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EXCESS ACTIVATED SLUDGE TREATMENT WITH FERRITE PARTICLES AND ELECTRO MAGNETS

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ABSTRACT

The production of excess sludge is increasing in Waste Water Treatment Plants (WWTPs) in most of the countries with the modernization of the living style; i.e. increasing of the ratio of sewerage populations. Many approaches are being carried out to treat the excess activated sludge. We have developed a new approach to reduce excess activated sludge by using magneto-ferrite treatment. We have succeeded to use magneto-ferrite treatment in lab. scale to reduce excess activated sludge production. Ferrite particles and electro magnets (EMs) are used in this method. Ferrite particles are non-toxic and safe for biological substances. They can be easily separated from activated sludge by using magnets from the biological substances. In this paper, we will describe the theoretical analysis of our method. We also consider our treatment method with the view of the theoretical analysis. This knowledge in activated sludge treatment process is very important to reduce the production of activated sludge.

KEYWORDS: excess activated sludge, ferrite particles, electro magnet, sludge treatment.

I. INTRODUCTION

Excess activated sludge is one of the major problems in Sewerage Treatment by using activated sludge method [1]. Activated sludge method itself is a low cost and easier way to run WWTPs and therefore, it is used in most of the public sewerage systems in Japan. But the additional excess sludge and their treatment are the main problems in this method. Again it is to be noted that the excess activated sludge containing a large amount of water is difficult to reuse them as natural resources.

Several reports are available for reducing of access sludge including chemical treatment, ultra-sonic treatment, ozone treatment etc. [2-5]. These methods are effective in a sense but still there is need of more effective and easier treatment method of excess activated sludge treatment. We have developed a unique method for treating of activated sludge by using ferrite particles with an AC magnetic flux with low frequency [6-9]. The process deals with ferrite particles with excess activated sludge and works as a microscopic ball mill. Ferrite particles are magnetic materials and they can be easily controlled by certain magnetic flux density. Our method showed good results in reducing excess activated sludge and it also paved the way for a zero emission water treatment system in laboratory scale [6, 7].

Ferrite particles and Electromagnets (EMs) are used in our method. Ferrite particles are non-toxic and safe for biological substances. They can be easily separated from activated sludge by using a permanent magnet or any kind of magnets. A certain amount of ferrite particles with certain amount of activated sludge is taken into a treatment container which is placed in between two EMs. The ferrite particles are ferromagnetic materials and they can be taken along with the EMs. The ferrite particles gather together when they are within the magnetic flux and they are spread away when they are out of the magnetic flux. Thus, the movements of the ferrite particles cause a local pressure to the activated sludge and which cause the cell lysis of the activated sludge. In this paper, we will describe an approach to analyze this magneto-ferrite treatment from the knowledge of electromagnetics and try to evaluate our method both in theoretical and experimental process. The equations for electromagnetic force applied on the ferrite particles were derived and they were verified by some simple experiments. The knowledge of this paper can be helpful in both activated sludge reduction and cell lysis of the excess activated sludge.

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II. EXPERIMANTAL

Magneto-ferrite Treatment Setup

Two coils (1.51H each) were set up in vertical direction with a certain gap in between them. These coils were connected with an AC voltage source (BP4610, NF). The coils were connected with 2 diodes (10ETF10, VISHAY, I_{FAV} = 10A, V_{RRM} = 1000V) which were installed in opposite direction to each other. The experimental setup and the circuit model can be seen in Fig.1 [8]. The diodes were set up with the coil in a way that when the coils were connected with the AC power supply, the electric current was provided alternative directions to the coils. Thus, the coils become EMs alternatively with the AC voltage source. A certain amount of ferrite particles and activated sludge were taken to the treatment container. Detail information of the treatment container and other related parameters are available in the related papers published before [6,7]. Ferrite particles are magnetic substance and move with the magnetic flux. While they moved in the container, collisions occured with the activated sludge. For a certain AC power supply with frequency, these collisions may break down the cell wall or cell membrane of bioorganisms of activated sludge. It may switch to sterilization and cell lysis of the activated sludge. If these treated sludge is taken to the aeration tank where they can be decomposed by the non-treated sludge, then the sludge reduction can be achieved.

