Preparation of sewage sludge-based activated carbon for hydrogen sulfide removal

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Abstract

The circular economy concept boosts the use of wastes as secondary raw materials in the EU renewable and sustainable framework. In wastewater treatment plants (WWTP) sludge is one of the most important waste and its management is being widely discussed in the last years. In this work, sewage sludge from WWTP was employed as raw material for producing activated carbon (AC) by physical-chemical activation. The prepared AC was subsequently tested for hydrogen sulfide removal in view of its further use in deodorization in a WWTP. The effects of the activation temperature and the chemical agent used (NaOH and KOH) during the activation process were studied. On the one hand, the characteristics of each AC fabricated were analyzed in terms of BET (Brunauer-Emmett-Teller) surface area, pore and micropore volume, pore diameter, surface morphology and zeta potential. On the other hand, BET isotherms were also calculated. Finally, both the prepared AC and a commercial AC were tested for H_2S removal from a gas stream. Results demonstrated that the optimum physical and chemical activation temperature was 600ºC and 1000ºC, respectively and the best activated agent tested was KOH. The prepared AC showed excellent properties (specific surface area around 300 m^2/g) for H_2S removal, even better efficiencies than those achieved by the tested commercial AC.

1. Introduction

In the last years the emerging concept of circular economy is changing the mission of wastewater treatment plants. The main goal of these plants is no longer to discharge the treated effluent meeting the legal standards but to recover energy and materials from the wastewater. In this way, nutrients recovery(Peng et al. 2018; Ye et al. 2018), optimization of energy recovery from anaerobic processes(Kimura et al. 2017)and sludge valorization are topics of increasing interest.

Sludge management is a non-solved issue. The reuse of wastewater sludge for agricultural purposes is threatened by the presence of persistent organic compounds and pathogens and some countries have restricted the use of wastewater sludge in the agriculture(G. Mininni et al. 2015).

One of the applications studied for the wastewater sludge in recent years has been its use for making activated carbon. The interest for the preparation of activated carbon from organic wastes increased in the last decade of the 20th century as reported by Dias et al.(2007). These authors summarized the wastes used for the activated carbon preparation and the applications of the prepared carbons. In this way, cherry stones, corn cobs, olive pits, walnut shells and other wastes have been employed for this purpose.Chiavola (2013)reviewed the main findings about the valorization of organic wastes as activated carbon. This author summarizes the use of activated carbon prepared from peanut shells, olive stone and apricot stone of different works.

The aforementioned trend to circular economy implies that valorization of organic wastes as activated carbon is still a current goal especially when high amounts of organic wastes are available. As an example, Pandiarajan et al.(2018) prepared activated carbon from orange peel to separate herbicides. Activation was carried out using KOH in the ratio 1:2 and reaching temperatures of 700ºC.Other examples are works in which authors have used coconut(Andrade et al. 2018)and corncob(Zhu et al. 2018).

Focusing on wastewater sludge, it has to be highlighted that sludge is theoretically an appropriate source for activated carbon due to great availability and high organic matter content.Li et al.(2011)andWang et al.(2008) prepared activated carbon from activated sludge from a municipal wastewater treatment plant and from sludge from a paper mill wastewater treatment plant, respectively. In both cases the prepared activated carbon was used for dyes removal. More recently, Qiu and Huang(2015) made activated carbon from sewage sludge using $ZnCl_2$ for the activation with the aim of separating two commercial dyes from wastewater. Other applications of sludge-based activated carbons are the separation of heavy metals(Li et al. 2018) and pharmaceutical compounds(dos Reis et al. 2016).

Concerning the preparation processes, Hadi et al.(2015) concluded in a review article that chemical activation yielded considerable higher specific surface areas than physical activation procedures. In this way, it is very important to focus on chemical activation.

In this work, chemically activated carbon from sewage sludge has been prepared for hydrogen sulfide adsorption. Until now, there are limited papers dealing with this topic. Only Li. et al.(2015) aimed at this application. However, it would be of great importanceto use the sludge in the same wastewater treatment plant for odour elimination, for examplein the final step of thickeners orin the sludge dehydration. In addition, preparation of the activated carbon in the same plant would avoid transport costs. This fact together with the uncertainty about the future sludge management alternatives make that the preparation of activated carbon for hydrogen sulfide removal may have a promising future.

