PHYSICAL CHARACTERISTICS OF BIOSOLID ADSORBENT

Chiang Hung-Lung, Yan-Li Chen, Wei-Han Chen, and Sen-Yi Ma

Department of Environmental Engineering, Fooyin Institute of Technology, Kaoshiung, Taiwan

Introduction

Biosolid is produced in a great quantity when the wastewater is treated by a biological process. The cost of disposal of this sludge is high, which has been estimated that the disposal cost is around that of 50 % of the total wastewater treatment (1). Bio-sludge can be used as a fertilizer. However, since bio-sludge contains the heavy metal or toxic organic compounds, it will effect the use of sludge-derived fertilizer. Thermal treatment processes are included of combustion and pyrolysis that offer an alternative for the stabilization or elimination of the sludge. The pyrolysis process heats the sludge in an inert atmosphere, which can concentrate the heavy metal (except mercury and cadmium) in the pyrolytic residue (2-3). The leaching of these metals in ashes from pyrolysis is less than from incineration (4). But the pyrolytic residue disposal is a problem for the sludge treatment in the pyrolytic process. The reisdue is potential for using in road surfacing, building materials and metal reclamation. In 1987, Chiang and You added the chemicals into sewage sludge and then pyrolyzed the sewage sludge to obtain high surface area adsorbents for VOCs adsorption (6). In 1996, Lu and Lau obtained an adsorbent from sewage sludge by a chemical activation process and used the adsorbent for H_2S separation (7).

In this study, we selected the biosolid from a wastewater treatment plant as the raw material. Chemical activation process was used to develop the pore volume of pyrolytic residue. SEM photography, surface area and pore size distribution of pyrolytic residue were investigated to understand the characteristics of biosolid adsorbent.

Experimental

Raw material

Biosolid samples were obtained from a biological wastewater treatment plant. In each run, two kilograms of the sludge sample were heated at 105 ^{o}C for 24 hours. Pre-dried sludge was immersed in a 0 to 5 M $ZnCl_2$ solution and mixed for 24 hours. The sludge was filtered out and dried at 105 ^{o}C for 24 hours. Each sample was brought

back to the laboratory and kept in a desiccator for further utilization.

Pyrolytic processes

Sludge was pyrolyzed at different temperatures. The pyrolytic process was carried out in an isothermal reactor that was heated by a horizontal electric furnace. At the beginning of each run, 40 g of the oven-dried sludge was placed in the middle of a quartz reactor tube [ID (30 mm) and length (70 cm)]. Two L/min high purity Nitrogen (99.995%) was used as the sample bed purge gas. The reactor was heated to the desired temperature in 15 K/min increments. When the furnace was heated to the reaction temperature, the quartz reactor was put into the furnace for the pyrolytic process. Pyrolysis temperatures varied from 673 to 1073 K and the residence times ranged from 1 to 60 minutes. When the pyrolysis process was completed, the Nitrogen gas continued flowing to quench the residue temperature. After the residue was cooled to room temperature, it was removed from the reactor and then weighed and characterized.

Physical Characteristics of Adsorbent

The physical characteristics of activated carbon, including of specific surface area, pore size distribution and pore diameter, were measured with N_2(g) adsorption using an ASAP 2010 micropore analyzer at 77 K in liquid N_2. Micropore characteristics diameter was measure d with Ar(g) adsorption also using an ASAP 2010 micropore analyzer at 77 K using liquid N_2. The surface area was calculated by the BET method (Brubauer et al., 1938). The pore size distribution was determined by the BJH method (Barrett et al., 1951).

Results and Discussion

SEM photograph

Figure 1 shows the SEM photos for these pyrolytic residue samples. SEM pictures are carefully examined and found there are many pores in the grains of pyrolytic residue and the diameter is from a little to 20 μm. SEM photos also reveal that the flake of $ZnCl_2$ was formed on the surface of pyrolytic residue of $ZnCl_2$-immersed sludge, because the cleaning process of pyrolytic residue can not be completely cleaned up.

N_2 adsorption isotherm

The typical N_2 adsorption isotherm was shown as Figure 2. The adsorbent was obtained from 3M-$ZnCl_2$ immersed sludge that was pyrolyzed at various temperatures for 60 mins. Results indicated the pore volume was developed at the pyrolytic temperature over 400 ^oC. When the pyrolytic temperature was higher than 600 ^oC, the pore volume might be enlarged and reduced the pore volume. Therefore, the sequence of the pore volume of pyrolytic residue of 3M-$ZnCl_2$ immersed

sludge was 600 ^{o}C >700 ^{o}C >500 ^{o}C >400 ^{o}C.

