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Utilization of Paper Sludge Wastes for Treatment of Wastewater from Food Processing Industries

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Abstract

The food processing industries usually produced large amount of wastewater containing fine and small particles. It takes long time for complete settlement of the fine and small particles in the wastewater. The coagulation method appears to become one of the useful treatments. New inorganic coagulant named "Agoclean–P" has been developed from paper sludge ash. The treatment by coagulation and flocculation were carried out for the wastewater from three different food processing industries namely soup, tofu, and natto. "*Hi–Biah–System*", which is an in–situ solidification system, was used for the continuous treatment of wastewater. The parameters for the water quality were pH, five–day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP). These parameters after the treatment became much lower values relative to those obtained before the treatment.

***Keywords*:** Food processing industries; Paper sludge ash; Coagulant; Wastewater treatment; Chemical oxygen demand.

Introduction

Wastewater treatment from the food processing industries needs special treatment method owing to high chemical oxygen demand (COD), high concentration of fats, oils, greases, ammonia, and minerals, and high levels of suspended solids with low settling property. Generally, the food treatment processing uses large amount of water at different stages. Because large amount of wastewater contains fine and small particles, it takes long time for complete settling. Different approaches for wastewater treatment have been investigated in order to develop effective methods for the treatment of wastewaters from food processing before releasing the wastewater into the open environment. Therefore, the coagulation method seems to be one of the promising treatments, because it is simple, easy to operate and low cost.

Paper sludge is generally dried in air, and subjected to incineration. The resulting ash is then disposed by landfilling or is used by mixing in cement. The quantity of paper sludge produced is approximately 1.5 million tons per year in Japan, and about 0.6 million tons of incinerated ash is formed thereby [1]. Paper sludge ash has been used in many applications such as cement replacement materials [2], raw material for constructional brick [3], and effective adsorbent for arsenic, cadmium

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and lead ions in the wastewater [4].

In the present work, new inorganic coagulant named "Agoclean–P" has been developed from paper sludge ash. Furthermore, the inorganic coagulant has been applied to the treatment of wastewater from food processing industries.

Materials and Methods

Preparation of inorganic coagulant named "Agoclean–P"

Waste paper sludge was provided from the paper mill wastewater treatment plant. The paper sludge was dewatered and given to the incinerator for the generation of heat energy. Paper sludge ashes were collected from fluidized bed–reactor in the incinerator. The temperature in the incinerator was 800 ºC or higher in order to operate the system without the formation of dioxins. Since the paper sludge ashes alone could not become a coagulant, the addition of other inorganic materials was necessary.

Wastewater from food processing industries

The slurry wastewaters were collected from three food processing industries (soup, tofu and natto factories). Approximately 5 m^3 of each wastewater was applied into the continuous flow wastewater treatment process.

Jar tester experiment (Coagulation and flocculation)

The Jar–tester was used to evaluate the optimum time for coagulation and flocculation with inorganic coagulant (Agoclean–P). The tests were performed in one liter plastic jar (rectangular shape) at ambient temperature (about 25ºC).

Continuous wastewater treatment with Hi–Biah–System (HBS)

The in–situ solidification system named "*Hi–Biah–System*" was used for the continuous wastewater treatment. The detailed information has been described previously [5,6]. The HBS consists of a main stock tank of sediments, a coagulant chamber, reactors (coagulation and flocculation) and a dewatering section. The treatment capacity was approximately 1~2 m^3/hour. The agglomeration of small particles into big flocks, the separation, handling and disposal for the sludge were performed during the continuous treatment.

Analytical methods

Chemical oxygen demand (COD), five–day biochemical oxygen demand (BOD_5), total nitrogen (TN) and total phosphorus (TP) were measured by Japanese Industrial Standard (JIS)–standard analytical methods. The concentrations of total suspended solid (TSS) was determined by a spectrophotometer with a resonance line of 660 nm, based on the Japanese Industrial Standard (JIS)–standard analytical methods (K0101).

Results and Discussion

The developed inorganic coagulant was applied into the treatment of wastewater from Japanese food processing industries such as soup, tofu and natto factories. Soup is used in the instant noodle making. Tofu is very popular in Japan and Japanese people have had the tofu in daily life. Tofu is prepared from grained soybeans. Natto is produced from the ferment of soybeans.

The chemical compositions of paper sludge ash are shown in (Table 1). Since the paper sludge ashes alone cannot be applied as the coagulant, the inorganic coagulant Agoclean–P was prepared by the addition of other inorganic materials. The chemical compositions for Agoclean–P are shown in (Table 2).

