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Highly effective sorbents obtained by treating agrowaste products in cold plasma

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Abstract: Sorbents are widely used in purification of various liquids and gases, offering a universal means for wastewater and air cleaning. The most promising sorbents are those obtained from agrowaste products such as rice or buckwheat husk. Processing of husk in cold plasma modifies the composition, structure and surface properties of the raw material and raises its porosity, thus substantially improving the sorption properties of the final product.

Husk as a raw material for producing sorbents has the following advantageous properties: (1) appropriate chemical composition; (2) low cost; (3) high dispersity, due to which there is no need in any special treatment of the material prior to its exposing to plasma; (4) scaly structure and developed porous surface ensuring a high surface-to-volume ratio. The best properties are displayed by the sorbents obtained in cold plasma under reduced pressures of 53.2 Pa. The raw material traverses the region occupied by the plasma and, as it does so, it gets heated up to a temperature of 250 - 350 ℃. The whole process involves two stages: combustion of the raw material and modification of its properties under the action of the plasma. The combustion proceeds due to the oxygen contained in the starting material. During the combustion, the hydrogen contained in the starting material and some part of the carbon also burn out. The resultant scaly sorbent is accumulated in a cooler. The scales are black; they range in sizes from 1mm to 5 mm.

The sorbents obtained are remarkable for their useful properties and outperform most of the traditional sorbents used in modern industry. The starting materials are inexpensive, and their resources are almost unlimited. The sorbents have rather a low production cost (1.8-2.5 $/kg). The sorbents can be used for cleaning hydrosphere from water pollutants on a large scale. The degree of cleaning water surface from oil products with sorbents was a subject of investigation. The highest degree of purification the sewages up to 96.6% was observed in those cases where sorbents obtained from rice and buckwheat husk were used. Another advantageous feature of the sorbents stems from the practical good that can be benefited from their utilization. The sorbents saturated with pollutants can be used as fuel or in producing asphalt concrete. The sorbents may prove useful in pharmaceutical and food industries. Most advantageous conditions for producing such sorbents are available in rice-growing countries such as China, India, Japan and Korea.

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wastewater and air cleaning. The search for new, more effective and inexpensive sorbents is currently underway. The most promising sorbents are those obtained from agrowaste products such as rice or buckwheat husk. Processing of husk in arc or RF cold plasma modifies the composition, structure, and surface properties of the raw material and raises its porosity, thus substantially improving the sorption properties of the final product.

Husk as a raw material for producing sorbents has the following advantageous properties: (1) appropriate chemical composition; (2) high dispersity, due to which there is no need for any special treatment of the material prior to its exposing to plasma; (3) scaly structure and developed porous surface ensuring a high surface-to-volume ratio; (4) low cost.

The raw material transforms into a highly effective sorbent when treated in arc or RF plasma under a reduced pressure. The best properties are displayed by the sorbents obtained in RF argon plasma under a pressure of 53.2 Pa. The raw material traverses the region occupied by the plasma and, as it does so, it gets heated up to a temperature of 250-350℃. The whole process involves two stages: combustion of the raw material and modification of its properties under the action of the plasma. The combustion proceeds due to the oxygen contained in the starting material. During the combustion, the hydrogen contained in the starting material and some part of the initially present carbon also burn out. The resultant scaly sorbent is accumulated in a cooler. The scales are black, insoluble in water, uninflammable and non-explosive; they range in sizes from 1mm to 5 mm.

The sorbent obtained from rice husk (RH) exhibits considerable porosity; its mineral composition is indicated in Table 1.

Table 1 Mineral composition of the sorbent obtained from rice husk (RH)

Substance	Content of the total sorbent mass/%
$SiO_2 + C$	93.76
CaO	0.74
Al_2O_3	0.1
Fe_2O_3	0.1
MgO	0.69
Mn	0.22
Na_2O	0.09
K_2O	3.50
Microelements	0.80

The main constituents are silicon oxide (~ 52%) and carbon (~ 42%), these components impart the sorbent with sorption properties comparable with those of silicagel or activated carbon. The sorbent floats on water surface, can be easily extracted from mixtures, and is transportable.

The degree of cleaning water surface from oil products with the sorbents obtained from agrowastes was a subject of much investigation. The typical testing procedure was the following. A sorbent of mass $m$was poured onto a water surface polluted with oil products to a concentration C_x. The time required for the sorbent to be saturated with the pollutants was 30 minutes. Afterwards, the sorbent saturated with the pollutants was mechanically removed from the water surface. The concentration C_0 of the pollutants after the

cleaning procedure and the cleaning degree Swere estimated by performing weighing tests (Table 2).

