Study on the Influencing Factors of PAM Dosage for Sludge Dewatering in Municipal Sewage Treatment

Fang Liu, Jun Li
Beijing University of Technology, Beijing, China

Abstract. This paper introduces the action mechanism of PAM chemical and the influencing factors of PAM dosage for sludge dewatering in municipal sewage treatment plant, and the PAM dosages of several sewage treatment plants is analyzed. It is found that the chemical dosage of sewage treatment plant with high concentration of inlet water is more than that with low concentration when the same belt pressure filter were used, and meanwhile the chemical dosage with belt pressure filter is more than that with centrifuge dewatering equipment under the premise of the same inlet water quality. When the temperature is low, the chemical dosage is more than that when the temperature is high in the same sewage treatment plant. According to the level of temperature and the differences in influent water quality and dewatering equipment, the operators of municipal sewage treatment plant could select the appropriate model of chemical and optimize the chemical dosage to reduce costs in the production process, through the refinement of management and adjustment of equipment parameters in time.

1. Introduction
Municipal sewage treatment plant as a unit of centralized control of pollutants has a very important role in the pollutant emission reduction strategy. In recent years, the total size and number of sewage treatment plants in China continue to increase. Municipal sewage treatment plants need to use the phosphorus removal chemical, disinfectants, carbon chemical and desliming chemical for different purposes during the production and operation. The reasonable use of various chemical can ensure water quality and sludge moisture content to reach the standards. It becomes new focus of attention by the managers of sewage treatment plants that how to reduce the amount of various chemical and ensure a proper cost.

This paper analyzes the mechanism and influencing factors of PAM chemical when the belt pressure filter and centrifuge dewatering equipment are used in municipal sewage treatment plant for sludge dewatering. On the basis of ensuring the proper selection of chemical and the best operating status of the desliming equipment, the chemical dosages of multiple sewage treatment plants is analyzed and the specific influencing factors on the chemical dosage are verified to provide direction for the operation adjustment and fine management of the sludge treatment plant.

2. Action Mechanism of Pam
PAM chemical are divided into cationic chemical and anionic chemical. Cationic chemical are mainly used in sewage treatment plant for sludge dewatering, and anionic chemical are used for flocculation or coagulation aid. The action mechanism of cationic chemical is discussed as follow.
2.1. Characteristics of Pam
The molecular weight of PAM chemical which ranging from 3 million to 20 million is large, that make it easier to coagulate stable molecules into clusters. PAM chemical have different physical forms of the product such as powder, ball-shaped and emulsion.

The powder products are formed by grinding, crushing and granulating after the monomers are polymerized into a gel form, the advantage of powder products is that the active ingredient can reach 100%. The sphere-shaped products are obtained by evaporation after the monomers are suspended and polymerized a solvent, the advantage of sphere-shaped products is that they are dust-free and dissolve rapidly.

The emulsion products are formed after the monomers are emulsified in a solvent and then a surfactant (also called a converter) is added at the polymerization end to dilute the emulsion in water, the advantage of it is that the liquid form is easy to use and improve the efficiency of some applications to obtain a specific molecular structure. Emulsions include liquids and dispersions. Liquid monomers polymerize at low concentration in aqueous solutions, the advantages of liquids products are simplicity of use. Dispersed monomers are scattered in the concentrate and then polymerized, the advantage of dispersed products is direct online dosing without the preparation and maturation which could reduce the investment in preparation equipment and improve the efficiency especially in the flotation separation stage.

The powder products are commonly used as PAM chemical for desliming in municipal sewage treatment plants, because the powder product is easy to transport and store, the price has obvious advantages compared with the liquids products, but a high-quality preparation system is needed.

2.2. Action Mechanism of Pam
When PAM chemical present in water, active groups with positive (+) or negative (-) charge are formed. Depending on the degree of ionic flocculant, ions or hydrogen bonds (such as non-ionic polymers) interact with the particles in the water [1], [2].

The molecular weight of the flocculant is very high and can increase the detachment of the particles and the coagulation of the small flocs, by adsorbing and bridging function or trapping the particles with flocs, to form larger flocs and accelerate the liquid / solid separation, as shown in Figure 1 [3], [4].

2.3. Main Action Parameters of Pam
The main action parameters of PAM chemical include charge type, charge density, molecular weight, molecular structure and monomer type.

![Figure 1. The function mechanism of PAM](image-url)
2.3.1. Charge type (+ or -). The type of flocculant charge is selected based on the type of particle. In general, anionic (-) flocculants are used to capture inorganic particles and cationic (+) flocculants are used to capture organic particles [5].

