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MOISTURE DISTRIBUTION AND REMOVAL EFFICIENCY OF WASTE ACTIVATED SLUDGES

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ABSTRACT

A classification scheme based on the bound water content measured via filtration (W_{FIL}), expression (W_{EXP}) and drying test (W_{DRY}) was utilised for constructing the moisture distribution in excess activated sludges. The differences W_{FIL}-W_{DRY}, W_{DRY}-W_{EXP} and W_{EXP} were respectively interpreted as the interstitial water, surface water and internal water. The distribution and removal efficiency of moisture in excess activated sludges taken from a large wastewater treatment plant were found. The relative moisture removal efficiency for a belt filter press was near constant. Copyright © 1996 IAWQ. Published by Elsevier Science Ltd.

KEYWORDS

Bound water; drying; expression; filtration; moisture distribution.

INTRODUCTION

Sludge dewatering is one of the most difficult processes in wastewater sludge treatment. Since the moisture distribution within a sludge shows a strong correlation with the performance of many processes, people have tried for years to differentiate the water content which is in different states. The simplest way of differentiation is to divide the water content into bound water and free water (Robinson and Knocke, 1992).

Bound water content in a sludge is the theoretical limit of mechanical dewatering processes (Vesilind, 1994). Various methods had been proposed to measure the bound water content in a sludge (a brief review can be found in Lee (1994a)), nevertheless, some recent studies had demonstrated that the bound water was an operationally defined value depending on the measurement methods (Robinson and Knocke, 1992, Lee and Hsu, 1995). Based on the bound water measured via centrifugal settling, differential scanning calorimetry (DSC), drying and expression tests, a moisture classification scheme was proposed (Lee and Hsu, 1995). However, inherent limitations were found to exist in the centrifugal settling (Lee, 1994b) or the DSC (Lee and Lee, 1995). In the present report, drying, expression and vacuum filtration tests were employed for bound water measurements, and based on which, a modified moisture classification scheme was proposed and compared with the remaining moisture contents in the sludge cake treated by an on site belt filter press.

EXPERIMENTAL

The samples

The samples were taken from a wastewater treatment plant in a fibre plant in Hsinchu, Taiwan, and were tested within two hours after sampling. The wastewater treatment capacity was in the range of 12000-16000 m^3/day with waste sludge cakes generated at a rate of approximately 50 tons/day. The biological oxygen demand (BOD), chemical oxygen demand (COD) and suspended solid (SS) data in Table 1 were the results for supernatant drawn from the sludge samples, measured using Environmental Protection Administration (Taiwan) standard methods. The last column of Table 1 lists the hindered settling velocity for the constant-rate period in a batch sedimentation test.

Table 1. The properties of activated sludge

No	%(w/w)	BOD(mg/L)	COD(mg/L)	SS(mg/L)	v(mm/hr)
1	0.65	7	74	63	8.7
2	0.54	129	323	21	1.3
3	0.47	5	41	20	12.4
4	0.69	4	22	7	15.3

Sludge samples No. 1, 3 and 4 were taken after some warm and sunny days and the sludges exhibited a low BOD/COD value and a good settleability. These sludges were referred to as "normal sludges" in this work. Sludge sample No. 2 was taken just after an attack of a typhoon which caused a sudden temperature drop and a heavy shower lasting for about three days. A large amount of filaments was found to appear in this sludge sample. This sludge sample was referred to as the "abnormal sludge".

Bound water measurements

A constant temperature/humidity drying apparatus was employed for the drying test. The drying temperature was set at 40°C and the humidity was kept at about 60%. An electronic balance connecting to a personal computer was employed for automatically recording the sample weight during an experiment. Other details could be found elsewhere (Lee and Hsu, 1994b). The moisture content per unit dry mass at transition from constant to falling rate period was defined as bound water W_{DRY} (Sato, 1982, Smollen, 1990, Matsuda et al., 1992, Robinson and Knocke, 1992, Lee and Hsu, 1994).

A constant head piston press (Triton Electronics Ltd., type 147) was employed for finding the moisture content in sludge in equilibrium with an applied pressure of 4500 psi. The remaining moisture per unit dry mass in the cake was defined as the bound water W_{EXP} (Lee and Hsu, 1995).

