Preparation of sludge derived carbon with Fenton and NaClO activated and the application on the odor abatement

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Abstract:

Sewage sludge could be disposed to prepare the sludge derived carbon (SBC) through pyrolysis, while the SBC quality is poor without any pretreatment, and activation process is necessary to applied to destroy the cell wall barrier and heterogeneous structure in sludge. Two activators of Fenton and NaClO are applied to prepare the precursors, and the SBC obtained are characterized and compared in terms of SEM, FTIR, BET and porous distribution. Under the optimum conditions, the maximum BET in the SBC-Fenton and SBC-NaClO reach to 253 and 423 m^2 g^{-1}, respectively, while that in control group is 38 m^2 g^{-1} only. The corresponding V_{micro}/ V_{total} are 42 and 46% in the SBC-Fenton and SBC-NaClO, higher than that of 6% in control group. The saturation adsorption capacity is around 71.5, 67.8 and 33.10 mg g^{-1} in SBC-Fenton, SBC-NaClO and SBC-control in series based on Langmuir isotherms using Methylene Blue. Thus, SBC might be one of the suitable substitutions for the soil cover in landfill, to realize carbon storage and reduce odor emission.

Keywords: Sludge derived carbon; Activation process; Adsorption capacity; Carbonization process

1. Introduction

Waste activated sludge (WAS) is the inevitable byproduct from waste water treatment plants, and increases greatly with the growing quantity of wastewater collected and more stringent sewage discharge standard implemented. Around 46.5 billion tons of municipal waste water was collected and treated in 2013, with around 35 Million ton sewage sludge generated (80% water content) in China (NBS, 2014). The sludge disposal is a big headache problem for the local government.

Landfill could be used as the emergency way for the sludge disposal with so much sludge generation. In order to implement the sludge landfilling, the water content of sludge is supported to be below 60% according to Standard for Pollution Control on the Landfill Site of Municipal Solid Waste (GB16889-2008) (MEP, 2008). However, sludge landfilling has its own inherent problems, such as huge landfill volume occupied and amounts of greenhouse gas (GHG)/odor emission (Chan et al., 2002; Tony et al., 2014). Odor emission from the sludge landfilling is also different from the municipal solid waste disposal in landfill, where sulfur compound and ammonia are the two main causes for the former one, while aromatic, sulfur compound, and oxygenated compound are the main contributions in the latter one (Fang et al., 2012). Generally, the landfill volume is limited due to the sharply increase of municipal solid waste, and the saving of the space is another requirement for the implement of the sludge landfilling. Therefore, how to make a balance between the volume consuming for sludge landfilling and the rapid increase of municipal solid waste is another challenge for the landfill manager.

Soil covers in landfill, including the daily soil cover, intermediate soil cover and the final soil cover, are the important part for landfill, while around 1/5-1/3 of the total landfill volume will be occupied by these covers (George 2000). On the one hand, sludge landfilling is the emergency disposal way due to the rapid increase of the generation amounts in China, while the landfill volume is limited. On the other hands, the soil cover will consume amounts of materials and landfill volume simultaneously. It is interesting to know whether the sewage sludge could substitute the traditional materials for the soil cover in landfill.

The direct utilization of sludge in landfill soil cover has been proven to be impossible due to the low mechanical strength and the serous odor emission (Tan 2004). The conversion of sludge into sludge derived carbon might be the suitable way though pyrolysis. As the microorganism aggregative, sewage sludge contains amounts of organic matter, such as lignin, cellulose, which provide the basic construction for the carbon preparation (Liu 2003; Smith et al., 2009). The application of SBC in landfill could reduce the sludge occupied volume, provide the suitable basement for the plant growth in the final soil cover, and enhance the odor adsorption process together. Green-house gas (GHG) of CO_2 and CH_4 could be also reduced greatly through the carbon storage in sludge derivate carbon. Most of important, the introduction of Sludge derived carbon (SBC) in the landfill might be also contribute to the landfill stabilization process though the neutral of pH value, adsorb the acidic compounds and toxicity compounds. Therefore, SBC might be the suitable substitute for the soil cover in landfill, and also be used as the adsorbent or the catalyst for odor removal (Dominic et al., 2012; Fontaine et al., 2012; Manyà. 2012).

