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NEW CARBON BASE NANO ABSORBENTS FROM MYANMAR MACADAMIA NUTSHELLS, APPLIED FOR THE ADSORPTION OF N-BUTANOL FROM VAPOR-GAS MIXTURE

Research article

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Abstract

The plant waste from Myanmar's numerous industries is generally used with low efficiency. Along with this, the data of scientific and technical information indicate that on the basis of waste similar in nature, it is possible to obtain high-value products of sufficiently high quality, in particular, carbon adsorbents, focused mainly on solving the problems of cleaning industrial effluents and emissions. Activated carbons offer a large spectrum of pore structures and surface chemistry for adsorption of gases, which are being used to design practical pressure swing and thermal swing adsorption processes for separation and purification of gas mixtures. The activated carbons are often preferred over the zeolitic adsorbents in a gas separation process because of their relatively moderate strengths of adsorption for gases, which facilitate the desorption process. Three commercial applications of activated carbons,

a) trace impurity removal from a contaminated gas;

b) production of hydrogen from a steam-methane reformer off gas;

c) production of nitrogen from air, are reviewed.

Four novel applications of activated carbons for gas separation and purification are also described. They include,

a) separation of hydrogen-hydrocarbon mixtures by selective surface flow of larger hydrocarbon molecules through a nanoporous carbon membrane produced by carbonization of a polymer matrix;

b) gas drying by pressure swing adsorption using a water selective microporous carbon adsorbent produced by surface oxidation of a hydrophobic carbon;

c) removal by selective adsorption and in-situ oxidation of trace volatile organic compounds from air by using a carbon adsorbent-catalyst composite;

d) storage of compressed natural gas on high surface area carbons.

The paper describes the preparation procedure, characterizes the yield and structural and adsorption properties of steam activated carbon based on macadamia nut shells, compared with those based on coconut shells and plum seeds. The kinetics and equilibrium of their absorption of n-butanol vapors from their mixtures with air are estimated, and the dependencies are modeled according to known equations. The conclusion is made about the prospects of the studied way of processing waste macadamia nuts.

Keywords: waste, coconut shells, macadamia nuts shells and plum pits, carbon adsorbents, volatile organic solvent vapor capture.

НОВЫЕ УГЛЕРОДНЫЕ НАНО-АДСОРБЕНТЫ ИЗ СКОРЛУПЫ ОРЕХОВ МАКАДАМИИ В МЬЯНМЕ, ИСПОЛЬЗУЕМЫЕ ДЛЯ УДАЛЕНИЯ Н-БУТАНОЛА ИЗ ПАРОВОЗДУШНОЙ СМЕСИ

Научная статья

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Аннотация

Растительные отходы многочисленных производств Мьянмы в целом используют с низкой эффективностью. Наряду с этим данные научно-технической информации свидетельствуют, что на базе сходных по природе отходов можно получать продукты повышенной стоимости достаточно высокого качества, в частности, углеродные адсорбенты, ориентированные в основном на решение задач очистки производственных стоков и выбросов. Активные угли предлагают широкий спектр пористых структур и его поверхностной химии для адсорбции газов, которые используются для разработки практических процессов адсорбции с колебанием давления и температур для разделения и очистки газовых смесей. Активные угли часто предпочитают цеолитным адсорбентам в процессе разделения газов из-за их относительно умеренной силы адсорбции газов, что облегчает процесс десорбции. Рассмотрены три коммерческих применения активных углей:

а) удаление следов примесей из загрязнённого газа;

б) производство водорода из отходящего газа парового риформера метана;

в) производство азота из воздуха.

Также описаны четыре новых применения активных углей для разделения и очистки газов. Они включают в себя:

а) разделение смесей водорода и углеводородов путём селективного поверхностного потока более крупных молекул углеводородов через нано-пористую углеродную мембрану, полученную путём карбонизации полимерной матрицы;

б) осушку газа путём адсорбции при переменном давлении с использованием селективного для воды микропористого углеродного адсорбента, полученного путём поверхностного окисления гидрофобного углерода;

в) удаление путём селективной адсорбции и окисления на месте следов летучих органических соединений из воздуха с использованием композита углеродного адсорбента-катализатора;

г) хранение сжатого природного газа на углях с большой площадью поверхности.