A standard vacuum filtration apparatus was installed as that in Lee and Hsu (1993). After the sludge was exhausted in a test, the suction was not cut off but was continuously employed for sucking out the remaining moisture till cracks appeared on the cake surface. The remaining moisture per unit dry mass was measured and was defined as bound water W_{FIL}.

Belt filter press

An on site belt filter press (KLEIN, type KS30) was employed for estimating the sludge moisture removal efficiency. This filter houses four dewatering zones: the first and second drain zone, wedge-shaped zone, and the crimp-and-squeeze zone. The squeezing and shearing of sludge was mainly provided by seven pressure rolls of decreasing diameters in the last zone. No flocculant was added in the sampling period to keep the conditions comparable.

RESULTS AND DISCUSSION

Bound water contents

The bound water contents measured via drying, expression and filtration tests are listed in Table 2. Clearly the data support the previous conclusions that the bound water is an operationaly defined value (Robinson and Knocke, 1992, Lee and Hsu, 1995). For the normal sludges the bound water contents are low (approx. 3 to 9 kg/kg dry solid, depending on the measurement methods); whilst for the abnormal sludge the bound water content is rather high (about 7 to 12 kg/kg). In either case, the sequence $W_{FIL}>W_{DRY}>W_{EXP}$ holds.

Moisture distribution

The moisture is divided into four categories: free, interstitial, surface, and internal water, as demonstrated in Lee and Hsu (1995). Owing to the extremely high pressure exerted in the expression test, W_{EXP} can be taken as the upper limit of any mechanical dewatering processes. It is hence interpreted W_{EXP} as the internal water. The bound water contents measured via drying tests had been shown to be the portion of water whose minimum solid/liquid binding strength is close to that for physical sorption (Lee and Lee, 1995). W_{DRY} is hence interpreted as the sum of internal and the surface water. The continuous passage of air stream through the filtration cake should have carried out most free moisture, W_{FIL} is therefore taken as the sum of internal, surface and interstitial water.

Based on this scheme, the corresponding interstitial, surface and internal water can be calculated from the bound water data and the results are also listed in Table 2. The interstitial or surface water for normal and abnormal sludges are similar, nevertheless, the internal water contents are very different. It is thereby the portion of moisture most tightly binding to the sludge flocs that makes the major difference.

Removal efficiency

The moisture contents remaining in the sludge cakes after the belt filter press (W_B) were measured and listed in Table 2. Under normal conditions, the moisture contents remaining in the sludge is 5.6-6.3 kg/kg, or equivalently, 13-15% (w/w) solid content. For abnormal sludge, W_B is about 9.4 kg/kg. Note the strong correlation between W_B's and the bound water contents measured.

Table 2. Bound water, moisture distribution and removal efficiency in sludges

No	W_{FIL} kg/kg	W_{DRY} kg/kg	W_{EXP} kg/kg	W_v kg/kg	W_s kg/kg	W_i kg/kg	W_B kg/kg	R -
1	7.8	4.6	2.8	3.2	1.8	2.8	5.6	0.44
2	11.6	8.4	6.7	3.2	1.7	6.7	9.4	0.45
3	8.1	5.7	3.6	2.4	2.1	3.6	6.3	0.39
4	8.5	4.9	3.3	3.6	1.6	3.3	5.9	0.5

Based on the dry solid content, the moisture removal capacity for the belt filter press varies between sludge samples. A relative moisture removal efficiency can be defined as follows:

$$R = 1 - (W_B - W_{EXP})/(W_{FIL} - W_{EXP})$$

The R values calculated are listed in Table 2. For both normal and abnormal sludges, R is nearly constant (40-50%), which suggests that the action of the belt filter press is to remove a certain portion of the "removable" moisture content.

CONCLUSIONS

A classification scheme based on the bound water content measured via filtration, expression and drying test is utilised for constructing the moisture distribution in the excess activated sludge taken from a large wastewater treatment plant. The internal water for the abnormal sludge was found to be much higher than those for the normal sludges, while the surface or interstitial water contents are found to be similar for both the normal and abnormal sludges. A relative moisture efficiency was defined. For a belt filter press, the relative removal efficiency is 40-50% and is approximately constant.

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