Generally, the SBC preparation includes the activation process and carbonization process, and the most common activation reagents used are $ZnCl_2$, H_3PO_4, KOH and KCl (Meyer et al., 2011; Raymundo-Piñero et al., 2005). For example, KOH has been intensive reported based on a hypothesis that the reactions between KOH and carbon (C) would improve the surface area and porosity, while the results showed that the corresponding BET are still as low as 100-200 m^2 g^{-1} (Zhu, 2013). To find an effective activation reagent is a big challenge for SBC products, even it used in the landfill.

The destruction of the macro-molecular weight organic matters might be useful for the porous carbon generated in SBC. Fenton oxidants could destroy the cell wall due to the generation of hydrogen radical (HO•) with the EV of +2.8 eV (Ema and Malay, 2012; Gu et al., 2013), which might contribute to the carbon porosities generated. The introduction of NaClO could also enhance the indirect oxidation through the generation of active chlorine (Cl_2, HOCl, and OCl^-) and NaOH (Zhang et al., 2011). Both of the powerful oxidants could convert the high biopolymer substances in sludge to low-molecular-weight products efficiently. Besides, the intermediate products of

Fe_2O_3 and NaOH could react with carbon in sludge, and produce CO_2 and other gas emission, which will benefit for the porous generated in the SBC.

In this work, two activation reagents of Fenton, and NaClO were introduced to improve the SBC quality, and the morphology and structure property in SBC were compared. The adsorption capacity was tested using the methyl blue (MB) simulated dying wastewater. The removal efficiency of odor was simulated and the potential utilization routes for SBC in landfill were also proposed.

2. Materials and methods

2.1 Sludge samples

Sludge samples were collected in the secondary sludge tank from Minhang municipal wastewater treatment plant in Shanghai, China, with a typical A/O activated sludge treatment process. The sludge obtained was dewatered by the centrifuge at the rate of 4,000 rpm (round per minute) for 5 minutes in laboratory. The sewage sludge properties are listed in Table 1.

Table 1 Properties of sewage sludge

TS (%)	pH	VSS/TSS (%)	TCOD (mg L^{-1})	TN(mg L^{-1})	TP(mg L^{-1})
0.8-1.05	6.00-6.66	68.00-69.58	25000-37000	92-130	217-268

2.2 Activation and preparation processes

SBC was prepared with chemical activation methods, involving pre-drying, preparation, carbonization, and washing processes (Lillo-Ródenas et al., 2008; Meyer et al., 2011). Dewatered sludge was dried at 105 ℃ until constant weight obtained. Sludge was then soaked in 0.8 mol L^{-1} NaClO solution (Sinopharm Chemical Reagent Co., Ltd, active chlorine, 5.68% w/v, aqueous solution), with the optimum ratio of 0.5 according to our previous works (Zhu, 2013). Samples of 500 mL raw sludge solution were placed in the reactor at room temperature and stirred with the dropwise addition of 1.0 M H_2SO_4 until a desired pH of 3 reached. The $H_2O_2/FeSO_4{\cdot}7H_2O$ molar ratio of

5:1, and H_2O_2 dosage of 5% were added into the solution based on our preliminary work (Gu et al., 2013). Both of sludge activated by NaClO and Fenton were stored as the precursors for the next step.

