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A Kh Aripov
Tashkent State Technical University named after Islam Karimov

S M. Turabdzhanov
Tashkent State Technical University named after Islam Karimov

Sh Komilova
Tashkent State Technical University named after Islam Karimov

O Sh Qodirov
National University of Uzbekistan named after Mirzo Ulugbek

G S. Rakhimova
Kokand state technical university named after Mukimiy

See next page for additional authors

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A.Kh. Aripov[1], S.M. Turabdjanov[1], Sh. Komilova[1], O.Sh. Qodirov[2], G.S. Rakhimova[3], T.V. Drabkova[1], Zh. Aimenova[4], L.S. Rakhimova[1]

[1]Tashkent State Technical University
University st.,2 100095, Tashkent, Uzbekistan
[2]National University of Uzbekistan
University St, 4 100174, Tashkent, Uzbekistan
[3]Kokand State Technical University
U. Nasir st, 4 373, Kokand, Fergana, Uzbekistan
[4]South Kazakhstan University
Taukekhan avenue 5, 160012, Shymkent, Kazakhstan

Abstract. *An overview of current developments in biochar application in water and wastewater treatment is given in this article, along with a brief explanation of the sorption mechanisms for removing contaminants and the techniques for biochar preparation. In order to encourage the continued use of biochar in effective water and wastewater treatment, future research directions and environmental concerns about biochar are also presented.*

Key words: *adsorbent, biochar, pyrolysis, nanopores, organic pollutants, heavy metal.*

INTRODUCTION. As industry and agriculture have developed steadily over the past few years, the amount of organic pollutants in the environment has increased [1-4], seriously polluting the ecosystem. Organic pollutants can now be removed affordably and effectively via a process called adsorption [5]. Many waste materials used for producing biochar, include fruit wastes [6-9], coconut shell [10-13], scrap tyres [14-16], bark [17-18] and other tannin-rich materials [19], sawdust and other wood type materials [20], rice husk [21], petroleum wastes [22], fertilizer wastes [23-24], fly ash [25-27], sugar industry wastes blast furnace slag [28-30], chitosan and seafood processing wastes [31], seaweed and algae [32-34], peat moss [36], clays, red mud, zeolites, sediment and soil, ore minerals etc. [37].

Under the climatic conditions of Uzbekistan, it is possible to cultivate fresh fruits, fruits and vegetables, berries, in huge quantities and assortment, meeting the needs of the population within the country, and creating competition in the foreign market [38]. In addition, the global biochar market is expected to grow from USD 164.5 million in 2021 to USD 365.0 million by 2028 at a compound annual growth rate of 12.1% in the forecast period [39]. Since biochar as adsorbent has many advantages such as various types of raw materials, low cost, and recyclability, it can achieve the effect of turning waste into treasure when used for environmental treatment [40].

Biochar effectively remove dye substances from industrial effluents [41], antibiotics such as tetracycline [42] and heavy metals [43]. Due to the growing interest of the biochar production and application, number of scientific publications of Web of Science and Scopus database related to the biochar is gradually increasing, which showed, the most of these publications (since 2016) are from Republic of China, USA, Australia, South Korea, and India [44]. So far, research work on the biochar-related field in Uzbekistan is extensive in local universities and research institutes, where institute of General and Inorganic chemistry under Academy of Science Republic of Uzbekistan (GIC) is the leading organization in the biochar research [45]. The purpose of this research was review the current literature on the synthesis and application of biochar derived materials used in waste water treatment processes. The methods of obtaining biochar and prevailing reaction conditions, properties and possibility of using biochar as adsorbent for wastewater treatment aspect are discussed in this review.

MATERIAL AND METHODS. The composition and structure of a material determines its characteristic and application. The pyrolysis condition and feedstock types are the two main factors controlling biochar's properties [46].

2.1. Pyrolysis. The most common method to produce biochar is pyrolysis, which can be dated to thousands of years ago. Pyrolysis is the thermochemical decomposition of biomass at a temperature between 350-700 °C in the absence of oxygen [47]. The mechanism of the pyrolysis process is shown in Fig. 1.