Pore size distribution

The typical pore size distribution was shown as Figure 3. Results indicated the pore volume of biosolid adsorbent was in the vicinity of several decades Angstroms and several hundreds Angstroms in diameter. According to the classification of the IUPAC, the pore diameter between 20 and 500 Å is categorized to the mesopore. Therefore, the biosolid adsorbent is regarded as a mesopore adsorbent.

Surface area

The surface area of biosolid adsorbent was shown as Table 1. Results indicated the surface area of pyrolytic residue of 0M-$ZnCl_2$ immersed sludge has a significant increase when the pyrolytic temperature was higher than 800 ^{o}C. When the pyrolytic temperature was higher than 500 ^{o}C, the surface area of pyrolytic residue of $ZnCl_2$-immersed sludge was significantly increased. At the temperature over 700 ^{o}C, the high temperature destroyed the pore structure and enlarged the pore diameter, which caused the surface area of pyrolytic residue could be reduced.

Conclusions

Results indicated the surface area had significantly increased for 0M-$ZnCl_2$ immersed sludge at the pyrolytic temperature over 800 ^{o}C. For $ZnCl_2$ immersed sludge, the surface area developed when the pyrolytic temperature was higher than 500 ^{o}C. According to the pore size distribution of biosolid adsorbents, results indicated their pore volume was mostly in mesopore. The surface area of pyrolytic residue appeared the biosolid could be reuse as an adsorbent after the proper treatment.

References

1.Proctor and Redfern Ltd. Final Report to Environment Canada, 1987.

2.Kaminsky W, Kummer AB. Fluidized bed pyrolysis of digested sewage sludge. Journal of Analytical and Applied Pyrolysis 1989; 16:27-35.

3.Stammbach MR, Kraaz B, Hagenbucher Richarz W. Pyrolysis of sewage sludge in a fluidized bed. Energy and Fuel 1989; 3: 255.

4.Bellman M, Kummer AB, Ying Y, Kaminsky W. in: GL. Ferrero, K. Mamiatis, A., Buekens, A. Bridgewater (Eds), Proceedings luxembourg. fluidized bed pyrolysis of sewage sludge, Elsevier, Amsterdam, 1989, 191-194.

5.Brunner CR. Design of sewage sludge incineration system. p. 48, Noyes Data Corporation, Park Ridge, New Jersey, 1980.

6.Chiang PC, You JH. Use of sewage

sludge for manufacturing adsorbents. The Canadian Journal of Chemical Engineering 1987; 65:922-927.

7.Lu GQ, Lau DD. Characteristics of sewage sludge-derived adsorbents for h_2s removal. Part 2: Surface and pore structural evolution in chemical activation. Gas Sep. Purif. 1996; 10:103-111.

8.Brubauer S, Emmett HP, Teller E. Adsorption of gas in multimolecular layers. J. Am. Chem. Soc. 1938; 60:309-319.

9.Barrett EP, Joyner LS, Halenda PP. The determination of pore volume and area distributions in porous substances. I. Computations from nitrogen isotherm. J. Am. Chem. Soc. 1951; 73: 373-380.

Acknowledgments

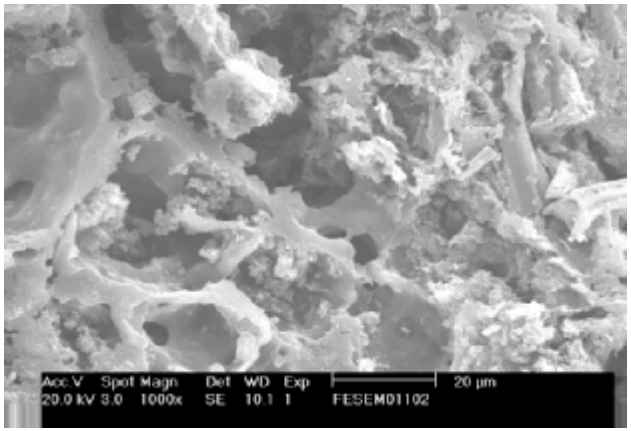
The authors express their sincere thanks to Fooyin Institute of Technology and the National Science Council, Taiwan, ROC for their financial support (Contract no. NSC 89-2211-E-242-011) of this study.

