Preparation of Granular Activated Carbons Using Various Binders †

Remigiusz Gumiński 1 and Iwona Skoczko 2,*

1 Faculty of Civil and Environmental Sciences, Białystok Technical University, 15-351 Białystok, Poland; guminski@grand-activated.pl
2 Department of Technology in Environmental Engineering, Białystok Technical University, 15-351 Białystok, Poland
* Correspondence: i.skoczko@pb.edu.pl; Tel.: +48-585-850-010
† Presented at the 9th Innovations-Sustainability-Modernity-Openness Conference (ISMO'20), Białystok, Poland, 20–21 May 2020.
Published: 6 August 2020

Abstract: The purpose of this work was to verify the binders available on the Polish market due to their physical features and effectiveness of building permanent active carbon granules. The conducted tests concerned a comparison of sorption properties and strength of activated carbon formed from hard coal depending on the type of binder used. Raw material preparation, granulation, drying and carbonization, as well as activation processes were carried out. The results obtained are presented in the form of tables. Based on the reached results, one of the most important effects in terms of operating conditions is the greatest advantage of the aqueous glycocell solution as a binder.

Keywords: activated carbon; iodine number; mechanical strength; specific surface; beet molasses; tall oil; glycocell; gas tar

1. Introduction

Production of activated carbons is based on natural, organic, raw materials of polymeric structure, mainly hard coal [1]. The products of carbonization of this type of raw matter are described by a level of microporosity which develops to varying size dependent on the nature of the organic material and the carbonization mechanism. The presence of micropores is a result of small dimensions and random mutual orientation of graphene layer packets, i.e., crystallites. However, for most applications of charcoal, this natural porosity is insufficient [2–4]. Therefore, activation is the process of developing the porosity in a non-porous starting material as a result of special physico-chemical treatment. By widening existing pores and making closed porosity available, a significant increase in micropore content can be achieved. Activated carbon is produced from the raw materials by thermochemical processes. One of the most common ways to produce activated carbons in the world is the so-called physical activation [5,6]. It consists of two stages, i.e., carbonization of the organic raw matter and subsequent appropriate activation by partial gasification of the carbon material with a gaseous agent, which may be water vapour or carbon dioxide. The next step is granulation using a suitable binder, which will ensure the correct size of the granules, their durability, mechanical and chemical strength and resistance to high temperatures. The binder should be neutral and not wash out of the granules. It should not leach into the treated water or introduce substances of potential danger to it [7,8].

Due to the above-mentioned, the purpose of the research was to verify the binders available on the Polish market due to their physical properties and effectiveness of building permanent active
carbon granules. The research concerned all applied binder during granulation and drying in terms of operating conditions.

2. Materials and Methods

Production of activated carbon from hard coal formation for conducted research was a four-step process including: granulation (with a suitable binder), drying, carbonization and activation. The raw material was directed to the drying process in the form of granules in an amount of 900 kg/h. Dried granules were directed to the carbonization process in the amount of 800 kg/h. After the carbonization, 300 kg/h of granules were forwarded to the activation process. Considering energy efficiency by the whole line of production: the drying process absorbed approx. 30 m³/h of propane-butane gas; the carbonization process is autothermal and the activation process consumes up to 30 m³/h of propane-butane gas.

The tests included five repeated tests. The experimental stand for testing consisted of full use of the quality control department laboratory and included: conditioner, pellet machine, muffle furnaces, laboratory carbonization and activation furnace and laboratory dryers.

Binders accepted for experiments: gas tar, beet molasses, glycocell, tall oil.

| Table 1. Properties of tested binder substances. |
|--------------------------------------------------|
| **Batch Characteristics of Binders** | **Sample Number** | **Density [g/cm³]** | **Concentration [%]** | **No. of Coking [mPa*s]** | **Viscosity in 50 °C [mPa*s]** | **Viscosity in 60 °C [mPa*s]** | **Viscosity in 65 °C [mPa*s]** | **Viscosity in 70 °C [mPa*s]** |
| Molasses | 1 | 1.3984 | 8.77 | 860 | 679 | 509 |
| | 2 | 1.3676 | 11.99 | 1584 | 96 |
| | 3 | 1.3716 | 7.71 | 792 | 656 |
| Glycocell 1 | 1 | 6.52 | 143.9 | 98.2 | 50.2 |
| | 2 | 5.87 | 145 | 101.6 | 41.1 |
| | 3 | 5.96 | 147 | 100.5 | 43.4 |
| | 4 | 6.79 | 125.9 | 100.5 | 50.2 |
| Glycocell 2 | 1 | 6.12 | 146 | 102.3 | 51.3 |
| | 2 | 5.5 | 145 | 106.2 | 59.4 |
| Glycocell + gas tar | 1 | 5.82 | 123.3 | 89.1 | 39.9 |
| | 2 | 1.1916 | 24.2 | 123.3 | 73.1 | 45.7 |
| Tall oil | 1 | 1.0219 | 0.82 | 181 | 792 | 29.4 |

Conducted analyses met norms regulation: PN-83 C-97555.04; EN 12902:1999; PN-76 R-64772; PN-ISO 9277; PN-90/C-97554; PN-EN 12915-1.

