Application of screw stacker combined with plate and frame filter press for dewatering of ultra magnetic sludge from river suspensions

Lijun Wu[1,2]*, Shengsheng Han[1,2], Wenyu Shi[1,2], Shiyi Li[1, 2], Qiao Yan[1,2], Xiangru Li[1,2], Xin Luo[1,2]

[1]Power China Huadong Engineering Corporation Limited, Hangzhou 311122, Zhejiang, China;
[2]Huadong Eco-Environmental Engineering Research Institute of Zhejiang Province, Hangzhou 311122, Zhejiang, China.

Abstract. The black and odorous water body treatment projects promoted the application of various engineering solutions but also produced large quantity of solid waste, like the ultra-magnetic sludge (UMS) which is the river suspensions thickened and discharged by ultra-magnetic separator. Characterized by high concentration of water content, organic matter and compact structure, the dewatering of UMS will greatly benefit transportation and further use. In this study, the mechanical dewatering methods were tested and combined onsite in order to reduce the water content of UMS to 42~48%. The operating parameters and effects were discussed while the indexes of resultant UMS was analyzed shows promising use as land improvement agent.

1. Introduction

China's urban water bodies are commonly black and odorous polluted by various sources. River water environment management is a long-term, complex and costly system work, which requires multiple measures such as source control and pollution interception, internal source management and ecological restoration. For black and smelly water bodies or closed water bodies without external recharge cannot achieve full interception of pollution, bypass treatment technologies can be used to improve river water quality. Bypass treatment technology refers to the setting up of suitable treatment facilities in the vicinity of the water body, abstracting and purifying polluted river water before discharging to the downflow. In recent years, the mostly commonly used bypass treatment technologies in urban river water include chemical flocculation and sedimentation, ultra-magnetic separation, biochemical combination process and artificial wetland technology.

The ultra-magnetic separation technology removes pollutants by magnetic inoculation. By mixing magnetic powder and coagulant, a magnetic network is formed so that pollutants can be captured and trapped. Under the action of the applied magnetic field, the flocs with magnetic properties are then separated from the water body. This technology has the advantages of short residence time, small land use, and low operation cost. Hence it is growly applied to reduce phosphorus, suspended matter, algae and organic pollutants in urban water bodies[1]. However, due to the large sums of suspended particulates, the resultant UMS becomes a serious problem which often requires dewatering to reduce its volume for the benefits of transportation and end use. To meet legal regulations, municipal sludge is required to reduce water content blow 80% before transported offsite. Despite no legal regulations is applicable towards UMS, dewatering of UMS economically onsite has becoming a topic of great interest.

Using municipal sludge as the treatment target, the existing relevant studies stressed that mechanical dewatering equipment includes centrifugal dewatering machines, stacked-screw dewatering machines and plate and frame filter presses are choices of economical preference. The stacked-screw machine uses screw extrusion force to realize the thickening and dewatering of sludge. The stacked screw machine can run continuously, but the water content of the output mud can only reduce to 75%~80% at most. The plate and frame filter press mainly uses the pressure difference between the two sides of the filter medium as the driving force, and uses the filter cloth to realize the separation of water from the sludge. The plate and frame filter press can produce out mud with 65% water content. But the biggest problem is that it can only operate intermittently. In case of large treatment capacity, multiple units need to be equipped implying higher equipment investment costs. In order to overcome the faults of both machines, some studies used stacked screw machine as preliminary dewatering device before plate and frame filter presses. In combination, positive results were achieved in the dewatering application of municipal sludge and dyeing sludge [2, 3]. But no studies were done on UMS from urban water body suspension. By comparing the

*The corresponding author's e-mail address: wu_lj2@hdec.com

dewatering of UMS using a stacked screw machine solo and combination with a plate and frame filter press, this study aims to investigate the technical feasibility of both. By analysing the nature of the dewatered UMS, its resource utilization being explored.

2. Materials and Methods

2.1 Experiment objectives

In this study, two common mechanical dewatering equipment and three common flocculants were used to dewater and reduce the volume UMS originated from suspense of a river in Nanhu District, Jiaxing city. The process and recommend operating parameters were explored, and the characteristics of dewatered UMS were investigated to provide the reference for the operation of similar projects.