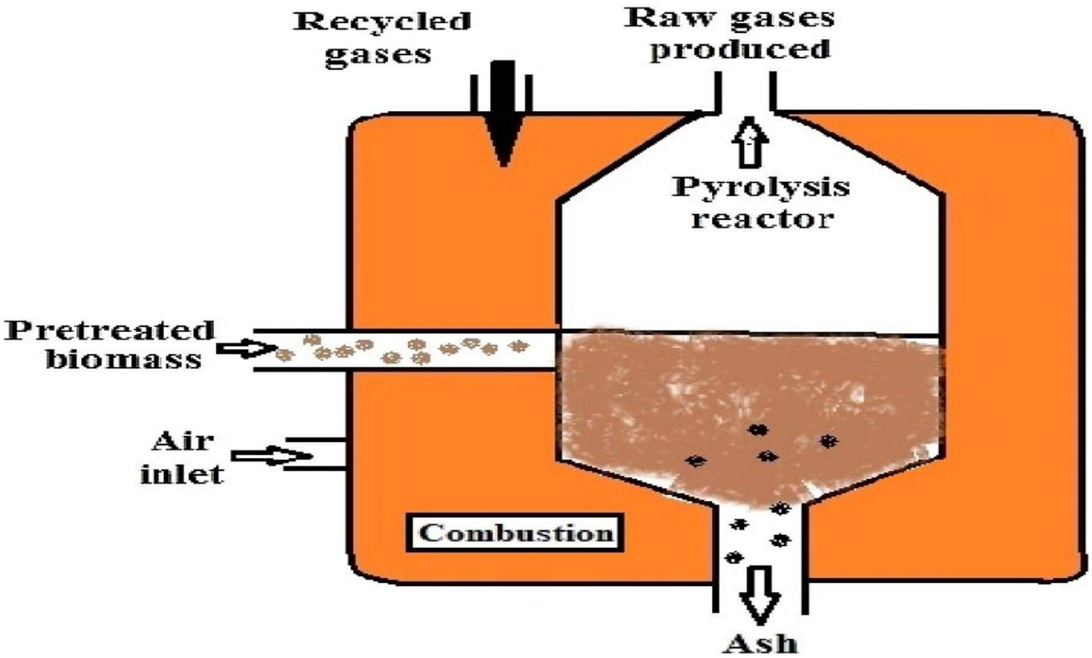

Fig. 1. Mechanism of pyrolysis [48].

Overall, pyrolysis is composed of two mechanisms – primary and secondary. The primary mechanism comprises the processes in which breakdown of chemical bonds of feedstock and releases volatile compounds in the reactor under the heat, which undergo further reactions as part of the secondary mechanism [49-50].

2.2. Biochar activation methods. The process of increasing specific surface area and pore density is called activation. In general, there are two types of activation techniques, i.e. physical and chemical [51]. In physical activation, porosity and surface area of biochar was increased exposed to the flow of gas agents CO_2, steam or mixture at above 700 ◦C [52], recently developed ultrasound waves, plasma, and electrochemical methods as well [53]. In chemical activation, the surface area and porosity are introduced inside the carbon by impregnating the raw material by desired chemical such as Phosphoric acid (H_3PO_4) [54], alkaline chemicals (e.g., KOH) [55], followed by thermal treatment at temperatures typically between 300 and 800 °C (Scheme 1).

The biochar is achieved through a direct or a two-step method with subsequent chemical activation using KOH. A theory is developed on the biochar propensity to be chemically activated based on the lignocellulosic structure composition [55]. The advantages of chemical activation over the physical activation are (1) lower temperature, (2) greater carbon yield, (3) high surface area (~ 3600 m^2/g), (4) qualitative and quantitative micro-porosity (well developed and controlled), and (5) higher efficiency [56].

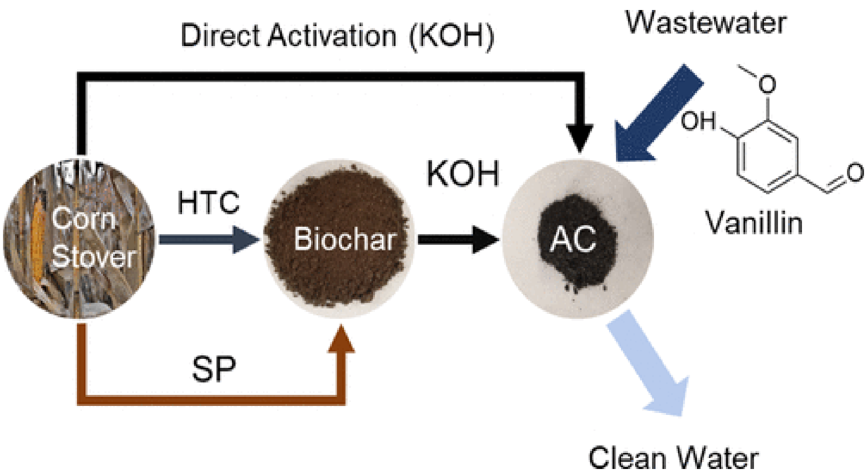

Fig 2. Chemical activation of obtaining biochar with hydrothermal carbonization (Slow pyrolysis-SP) for vanillin adsorption [55].

