Features of sewage sludge dewatering process at the use offlocculant based on epichlorohydrin and dimethylamine

L R Asfandiyarova, G V Khakimova and A A Islamutdinova

Ufa State Petroleum Technological University, Branch in the Sterlitamak, 2, October Pr., Sterlitamak, 453100, Republic of Bashkortostan, Russia

E-mail: asfand_lilya@mail.ru

Abstract. The paper presents the results of experimental studies on the use of new synthesized reagent based on epichlorohydrin (chloropropylene oxide) and dimethylamine at the mechanical sludge dewatering unit; the effect of the residual flocculant content on sludge dewatering process is determined. In particular, it was found that the use of the proposed reagent led to an increase in the efficiency of settling industrial effluents at the primary settling unit up to 95%; it had a beneficial effect on further wastewater treatment at biological treatment facilities, which led to a 1.5-fold decrease in the consumption of flocculant. The use of this reagent made it possible to achieve a high degree of dewatering of sewage sludge and reduce the moisture content of the formed cake from 98 to 73%. Consequently, this allowed to significantly decrease the volume of sludge further placed in sludge collectors and to reduce the amount of land allotted for its disposal.

1. Introduction

Dewatering is one of the main stages of sludge treatment providing a decrease in sludge volume by various methods such as flotation, flocculation, coagulation and others, followed by mechanical dewatering of the sludge [1,2].

In the process of wastewater treatment at biological treatment facilities, sediment is formed in primary radial settling tanks, which is recycled after mechanical dewatering.

Disposal of urban wastewater sludge is an extremely urgent global problem due to the large volume of sludge, its bacterial contamination and the presence of organic substances that can quickly decay with the release of unpleasant odors. The heterogeneity of the composition and properties of the sludge complicate its processing. Reduction of sludge volume and its preparation for disposal are achieved by the method of mechanical sludge dewatering [3].

2. Research methods

At biological treatment plants before biological treatment, wastewater undergoes preliminary treatment which consists in adding excess activated sludge to it. This provides partial removal of pollutants by retaining them in the volume of sludge. Further, excess activated sludge is removed from the wastewater stream by means of settling. Various flocculants are used to intensify the settling process.

To intensify the purification process, we determined the possibility of replacing the used reagent based on polydiallyldimethylammonium chloride (PolyDADMAC) with polyepichlorohydrin-dimethylamine (polyECHDMA) dosed into the primary sedimentation tanks to precipitate small impurities.
It was found that in the sample with the flocculant polyECHDMA, a fairly rapid settling of small but clearly coagulated flocules was observed. The liquid gradually acquired transparency. After 30 minutes of sedimentation, the amount of suspended solids was 60 mg/l, while the purification efficiency was 95%.

In the sample with the reagent polyDADMAC, precipitation of suspended solids was also observed; there was a slight turbidity in the sample. After 30 minutes of sedimentation, the concentration of suspended solids in the clarified liquid was 68 mg/l, while the purification efficiency was 93%.

According to the results obtained, it was found that the settling velocity, flocculation and the content of suspended particles are almost identical. Therefore, the interchangeability of these polyelectrolytes is not excluded [93]. Preliminary experiments have established that the concentration of polyECHDMA (0.08 ml/dm³) is close to the optimal one, which is similar to the concentration of the used polyDADMAC.

At the tested industrial unit for mechanical dewatering of effluents, a cationic flocculant Praestol 853BC is currently used as a reagent. It is a copolymer of acrylamide with increasing proportions of cationic comonomers. The cationic groups introduced by them into the polymer have positive charges in the aqueous solution. The determinant factor for optimal action of the Praestol flocculant are the potentials acting on the surfaces of particles, which depend both on the particles themselves and on the surrounding conditions (pH value, electrical conductivity, hardness and content of suspended solids) [4,5].

The purpose of these studies is to determine the possibility of using the flocculant polyepichlorohydrindimethylamine (polyECHDMA) synthesized by us in the mixture with Praestol 853 BS used in manufacture.

Laboratory tests were carried out on mixed sediments taken from the receiving tanks of industrial mechanical dewatering unit. The consumption of the Praestol 853 BS flocculant was 2–4 kg/t of dry matter in the 5% working solution [6]. The required amount of flocculants polyECHDMA and Praestol 853 BS was determined in various ratios. It was found that the most effective is a mixture of Praestol 853 BS and polyECHDMA in a volume ratio of working solutions 1:14. The results are shown in Figure 1.

The studies carried out made it possible to establish that the use of polyECHDMA at the stage of primary settling of industrial effluents significantly affects the quality of raw sludge which is further supplied for dewatering. In particular, the raw sludge becomes looser and lighter in comparison with the sludge obtained with the previously used flocculant based on polyDADMAC at the same stage of purification.

With an optimal amount of added flocculant polyECHDMA of 0.08 ml/dm³, unbound aggregates are formed that are capable of rapid precipitation. It is explained by the fact that when the Praestol-853 BS flocculant is dosed into the sediment, large and heavy flocules are formed, some of which during the phase separation come to the surface of clarified part. This is due to the fact that during the formation of flocules, voids filled with water are formed between their particles. It is known that Praestol-853BS has a high binding capacity; when interacting with suspended particles, fast setting occurs, which leads to incomplete dewatering.

We revealed a decrease in the stability of hydrophilic macromolecules due to their interaction with positively charged amino groups of polyECHDMA located on the main molecular chain by the formation of bridging bonds (cross linking).
Figure 1. Efficiency of wastewater treatment with the combined use of polyECHDMA and Praestol-853BS in terms of clarity.