2.2 Experiment materials

In this experiment, UMS with a water content of 97.5% was stored in the sludge thickening tank before used as the test object. In order to overcome the electrical repulsion and hydration properties of UMS, cationic polyacrylamide (CPAM), polymeric aluminium chloride (PAC) and lime (CaO) were used as conditioning agents. The solid contents, molecular weight and degree of hydrolysis of CPAM used is 97%, 12million and 10.8% respectively. Anionic and neutral ionic polyacrylamide was opted out based on the experimental results from previous research [4].

2.3 Experiment equipment

The stacked-screw machine and plate and frame filter press were selected as sludge mechanical dewatering equipment. The plate and frame filter press used is Jingjin single chamber feed filter press model 630, with a serious of supporting facilities include screw pump, air compressor, mud storage drum and flocculation drum. The stacked-screw machine in use were Zhongjian Huaneng stacked-screw dewatering machine model 303, with capacity of 300~450kg/h.

Figure 1. Stacked-screw machine (right) and plate and frame filter press (left).

2.4 Experimental set-up

2.4.1Frame filter press procedure

Firstly, the UMS (97.5% water content) from the sludge thickening tank was pumped into the conditioning tank in which conditioning agents (CPAM and PAC) were added at a certain proportion (based on the dry mass of UMS). In conditioning tank, quick stirring for 5 min followed by slow stirring for 5 min were conducted before mixture was pumped into the plate and frame machine for 20-30 min. Upon stopping feeding, the air compressor was turned on in order to increase squeezing pressure of 1.2-4 MPa. At the end of the pressing, the plate and frame were dismantled to observe the shape of the mud cake, then the thickness and water content of the mud cake were measured.

2.4.2Frame filter press procedure combined with preliminary Screw stacker plate

The UMS (97.5% water content) from the sludge thickening tank was firstly pumped into the stacked screw machine for preliminary dewatering. The water content of UMS is reduced to ~93% at the outlet of stacked screw machine. It is then pumped into the sludge conditioning tank in which conditioning agents (CPAM, PAC and lime) were added at a certain proportion (based on the dry mass of UMS). The mixture was then followed the same procedure as was described in 2.4.1. In the end, the thickness of the sludge cake is measured, and the sludge cake is taken for water content determination.

2.4.3Water content determination

Beakers were weighed as w1, a certain amount of sludge was put into beakers and weighed as w2. After drying at

105℃ overnight in an oven, the beakers were then weighed as w3. Then the water content of sludge can be calculated from the formula:

$$\text{water percent} = \frac{w2-w3}{w2-w1} \times 100\% \quad (1)$$

3. Discussion

3.1 UMS dewatering using Frame filter press

When the plate and frame dewatering machine was used alone, the feeding time was prolonged and the pressing time was also extended to more than 30 min because the cake is hard to formulate. In the meanwhile, the discharge flux was small and turbid due to high solid content. The water content of mud cake reduced to 45-55% can be celebrated because mud cake thickness was less than 15 mm. Trial A1 had the least thickness at 2mm showing solid -water separation effect was poor. Despite the aid of CPAM and PAC, trial A2 and A3 could not improve the mud forming effect to a satisfactory level due to high concentration of water content and compact structure of UMS. Overall, it is high not recommend to use plate and frame dewatering machine solely as a mean of UMS dewatering.

Table 1. UMS dewatering trials using frame filter press only

Trials	Conditioning Agents		Time(min)		Pressure (MPa)		Water Content (%)	Mud Cake Thickness (mm)
	CPAM	PAC	Infeed	Pressing	Infeed	Pressing		
A1	0	0	10	30	1.0	1.2	45.4	2
A2	0.05%	5%	40	35	1.4	2.0	52.4	10
A3	0.05%	10%	40	30	1.5	2.0	54.7	11

3.2 UMS dewatering using combined machinery

Combined mechanical dewatering is a simplified referring to a stacked screw dewatering process added before plate and frame dewatering as preliminary dewatering device. As a result, UMS at the output of stacked screw is characterizes with a moisture content of 93% before entering the plate and frame press. Its benefits were dramatic. Both the feeding time lower and the pressing time were reduced, in add to increase of the discharge flux and transparency. Most importantly, the mud cake produced is more than 15mm thick demonstrating good molding effect.