Table 1. **Chemical compositions for paper sludge ash**

Components	Content (%)
CaO	10~35
SiO_2	25~35
Al_2O_3	23~40
SO_3	3~8
Fe_2O_3	1.5~5
MgO	1.5~5
TiO_2	0.5~1.5

K_2O	0.3~1

Table 2. **Chemical compositions for Agoclean-P coagulant**

Components	(%)
CaO	44.2
SiO_2	26.9
Al_2O_3	12.7
SO_3	12.2
Fe_2O_3	1.2
MgO	1.2
TiO_2	0.8
K_2O	0.4
Others	0.4

Although the traditional coagulants such as polyaluminium chloride (PAC) and polymer coagulant were tested for the treatment of wastewater from Japanese food processing industries, the coagulation could not occur for the wastewater. The reason is not clear. May be, high concentration of fats, oils and greases in the wastewater hinder the coagulation and flocculation processes.

First, the Jar–tester was applied to evaluate the optimum time for coagulation and flocculation with Agoclean–P. Rapid mixings at 200 rpm for 4 minutes after the addition of Agoclean–P, followed by slow mixing 20 rpm for 1 minute, were selected as the optimum conditions.

The purification parameters before and after the treatment are pH, 5–day biochemical oxygen demand, chemical oxygen demand, total suspended solids, total nitrogen and total phosphorus. The continuous HBS treatment with inorganic coagulant Agoclean–P was applied into the treatment of wastewater from Japanese food processing industries. The results are summarized in (Table 3). Although the initial pH for the three wastewaters was in the acidic range from 5 to 6, pH values were neutral between 8–8.5 after the treatment.

The values for chemical oxygen demand and five–day biochemical oxygen demand drastically decreased after the treatment, and the removal efficiencies for COD and BOD_5 were 88–92 and 85–97%, respectively. Although the total suspended solid before the treatment was very high (>8000 ppm), all of the values became less than 100 ppm after the continuous HBS treatment with inorganic coagulant Agoclean–P. Also, the values of total nitrogen and phosphorus after the treatment were much lower compared with those obtained before the treatment.

Table 3. **Continuous wastewater treatment with HBS with inorganic coagulant Agoclean–P**

Food factory		pH	BOD_5 (ppm)	COD (ppm)	TSS (ppm)	TN (ppm)	TP (ppm)
Soup	before	4.5	600	1100	>8000	80	39
	after	8.2	16	120	<100	18	<1
Tofu	before	4.5	1100	2100	8000	100	52
	after	8.0	92	170	<100	5	<1
Natto	before	5.5	660	1500	>8000	30	27
	after	8.5	100	180	100	19	2.6

Flow rate; 1.5 ton/hour.
Dose of Agoclean–P; 2000 ppm for soup, 1000 ppm for tofu, 2500 ppm for natto.

In order to explain possible basic fundamental coagulation mechanisms for the wastewater treatment with Agoclean–P, the micro structure of the surface of the dried products after the coagulation was evaluated by scanning electron microscopy (SEM). The needle–shaped ettringite was observed in the coagulated products (Fig. 1). We can conclude that the ettringite formed a three–dimensional network structure in the coagulated products for the wastewater treatment [7]. Therefore, the coagulation owing to the formation of ettringite may play the significant role on the purification of wastewater.

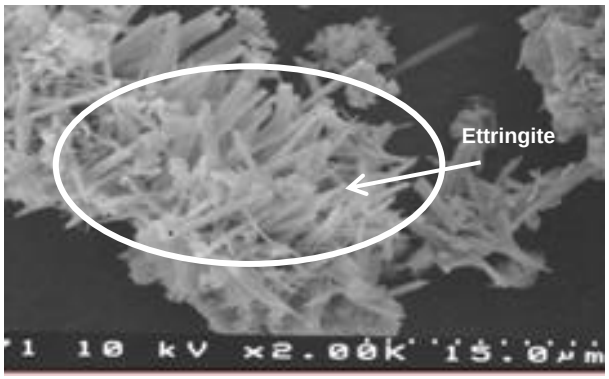

Figure 1. **Ettringite observed in the dried products after the coagulation.**

Conclusion

The wastewater treatment by the coagulation with Agoclean−P inorganic coagulant, which consisted of paper sludge ash wastes, appears to become one of very effective methods for the wastewater from food processing industries. The continuous HBS treatment system with inorganic coagulant Agoclean−P can be applied into 5m^3/h of wastewater. The quality of aqueous solution released from different food processing industries after the treatment could be drastically improved by the present methods

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