The dried mixtures were pyrolysis in a horizontal quartz glass tube furnace (HTL1100-60, HAOYUE, Shanghai, China) at 600℃ for 2 h, taking N_2 as protect gas with flow rate of 400 mL min^{-1}. The pyrolysis carbon was washed by 10% (v/v) HCl at 105˚C and successive soaking in distilled water until constant pH reached. The final SBC products were obtained after dried at 105˚C. All the samples were labeled as number and reagent. Meanwhile, a control sample was prepared in the same processes without reagent impregnation, and the same carbonization process was implemented to produce SBC.

2.3. Characterization of SBC-carbon

SBC surface is an interconnection network of micro pores, meso pores, and macro pores (Nguyen et al., 2010). The porous structure was observed by scanning electron microscopy (SEM) at 15.0 kV. Pore size distribution and specific surface area were measured by N_2 adoption and desorption isotherms at 77 K by Quantachrome Instruments. Desorption data of N_2 isotherm were used to determine pore size distribution with Barrett-Joyner-Halenda (BJH) method. Evaluated pore sizes range from approximately 1.5 to 100 nm in radius. Specific surface area of activated SBC was calculated with BET function, and dubinin-raduskevitch (DR) method was used to evaluate the micro pore volume.

Percentage of elements carbon (C), hydrogen (H), and oxygen (O) were determined, and C was oxidized to CO_2 and analyzed by CS analyzer (CS-3000, NCS Testing Technology, Shanghai, China). Elements H and O were tested using ONH analyzer (ONH-3000, NCS Testing Technology, Shanghai, China), which H in samples was released in form of H_2 and content was determined by a thermal conductivity cell, while O was converted into CO at 2300℃and measured by infrared spectroscopy. Activated SBC was measured by a FTIR spectrometer (Nicolet 6700, ThermoFisher) at 25℃. Samples were diluted in potassium bromide (KBr) and compacted into a thin membrane at 8.0 T cm^{-2} for 2 min.

2.4 Adsorption capacity and adsorption isotherms

Varied dose (0.5 to 2.5 g L^{-1}) of SBC was added into 100 mL Methylene Blue (MB) solution (with the initial concentration of 20-125 mg L^{-1}) in a 250 mL flask and shaken for 60-120 min until the equilibrium obtained at 25℃. The exhausted adsorbent was filtered by 0.45 μm filter. Batch experiments were performed at 100 rpm. Solution samples were taken at a given time and immediately centrifuged at 14,000 rpm for 3 min to remove the adsorbent. MB concentrations were measured by UV spectrophotometer (Unico, UV 2102, Shanghai) at 664 nm and the effect of dose of SBC was determined accordingly.

The amount of adsorbed at equilibrium was estimated by:

$$q_e = \frac{(C_0 - C_e)V}{W} \quad (1)$$

where q_e (mg g^{-1}) is the amount of adsorbed at equilibrium, C_0 and C_e (mg L^{-1}) are the initial and equilibrium MB concentration respectively. V (L) is the volume of the solution and W (g) is the mass of adsorbent. MB removal efficiency is estimated as:

$$\text{MB Removal (\%)} = \frac{C_0 - C_e}{C_0} \times 100 \quad (2)$$

where C_0 and C_e (mg L^{-1}) are the initial and equilibrium MB concentration respectively. Langmuir isotherm was used to analyze equilibrium based on the assumption of monolayer coverage of adsorbate over an adsorbent surface, which has been successfully used to explain the adsorption of dyes from solutions (Hameed, et al., 2007).

Langmuir isotherm is shown as:

$$q_e = \frac{q_m K_l C_e}{1 + K_l C_e} \quad (3)$$

where q_m (mg g^{-1}) represents maximum monolayer coverage capacity of adsorbent and K_l (l mg^{-1}) is Langmuir isotherm constant. The essential features of Langmuir isotherm would be expressed in terms of equilibrium parameter R_l:

$$R_l = \frac{1}{1+(1+K_l C_0)} \tag{4}$$

in which value of Rl indicates the adsorption nature be either unfavorable (R_l >1), linear (R_l =1), favorable (0< R_l <1), or irreversible (R_l =0).