Table 2. UMS dewatering trials using combined machinery

Trials	Conditioning Agents			Time(min)		Pressure (MPa)		Water Content (%)	Mud Cake Thickness (mm)
	CPAM	PAC	CaO	Infeed	Pressing	Infeed	Pressing		
B1	0.1%	15%	0	20	20	1.3	3.0	48.6	18
B2	0.1%	20%	0	30	20	1.3	4.0	45.1	19
B3	0.1%	0	10%	30	20	1.3	4.0	46.0	19
B4	0.1%	0	20%	30	20	1.3	4.0	42.5	20

The key parameters for this procedure include conditioning agents, feed water content, solid sludge type and quantity, pressing time and pressure, etc. In terms of conditioning agents, both PAC and lime can be used. But in reality, the alkane leak from lime can be troublesome. By comparing trials b1 and b2, the gain in respect to water content reduction was achieved at the cost of conditioning agents in the case of UMS.

3.3 End use of dewatered UMS

Test data show that Dewatered UMS has an organic matter content of 130 g/kg and a total nutrient content of 55.45 g/kg, pH of Dewatered UMS was about 6.2 and the heavy metal content was far below the standard requirements, making it a resource of certain value.

Despite UMS failed to meet the standard of “The disposal of sludge from municipal wastewater treatment plant - The quality of sludge used in gardens or parks (GB / T 23486-2009)”、 “Disposal of sludge from municipal wastewater treatment - Control standards for agricultural use(CJ / T309-2009)“, its used as land improvement agent can be recommended according to the requirement in ”Disposal of sludge from municipal wastewater treatment plant - Quality of sludge used in land improvement (GB / T24600-2009)”.

Table 3. Dewatered UMS characterization and standards requirement

Test Items	Units	Dewatered UMS	Gardens or Parks Use (GB/T 23486-2009)	Agricultural Use (CJ/T 309-2009)	Land Improvement Use(GB/T 24600-2009)
pH		6.2	5.5-8.5	5.5-9	5.5-10
Water Content	%	45.1	<40	<60	<65
Organic Content	g/kg DS	130.6	≥250	≥300	≥100

Nutrient Content ($N+P_2O_3+K_2O$)	g/kg DS	20.3	≥30	≥30	≥10
As	mg/kg DS	3.8	<75	<75	<75
Ge	mg/kg DS	0.24	<20	<15	<20
Cr	mg/kg DS	72	<1000	<1000	<1000
Cu	mg/kg DS	29	<1500	<1500	<1500
Pb	mg/kg DS	20	<1000	<1000	<1000
Ni	mg/kg DS	37	<200	<200	<200
Zn	mg/kg DS	93	<4000	<3000	<4000
Hg	mg/kg DS	0.22	<15	<15	<15

Since the UMS in this study is originated from magnetic coagulation treatment plant of urban river water bodies in vicinity to residence area, the toxic and hazardous substances such as heavy metals in their water bodies are well below the standard. If the river is discharged with industrial wastewater, it is necessary to test the UMS composition with the characteristics of pollution sources to analyse the feasibility of its utilization as resource.

4. Conclusions

(1) Deep dewatering of UMS only by means of plate and frame filter press only is difficult to be pressed into shape, and the efficiency is too low to be practical. In operation, it is not recommended to use plate and frame dewatering machine directly for UMS dewatering treatment.

(2) Combined use of stacked screw machine followed by plate and frame dewatering can be a viable option for deep dewatering of UMS. The resultant mud cake has a thickness of 19-20mm as well as moisture content 42-48% when operation parameters various.

(3) The organic matter content of mechanically dewatered UMS is 130.6 g/(kg dry sludge) and the nutrient content is 20.3 g/(kg dry sludge), which is high in nutrients and low in heavy metals . Therefore, it can be further used as agents for soil improvement.

References

[1] Zhang Q, Wang Z and Li C 2021 *Chinese J. Environ. Eng.* **15** 3133-40

[2] Li R, Sun X and Ma J 2020 *Text. Dyeing Finish. J.* **42** 39-41

[3] Wang X, Hu H and Zhu W 2017 *Environ. Sustainable Dev.* **42** 237

[4] Huang G, Wang Z, Ji Q, Yi Y and Xiao B 2019 *Energy Conserv. Environ. Prot.* **10** 79-81