3. Results and Discussion

It has been observed that granules using molasses as a binder were very reactive and after thermal treatment processes i.e., carbonization and activation, granules could be cooled without air access, otherwise they glowed and incinerated, as noted by Heijman and Hopman [1], as well as Saeidi and Lotfollahi [4]. In the drying process, weight loss occurred by evaporating the water together with light hydrocarbons. Experiments on charcoal production were also conducted by Deina’s team [3] and proved that the weight loss in the carbonization process occurred as a result of evaporation and oxidation of volatiles from the coal and binder, which also ensured the energy self-sufficiency of the process.

Our own research showed that all quality requirements were met by AG-2u, AG-5 carriers derived from AG activated carbon using molasses as a binder, while these carriers were characterized by very high sorption properties in comparison to other materials tested by Skoczko [2,8]. These also met all the requirements of the second glycocell test. Carriers A-2 with other binders were normative, while carriers AG-2u and AG-5 raised reservations regarding mechanical strength or dynamic activity in relation to ethyl chloride.

Among laboratory samples, the lowest reactivity was observed for samples with tall oil and those obtained under the second glycocellular test, which in production conditions also required the longest activation time, confirmed also by Kelly and McFaddin [5]. The features of charcoal activity
were tested by Zou and Han [7] using Chinese hard coal. Their conclusions confirmed the outcome observed by authors of this work. All activated carbons were characterized by dynamic activity in relation to chloropicrin over 120 min. The longest time - about 161 minutes of action was noted for carbon compounds built with molasses. All of them had a normative parameter of dynamic activity in relation to ethyl chloride, while in the granulation and sorption processes described as granulation process time calculated per iodine number (G/I) tests it was within the lower requirements. The highest rate calculated G/I as of 40.7 minutes was observed for charcoal with molasses.

4. Conclusions

1. During granulation and drying, arduous gassing and harmful working conditions occurred when using tall oil and adding gas tar to the glycocell.
2. In terms of operating conditions, the greatest advantage is the aqueous glycocell solution as a binder.
3. Granules with molasses as a binder were very reactive and after the thermal treatment processes they should be cooled without air access, otherwise they glowed and incinerated.
4. The abrasion of activated carbons did not exceed 1%, except in the tall oil test where it was 1.3%.

Author Contributions: R.G. and I.S. developed and designed the experiments; R.G. conducted experiments; R.G. and I.S. analyzed the data; R.G. contributed materials; R.G. and I.S. wrote an article. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: Grand Activated Sp. z o. o.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Heijman, S.G.J.; Hopman, R. Activated carbon filtration in drinking water production: Model prediction and new concepts. Colloids Surf. A Physicochem. Eng. Asp. 1999, 151, 303–310, doi:10.1016/S0927-7757(98)00643-8.
2. Skoczko, I.; Szatylowicz, E. The analysis of physico-chemical properties of two unknown filter materials. J. Ecol. Eng. 2016, 17, 148–154.
3. Deiana, A.C.; Granados, D.L.; Petkovic, L.M.; Sardella, M.F.; Silva, H.S. Use of grape must as a binder to obtain activated carbon briquettes. Braz. J. Chem. Eng. 2004, 21, 4, doi:10.1590/S0104-66322004000400007.
4. Saeidi, N.; Lotfollahi, M.S. Effects of Powder Activated Carbon Particle Size on Activated Carbon Monolith's Properties. Mater. Manufact. Proc. 2016, 31, 1634–1638, doi:10.1080/10426914.2015.1117630.
5. Kelly, W.L.; McFaddin, M.C. Process for Producing Bonded Activated Carbon Structures and Articles. U.S. Patent 679,866,682, 21 September 2001.
6. Burchel, T.D. Carbon Materials for Advanced Technologies; Elsevier Science: Oxford, UK, 1999.
7. Zou, Y.; Han, B.X. High-Surface-Area Activated Carbon from Chinese Coal. Energy Fuels 2001, 15, 1383–1386, doi:10.1021/ef0002851.
8. Szatylowicz, E.; Skoczko, I. studies on the efficiency of groundwater treatment process with adsorption on activated alumina. J. Ecol. Eng. 2017, 18, 211–218.

© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).