3. Results and discussion

3.1. Effect on porous structure of SBC

The porous structure and morphology of SBC are shown in Table 2. It could be found that BET in SBC increased from 38 to 253 and 423 m^2 g^{-1} after activated by Fenton and NaClO, respectively. The total pore volume increased from 0.066 (SBC-control) to 0.184 (SBC-Fenton) and 0.513 cm^3 g^{-1} (SBC-NaClO), and the corresponding micropore volume increased from 0.004 to 0.078 cm^3 g^{-1} and 0.238 cm^3 g^{-1}. The highest V_{micro}/ V_{total} ratio of 46% was observed in SBC-NaClO, and the corresponding ratio in control and Fenton were 6 and 42%, respectively.

Table.2. Surface Characteristics of porous structure of sludge-based carbon

	BET (m^2 g^{-1})	V_{total}(cm^3 g^{-1})	V_{micro} (cm^3 g^{-1})	V_{micro}/ V_{total} (%)
Control	38.7	0.066	0.004	6
SBC-Fenton	253	0.184	0.078	42
SBC-NaClO	423	0.513	0.238	46.39

It could be found that SBC-NaClO had more uniform pores, and the radius was small but its cumulative volume was large, which resulted in a large BET area. Radii of all samples were mainly arranged between 15-25Å. SEM images of SBC-activated are shown in Fig. 1. Surface of control sample (Fig. 1a, 1c) was smoother than the other SBC samples. SBC-NaClO (Fig. 1b) contained much more small pores. For

SBC-Fenton sample (Fig. 1d), the surface showed more rough, with the presence of irregular coral, and the micro and mesopore predominated in the structure.

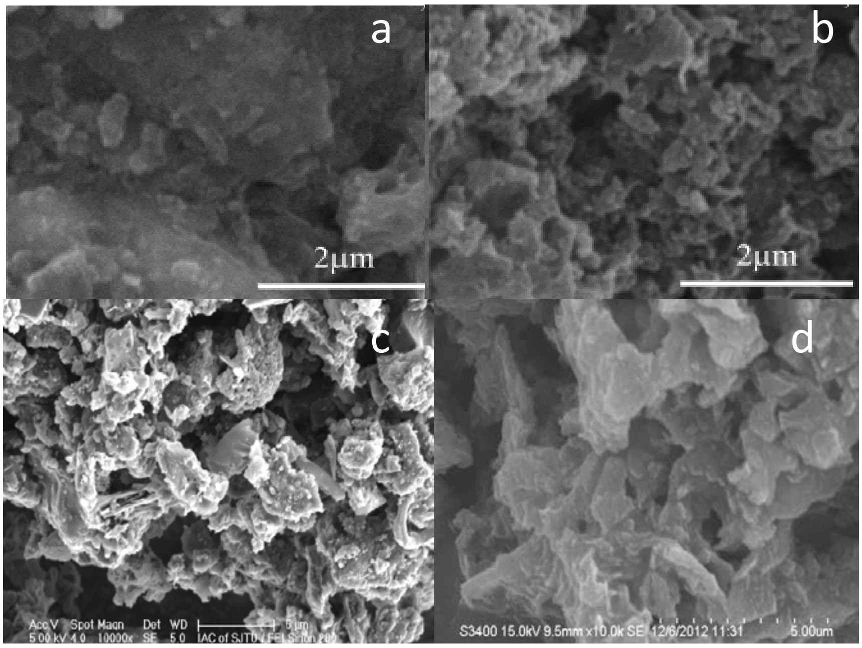


Fig. 1 SEM image of SBC, a) SBC-control and b) SBC-NaClO; c) SBC-control and d) SBC-Fenton