2.3.2. Charge density (%). The charge density represents the amount needed to obtain the optimal flocculant at the lowest dose. Charge density depends on the type of sludge. For sludge produced with municipal sewage, the primary function of charge density is to reflect the organic content of the sludge, which is usually absorbed by the volatile solids content. The charge on the cation is higher with volatile solids content increase. The effect of sludge types on PAM chemical charge is shown in Table 1.

| Type of sludge               | Applicable charge          |
|------------------------------|----------------------------|
| Mineral sludge               | Low to middle anions       |
| Physical and chemical sludge | Low anions, low cations    |
| Digestion and raw sludge     | Low cation                 |
| Mixed sludge                 | Medium cation              |
| Biological sludge            | High cation                |

2.3.3. Molecular weight (MW). The choice of molecular weight which equals to the length of the polymer chain, depends on the type of dewatering equipment. Generally, centrifuge dewatering equipment is suitable for high molecular weight, while belt press filter is suitable for low molecular weight.

2.3.4. Molecular structure. The choice of molecular structure depends on the dewatering performance desired. For the cationic PAM chemical, there are three kinds of molecular structure as shown in Figure 2.

![Figure 2. Molecular structure of PAM](image)

The advantages of linear structure and branched structure are less dosage and broader molecular weight range; the disadvantage is the low floc strength and the risk of overdosing. The advantages of cross-linked structure is the higher floc strength, better drainage performance and lower moisture content of sludge; the disadvantage is the higher dosage.

2.3.5. The type of monomer. The type of monomer used to synthesize the PAM chemical also affects the flocculation effect. Usually, two different cationic monomers, ADAM-MeCl and APTAC, are used in the production of cationic PAM chemical. APTAC monomers are not sensitive to the cationic charge hydrolysis. The most common anionic monomer is sodium acrylate.

3. Pam Dosage of Factors
The dosage of PAM chemical is affected by the factors such as influent water quality, the operation of dewatering equipment, the temperature and other external conditions. The specific analysis is as follows and the actual operation data of several sewage treatment plant is compared.
3.1. The Impact of Influent Water Quality
Different influent quality leads to different sludge character. Different sludge character will result in large differences in the characteristics and dosage of the required PAM chemical by the same sludge moisture content treatment standard.

3.2. Impact of Dewatering Equipment
The main working mechanism of belt press filter is that the suspended material after flocculation is removed most of the free water by the function of flocculant and gravity during concentration, and then dewatered by gravity through the cloth bucket evenly arranged in the two closed filter belt, under the action of the pressure roller, the filter cake is squeezed and sheared so as to remove most of the free water and some capillary water in the material.

The main working mechanism of centrifugal dewatering equipment is that the flocculated suspended material can be separated from water under the action of centrifugal force generated by high-speed rotation.

The main mechanism of the above different equipment will result in the required characteristics and dosage of PAM chemicals may also be different.

3.3. Impact of External Conditions
External conditions such as temperature will have an impact on the amount of dosage, the effect of the chemical is generally poor when the temperature is low, and the sludge will change, then dosage will change, generally it can be optimized by chemical type re-selection.

4. Experimental Data Analysis of Pam Dosage
Based on the above analysis of various influencing factors, the PAM dosage of 12 sewage treatment plants were compared to verify the specific factors affecting the dosage, to provide direction for the operation adjustment and fine management of the sludge treatment plant. The analysis result is shown as follow.

4.1. Dosage Analysis with Different Influent Water
In order to verify the impact of different influent water quality conditions on the dosage, we selected eight sewage plants in the south and north China, the influent water quality were domestic sewage, but the influent concentration of the northern sewage treatment plant was significantly higher than that of the south. In the northern sewage treatment plant, the average COD of influent water was 300-500mg / L, while the average COD of South was 150-300mg / L. The primary sedimentation tank was set in the north, which was not set in the south. The effluent water standards are all Grade A, the sludge moisture content is 80% at last. All eight water plants adopted a belt press filter, which adjusted the operating status to the best level and optimized the PAM type ensure the best sludge removal effect. In the eight sewage plants, annual average chemical dosages of dry sludge per ton were shown as Figure 3.

As shown in Figure 3, under the same basic conditions, the dosage of sewage treatment plants in the north is generally higher than that in the south, and the consumption of dry sludge in the north is in the range of 3.87 kg / t to 5 kg / t, Whereas that of southern plants is between 1.36 kg / t and 2.80 kg / t, thus verifying that the difference in influent water quality conditions resulted in a large difference in dosage. This may be due to the proportion of biological sludge is high while the COD content of mixed sludge is high, and the surface charge of the biological sludge is negative electricity, the action mechanism of PAM is adding electric neutralization and adsorption bridging, so that a higher dosage is required [6], [7], [8].
4.2. Dosage Analysis with Different Dewatering Equipment

In order to verify the impact of dewatering equipment on the dosage, eight sewage treatment plants were selected in the northern China. The influent water quality was both domestic sewage and influent COD averaged 300-500mg/L. The primary sedimentation tanks were set and effluent standards were grade A, the sludge type was mixed sludge, the water content of treated sludge was 80%. The centrifugal dewatering equipment or belt press filter were used in the eight sewage treatment plants, annual average chemical dosages of dry sludge per ton were shown in Figure 4.