Mathematical Analysis

A model is introduced from the knowledge of electromagnetics for a ferrite particle facing the force from the electromagnet. Fig. 2(a) shows a model of the assumption of the electromagnetic force F_{EM} working on a ferrite particle. The coils (electromagnets; EM) are separated by Δx [m] and then the F_{EM} can be expressed by the following equation,

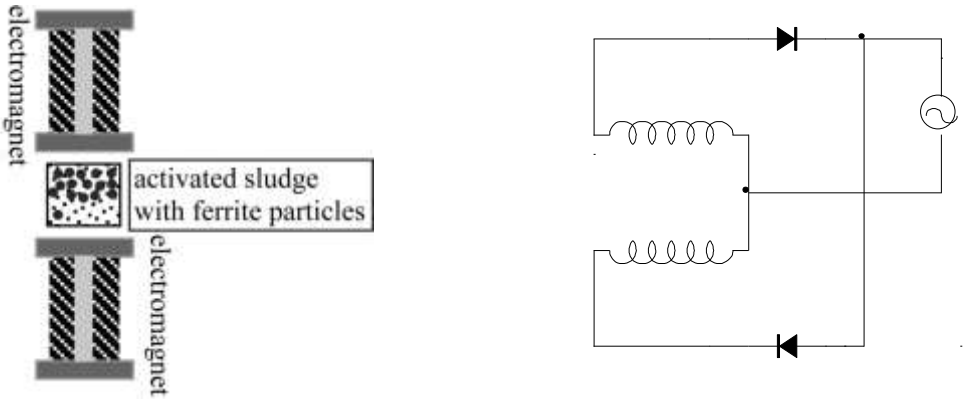
$$F_{EM} = \frac{B^2 S}{2\mu_0} \tag{1}$$

Here, B [T] is the magnetic flux intensity of the electromagnet (EM) and the S [m^2] is the surface area of the coil core and the μ_0 is the permeability of the vacuum; $4\pi\times10^{-7}$ [H/m]. In order to eliminate the complexity the equation is assumed for ideal conditions.

For the medium of air and considering the number of turns of a coil is N and the r.m.s. value of the electric current in it is I, the value of the magnetic flux density B can be assumed as,

$$B = \frac{\mu_0 N I}{\Delta x} \tag{2}$$

And finally, from equations (1), (2) the force F_{EM} can be determined like the equation (3).



(a) EMs with the treatment container ***(b) equivalent circuit***

Fig.1. Experimental setup for the excess sludge treatment [8]

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$$F_{EM} = \frac{S\mu_0 N}{2}\left(\frac{I}{\Delta X}\right)^2 \quad (3)$$

When the electromagnetic force satisfies the condition for $F_{EM} - mg > 0$, only then a ferrite particle with a mass of m [kg] can be moved upwards defeating the force of gravity. Here, g [m/s^2] is the acceleration due to gravity. We have defined the certain value of F_{EM} as the critic value when the F_{EM} becomes equal to mg; $F_{EM} = mg$. The critic values of F_{EM} change with the distances Δx [m] and we can calculate the related values of electric current of the EM with it. Calculations were carried out for a number of ferrite particles with a total mass of 1×10^{-3} kg. The distance Δx [m] was changed to 1×10^{-2} m to 7×10^{-2} m by increasing 1×10^{-2} m. Again a simple setup was prepared to verify the mathematical equations for 1×10^{-3} kg of ferrite particles. The setup can be seen in Fig.2 (b).

Measurement of Magneto-ferrite Treatment

After the verification of the mathematical model, we performed the cell lysis process with the ferrite motion particles and EMs. A certain amount of activated sludge with certain concentration was put in a treatment container. Then a certain amount of ferrite particles were put in the treatment container and the magneto ferrite treatment was applied for 3 h. The values of MLSS (Mixed Liquor Suspended Solids), COD (Chemical Oxygen Demand) and SV_{30} (Sludge Volume in 30 minutes) were measured before and after the magneto ferrite treatment. The experimental results were compared with the initial values of the samples. We performed the experiments with 4 times with different MLSS values of the excess activated sludge.