2. Materials and methods

2.1. Sludge characterization

Sludge from municipal WWTP located in Murcia Region (Spain)was used for activated carbon preparation. The characterization of the sludge included the measurementof pH,conductivity, total suspended solids (TSS), volatile suspended solids (VSS), totalCOD (chemical oxygen demand) and ammonium nitrogen (NH_4-N). In addition, sludge was also pre-treated in order to measure the following parameters in the soluble fraction: soluble COD, total nitrogen (TN), nitrates (NO_3-N), total phosphorous (TP), calcium (Ca^{+2}) and magnesium (Mg^{+2}).The pre-treatment consisted in centrifuging at 10.000 rpm for 15 min and filtering the clarified water for the analysis.

pH and conductivity measurements were carried out with pHMeter GLP 21^+ and EC-Meter GLP 31^+ (CRISON), respectively. TSS and VSS were measured according to Standard Methods(APHA, AWWA, WEF, 2005). COD, TN, NO_3-N, TP, Ca^{+2} and Mg^{+2} were analyzed using kits from Merck (Spain). NH^4-N content was determined using a “Pro-Nitro M” distiller (P-Selecta, Spain).

The properties of the analyzed sludge are in Table 1. It can be observed that all the parameters are in the range for sludge characterization(Ping et al., 2020). In addition, the high COD content is especially favourable for activated carbon preparation(Li et al. 2020).

Table 1: Sludge characterization for activated carbon preparation.

Parameter	Value
TN (mg/L)	1370
NO_3-N (mg/L)	8.84
PT (mg/L)	51.30
Total COD (mg/L)	7683
Soluble COD (mg/L)	1569
Ca^{+2} (mg/L)	180.30
Mg^{+2} (mg/L)	60
NH_4-N (mg/L)	949.45
pH	7.80
Conductivity (mS/cm)	16.71
TSS (g/L)	7.55
VSS (g/L)	4

2.2. Activated carbon preparation

Two series of experiments were performed in the AC preparation. In the first one, NaOH and KOH (from Panreac) were used as activating agents. Table 2 summarizes the experimental values of the variables used during the first set of experiments. The physical activation is a pyrolysis process and the chemical activation was carried out by mixing the sludge with the activated agent. The heat treatment of the samples was conducted in a furnace from Nabertherm model RSRB 120/750/11. Pure nitrogen gas was used to produce an inert gas atmosphere.The flow rate of nitrogen was 300 ml/minand samples were heated up to thepreviously programmed temperature at a heating rate of 20ºC/min.

From the first set of experiments the optimal experimental conditions were chosen: physical activation temperature of 600ºC, chemical activation temperature of 1000ºC and KOH as activated agent. At these experimental conditions the second series of experiments was performed (Table 3). It was decided to include also $ZnCl_2$ as activated agent in order to take into account results from previous publications (Rawal et al., 2018; Tian et al., 2019).

Table 2: Data for the activated carbon preparationin the first set of experiments.

Physical activation (ºC)	Chemical activation (ºC)	Activatingagent	Reference
600	1000	NaOH	A1
600	1000	KOH	A2
800	1000	NaOH	A3
800	1000	KOH	A4
1000	600	NaOH	A5
1000	600	KOH	A6
1000	800	NaOH	A7
1000	800	KOH	A8

Table 3: Data for the activated carbon preparation in the second set of experiments.

Activatingagent	Activating agent/sludge ratio(mL/g)	Reference
KOH	0.3	B1
KOH	0.4	B2
KOH	0.5	B3
KOH	0.7	B4
$ZnCl_2$	0.3	B5
$ZnCl_2$	0.4	B6
$ZnCl_2$	0.5	B7
$ZnCl_2$	0.7	B8

2.3. Commercial activated carbon

In order to compare the effectiveness of the prepared AC, a commercial granular AC for gas adsorption was tested in this study. This AC is from VWR (reference number 22631.293). Table 4 illustrates the main characteristics given by the supplier.

Table 4: Technical characteristics of the commercial AC.

Parameter	Values
Density (g/cm^3)	2
Molecularweight (g/mol)	12.01
Meltingpoint (ºC)	3550
Benzeneadsorption	38-42%

2.4. Characterization of prepared activated carbon

2.4.1. Specific surface area and isotherms analysis

The preparedactivated carbon wascharacterized in terms of surface area (S_{BET}), total pore volume (V_t) and average pore diameter (d_a). BET method was applied using a Multi-port surface area and porosimetry analyser ASAP 2420 from Micromeritics (USA). Using this technology the micropore volume (V_m) was also calculated. Total pore volume was calculated from the amount of adsorbed N_2 at relative pressure (P/P_0) of 0.99 and average pore diameter was calculated following Eq. 1 as previously published in several studies (Pezoti et al. 2016; Zhang et al. 2019):

$$d_a = \frac{4000 \cdot V_t}{S_{BET}} \quad (1)$$

In addition, adsorption isotherms were obtained using the prepared AC as shown in Table 2 and 3. Adsorption isotherms analysis is very important to study the interaction between the adsorbate and the adsorbent of a system (Cheng et al. 2018). In this study, BET isotherms were calculated. BET model assumes that adsorption process occurs in a multilayer of adsorbates with lateral interactions (Carrete et al. 2011).