As shown in Figure 4, when the other conditions are basically similar, the belt press filter generally consumes higher chemical consumption of dry sludge than the centrifugal dewatering equipment, and the belt press filter consumes 3.20kg/t to 3.80kg/t, while the centrifuge dewatering equipment consumes 3.87kg/t to 5kg/t. Maybe due to belt press filter can not be woven too dense, in order to
prevent small sludge leakage, more flocculant needed to add to form the sludge to larger flocs, so the dosage is higher than the centrifuge dewatering equipment.

4.3. Dosage Analysis with Different Temperature Condition
In order to verify the effect of temperature on chemical dosage, the same type of chemical is used in winter and summer by taking a sewage plant in the north as an example. The treated sludge had moisture content of 80% and the dosage of dry sludge for different seasons is shown in Figure 5.

![Figure 5. Dosage analysis in different temperature condition](image)

As shown as Figure 5, with the same chemical in different seasons, the chemical consumption of dry sludge at the first and the fourth quarter of the year is between 5.50 kg/t and 6 kg/t in the same municipal sewage treatment plant. In the second and the third quarter, when the temperature is high, the chemical consumption of dry sludge is between 3 kg/t and 4 kg/t. The dosage is obviously higher when the temperature is lower, it may be due to the less rainfall when the temperature is lower, it leads to higher influent concentration and more difficulty in processing the sludge than the high temperature, and the low temperature causes the viscosity of the dissolving water to be larger when the chemical is dispensed, resulting in poor solution effect. The dosage can be optimized by re-selecting chemical type in winter.

5. Conclusion
Totally twelve sewage treatment plants is analyzed in this paper, when chemical dosages of dry sludge per ton is in the range of 1.35-5 kg/t, the chemical dosage is affected by the influent quality, dewatering equipment and temperature, respectively. It concludes that the chemical dosage of sewage treatment plant with high concentration of inlet water quality is more than that with low concentration of inlet water quality when the same belt pressure filter are used, and meanwhile the chemical dosage with belt pressure filter is more than that with centrifuge dewatering equipment under the premise of the same inlet water quality. When the temperature is low, the chemical dosage is more than that when the temperature is high in the same sewage treatment plant. According to the level of temperature and the differences in influent water quality and dewatering equipment, the municipal sewage treatment plant operators could select the appropriate type of chemical and optimize the chemical dosage to reduce costs in the production process, through the refinement of management and adjustment of equipment parameters in time.
Acknowledgements
Major Science and Technology Program for Water Pollution Control and Treatment (2014ZX07201-011-004-3).

References
[1] Shu X.W., Zheng H.L. Advances in cationic organic flocculent. Modern Chemical Industry, 2001, 21(10): 13-16.
[2] Lu H.X., Liu S.F., Yu S.T., et al. Preparation of cationic polyacrylamide flocculant and its flocculating effect. Environmental Protection of Chemical Industry, 2007, 27(4): 374-378.
[3] Lin C.F., Shien Y. Sludge dewatering using centrifuge with thermal/polymer conditioning. Water Sci. and Technol., 2001, 44(10): 321-325.
[4] Zheng H.L., Li L.C., Wei Y., et al. Synthesis of cationic polyacrylamide flocculant for sludge dewatering Chemical Industry and Engineering Progress, 2007, 27(4): 564-568.
[5] Pei Jin, Yu Xiaohua, Yao Hong, Wang Hui, Ma Lanqianya. “Dewaterability improvement and toxicity reduction of pharmaceutical sludge using PAM”. 2014, 9(8): 3939-3945.
[6] Liu C.G., Zhang P.Y., Zeng G.M, et al. Sewage sludge conditioning by bioleaching-dual PAC and PAM. Environmental Science, 2010, 31(9): 2124-2128.
[7] Zheng H.l., Li L.T., Jiang S.J., et al. Study on influencing factors and function mechanism of CPAM for regulateon of concentrated sludge. Chinese Journal of Environmental Engineering, 2009, 3(6): 1009-1102.
[8] LI Ting, Wang Yili, Feng Jing, Xu Meng. Relationship Between Physicochemical Characteristics of Activated Sludge and Polymer Conditioning Dosage. Environmental Science. 2012, 33(3): 889-895.