В работе описана процедура приготовления, охарактеризованы показатели выхода и структурно-адсорбционных свойств активного угля паровой активации на базе скорлупы орехов макадамии, сопоставленные с таковыми на основе скорлупы орехов кокосовой пальмы и косточек сливы. Оценены кинетика и равновесие поглощения ими паров н-бутанола из их смесей с воздухом, проведено моделирование зависимостей по известным уравнениям. Сделан вывод о перспективности изученного пути переработки отходов орехов макадамии.

Ключевые слова: отходы, скорлупа кокосов, скорлупа макадамии, косточки сливы, углеродные адсорбенты, улавливание паров летучих органических растворителей.

Introduction

More and more attention is being paid to the issues of engineering protection of the environment and, in particular, the development of processes for the disposal of industrial waste and the protection of the hydrosphere. The above areas correspond to the goals of UN SDG 6 "Clean Water and Sanitation" and UN SDG 12 "Ensuring sustainable consumption and production patterns" and are included in the concept of a circular economy, which undoubtedly confirms their relevance [1].

Recently, a significant number of scientific groups have been inclined towards the rejection of traditional inorganic reagents, in favor of materials obtained from plant raw materials (sorbents, ion-exchange materials, etc.). A lot of work has been devoted to the development of technologies for processing industrial [2] and agricultural [3] waste with the production of reagents for water purification processes of waste, as well as a pronounced economic effect due to cost reduction.

It is known that the quality of carbon adsorbents largely depends on the raw materials used [5]. For example, materials obtained from coconut bark, seeds of various plants and other agricultural wastes have proven to be good sorbents [6], [7].

Macadamia fruits are hard and very strong spherical drupes, usually 1.5-2 cm in diameter with 1-2 kernels (seeds) inside, because of the original taste of their kernels, are ubiquitous, despite the rather high cost, Increasingly growing interest [8]. In 2019, the global production of macadamia nut kernels amounted to 59 thousand tons, or less than 8% of the pulp of other nuts, such as almonds, walnuts, cashews, pistachios, etc. However, between 2009 and 2019, the production of macadamia nuts grew by 57%, faster than any other tree nut [9]. In Myanmar, macadamia has been cultivated for more than a decade, and the main product is not the kernel, but the nut in the shell (OSM). By 2019, Myanmar is estimated to have produced 300–500 tonnes per year, or less than one percent of global production [10], [11], [12]. The production of marketable products (nuts, pulp, concentrates) is accompanied by the formation of a huge amount of waste in the form of shells.

The main purpose of this work is to assess the possibility of using Makadam nutshells as a precursor for the production of carbon adsorbents, as well as to assess the sorption efficiency of the obtained materials.

Experimental part

A representative sample of macadamia nutshells (MNS) selected at a macadamia nut farm in the village of Pwe Gauk in the village of Pyin-Oo-Lwin in Mandalay District of the Republic of the Union of Myanmar was used in the work. For this purpose, the shell was subjected to rough cleaning with tap water in order to separate the sand, and then several successive washes with distilled water to remove dirt and thin fragments of nuts (dust, dispersed fines). After that, the purified raw materials were dried in the sun for 7 days to remove external and, partially, adsorbed moisture, and then in an oven at 110 °C for 5 hours, providing a constant mass precursor, the appearance of which is characterized by photo (a) of Figure 1. The resulting precursor was mechanically crushed and a fraction of particles with a size of 2-5 mm was separated from the grinding product using a sieve, which is most suitable for good heat distribution and pore formation in the processes of pyrolysis and activation, placing it for storage in sealed containers photo (b) of Figure 1.

a

b

Figure 1 - Ensemble of fragments of prepared raw materials:
a - raw materials; *b* - sealed containers
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The study of the rational conditions for pyrolysis of the prepared raw material was carried out based on the results of preliminary experiments at a heating intensity of 10 °C/min, a final temperature of 700 ° C and a 60-minute duration of isothermal holding of the processed material. Activation of the target pyrolysis product was carried out at a temperature rise at a rate of 15 °C/min to 900 °C without thermal exposure, the specific consumption of water vapor was 5 g per 1 g of the resulting activated carbon. The yield and structural-adsorption indices of the obtained carbonisate and activated carbon based on Macadamia nutshells and the above-mentioned carbon adsorbents are compared in Table 1 [13], [14].