Table 1. Surface area of biosolid adsorbents

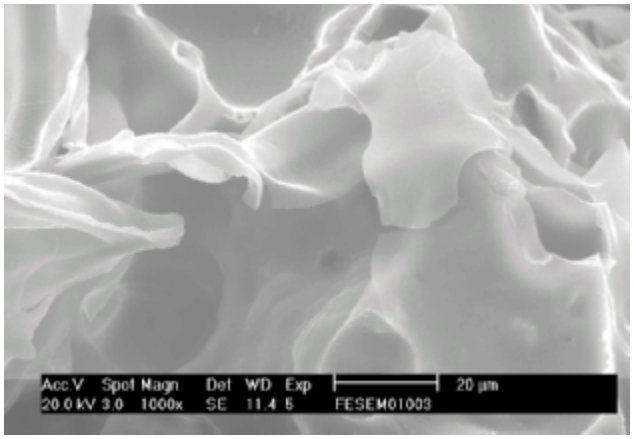
Pyrolytic temperature (^oC)	$ZnCl_2$ additives (M)				
	0	0.5	1.0	3.0	5.0
400	6.4±3.4	14.6±6.2	15.4±5.0	14.4±9.7	56.8±14.9
500	8.9±3.7	254±294	521±186	562±47.0	645±179
600	6.9±3.7	539±51	759±149	848±85.0	869±41
700	9.3±2.7	426±272	561±361	821±95	578±383
800	28.0±18.5	NA	NA	NA	NA
900	32.9±20.6	NA	NA	NA	NA

NA: not available

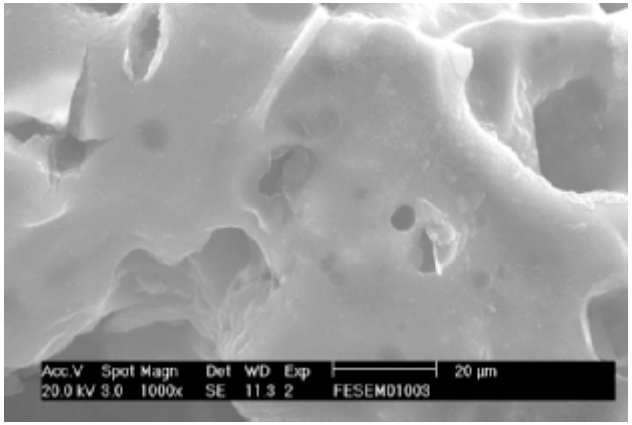
(a)700 ^{o}C, 30min



(b)500 ^{o}C, 3M $ZnCl_2$, 30min



(c)600 ^{o}C, 3M $ZnCl_2$, 30min



(d)700 ^{o}C, 3M $ZnCl_2$, 30min

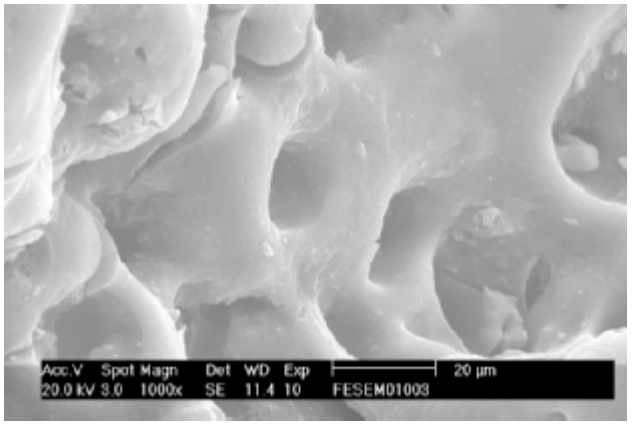


Figure 1. SEM photograph. (a)Sludge was pyrolyzed at 700 ^{o}C for 30 min. (b) 3M $ZnCl_2$ immersed sludge was pyrolyzed at 500 ^{o}C for 30 min. (c) 3M $ZnCl_2$ immersed sludge was pyrolyzed at 600 ^{o}C for 30 min. (d) 3M $ZnCl_2$ immersed sludge was pyrolyzed at 500 ^{o}C for 30 min.

