640**	**850**	**67.81**
10	20	10	9	200	2640	1260	52.28
11		10	8	250	2640	1500	43.19
12		15	7	200	2640	1140	56.82

According to the values obtained for COD reduction efficiency, it is observed that the highest reduction efficiency was 67.81%. In this experiment, the mixing speed was 100 rpm, the contact time was 12 hours and the adsorbent dose was 15 g/l and the pH was 7 (neutral). On the other hand, in the same contact time and the adsorbent dose, it seems that the mixing speed is the determinative factor. This means that with increasing in mixing speed, the efficiency (COD reduction) decreases. Also, in the same contact time and mixing speed, the determinative factor is the adsorbent dose. This means when the adsorbent dose increases, the efficiency (COD reduction) will be increased.

4. Conclusions

Regarding the efficiency of COD reduction from dairy sewage, it seems that granular mineral cartridge, with a contact time of 20 hours and a volume percentage of one third and the actual pH of sewage equal to 8 has the ability to decrease 56.9% of pollutant concentration. However, in the conditions of application of mineral pumice in a powder form, in 3 cases, higher efficiency than granular state has been observed; in all three cases the pH factor was in neutral or higher (alkaline) conditions. Therefore, it seems that acidic conditions will not have a positive effect on treatment efficiency.

According to the results obtained, it is clear that by increasing contact time, in most experiments, the amount of adsorption increased, which is due to the increased probability of collision with the adsorbent surface. In principle, the most important parameter can be the contact time because it affects absorption alone; while other parameters are interdependent to absorption. With increasing the adsorbent dose, the amount of adsorption increased. Especially with increasing the adsorbent dose in the range of 15 g/l, the adsorption increased greatly. This occurred because increasing the adsorbent dose leads to an increase in active surface points and an increase in the number of active sites adsorbed. Concerning mixing speed, no definite conclusion can be drawn. It seems that the mixing speed parameter cannot be considered as a main parameter. It becomes significant only along with other parameters, because in some cases increasing the mixing speed has led to exactly the opposite effect. This means that with increasing mixing speed, the COD reduction efficiency decreased. Regarding the use of mineral pumice in COD reducing, according to the obtained results, it is better to use mineral pumice in granular form. The results of this study regarding the optimal contact time (20 hours) are entirely consistent with the results of studies by Asantova et al (2012). Regarding the adsorbent dose, it can be concluded that this parameter is dependent on other parameters. This research has been carried out in Iran. The outlet of this type of sewage will be mostly used as water required for agricultural and irrigation purposes, so in Table 6 the results of the sewage discharge are compared with the Iranian standard and the standard of the US Environmental Protection Agency. The results show that a significant reduction in the amount of COD is observed in both cases (granules and powder), which indicates the ability of mineral pumice to adsorb pollutants. However, the results are still far from Iranian and International standards and indicate the need for a complementary adsorption process.

Table 6. Comparison of the results obtained in the best conditions of the application of mineral pumice with Iranian and foreign standards

Factor	Standard of the Environmental of Iran (IRAN DOE) Protection Organization [mg/l]	Standard EPA [mg/l]	Sewage passed through mineral pumice (granules) [mg/l]	Sewage passed through mineral pumice (powder) at the highest efficiency [mg/l]
BOD_5	100	30	385	440
COD	200	120	750	850
TSS	100	5	225	260

Statements

The authors declare no conflicts of interest. Both authors designed the study, collected data, wrote the manuscript and revised it. No funding nor grants were received for this work. Some or all data, models and the code generated and used during this study are available on request from the corresponding author.

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