The mathematical expression BET isothermisdescribed in Eq.2:

$$\frac{P}{V\cdot(P_0-P)} = \frac{1}{V_m\cdot c} + \frac{c-1}{V_m\cdot c}\cdot\frac{P}{P_0} \quad (2)$$

Where, P (mm Hg) and P_0(mm Hg) are the equilibrium and the saturation pressures, respectively, of adsorbates at the adsorption temperature, V(cm^3/g) and V_m(cm^3/g) are the adsorbed gas quantity and the monolayer adsorbed gas quantity, respectively and, c is the BET constant.

2.4.2. Microscopy analysis

The surface morphologies of the prepared AC were examined by observation of the microporous structure by means of a Field Emission Scanning Microscopy (FE-SEM) model Ultra 55 from Oxford Instruments (United Kingdom).

2.4.3. Zeta potential

Zeta potential of the prepared AC was measured by Zetasizer Nano ZS90 (Malvern instruments, Malvern, United Kingdom). Zeta potential of the AC was measured by mixing the AC with distilled water at pH 7.5.

2.5. Activated carbon regeneration procedure

A regeneration process was carried out for the prepared activated carbon.The spent AC was placed in a laboratory beaker with 500 ml of NaOH at pH 10. This solution was stirred in a temperature controlled shaker at 200 rpm and 90ºCduring 2 hours. After this chemical regeneration process, the AC was filtered (with a paper filter of 60 μm) and rinsed with water until a neutral pH was reached. Afterwards, the AC was filtered again and was dried at 105ºC during 12 hours.

2.6. Hydrogen sulphide adsorption equipment

Tests with laboratory columns were used for gas adsorption with the selected AC. Gas cylinders (provided by Abelló-Linde, Spain) containing a mixture of H_2S/N_2witha H_2S concentration of 80 mg/L provided the feed to the adsorption column. These experiments were carried out in a glass column of 1.5 cm internal diameter and 20 cm length. A felt layer and a circular mesh were placed at the bottom of the column to ensure the correct package of the activated carbon. Fig. 1 shows the experimental set up used for the experiments.

Bed heights of the packed AC, mass of the ACand feed gas flow rate used in the tests are summarized in Table 5. The tests were stopped when the outlet and inlet H_2S concentrations were approximately the same. It is important to mention that only the prepared ACs under the selected conditions wastested in the adsorption column.

In addition, in order to compare the saturation capacity of each AC tested, it was calculated the amount of H_2S adsorbed per gram of AC used as it was expressed in Eq. 3. This equation was previouslyapplied also employed by Kuroda et al.(2018).

$$\text{Capacity (mg } H_2S \text{ adsorbed/g AC used)} = \frac{\left[C_f \cdot t_f - \int_0^{t_f} C(t)dt\right] \cdot \frac{34g}{mol} \cdot Q}{m_{AC} \cdot 22{,}4\ L/mol} \quad (3)$$

Where, C_f and t_f are the final H_2S concentration and time detected, respectively, Q is the flow rate employed and m_{AC} is the AC mass used for each experiment.