3.2 Elements distribution

Element distribution could be used to reflect the efficiency of activation process. The generation rate, ash content and main elements in SBC-Fenton and SBC-NaClO are shown in Table 3. Percentages of C, H, and O in control sample were 32.45, 2.11, and 13.25%, respectively. The C ratio increased after activated by NaClO, since NaClO was able to disrupt the binding interaction between extracellular polymeric substances (EPS) and cell, and the detached EPS could furthermore dissolve into solution under the centrifugal force (Abelleira et al., 2012), although parts of element C might lose in the preparation process. The amount of O contents in SBC-NaClO was evidently higher than the control group, because some water was added with the activation reagent solution during preparation and increased the percentage of O and H, which was shown in Eq. (5)

$$4NaClO + 2H_2O \longrightarrow 4NaOH + 2Cl_2 + O_2 \quad (5)$$

Then, the intermediate product of NaOH reacted with C during the activation at 600℃ as follows(Raymundo-Piñero et al., 2005):

$$6NaOH + C \longrightarrow 2Na + 3H_2 + 2Na_2CO_3 \quad (6)$$

Residual of Na_2CO_3 might also contribute to the high O contents in SBC-NaClO.

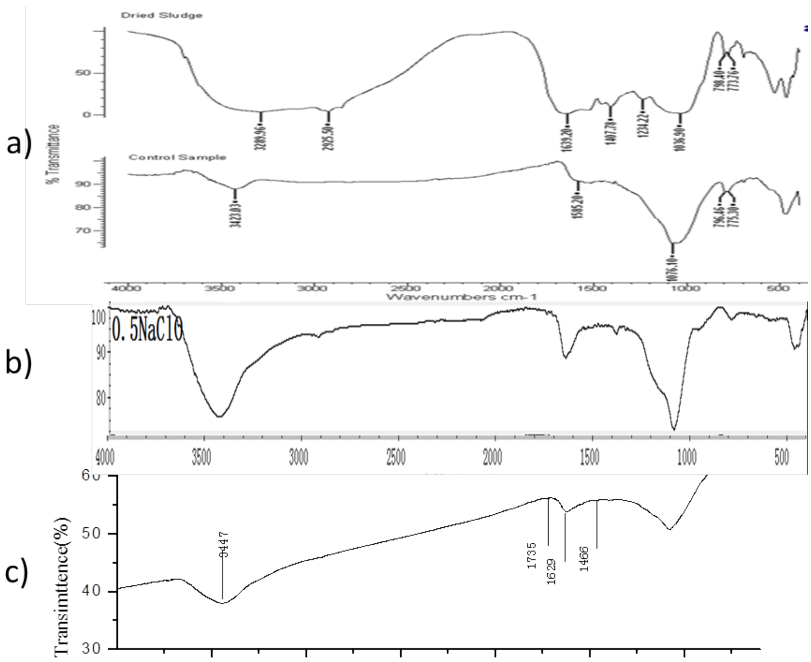
Table.3 The element distribution in SBC

	SBC-Control	SBC-NaClO	SBC-Fenton
Yield(%)	32.3	31.2	35.7
Ash content(w%)	52.8	50.4	60.9
C(w%)	35.6	37.51	32.3
N(w%)	1.75	1.65	1.57
S(w%)	0.44	0.72	0.56
H(w%)	0.99	3.30	0.83
O(w%)	14.5	15.77	17.3
Fe(w% in the ash)	18.9	20.1	49.7

Compared to the control group, the ash content in SBC-Fenton increased from 52.8 to 60.9%, and the C/H/N decreased apparently, among which C content decreased from 35.6 to 32.3%, since some carbon was released in terms of CO_2 during the Fenton reaction. It should point out that the oxidation capacity of·OH (2.85 mv) was higher than that of ClO^- (1.61 mV), which lead to the decrease of C ratio and the increase of ash ratio in SBC-Fenton, compared to the SBC-NaClO, meaning that the oxidant capacity is an important factor from the SBC generation rate perspective. In addition, S in sludge could convert into SO_4^{2-} in Fenton reaction system, instead of H_2S, and thus increase S percentage. Fe content in SBC- Fenton increased apparently from 18.9 to 49.7% in the ash due to the introduction of $FeSO_4$.