Therefore, the destruction of hydration layers formed on the surface of dispersed phase and the release of a part of colloid-bound water occur. This demonstrates the change in sludge quality with the addition of polyECHDMA. There are hydroxyl groups on the main chain of polyECHDMA, which upon the subsequent addition of Praestol-853BS interact with the positively charged active centers of the flocculant macromolecule. In other words, when polyECHDMA is added, primary flocules of small size are formed; upon the subsequent addition of Praestol-853BS, they form secondary flocules which are larger than the primary ones and settle at a higher rate [7].

To determine the possible effect of residual concentration of polyECHDMA in sediments on reducing the consumption of Praestol-853BS, studies were carried out on industrial sediments on the main adjustable parameters of mechanical dewatering process in a laboratory centrifuge, which results in the separation of the test mixture into cake and filtrate water (centrifugecentrifuge). The results obtained shown in Table 1 indicate that the residual content of polyECHDMA in the sludge makes it possible to reduce the dose of the applied flocculant without deteriorating the main indicators of clarity of the separated filtrate water (not less than 40%) and the moisture content in the cake (70.0 ÷ 75, 0%) [8].

3. Result and discussion
So when using the flocculant polyDADMAC with a monthly average consumption of 19.6 tons for sedimentation of suspended solids of industrial wastewater, the consumption of Praestol for dewatering sludge after the primary radialsettling tanks averaged 2.310 kg/month. Under our long-term tests, the monthly average consumption of polyECHDMA is 0.68 tons, while the consumption of Praestol is 1.357 kg/month. The performance factors of the flocculant polyECHDMA in the process of sedimentation of suspended solids supplied with industrial wastewater exceed those of the previously used flocculant polyDADMAC.
The synthesized reagent polyECHDMA has demonstrated that the use of Praestol makes it possible to obtain an effective (up to 95%) flocculant in the processes of settling wastewater in primary radial settling tanks. This significantly reduces the costs of the process.

Thus, in order to intensify the technology of treatment of sewage sludge which is a waste of petrochemical industries, the synthesized reagent polyECHDMA has been tested and recommended as an effective (up to 95%) flocculant in the in settling and dewatering processes. Its use in the processes of settling wastewater in primary radial settling tanks makes it possible to significantly reduce the content of suspended solids from 1.000 to 60 mg/dm³ at high sedimentation rate (about 4.8 ml/min).

It has been determined that the use of polyECHDMA makes it possible to obtain sludge with a denser structure which has a beneficial effect on water-yielding capacity during mechanical dewatering of wastewater. In addition, it is demonstrated that the dose of Praestol-853BS flocculant is reduced by 1.5 times without deterioration of the main indicators of clarity of the filtrate water (separated centrate) (at least 40%) and moisture content in the cake (70.0 ÷ 75.0%) used in combination with polyECHDMA for dewatering of sewage sludge.

### Table 1. Test results for industrial sludge dewatering by using flocculant polyECHDMA.

| No | Indicators | Settled sludges | Filtrate water (centrate) | Cake |
|----|------------|-----------------|---------------------------|------|
|    | Residual concentration of polyECHDMA | Dosage, kg/t dry matter | pH | Moisture, % | Suspended solids content, mg/dm³ | Indicator pH | Suspended solids content, mg/dm³ | Clarity, % | Moisture, % |
| 1  | 0.9        | 7.5             | 6.27 | 98.3     | 12000 | 7   | 200 | 64 | 77.1 |
| 2  | 0.75       | 7.0             | 6.27 | 98.2     | 11600 | 6.9 | 190 | 62 | 77.4 |
| 3  | 0.64       | 6.5             | 6.25 | 98.2     | 13000 | 6.7 | 210 | 55 | 77.0 |
| 4  | 0.8        | 6.0             | 6.95 | 98.1     | 12500 | 6.8 | 220 | 50 | 76.5 |
| 5  | 0.7        | 5.5             | 7.00 | 98.4     | 7600  | 7.3 | 120 | 53 | 76.2 |
| 6  | 0.5        | 5.0             | 6.80 | 98.3     | 7900  | 7.4 | 140 | 55 | 75.0 |
| 7  | 0.4        | 4.5             | 7.15 | 98.3     | 8350  | 7.4 | 155 | 52 | 74.3 |
| 8  | 0.8        | 4.0             | 7.13 | 98.2     | 8500  | 7.6 | 150 | 59 | 72.6 |
| 9  | 1.6        | 3.5             | 7.18 | 98.1     | 11000 | 7.6 | 140 | 50 | 74.5 |
| 10 | 0.7        | 3.0             | 7.15 | 98.2     | 8000  | 7.5 | 190 | 55 | 74.7 |
| 11 | 0.9        | 2.5             | 7.23 | 98.1     | 10000 | 7.5 | 210 | 57 | 74.8 |
| 12 | 1.2        | 2.0             | 7.25 | 98.5     | 11000 | 7.6 | 220 | 53 | 74.7 |
| 13 | 1.4        | 1.5             | 7.54 | 98.9     | 10200 | 7.2 | 210 | 54 | 74.6 |
| 14 | 0.9        | 1.0             | 7.75 | 98.7     | 9800  | 7.3 | 200 | 48 | 75.0 |
| 15 | 0.65       | 0.5             | 7.91 | 98.8     | 10000 | 7.1 | 270 | 42 | 74.8 |

### 4. Conclusion

It has been established that the residual concentration of polyECHDMA supplied with the sediments of the primary sedimentation tanks to the mechanical dewatering unit can significantly reduce the consumption of the expensive Praestol flocculant used at this unit and accordingly reduce the costs of the process.
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