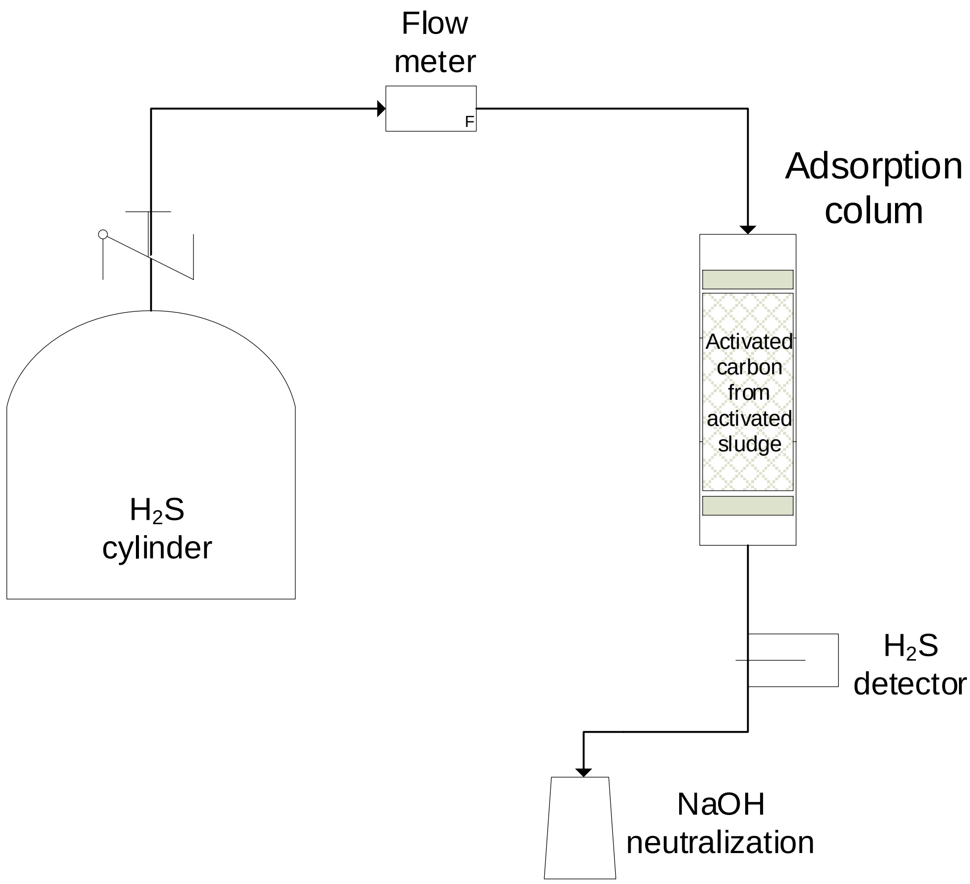


Figure 1: Experimental set up used for the adsorption column experiments.

Table 5: Experimental variables applied for the adsorption experiments.

Test number	AC type	AC mass (g)	Bed heights (cm)	Flow rate (L/h)
1	Commercial AC	10.21	4	43
2	Prepared AC 1	2.09	2	43
3	Prepared AC 2	3.51	2	43
4	Regenerated AC 2	2.04	2	43

3. Results and discussion

3.1. Prepared activated carbon characteristics

3.1.1. Effect of temperature and activating agent

Pyrolysis temperature, carbonization time and impregnation ratio are the main parameters that can influence the surface area of the made ACs(Kacan, 2016). In order to study the effect of temperature, Table 6 illustrates the Brunauer-Emmet-Teller surface area (S_{BET}), the total pore volume (V_t), the micropore volume (V_m) and the average pore diameter (d_a) of the different samples of activated carbons that were obtained by means of the analysis of N_2 adsorption. These results indicated that there was no direct influence of the physical activation temperature on the $S_{BET,}$ V_t and V_m since the highest results were achieved for the lowest temperatures tested. The same conclusion was reported by Wang et al.(2018) who stated that a pyrolysis temperature of 600º was sufficient for sludge carbonization.However, it can be observed that when chemical activation temperature increased, the $S_{BET,}$ $V_t$and $V_m$increased. In addition, the best activating agent wasKOH,also in terms of $S_{BET,}$ V_t and $V_{m.}$Concerning the average pore diameter, all the values ranged between 2 and 20 nm, which means that no significant differences among the prepared ACs were found. The average pore diameter depends mainly on the reaction time, which was maintained constant in all the tests. Temperature also influences the pore size. However, the relation between temperature and pore size is complex. In this way,Satya Sai and Krishnaiah (2005) reported that at 800ºC low size pores are formed, but at 850ºC the smaller pores become larger by coalescence phenomena. It explains that no relation between the experimental conditions and the average pore diameter was found.Taking into account these results, the best AC was the AC *A2* since it was made with the highest S_{BET},V_t and $V_{m.}$

These results are in concordance with other studies found in the literature of AC preparation from sewage sludge. For example,Li et al.(2011) fabricated AC from sludge and achieved an AC with specific surface area between 130-140 m^2/g.Wang et al.(2018)obtained an AC from sludge with a higher surface area (641.56 m^2/g).

Regarding AC preparation from other raw materials, Li et al., (2019) reported that AC preparation from petroleum coke by KOH activation achievedS_{BET} between 892-1,763 m^2/g and V_t values between 0.39 and 0.48 cm^3/g.Kazak et al.(2018) published that AC preparation from molasses-to-ethanol-process waste by KOH activation presented a S_{BET} area of 1,042 m^2/g and V_t of 0.691 cm^3/g. Sulaiman et al.(2018)fabricated AC from cassava stem and the carbon fabricated showed a maximum S_{BET} area of 653.93 m^2/g. The difference between the previously published results and those reported in this study in terms of surface area was due to the raw material employed. Sewage sludge is not the best optionto produce AC but results presented here demonstrated that it is a waste whose activation can produce an adsorbent with a S_{BET} high enough to be competitive compared to other activated carbon materials (Chen et al. 2019).

3.1.2. Comparison of KOHand $ZnCl_2$ as activating agents

According to Tian et al.(2019), H_3PO_4, KOH, and $ZnCl_2$ are common activating agents in the AC preparation. In order to study the $ZnCl_2$ effect on the AC characteristics (Table 7), the experimental conditions from the first set of experiments (physical temperature of 600ºC, chemical temperature of 1000ºC and KOH as activated agent, AC type *A2*) study the effect of $ZnCl_2$ in comparison with KOH as activating agent. It can be observed in Table 7 that using KOH as activating agent (AC *B1*, *B2*, *B3* and *B4*)led to higher S_{BET} and $V_t$than those obtained by using $ZnCl_2$ (AC *B5*, *B6*, *B7* and *B8*).These resultsare interesting since KOH is less expensive toxic than $ZnCl_2$(Arami-Niya et al. 2010; Donald et al. 2011). In addition, as it can be observed in Table 7, as activation agent/sludge ratio increased, S_{BET} increased for both activating agents.These results are in the same range as those previouslypublishedby Sun et al.(2018), who prepared activated biochar from mixed waste plastic using $ZnCl_2$ as activated agent and obtained values of S_{BET} between 661 and 1032 m^2/g, V_t values between 0.44 and 0.64 cm^3/g and d_a values between 2.15 and 3.62 nm.