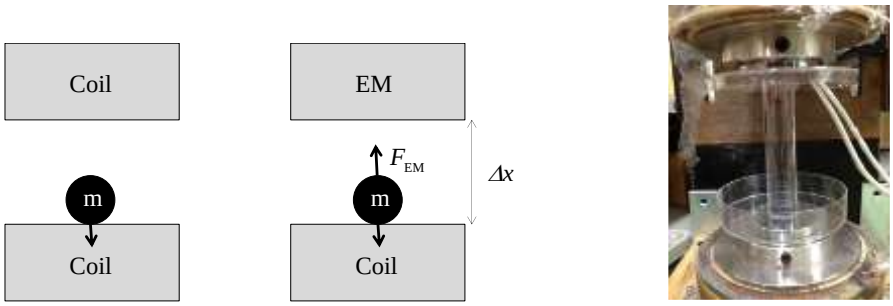
III. RESULTS AND DISCUSSION

Comparison of the calculated values and measured values of *I* for critic values of F_{EM}

The values of *S* and *N* are constant numbers for a certain EM, and μ_0 is also a constant number. The *N* was 500 turns for the EMs. The S was 1.96×10^{-3} m^2. We calculated the critic values of F_{EM} by changing the distance of EM from the ferrite particles from 1×10^{-2} m to 7×10^{-2} m while increasing the distance with 1×10^{-2} m. The critic values of F_{EM} indicate the values which satisfied with the condition of $F_{EM} - mg = 0$. Square wave voltage with the frequency of 1Hz was used for the measurement. Again, the size of the ferrite particles was less than 53μm. The voltage and size of ferrite particles were chosen considering the previous papers [6-9]. The calculated values and measured values are sown in Fig. 3. It can be seen that the calculated values are well fit with the measured values and which indicates the validity of the mathematical model of this treatment process.

Magneto ferrite treatment

The seed activated sludge was taken from the Yabase waste water treatment plant, Akita, Japan. Activated sludge was cultured at a miniature waste water treatment plant at Akita University, Japan. The cell lysis process was performed 4 times with different concentration of activated sludge; 1500, 2000, 4000 and 6000mg/L. For simplicity of the experiments, we mentioned the samples as a, b, c and d with the related initial concentrations of activated sludge. The MLSS of the samples were measured by an electronic moisture meter (MOC-120H, Shimadzu). 290 mL of the related samples were taken to the container with 85.3 g of ferrite particles. The ferrite



(a)EMs with a ferrite particle ***(b) setup for theoretical analysis***

Fig.2. Theoretical analysis of the magneto-ferrite treatment

particles were good ferro magnetic particles (JR41G, Metals and Chemicals Co. Ltd.). The values of ferrite

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particles' size and amount were chosen from the previous reports [6-9]. From the mathematical analysis, it was clear that the critic value of the electric current to lift up the ferrite particles against the gravity; I =3.1 A. An AC voltage source (BP4610, NF) was connected to the EMs and the square voltage of 100Vp-p was supplied. The current in the coils was 7.8 Ap-p and that was more than the critic value. The voltage was applied for 3 h for each experiment. Again, for each experiment the MLSS of activated sludge was measured before and after of the experiments. The values of pH of the samples were measured with a twin pH meter (B-211, Horiba). And the COD values of the samples were measured by a COD meter (UV-M3, Sky Science). We also measured the SV_{30} for all the samples. The values of the related parameters can be seen in Table 1. The results will be explained with the sample a. The initial value of MLSS of the sample a was 1500 mg/L and it changed to 110 mg/L after the cell lysis. Snapshots were put in Fig.4 (a, b) where SV_{30} measurement was carried out for the sample a. It can be seen that after the treatment, the MLSS decreased and which might increase the COD of the sample. The values of the COD at Table 1 also supported it. However, the values of pH did not change so much after the treatment. And for all the samples, the values of the SV_{30} could not be determined. It is to be mentioned that during all the treatment time, an electric fan was used to the coils of the EMs as an air cooling system. The temperature of the treatment container was not mentioned here as they were always found same to the room temperature.