3.3 FTIR Spectroscopy

FTIR spectra of dried sludge and control sample are shown in Fig. 2a. All of samples spectra exhibited a prominent peak located at 3300–3500 cm^{-1}, which was associated with the presence hydroxyl groups. As seen from spectrum of dried sludge, transmittance peak at about 2925 cm^{-1} was assigned to vibration of O-H stretching. Peak of O-H deformation was found at 1407 cm^{-1}. Peak at 1234 cm^{-1} was related to the strong infrared vibration of the C-O stretching. Those peaks could not be found at spectrum of SBC, since the carbonization process destroyed the structure of SBC greatly. Peak at 3289 cm^{-1} was the vibration of O-H stretching in broad region of 3700-3200 cm^{-1}, which shifted to 3423 cm^{-1} in spectra of SBC (Gómez-Serrano et al., 2002). C=O stretching in spectrum of dried sludge was found at 1639 cm^{-1}, whereas it was detected at 1585 cm^{-1} in spectrum of SBC. The frequency range of 1100-1000 cm^{-1} was associated with C-O stretching. It could be seen at 1036 and 1076 cm^{-1} in spectrum of dried sludge and SBC respectively. There were two vibration of C-H deformation at aromatics in dried sludge and SBC, which moved from the peak of 798 and 773 cm^{-1} in dried sludge to 796 and 775 cm^{-1} slightly in SBC.



(a) Dried sludge and SBC-control, (b)SBC-NaClO (c)SBC-Fenton

Fig.2 FTIR spectra scan of SBC with and without activation

FTIR spectra of SBC-NaClO are shown in Fig. 2b. The stretching vibration of

O-H bond, C=O bond, and C-O bond could be found at 3423, 1585, and 1076 cm^{-1}, compatible with those in the spectrum of SBC. There was one deformation of C-H bond in the range of 760-800 cm^{-1} in SBC-NaClO sample. NaClO solution might modify a C-H bond of SBC during activation process. On the other sides, more peaks were disappeared in SBC-Fenton (Fig. 2c). The stretching vibration of O-H bond could be seen at frequency of 3300-3500 cm^{-1} in SBC-Fenton, while peaks of $-CH_3$ and $-CH_2$ were disappeared at 2920 cm^{-1}, meaning that the polysaccharide, protein and high molecular polymer etc., in sludge were decomposed into small-molecular weight substances after Fenton reactions. The transmittance at 1735, 1629 and 1466 cm^{-1} decreased in the SBC-Fenton samples, which was related to the stretching vibration of C=O, O-H and C-O bond, ascribed that the polycyclic organic matter might be decomposed (Kaçan et al., 2012). Band at 1629 cm^{-1} was believed to arise from aromatic C-C bonds which were polarized by oxygen atoms bond. This might be related to the oxygen groups incorporated to the carbonaceous phase attacked by the hydroxyl radicals. The region near 1466 cm^{-1} was commonly associated with carbonyl (C=O) and alkene (C=C) bonds, which were normally from the vibration of small molecule organics.

3.4 The adsorption capacity of MB

NaClO activation could destroy the EPS and cell wall in sludge, and reduce the volatilization during pyrolysis of mesopores and macropores simultaneously. It was found that around 95 and 99% of MB could be adsorbed by the SBC-Fenton and SBC-NaClO under the dosage range of 0.5-2.5 g L^{-1}, respectively, with the initial MB concentration of 20-40 mg L^{-1} at 25 ℃.