Table 6: Surface area (S_{BET}), total pore volume (V_t), micropore volume (V_m) and average pore diameter (d_a) of the first set of experiments.

Activated carbon type	A1	A2	A3	A4	A5	A6	A7	A8
S_{BET} (m^2/g)	140.29 ± 7.01	375.13 ± 18.75	185.95 ± 9.29	236.4 ± 11.82	143.3 ± 7.17	1.57 ± 0.08	55.57 ± 2.78	187.34 ± 9.37
V_m (cm^3/g)	0.0488 ± 0.05	0.1587 ± 0	0.0617 ± 0	0.1031 ± 0.01	0.0468 ± 0	0.002 ± 0	0.012 ± 0	0.0595 ± 0
Vt (cm^3/g)	0.1765 ± 0.17	0.3152 ± 0.01	0.2321 ± 0.01	0.1465 ± 0.01	0.1148 ± 0	0.0072 ± 0	0.1594 ± 0.01	0.1917 ± 0.01
d_a (nm)	5.03 ± 5.03	3.36 ± 0.17	4.99 ± 0.25	2.48 ± 0.12	3.2 ± 0.16	18.32 ± 0.91	11.48 ± 0.57	4.09 ± 0.20

Table 7: Surface area (S_{BET}), total pore volume (V_t), micropore volume (V_m) and average pore diameter (d_a) of the second set of experiments.

Activated carbon type	B1	B2	B3	B4	B5	B6	B7	B8
Activated agent	KOH	KOH	KOH	KOH	$ZnCl_2$	$ZnCl_2$	$ZnCl_2$	$ZnCl_2$
S_{BET} (m^2/g)	287.99 ± 14.40	338.54 ± 16.93	342.78 ± 17.14	340.18 ± 17.01	184.42 ± 9.22	204.95 ± 10.24	228.25 ± 11.41	228.59 ± 11.42
V_m (cm^3/g)	0.1138 ± 0.01	0.1374 ± 0.01	0.1307 ± 0.01	0.1117 ± 0.01	0.0524 ± 0	0.0621 ± 0	0.0702 ± 0	0.0698 ± 0
Vt (cm^3/g)	0.2051 ± 0.01	0.2190 ± 0.01	0.2471 ± 0.01	0.2850 ± 0.01	0.1757 ± 0.01	0.1828 ± 0.01	0.2065 ± 0.01	0.2135 ± 0.01
d_a (nm)	2.85 ± 0.14	2.59 ± 0.13	2.88 ± 0.14	3.35 ± 0.17	3.81 ± 0.19	3.57 ± 0.18	3.62 ± 0.18	3.74 ± 0.19

3.1.3. Isotherm analysis

According to the International Union of Pure and Applied Chemistry (IUPAC) standard classification system, there are six different types of adsorptionSing et al.(1985) as it can be observed in a previous publication (Wei Yu, 2018). In this way, depending of the shape of the adsorption isotherm, the properties of the adsorbate and solid adsorbent and the pore-space geometry can be different. Detailed information about it can be found in (Sing et al.1985). Fig. 2 represents BET isotherms of prepared AC in the tests*A2* and *B3*. It can be observed that both curves showed a convex curvature at low relative pressures (P/P_0 lower than 0.2) and then a slight hysteresis towards saturation.Adsorption normally occurs in a nonporous or a macroporouslayer(Singet al.1985). In this way, adsorption process seems to be in the multi-layer coverage since there is a clear inflection in the isotherm (Lapham and Lapham, 2017a).

Table 8 shows the BET c-value for all the AC fabricated. According to Ladavos et al.(2012), who investigated the BET isotherm model in porous materials for gas adsorption, c-values should be greater than zero.Lapham and Lapham (2017b) published that BET c-values higher than 20 confirms that S_{BET} and adsorption isotherms previously calculated are reliable and valid. As it can be observed in Table 8, c-values were always positive and higher than 20.

