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Recycling Technology of Sewage Sludge by Carbonization

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This study has been conducted to develop a new recycling technology of sewage sludge using a carbonization process. The carbonizing yield, the calorific value and EC(electric conductivity) of carbonized sewage sludge had a tendency to be decreased with increase of the carbonizing temperature and time, but pH and the C/N were increased with increase the carbonizing temperature and time. The whole pore volume of carbonized sludge processed in the carbonizing furnace was 0.032㎤/g, which was smaller than that in the electric furnace. But, the rates of mesopore and macropore were found to account for 100% therein. Rate of color and organic materials removal for dyeing wastewater were determined 70~97%, 78~83% on cotton yarn, 88~96%, 69~80% on wool wastewater and 77~89%, 77~87% on towel compared with powder activated carbon. Effect of carbonized sludge on chrysanthemum growth was investigated. Plant height and number of leaves was better mixture of carbonized sludge than comparison.

Key Words : Carbonized Sludge, Adsorbent, Gardening soil

1. Introduction

Sewage sludge has been traditionally disposed by ocean dumping and landfilling, but this has been causes increasing environmental concerns in many countries, especially where land is scarce as in Korea. In Korea, as the population and development have grown, the production of sewage sludge has risen rapidly and amounted to $1,740\times10^3$ton per year in 2000. Disposal of sewage sludge on reclaimed land is no longer a viable solution. While farmland applications of sewage sludge are limited by the uptake capacity of the soil and potential pollution by the heavy metals, incineration can provide a large volume reduction and result in energy recovery. The incineration residue of sewage sludge can be used in road surfacing, building materials and metal reclamation.

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Research has been focused on the pyrolysis of sewage sludge in an oxygen free atmosphere in which the organic matter is transformed into liquid oil and gases containing hydrocarbons. The heavy metals, except mercury, are safely enclosed in the solid residues. In addition, the solid residues, i.e the carbide, can be used as an adsorbent and soil conditioner if pyrolysis was performed under controlled conditions.[1] The carbonization is the link of the pyrolysis technique. But the carbonization does for the generation of the carbide.[2]

This study has been conducted to develop a new technology using a carbonization process for establishing the resources circulation system and volume reduction of sewage sludge sanitarily and safely.[3,4]

2. Experimental Methods

2.1. Sewage sludge

Anaerobically digested and dewatered sewage sludge was used. The sewage sludge was sampled from Okcheon Sewage Treatment Works, Korea. The

Table 1. Physicochemical characteristics of dewatered sludge

Item	Unit	Result
Water contents	wt%	77.0
Solid contents	wt%	23.0
Ash contents	wt%	50.0
Organic compound contents	wt%	50.0
Calorific value	cal/g	2,492
pH	-	6.0

physicochemical characteristics of the sewage sludge sample is summarized in Table 1.

2.2. Carbonization

The carbonization was proceeded in the electric furnace and carbonizing furnace, respectively. The carbonization temperature and the sample hold time varied from 400 to 800℃ and from 15 to 60min, respectively. After the carbonization process, the reactor was cooled to room temperature before the sample was removed for weighing and characterization.

2.3. Soil for gardening

This study was examined with sludge, which was carbonized at 700℃ during 30 min, for using a gardening soil of cutting media of chrysanthemum.

The chrysanthemum was raised on 128-cell plug tray. The same volume of mixture of sphagnum peat moss and perlite was used as control substrate.

2.4. Characteristic of pore structure

The surface area and pore structure characterization of carbonized sludge were analyzed with an accelerated surface area and porosimetry system(ASAP 2010, Micromeritics). It is a fully automatic and computerized system which performs the adsorption(N_2 at -196℃)and collects and processes the data simultaneously. Surface area was calculated using the BET equation, and surface area of micropore was evaluated using the Halsey theory of adsorption film by the t-plot method.

2.5. Adsorption characteristics

The examination of adsorption characteristics follows KSM 1802.