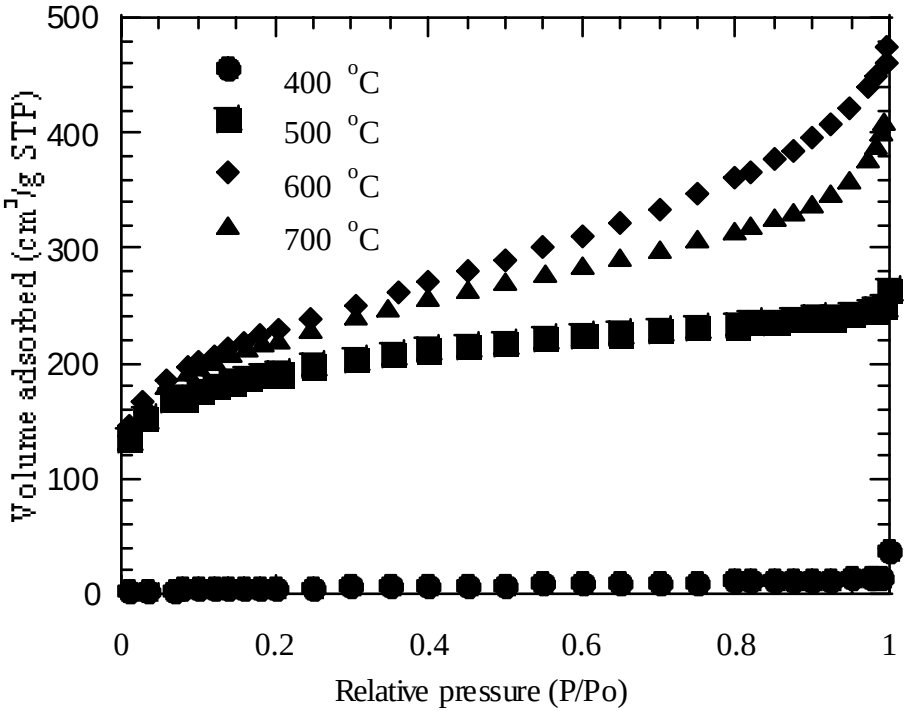


Figure 2. N_2 adsorption isotherm of pyrolytic residue of 3M-$ZnCl_2$-immersed sludge

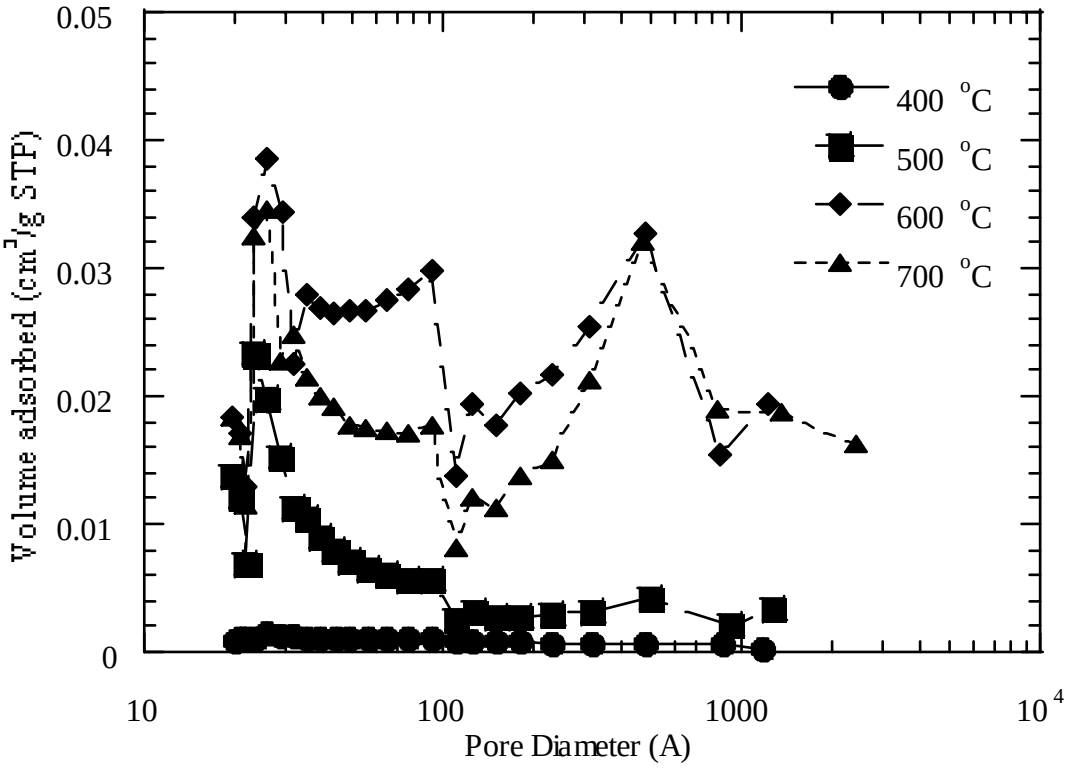


Figure 3. Pore size distribution of pyrolytic residue (Experimental conditions: 3M-$ZnCl_2$ immersed sludge was pyrolyzed at different temperature for 60 min.)