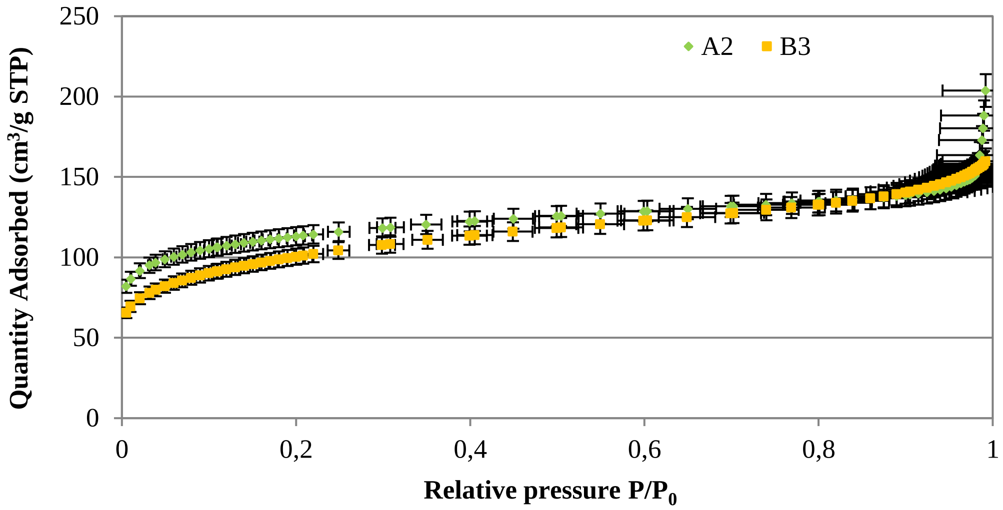


Figure 2: BET isotherm for AC *A2* and *B3*.

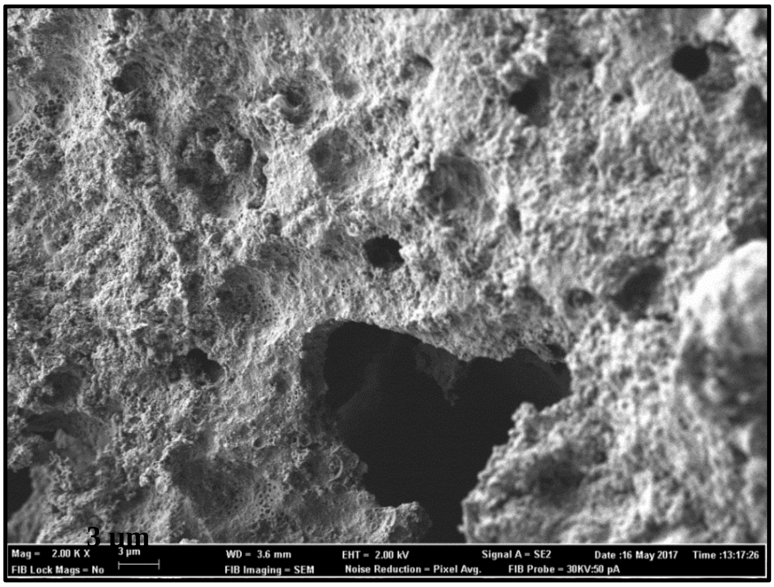
Table 8: BET c-value for each prepared AC.

AC first set of experiments	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**
BET c-value	335.44	302.08	291.86	179.92	339.55	29.84	1092.56	465.06
AC second set of experiments	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**
BET c-value	243.88	467.17	241.78	233.18	431.71	442.36	300.84	364.46

3.1.4. Microscopy results

The surfaces morphologies of the prepared AC with the highest areas (A2 and B3 for the first and second series of experiments, respectively)are shownin Fig. 3. Both AC had a very similar surface area (375 and 342 m^2/g for AC of A2 and B3, respectively) which is in agreement with these FE-SEM pictures since a very similar structurecan be observed in Fig. 3. FE-SEM images show a highly porous structure, a relatively uniform surface and without the crevices appearance. The surface seems to be heterogeneous and with a variety of randomly distributed micropores and nanopores of different sizes (diameter around 0.1 μm). The different pore sizes can be attributed to the organic matter decomposition during the carbonization process. In addition, the size and the presence of particles is reduced due to material loss during pyrolysis process.

a)



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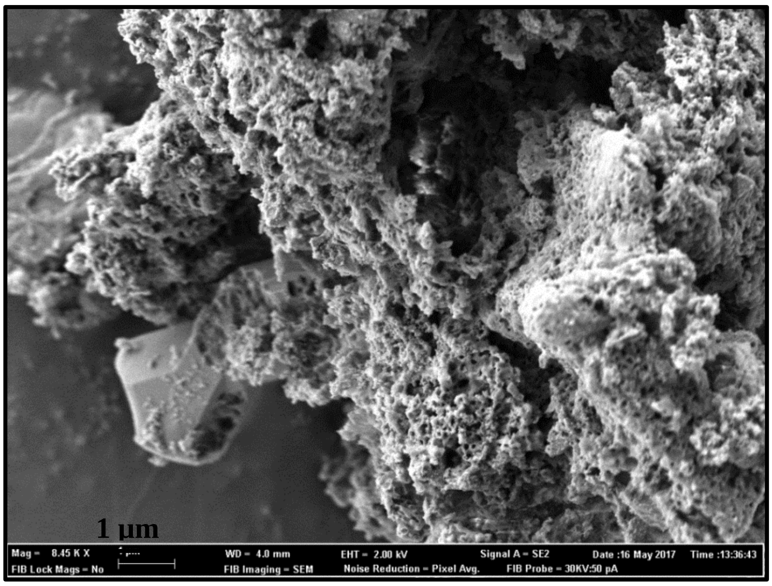