3. Results and Discussion

3.1. Composition characteristics

Experiment was conducted to assess the availabilities of floricultural soil and an adsorbent by using the final optimum carbide (Fig. 1).

Among characteristics of change in properties of sewage sludge, production yield, calorific value, EC, pH and C/N depending upon carbonizing temperature and time were indicated. It was shown that as the temperature went higher and the time was more lengthened, carbonizing yield was more decreased. Also, it was found that the heating value was equivalent to 63.4% of 2,492 cal/g of the raw specimen at 400℃, and 33.7% thereof at 800℃ so that as the carbonizing temperature and time was increased, the heating value was decreased.

EC was decreased with increase of the carbonizing temperature and time. The C/N ratio and pH had a tendency to be more increased as the carbonizing temperature and time was increased, and particularly, it was identified that pH was increased to 6.9 at 400

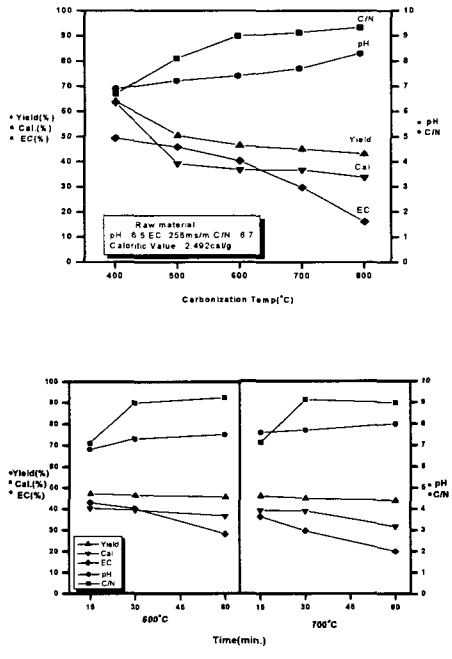

Fig. 1. Characteristics of yield, calorific value, EC, pH and C/N according to carbonization temperature and time.

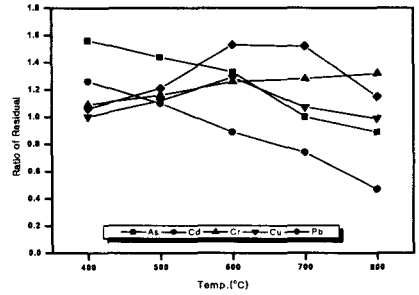

Fig. 2. Heavy metal behavior according to carbonization temperature(TS basis).

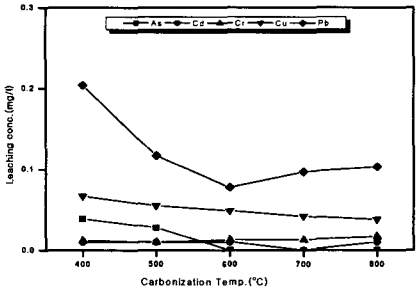

Fig. 3. Heavy metal leaching behavior according to carbonization temperature.

℃, and 8.3 at 800℃ in comparison with 6.5, pH of the raw specimen. The C/N ratio was increased along with the carbonizing temperature, and it showed a value below 10 in all conditions. Consequently, the carbonizing yield, the calorific value and EC had a tendency to be decreased as the carbonizing temperature and time was increased. Meanwhile pH and the C/N showed the result that they were increased as the carbonizing temperature and time was increased.

As for behavior of heavy metals, Cd began to be volatilized at 600℃ or higher and volatilized upto 53% at 700℃ for 60 minutes (Fig.2).

Arsenic compound(As) was volatilized to 22% at 700℃ for 60 minutes and other heavy metals (Cr, Cu and Pb) were found not to be volatilized. And, as a result of conducting an leaching test for fixed heavy metals, the leached values were found to be adequately within the allowable standard values(Pb 3.0, Cu 3.0, As 1.5, Cr^{+6} 1.5, Cd 0.3㎎/ℓ) in Fig. 3.