Fig.4 (c) shows the relation ship of MLSS changing with the initial values of the samples. Again, it shows the relationship of the COD values of the samples. Before the treatment, it is clear that the values of COD do not depend on the values of the samples' initial amount of the sludge concentration. But the values of COD were obviously increased after the treatment of the activated sludge with the EMs. It can easily be understood that it is possible because of the cell lysis of the activated sludge performed by our method.

IV. CONCLUSION

Increasing of excess sludge production is a great problem in expanding of Sewer networks in Japan. A method was introduced to reduce excess sludge in WWTPs by using ferrite particles and EMs. In this work, we proposed a theoretical model to understand the movement of ferrite particles within the magnetic flux in between the EMs. Simple model was introduced with the general knowledge of electromagnetics. The model was justified with the experimental results. Again, we performed the magneto-ferrite treatment to reduce the excess sludge and again the results showed the cell lysis of the activated sludge. Thus, our method can hopefully be a pioneer in reducing the excess activated sludge in WWTPs.

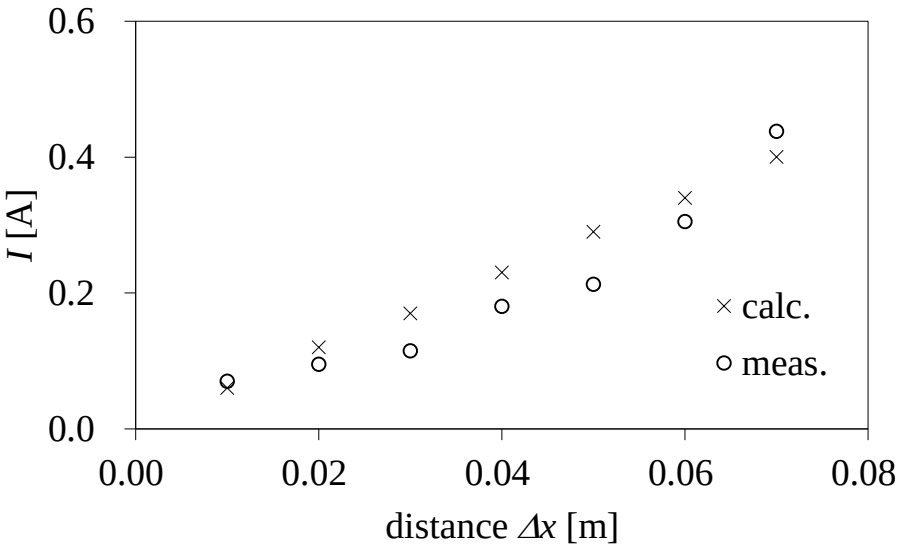

Fig.3. The theoretical and measured values of the critic electric current needed to lift up of 1 g of ferrite particles against the gravity

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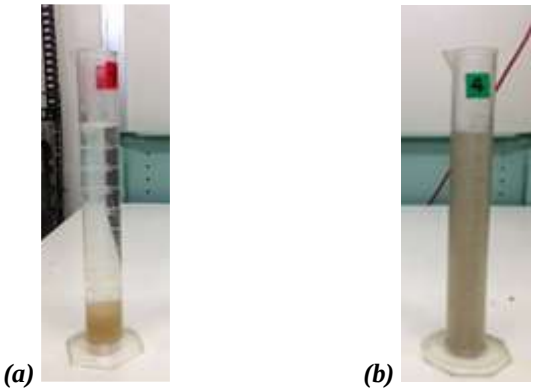
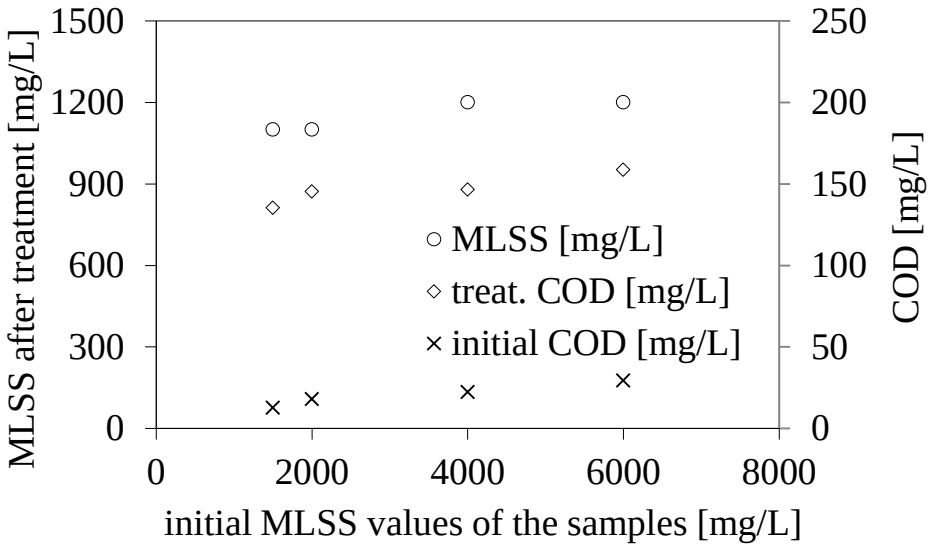
Table 1. Magneto-ferrite treatment results

