Study of the effect of quicklime on the sludge treatment and dehydration

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Abstract. The article discusses the chemical processes causing the intensification of treatment and dehydration of sludge. Sediments dominate in industrial and domestic wastewaters. The effect of such additive as quicklime on a decrease in the degree of moisture and, accordingly, on a decrease in the volume of treatment facilities’ sludge over time has been studied. It has been proven that adding quicklime leads to an increase in the alkalinity of the sludge.

1. Introduction
Sediments are the main and largest waste coming from wastewater treatment plants. Over decades, the large amount of sediments in an untreated form has been poured into overloaded sludge platforms, to dumps, various types of storage facilities, quarries, which lead to a violation of environmental safety and living conditions of the population. Sediment handling and disposal is a very complex problem in terms of both design and operation. Wet sediments contain a huge number of microorganisms [1–3], mainly of fecal origin; many of them are pathogenic and potentially dangerous to humans. The choice of the sediment treatment process is further complicated by the variability of its composition and the relatively low concentration of dry matter [3, 4–7]. Preference is given to a method that achieves better stabilization of the sediment, facilitating its removal, and converting the sediment into an inert and stable mass [2, 7–10].

At the biological treatment facilities of the city of Veliky Novgorod, sediment treatment takes place in sludge compactors, in a mineralizer and in a mechanical dehydration department (dehydration is carried out on filter presses). The dehydrated sludge (cake), having a moisture content of 75-85%, is transported to the sludge storage areas. Sewage sludge treatment should be carried out in order to minimize its volumes and prepare for subsequent disposal in the environment while maintaining or restoring its favorable condition.

This article presents the results of a study of the effect of the added share of quicklime on the treatment and dehydration of sludge.

2. Objects and methods of research
The research object was the sludge after mechanical dehydration (cake), which looks like wet soil (color from black to dark gray), has a fecal odor; the pH value of the sludge is in the range of 7.13–7.26. The moisture content of the sludge was in the range of 75–85%. In the course of the study, a series of experiments was carried out, during which quicklime was added to the sludge in an amount of 5 to 50% of the dehydrated sludge (cake) weight. After adding quicklime, moisture, pH, dry matter, and volume of sludge were measured in order to determine the optimal dose of quicklime and the stabilization time of the sludge.

Quicklime is one of the cheapest alkaline reagents. This form of lime is a product of limestone calcination with a less degree of calcination. The process of quenching each molecule of quicklime CaO with sludge water leads to the formation of calcium hydroxide Ca(OH)2; and, consequently, to a decrease in the residual moisture of sludge, including the partial evaporation of water due to the exothermic nature of the reaction.
3. Results and discussion

The research concerned the effect of the introduced dose of quicklime on such sludge parameters as moisture, mass, volume of dry matter of the sludge, and pH. The data obtained are presented in tables 1–4. According to table 1, the moisture content of the sludge decreases with an increase in the amount of added quicklime over time. The moisture content of the original sludge is 81.2%, after adding 5% of quicklime, a decrease in moisture content by 5.2% is observed; with the addition of 30% of quicklime, the moisture content becomes 1.6 times lower. Along with moisture measurements before and after the addition of quicklime, moisture measurements were carried out over time, i.e. moisture measurements were made a day and two days after mixing the sludge with a certain amount of quicklime and compared with the moisture values obtained during natural drying of the original sludge during the same time. For example, according to the research results, on the second day, the moisture content of the sludge with the addition of 25% of quicklime became 1.7 times less, and on the third – 2.2 times less compared to the initial one. With the addition 35% of quicklime to the sludge, the moisture content on the second day decreased by an average of 2.2 times, and on the third day by an average of almost 4 times.

| Table 1. Dependence of the sludge moisture content on the dose of quicklime in dynamics. |
|---------------------------------|-------------------------------|
| Time of research | Dose of CaO, % | Moisture, % |
|------------------|-----------------|-------------|
| Day 1            | 0 5 10 15 20 25 30 35 40 45 50 | 81.2 76.0 70.4 66.6 62.1 56.9 50.9 46.8 42.59 38.06 33.45 |
| Day 2            | 79.5 70.7 65.4 59.26 53.92 47.46 40.71 37.44 33.25 29.64 26.33 |
| Day 3            | - - - 48.1 39.6 36.5 29.0 21.79 20.55 - - |

If any amount of quicklime is added to the sludge, moisture decreases faster, than when it naturally dries out. The final research aim was to determine the optimal amount of quicklime that is required to minimize the moisture content of the sludge. According to the results of the study, the greatest decrease in the moisture content of the sludge during the day occurs with a dose of quicklime from 20 to 30%; it can be seen in table 1. A decrease in moisture, respectively, leads to an increase in dry matter, and, consequently, to a decrease in the volume taken by the sludge, which is a big plus when disposing of it. The data obtained are presented in tables 2 and 3.

| Table 2. Change in the dry matter mass of the sludge depending on the dose of quicklime. |
|---------------------------------|-------------------------------|
| Time of research | Dose of CaO, % | Dry matter mass, g |
|------------------|-----------------|-------------------|
| Day 1            | 0 5 10 15 20 25 30 35 40 45 50 | 188.0 239.65 296.25 334.4 378.95 431.3 490.65 531.9 574.1 619.4 665.5 |
| Day 2            | 202.6 293.35 343.9 407.15 460.8 523.4 592.9 625.6 667.5 703.6 736.7 |
| Day 3            | - - - 518.95 603.8 635.25 709.85 782.1 794.55 - - |

| Table 3. Dependence of the volume of dry sludge on the dose of quicklime. |
|---------------------------------|-------------------------------|
| Time of research | Dose of CaO, % | Volume of dry sludge, m³ |
|------------------|-----------------|---------------------------|
| Day 1            | 0.0228 0.179 0.144 0.128 0.113 0.099 0.087 0.080 0.074 0.069 0.064 |
| Day 2            | 0.212 0.146 0.124 0.105 0.093 0.081 0.072 0.068 0.064 0.060 0.058 |
| Day 3            | - - - 0.082 0.071 0.067 0.060 0.054 0.053 - - |

As can be seen from Table 3, the sludge without quicklime occupied a volume of 0.228 m³, then with the addition of 5% of quicklime, the sludge volume decreased to 0.179 m³. With the addition of 35% of quicklime, the volume of sludge decreased almost 3 times in a day, 4 times on the third day.