Figure 3: FE-SEM images of the prepared AC samples number a)A2 and b) B3.

3.1.5. Zeta potential results

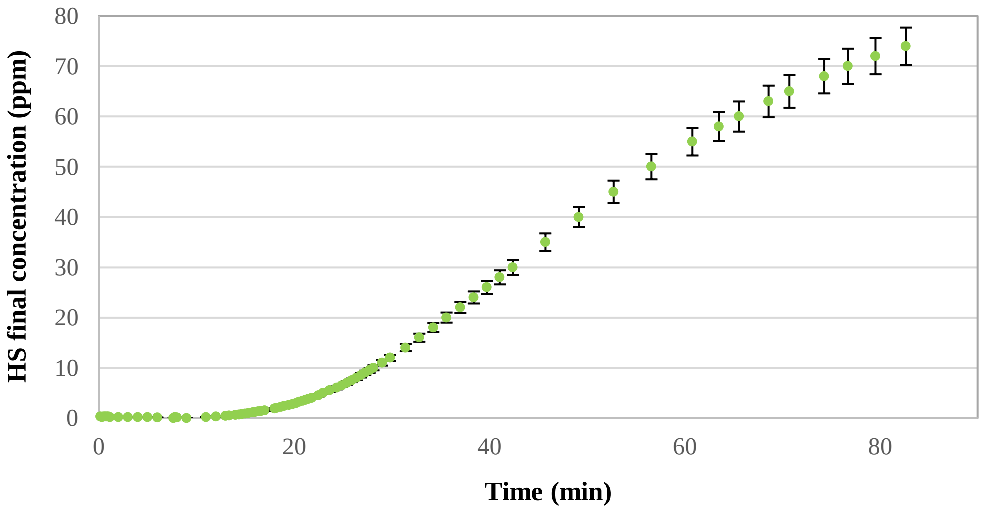
Zeta potential of the tested AC for H_2S adsorption (*AC1* and *AC2*) was measured to study possible interactions between the AC and the H_2S during the adsorption process. The mean value of zeta potential of *AC1* and *AC2*was -24.9 ± 0.8 mV and -25.2 ± 1 mV, respectively. Thus, both values were very similar. Theyclearly showed the negative charge of the prepared AC. This fact suggeststhat positively charged pollutants will be more easily adsorbed by these AC. For H_2S adsorption, the presence of H^+ protons forming a dipole moment with S^{-2} can result favourable for theH_2S adsorption. This fact is due to the negative charge of the prepared AC and the positive electric density of the H^+.In addition, this result is in concordance withLi et al.(2011) who also published a negative zeta potential value of sludge-based AC (between -35 and -37 mV).

3.2. Hydrogen sulphide adsorption

In order to study the effectiveness in the H_2S removal of the prepared AC, regenerated AC and a commercial AC, breakthrough curves have been plotted (Fig. 4).H_2S retention capacity was measured using an H_2S initial concentration of 80 ppm in the feed gas. It can be observed that the breakpoint occurred atapproximately 30 min for commercial AC whereas for the AC 1, AC 2 and regenerated AC 2, it occurred at about 140, 90 and 7 min, respectively.It can be observed that the prepared ACs showed higher affinity to H_2S retention than the commercial AC since the breakpoints occurred later than in the case of the commercial AC. As expected, since no thermal treatment was performed, the regenerated AC 2 did not show the same efficiency than the new AC 2. These results are in concordance with previous studies such us Zhang et al. (2016)who prepared AC from blackliquor for hydrogen sulphide removaland reported that the breakpoint was around 150 minutes. Regarding H_2S adsorption mechanism on activated carbon, accordingShen et al.(2018) AC can facilitate the H_2Smolecule dissociation and offers active sites for H_2S adsorption.