3.2. Adsorption characteristics

Gererally, the adsorption capacity of carbonized sludge increased with temperature and hold time(Table 2 and 3). In this study, the optimum temperature and hold time for maximum surface area and adsorption capacity development of carbonized sludge were found to be 700℃ and 30min, respectively. The highest iodine adsorption capacity was achieved 123.5mg/g.

3.3. Characteristic of pore structure

It was shown that the specific surface area of the carbonized sludge as generated in an electric furnace (E.F) was 43.8㎡/g and the average pore diameter thereof was 58.4Å.

On the other hand, it was shown that the specific surface area of the carbonized sludge as generated in a carbonizing furnace(C.F) was 14.3㎡/g and the average pore diameter thereof was 89.0Å(Table 4). This result indicated that the mesopore of the carbonized sludge processed in the carbonizing furnace was more developed than that in the electric furnace.

Also, the pore volume of the carbonized sludge processed in the electric furnace was found to be 0.064㎤/g, and macropore was found to account for 88.6% thereof. The whole pore volume of the

Table 2. Effect of carbonization temperature on yield and iodine adsorptivity (carbonization time : 30min)

Item \ Carbonization temp.	400℃	500℃	600℃	700℃	800℃
Iodine number (mg/g)	116.9	99.5	113.9	123.5	86.4
Yield (%)	64.0	50.5	46.5	45.0	43.0

Table 3. Effect of carbonization time on yield and iodine adsorptivity (carbonization temperature: 700℃)

Item \ Carbonization time	15min	30min	60min
Iodine number(mg/g)	109.4	123.5	104.6
Yield(%)	46.3	45.0	44.0

Table 4. Specific surface area, volume and pore size of carbonized sludge(700℃, for 30min)

Item / Condition	BET (m^2/g)	Average pore size (Å)	Pore volume (cm^3/g)		
			micro	external	Total
E.F	43.8	58.4	0.0073	0.0567	0.064
C.F	14.3	89.0	-	0.032	0.032

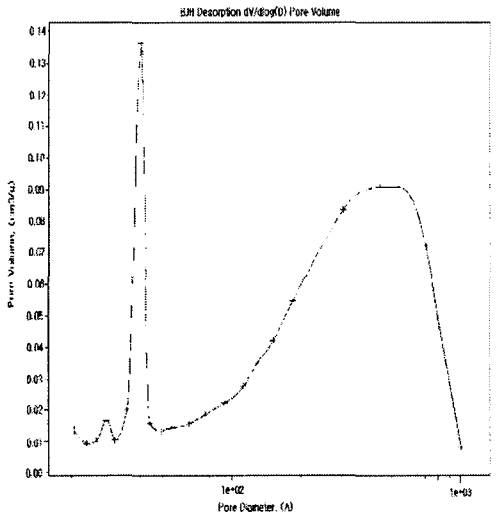

Fig. 4. Pore size distribution of carbonized sludge(E.F).

carbonized sludge processed in the carbonizing furnace was 0.032㎤/g, which was smaller than that in the electric furnace. But, the rate of mesopore and macropore was found to account for 100% therein. In the carbonized pore distribution diagram as indicated in Fig.4, it was shown that mesopore and macropore were well developed.

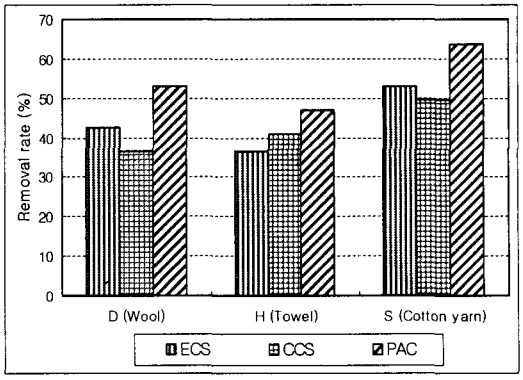

Fig. 5. Removal efficiency of COD on carbonized sludge and powder activated carbon.