Also, the stabilization of sludge with quicklime, regardless of the sludge type, leads to an increase in alkalinity. An increase in temperature and pH leads to a significant decrease in the concentration of pathogenic microorganisms. Streptococci of fecal origin are quite resistant to quicklime at low pH values; however, at pH = 12, these organisms are inactivated after one hour of contact of the sludge with quicklime.
According to the results of the experiment, the pH with the addition of quicklime from 5 to 50% rose to 12.6 and remained so. The data obtained are presented in table 4.

Table 4. Dependence of the sludge pH on the dose of quicklime.

| Time of research | Dose of CaO, % | pH  |
|-----------------|---------------|-----|
|                 | 0  | 5  | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| Day 1           | 7.26| 12.5| 12.56| 12.52| 12.54| 12.56| 12.57| 12.55| 12.57| 12.56| 12.58|
| Day 2           | 7.24| 12.52| 12.54| 12.52| 12.55| 12.56| 12.53| 12.54| 12.57| 12.54| 12.56|
| Day 3           | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |

The data of sanitary and bacteriological analysis showed that with a dose of 10% and higher of quicklime, there are no helminth eggs and bacteria of the E. coli group in the sludge, which corresponds to GOST requirements. According to the data of sanitary and bacteriological analysis, the sludge after its treatment with quicklime can be attributed to the sediments of the first group. The sediments of the first group are used for all types of agricultural crops, except for vegetables, mushrooms, greens and strawberries.

Sediments that have passed the stage of processing with the use of quicklime can be used as organo-lime fertilizers for soils with a pH of less than 5.5 in doses calculated in regards to the calcium content in the composition of the introduced sediment. However, after such treatment, the sediment contains less dissolved phosphates, nitrogen, and ammonia than the fermented sediment of the primary settling tanks or its mixture with activated sludge.

In the course of the experiments, it was found that the treatment of sediments with quicklime leads to a decrease in their unpleasant odor, besides, the deodorization effect is enhanced because the development of bacteria is prevented. If the stabilized sediment is mixed with soil, the odor problem will be solved.

4. Conclusion

The research results allow for the following conclusion:

Sediments treated with quicklime are dehydrated much more intensively than with natural drying; moreover, their volume is significantly reduced, it facilitates their further utilization. The maximum decrease in the moisture content of the sludge is achieved with a dose of quicklime from 20 to 30%.

A decrease in moisture is also achieved due to the partial evaporation of moisture as a result of the exothermic reaction of the interaction of quicklime with sediment water.

Quicklime treatment leads to an increase in the temperature and pH of sediments, which contributes to their disinfection.

The quicklime-stabilized sludge is suitable for use on agricultural land. Stabilization with quicklime is an effective way to eliminate the odor from sediments.

References

[1] Dzhumagulova N T, Volshanik V V and Golubka T V 2015 Organization of effective use of land allotted for sediment placement *Theoretical and Applied Problems of the Agro-Industrial complex* 2 28–32
[2] Awasthi M. K., Pandey A K, Khan J, Bundela P S, Wong J W C and Selvam A 2014 Evaluation of thermophilic fungal consortium for organic municipal solid waste composting *Bioresour. Technol.* 2 214–221
[3] Hasenova E Zh, Ayupova A Zh, Sembayev K D, Moldagulova N B, Sarsenova A S and Nagyzbekkyzy E 2020 Study of microbiocenosis of sludge at sewage treatment plants *Science, Technology and Education* 9 (73) 23–25
[4] Jin Y, Luo Y, Ning Y and Wang L 2018 Effects and mechanisms of microbial remediation of heavy metals in soil: a critical review *Applied Sciences* 8 (8) 1336
[5] Sibiyeva L M, Detyareva I A, Sirotkin A S and Babynin E V 2019 Composition of the activated sludge microbial community in the processes of combined biological and reagent wastewater treatment *HEI Bulletin. Applied Chemistry and Biotechnology* 9 (2) 302–312
[6] Bialobrzewski I, Miks-KrajnikM, Dach J, Markowski M, Czekata W and Gluchowska K 2015 Model of the sewage sludge-straw composting process integrating different heat generation capacities of mesophilic and thermophilic microorganisms *Waste Manage* 43 72–83
[7] Kulikowska D 2016 Kinetics of organic matter removal and humification progress during sewage sludge composting Waste Manage 49 196–203
[8] Juarez M F, Praehauser B, Walter A, Insam H and Franke-Whittle I H 2015 Cocomposting of biowaste and wood ash, influence on a microbially driven-process Waste Manage 46 155–164
[9] Nasyrov I A, Mavrin G V and Shayhiyev I G 2015 Problems of disposal of treatment facilities sludge Bulletin of Kazan Technological University 18 (19) 257–259
[10] Budykina T A 2017 Drying of industrial wastewater sludge in natural conditions RUDN Bulletin 25 (2) 242–252