Table 1 - Some Evaluated Characteristics of Carbonates (K) and Activated Carbons (AC) Obtained under Rational Conditions for Processing Dense Plant Waste in Myanmar

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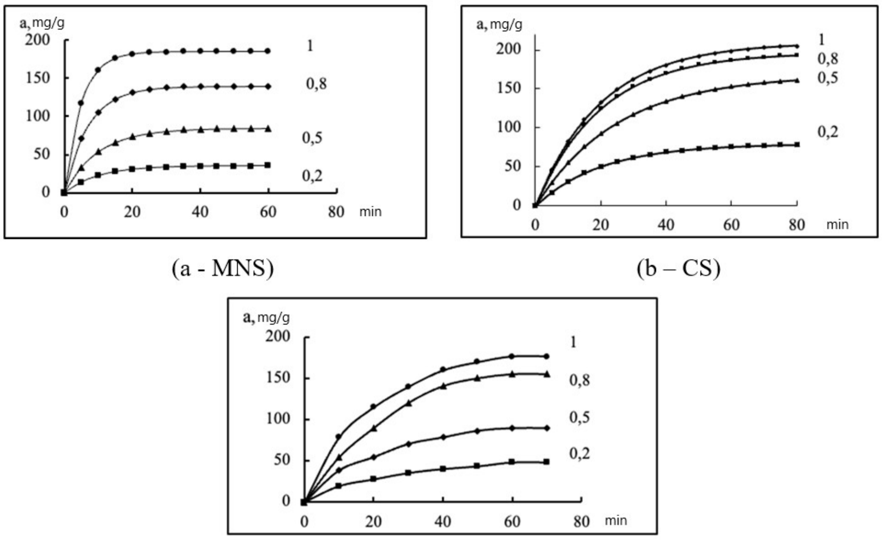
Adsorbent	Raw Material Yield, % mass.	I, mg/g	MB, mg/g	V_Σ, cm^3/g	Vs (cm^3/g) by vapour:		
					C_6H_6	CCl_4	H_2O
CS (K)	25.3	403	53	0.32	0.16	0.03	0.15
CS (AC)	15.2	620	281	0.8	0.37	0.24	0.36
PS (K)	31.0	108	40	0.56	0.07	0.11	0.07
PS (AC)	25.3	868	152	0.92	0.37	0.34	0.19
MNS (K)	55.3	864	230	0.56	0.02	0.03	0.19
MNS (AC)	25.5	1183	269	1.23	0.46	0.37	0.47

Note: CS – coconut shell; PS – plum seed; MNS – macadamia net shell

The obtained samples of adsorbents were tested in the processes of capturing vapors of volatile organic solvents (VOS) from their vapor-air mixtures (using the example of n-butanol vapors) [15]. Activated carbons obtained from coconut shells (CS) and plum seeds (PS) were used as a comparison sample [16]. In order to compare the expediency of using activated carbon obtained from MNS to extract vapors of volatile organic solvents from their VOS under almost identical conditions, the kinetics and equilibrium of these processes were studied using the examples of the use of n-butanol vapors and the characterized laboratory-made active carbons.

Experimental results and discussion

As emphasized in the paper [17], even with similar values of the composition, technical characteristics and conditions of processing raw materials in the form of similar wastes of geographically different places of formation, the yield and individual properties of carbon adsorbents obtained from them do not always correspond to their best samples. This circumstance is also confirmed by the experimental data described below. Nevertheless, with various, and in some cases with high efficiency, their use can solve a wide range of problems of purification from organic impurities of industrial emissions and discharges. The kinetic adsorption curves of n-butanol vapors from its PVS by the active carbon obtained in the work from MNS (a) are compared in Fig. 2 with similar for laboratory-made activated coals CS (b), PS (c).



(a - MNS) (b – CS)

(c - PS)

Figure 2 - Kinetics of adsorption at 20 ˚C of n-butanol vapors from their AVM by samples of used activated carbons (specific consumption of AVM is 2.5 l/(cm^2·min), the size of adsorbent grains is 3.0–5.0 mm, the numbers of the curves are the values of p/ps:

a - MNS; *b* – CS; *c* - PS

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A formal description of the kinetic curves of Fig. 2 is possible using an equation of the form $a = A(1-e^{-B\cdot\tau})$, the values of the coefficients A and B of which are given in Table 2 (a is the value of absorption, mg/g; τ is time, min).