3.4. Adsorption of organic matters and color

As a result of adsorbing organic substance and chroma contained in dyed wastewater and thereby removing them from it by using carbonized sludge, the efficiency of removing organic substance was found to be lower than the case of using a powder activated carbon. Such efficiency of adsorbing organic substance was shown to be equivalent to 69~87% of the efficiency in the case of using powder activated carbon available in the market(Fig.5).

The carbonized sludge used for removing chroma showed a removing efficiency equivalent to 70~97% of the efficiency in the case of using powder activated carbon, which was relatively high(Fig. 6).

3.5. Soil for gardening

Experiment for effect of carbonized sludge on

Table 5. Effect of gardening soil on the growth of Chrysanthemum at 14days after cutting

media	No.of roots (ea)	length of roots (cm)	plant height (cm)	No.of leaves (ea)	stem dia. (mm)	fresh weight (g)		dry weight (g)		T/R
						Shoot	Root	Shoot	Root	
PE:PM:VE(1:1:1)[z]	34.2a[y]	3.3cd	5.5d	6.9c	2.95b	0.88c	0.20b	0.081c	0.021a	3.8
PM:PE(1:1)	31.1a	3.9a	5.4d	6.4d	2.98b	0.88c	0.25a	0.106bc	0.023a	4.7
CS(1)	30.9a	3.6bc	7.2a	8.2a	3.17a	1.31a	0.22b	0.125a	0.024a	5.3
CS:PE(1:1)	20.5b	3.2b	6.3c	7.1c	2.96b	1.02b	0.16c	0.097b	0.021a	4.5
CS+PM(1:1)	30.2a	3.8ab	6.7b	7.6b	2.97b	0.95bc	0.16c	0.099b	0.021a	4.7

[y]Duncan's Multiple Range Test at 5% level within columns

[z] PE(perlite), PM(peatmoss), VE(vermiculite), CS(carbonized sludge)

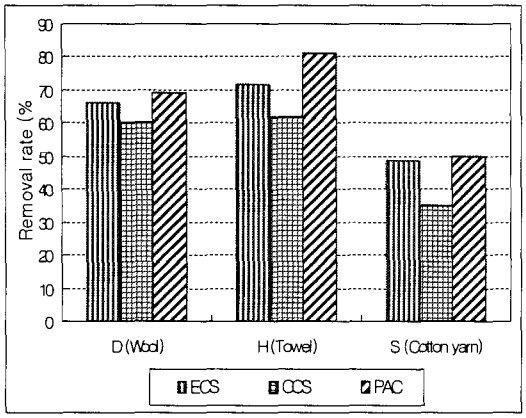

Fig. 6. Removal efficiency of chromaticity on carbonized sludge and powder activated carbon.

chrysanthemum growth was investigated. Plant height and number of leaves was better mixture of carbonized sludge. Two cases of gardening soil using only carbonized sludge and carbonized sludge+perlite(1:1) were not combined. On the other hand, carbonized sludge+sphagnumpeatmoss(1:1) were combined likely comparison(Table 5).

4. Conclusions

It was found that the properties of the carbonized sludge were similar to that of charcoal and activated carbon. And the resulting characteristics obtained are as follows;

1) The carbonizing yield, the calorific value and EC had a tendency to be more decreased as the carbonizing temperature and time were increased, and pH and the C/N ration showed the result that they were increased as the carbonizing temperature and time were increased.
2) In the carbonized pore distribution diagram as indicated, it was shown that mesopore and macropore were mostly well developed.
3) Rate of color and organic materials removal for dyeing wastewater were determined 70~97%, 6 9~87% compared with powder activated carbon.
4) As a result of conducting the growing test for examining whether this carbonized sludge would be available for flower culture, the growth of the root of the flower was much better than when the conventional control soil was used, and the growth of the shoot showed a similar result.

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