The adsorption balance between the agent and the adsorbent, affinity, adsorption mechanism and adsorption capacity could be measured by adsorption isotherms, and used to test the adsorption capacity of SBC. Langmuir and Freundlich model were applied to simulate the adsorbent capacity of SBC obtained, and the parameters of Langmuir and Freundlich model are listed in Table 4. Both of SBC-NaClO and SBC-Fenton have a good monolayer adsorbent capacity, with the value of 67.83 and

71.50 mg g^{-1}, while that in SBC-control was only 33.10 mg g^{-1}.

Table 4. Parameters of adsorption models of MB on SBC

Isotherms	Parameters	SBC-Fenton	SBC-NaClO	SBC-Control
	q_m(mg g^{-1})	71.50	67.83	33.10
Langmuir	K_l(L mg^{-1})	0.0148	2.01	0.03
	R^2	0.995	0.980	0.990
	Kf(mg g^{-1})	56.6	38.23	2.67
Freundlich	1/n	0.0534	0.20	0.50
	R^2	0.661	0.92	0.98

3.5 The odorous removal capacity of SBC

Odorous compounds from municipal solid waste (MSW) usually include reduced sulfur, nitrogen compounds, organic acids, aldehydes, and ketones, where hydrogen sulphide (H_2S) and ammonia (NH_3) are identified as the two predominant odorants (Dincer et al., 2006; Ding et al., 2012; Fang et al., 2012). Both of these two odors were considered for the potential odor reduction. SBC-NaClO was used to adsorb NH_3, and SBC-Fenton was used to remove H_2S according to their respective property.

Dynamic NH_3 adsorption was carried out in a fixed bed configuration at 20℃. 1 g of SBC-NaClO samples were packed into a U shape glass tube (9 mm of internal diameter) as the adsorbent. The input gas consisted of 500 ppmv (mol mol^{-1}) of NH_3 passed through the bed at flow rate of 100 mL min^{-1}, combined with the carrier gas of N_2. Concentration of input and outlet NH_3 was monitor by a gas detector (pGas200, Cnshsh Ltd.). Adsorption experiments were performed until the bed exhaustion, which 50 ppmv (mol mol^{-1}) NH_3 breakthrough capacities (mg of NH_3 per gram of carbon) were calculated by integration of the breakthrough curves taking into account the input concentration of NH_3, flow rate, breakthrough time and the mass of used carbon (ASTM, 2008). Three cycles of NH_3 adsorption breakthrough curves are shown in Fig. 3, and all samples presented a sharp adsorption profile, indicating fast kinetics of interactions between SBC and NH_3.