In order to compare the saturation capacity of each AC, Table 9 shows the relation between the H_2S adsorbed mass (in mg) and the AC mass (in g) employed in each test. It can be observed, as commented above, that the commercial AC had a lower capacity than the prepared AC, even than the regenerated AC. De Falco et al.(2018)tested a commercial AC impregnated with Cu and Zn for H_2S removal and achieved a adsorption capacity values between 6.8 and 49.64 mg/g. However, Aslam et al.(2015) prepared AC from oil fly ash for H_2S removal from a gas stream and obtained saturation capacity values around 0.1 mg/g. Taking into account these results, it can be concluded that the results published here are in the range with previous results published in the bibliography.

a)



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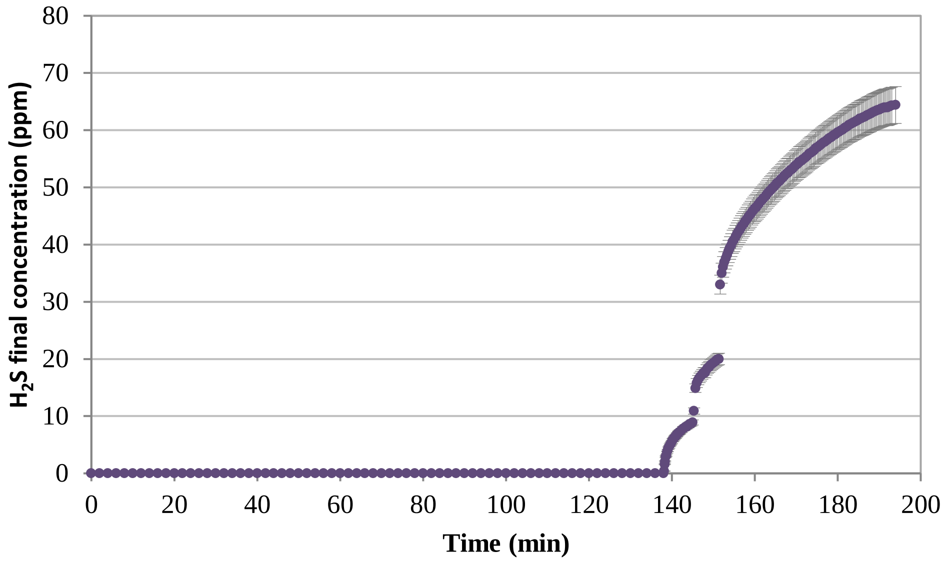

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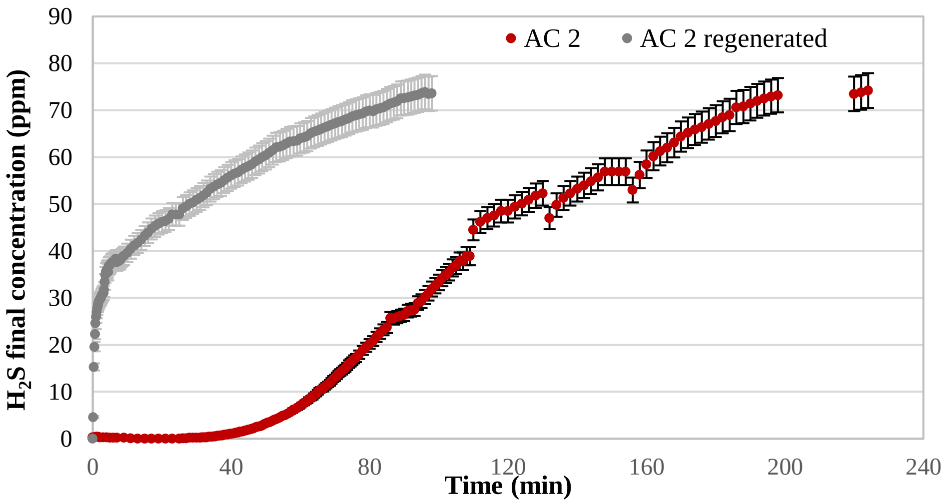

Figure 4: Experimental and breakthrough curves for a) commercial AC, b) AC 1 and c) AC 2.

Table 9: Capacity of each AC.

AC type	Commercial AC	AC 1	AC 2	Regenerated AC 2
adsorbed H_2S (mg)/AC mass (g)	0.37	5.0	1.96	0.78

4. Conclusions

In this study, AC with interesting properties for hydrogen sulphide removal was prepared from sewage sludge by physical-chemical activation. The optimum physical and chemical activation temperature was 600ºC and 1000ºC, respectively. Regarding the best activated agent, KOH achieved the most interesting results in terms of specific surface area (values around 300 and 340 m^2/gfor the tested conditions). Zeta potential of the prepared AC was negative (around -25 mV) and it was observed a heterogeneous pore size distribution in the surface morphology of the adsorbent materials. In addition, the experimental results were adjusted to BET isotherms, whichconfirms that the adsorption process occursin a multi-layer space. Finally, results from the prepared and the commercial AC tested for H_2S removal demonstrated that the prepared AC was effective, even more than the tested commercial AC, for H_2S removal. As a general conclusion, it can be confirmed that the use of prepared AC from sewage sludge for odours removal could be of great interest in a recent future.

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