Table 2 Degree of water cleaning from various oil products with the sorbents obtained from buckwheat and rice husk (respectively BH and RH)

Sorbent	Oil product											
	Black oil M-20				Diesel oil				Mineral oil			
	$C_w/(g \cdot l^{-1})$	m/g	$C_0/(g \cdot l^{-1})$	$S/\%$	$C_w/(g \cdot l^{-1})$	m/g	$C/(g \cdot l^{-1})$	$S/\%$	$C_w/(g \cdot l^{-1})$	m/g	$C_0/(g \cdot l^{-1})$	$S/\%$
BH	10	2.5	0.002	99.9	12	2	0.3	97.5	9	1.8	0.026	99.7
RH	10	2.5	0.0032	99.9	12	2	0.7	94.2	9	1.8	0.014	99.8

The invariably high degree of the water-surface cleaning from all oil products, up to 99.9%, proves the sorbents obtained to be highly effective ones (Table 2).

Table 3 compares the degrees of sewage purification from oil products with various sorbents. The highest degree of purification (up to 96.6%) was observed in those cases where sorbents obtained from rice and buckwheat husk were used.

Table 3 Wastewater cleaning from oil products with various sorbents

Sorbent	Sorbent weight/g	Liquid-trough time/min	Initial oil content in the water/$(mg \cdot l^{-1})$	Residual oil content/$(mg \cdot l^{-1})$	Degree of cleaning from the oil/%
Activated charcoal	12.5	25	35.6	15.5	56.5
Activated coke	35.8	60	35.6	1.7	95.3
Foamed polysterene	36.1	15	35.6	10.9	69.4
RH	9.9	15	35.6	1.2	96.6
BH	6.5	8	35.6	1.24	96.5

Table 4 compares the main properties of the most widely used sorbents with the sorbents obtained from plasma-treated agrowastes. The latter sorbents have a low density and display low moisture absorption; these properties allow them to easily float on water surface. The sorbents readily absorb oil products polluting water; their oil capacity amounts to 12 g/g.

Another advantageous feature of the sorbents obtained from plasma-treated agrowastes stems from the practical good that can be benefited from their utilization. The sorbents saturated with pollutants can be used as fuel or in producing asphalt concrete. It should be emphasized that the sorbents obtained from plasma-treated agrowastes have rather a low production cost (1.8-2.5 $/kg).

The performed tests showed that the process conditions largely affect the chemical activity of the sorbent. Oxygen bonds make RH and BH extremely active oxidants. The high sorption capacity of these sorbents suggests their use instead of activated carbon in pharmaceutical industry, in food waste utilization, in alcoholic beverage industry, and in air conditioning and water cleaning. The results of the work have been patented.

Table 4 Comparative characteristics of various sorbents

Parameter	Peatsorb	Turbojet	Powersord	BTK-1	Fegel	Sorboil	RH/BH
Sorbent base	Peat	Peat	Nonwoven fabric	Peat	Wood dust	Wood dust, agrowastes, peat, bark	Rice husk/ buckwheat husk
Appearance	Ground material	Ground material	Roll	Ground material	Ground material	Ground material	scales
Density, g/cm^3	0.16	0.11	—	0.06	0.22	0.25	0.08-0.14
Oil capacity, g/g	1.6-4.0	3.6	11.0-12.0	10.0-11.0	6.0-8.0	8.0	5.6-12.0
Moisture absorption, g/g	1.64	2.03	0.06	5.21	0.1	0.05	0.09
Toxicity level	Harmless	Harmless	—	Harmless	Harmless	Harmless	Harmless
Production cost, $/kg	7	5.8	—	7	3	2.5	1.8-2.5
Utilization method	Burning, burial ground disposal	Burning at T=365℃	Squeezing	Squeezing	Squeezing, burning	Squeezing, burning	Burning, producing of asphalt concrete

Conclusions

(1) Inexpensive, highly effective sorbents can be obtained by treating agrowastes-rice or buckwheat husk in arc or RF cold plasma. Most advantageous conditions for producing such sorbents are available in rice-growing countries such as China, Japan, India and Korea.

(2) The sorbents obtained from plasma-treated agrowastes are remarkable for their useful properties and outperform most of the traditional sorbents currently used in modern industry. The starting materials are inexpensive, and their resources are almost unlimited.

(3) The sorbents obtained in plasma can be used for cleaning hydrosphere from water pollutants on a large scale. They may prove useful in pharmaceutical and food industries.