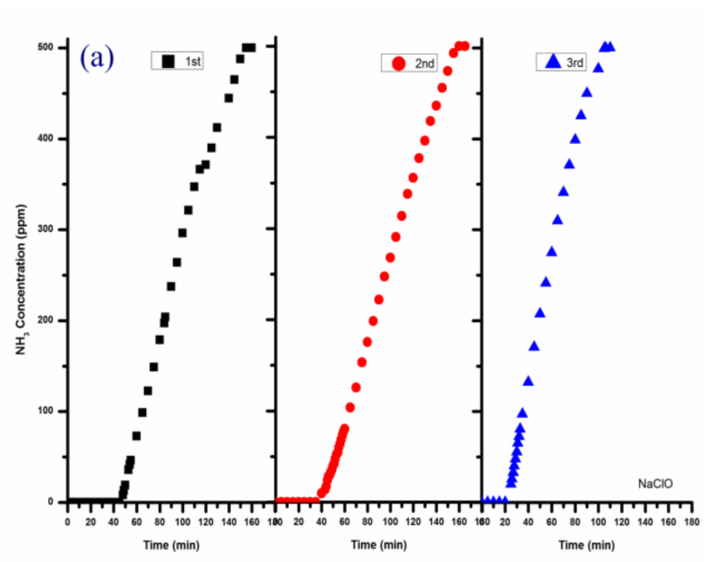


Fig.3 The isothermal equation of NH_3 adsorbent using SBC-NaClO

The regeneration was implemented using thermal treatment at 105℃. A small decrease was observed in the secondly round, while the amount of adsorbed was 52% of the original adsorption in the third cycle. The NH_3 breakthrough capacity for SBC-NaClO was around 2.1, 2.0 and 1.1 mg g^{-1} in the first 3 cycle, respectively. The effect of heating on regeneration reduced with cycle times increasing, suggesting that the preferential interactions between NH_3 and oxygen surface groups, especially the acidic groups, on carbon surface were the key factor of determining adsorption capacity. Generally, the adsorption capacity of SBC-NaClO for ammonia was relatively weak, and the amount of less stable oxygen surface groups played a crucial role in the adsorption-regeneration cycles, which resulted in a good regeneration effect due to the ammonia desorption ability.

SBC-Fenton could be the good adsorbent for H_2S removal (Ros et al., 2006). It was found that H_2S removal rate increased as the SBC-Fenton dosage increased, and around 29.2, 34.9, 37.1, 42.5 and 44.2% of H_2S were removed, with the SBC-Fenton additive of 2, 4, 6, 8 and 10 g and 10 mL H_2S in the initial stage. The high micro pore rate of 47% in SBC-Fenton contributes to the H_2S removal, and the presence of Fe is also helpful for the form the crystal as $Ca_2Fe_2O_5$ during the carbonization process. The formation of $Ca_2Fe_2O_5$ and other Fe form in SBC-Fenton was useful for H_2S reduction.

Therefore, the mixture of the SBC-Fenton and SBC-NaClO might be a good soil cover for landfill.

Generally, sewage sludge was the aggregation of microorganisms, which the cell wall was wrapped by EPS, and the binding water presented between polymer in the extracellular and cell wall. Polysaccharide and the binding water were decomposed and evaporated during the carbonization process between 550 and 650 ℃, which lead to the formation of large pores, and low BET value without any activation process. However, activation process by Fenton could improve the SBC property greatly, since the generation of ·OH destroyed the microorganism structure, and decomposed the large molecular weight organic matter into the small and medium organic matter. These intermediate organic matters were helpful for the formation of CO_2 and H_2O during the carbonization process. The SBC property benefit from the introduction of Fe, since the Fe_2O_3 and Fe_3O_4 in the precursor react with C in a high temperature as follows:

$$6Fe_2O_3 + C \rightarrow 4Fe_3O_4 + CO_2 \uparrow \quad (7)$$

$$Fe_3O_4 + 2C \rightarrow 3Fe^0 + 2\ CO_2 \uparrow \quad (8)$$

$$4Fe_3O_4 + O_2 \rightarrow 6\gamma - Fe_2O_3 \quad (9)$$

$$3Fe^0 + C \rightarrow Fe_3C \quad (10)$$

All of these reactions produced CO_2, with the molecular diameter of 0.33 nm, which contributed to form the micro-pore in SBC obtained.

For the NaClO additive, it could produce Cl_2 and NaOH during the activation process, and contributed to the generation of more porosities as shown in Eq. (5). The ClO destroyed the C-C bond in EPS and thus dewater the binding water between polymer EPS and cell wall. The intermediate product of NaOH could react with C during the carbonization process (550-650 ℃), and thus produce micro-pores, as shown in Eq. (6).

4. Conclusions

Higher quality SBC was prepared with the activators of Fenton and NaClO. Both of them contributed to the increase of BET and V_{micro}/ V_{total}, which were 6.7 and 11 times higher than SBC-control. Activation process was necessary to applied to improve the SBC quality by destroying of cell wall barrier and decompose of the complex macro compounds. The intermediate products of Fe and NaOH contributed to SBC-activated structure. The saturation adsorption capacity could be around 71.5, 67.8 and 33.1 mg g^{-1} in SBC-Fenton, SBC-NaClO and SBC-control using MB. SBC could be a promising substitute soil cover in landfill, instead of volume occupied.

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