Table 2 - Values of the coefficients A and B of the equation $a = A(1-e^{-B\cdot\tau})$

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Activated carbon	Values of the coefficients A (numerator) and B (denominator) at P/Ps			
	0.2	0,5	0,8	1,0
CS	80/0.05	167/0.04	197/0.05	208/0.05
MNS	35/0.10	85/0.10	140/0.14	185/0.20
PS	79/0.05	123/0.05	158/0.05	175/0.05

The characterized information allows us to state the difference in the shape of the presented kinetic curves. In the region of low P/P_S values, MNS activated carbon demonstrates a lower absorption capacity than PS and CS, which is due to the weak mutual attraction of the molecules of adsorbate and adsorbent MNS. Although the adsorption rate constant B is maximum for activated carbon MNS, at P/Ps = 1, this adsorbent absorbs more n-butanol in its pores than the adsorbent PS, but is inferior to active carbon CS.

According to the ultimate saturation values shown by the kinetic curves in Fig. 2, the corresponding adsorption isotherms are constructed (Fig. 3).

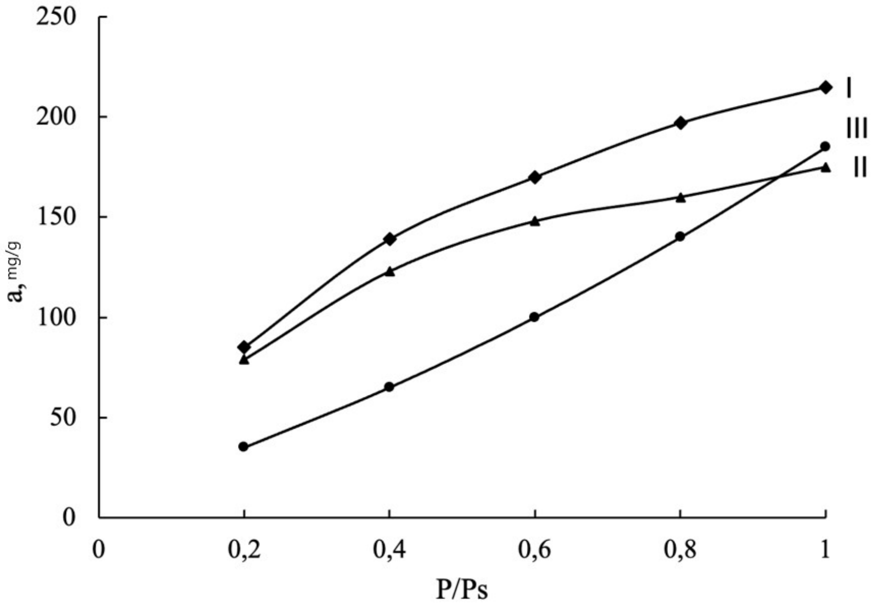

Figure 3 - Adsorption equilibrium of n-butanol on the compared active carbons:
I - CS; *II* - MNS; *III* - Ps
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A formal description of isotherms in Fig. 3 is possible with the help of an equation of the form $a = K(P/Ps)^{1/n}$, the values of the coefficients K and n of which are summarized in Table 3.

Table 3 - Values of equation coefficients $a = K(P/Ps)^{1/n}$

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Activated carbon	Coefficient	
	K	n
CS	222	0.61
PS	182	0.50
MNS	185	1.00

The highest value of K, which expresses the absorption capacity of the adsorbent, is observed for activated carbon among the active carbons of plant waste from Myanmar from a large volume of micropores. The parameter n, which characterizes the energy of interaction of coals with butanol, is the smallest for active carbon PS. This corresponds to the most convex adsorption isotherm (Fig. 3), which is favorable for capturing low concentrations of butanol vapors. In terms of value n, the resulting new macadamia nutshell activated carbon is comparable to other types of macadamia nutshell activated carbons.

Conclusion

Thus, the studies allow us to state quite satisfactory absorption properties of the obtained new activated carbon from macadamia nutshells, in the studied process of extracting n-butanol vapors from their mixtures with air, which indicates the probable competitiveness of this adsorbent in solving the problems of purification of organic substances from vapors of emissions of high concentrations, provided that its production is organized in the conditions of Myanmar.

Конфликт интересов

Не указан.

Рецензия

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Conflict of Interest

None declared.

Review

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