samples		MLSS [mg/L]	COD [mg/L]	pH	SV_{30} [%]
a	control	1500	12.7	6.1	15
	after the treatment	1100	135.4	7.1	-
b	control	2000	18.0	6.7	22
	after the treatment	1100	145.3	7.2	-
c	control	4000	22.4	6.1	34
	after the treatment	1200	146.4	7.2	-
d	control	6000	29.3	6.1	75
	after the treatment	1200	158.7	7.1	-



(a) ***(b)***

snapshots of settled activated sludge (a) initial and (b)after the treatment



(c) MLSS- COD relationship

Fig.4. Results of the activated sludge treated with magneto-ferrite treatment

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V. REFERENCES

[1] Jiri Wanner: Activated Sludge Bulking And Forming Control, Technomic Publishing Company (1997)
[2] Alfredo Cordova Lizama, Cristian Carrera Figueiras, Rafeal Rojas Herrera, Alejandro Zepeda Pedreguera and Juan Enrique Ruiz Espinoza: "Effects of ultrasonic pretreatment on the solubilization and kinetic study of biogas production from anaerobic digestion of waste activated sludge", International Biodeterioration and Biodegradation, vol.123, pp.1-9 (2017)
[3] G. Erden and A. Filibeli: "Ozone Oxidation of Biological sludge: Effects on Disintegration, Anaerobic Biodegradability, and Filterability", Environmental Progress and Sustainable Energy, vol.30, no.3, pp.377-383 (2011)
[4] LiangGuo, Zengshuai Zhang, Mengchun Gao, Zonglian She, Yangguo Zhao, Yiding Guo and Jian Sun: "Comparison of thermophilic bacteria and alkyl polyglucose pretreatment on two-stage anaerobic digestion with waste sludge: Biogas production potential and substrate metabolism process", Bioresource Technology, vol.249, pp.695-703 (2018)
[5] Audrey Battimelli, C Millet, J P Delgenès and R Moletta: "Anaerobic digestion of waste activated sludge combined with ozone post-treatment and recycling", Water Science and Technology, vol.48, no.4, pp.61-68 (2003)
[6] Masaya Endo, Mahmudul Kabir, Masafumi Suzuki and Noboru Yoshimura: "Reduction of Excess sludge by magneto ferrite treatment Applied to the return sludge", IEEJ Transactions on Industry Applications, vol. 136, no.3, pp. 198-203 (2016) (in Japanese)
[7] Mahmudul Kabir, Masaya Endo, Masafumi Suzuki and Noboru Yoshimura: "Study on the treatment of excess activated sludge on the return sludge line", IEEJ Transactions on Industry Applications, vol. 134, no.2, pp. 239-240 (2014) (in Japanese)
[8] Mahmudul Kabir, Masafumi Suzuki and Noboru Yoshimura: "Excess Activated Sludge Reduction by Using Electromagnets and Ferrite Particles, IEEJ Transactions on Electrical and Electronic Engineering, vol. 7, no.2, pp. 220-224 (2012)
[9] Mahmudul Kabir, Masafumi Suzuki and Noboru Yoshimura: "A New Method for Reduction of Excess Sludge by Using Ferrite Particles, Japanese Journal of Water Treatment Biology, vol. 43, no.4, pp. 189-187 (2007)

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