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2.3. Characterization. The physical and chemical characterizations are necessary to identify the basic structure and property of biochar and to predict its potential in various environmental application [57]. Physical characterization includes: bulk density [58] and particle density [59], particle size [60], macro and microporosity [61], surface area [62], water holding capacity [63]. The chemical characterizations can be FT–IR [64-68], SEM [69-70], and EDX [71-72] analyses. The thermal characterization using by thermogravimetric analyser TGA [73].

RESULTS AND DISCUSSION. Biochar is produced through pyrolysis of biomass. Due to its high carbon content and stability, it has been advocated as a climate change mitigation technology [74]. Some authors have studied the effects of pyrolysis temperature on biochar properties [75], pyrolyzed rice husk, rice straw, and wood chips of apple tree and oak tree at temperatures between 400 and 800 °C.

Some properties such as carbon (C), ash contents (%) specific surface area by Brauner-Teller-Emmit equation and other characterizes of biochars based on agricultural wastes, plants given on table 1.

Various environmental application fields of biochar including adsorption (for water pollutants and for air pollutants), catalysis (for syngas upgrading, for biodiesel production, and for air pollutant treatment), and soil conditioning are discussed [92]. Biochar present great potential for wastewater treatment due to their unique physicochemical properties, and were found to be promising candidate materials in pollutant removal by adsorption in the practical application process [93]. The applicability of steam activated pine and spruce bark biochar for storm water and wastewater purification has been investigated [94]. From the literature review, it is clear that biochar is a vital candidate for removal of dyes from wastewater with adsorption capacity of above 80% [95]. This review focuses on recent applications of biochars, produced from biomass pyrolysis (slow and fast), in water and wastewater treatment [96], heavy metal and organic pollutants (dyes, pharmaceuticals and personal care products), is summarized and discussed [97]. Application of the biochar as adsorbent at wastewater treatment processes given in table 2.

Table 1

The selected physicochemical characteristics of the biochar's

Biochar based on:	Pyrolysis temperature T °C	Specific surface area, m^2/g	C content, %	Ash content, %	Functional group	Reference
Fruit bunch	250	1,70	61,817	15,461	-COOH	[76]
Apple tree	400 500 600	7,0 37,24 108,59	65,6 61,4 73,6	1,96 1,33 2,42	C=C and C=O	[77]
Waste timber	700	268,41	81,18	3,41	O–H	[78]
Sawdust wood	350 450 550	2,567 45,78 221,0	81,64 89,90 92,35	4,05 4,32 4,75	-COOH, C=O for lactone, -OH of phenol	[79]
Peanut shell	300 700 800	3,1 448,2 571,0	68,3 83,8 -	1,2 8,9 -	aromatic -C -O –C-	[80,81]
Coffee husk	350 450 750	- - -	60,5 61,3 66,0	12,9 12,9 19,6	OH, COOH, and SO_3H	[82]
Pine wood	850	343	95,84	2,0	OH and -C=O	[83]
Rice husk	300	81	41,24	-	aromatic C-O group	
Corn grains	500 900	63 419	87,2 86,6	7,2 7,4	OH and C=O –COOH	[84]
Oil seed rape straw pellets	550	416,0	-	19,0	phenyl–CHOH–	[85]
Wheat straw pellets	700	461,0	-	21,9		
Miscanthus straw pellets	550	299,0	-	21,0		
Soft wood pellets	550	490,0	-	12,0		
Banana stem	400	0,786	42,34	-	–OH	[86]
Banana leaves	400	15,73	58,14	17,27	-C=O	
Castor grains	400 500 600	31,65 46,32 58,94	-	-	-OH	[87]
Tobacco stem	450	368,90	59,75	25,46	COOH,–OH	[88]
Oil Palm kernel shell	700	24,50	-	-	Aromatic ring C=C and C=O	[89]
Cassava stem	400	-	-	-	N–H group	[90]
Marine biomass of Sargassum fusiforme	300 500 700	1,55 2,71 76,10	43,19 45,56 53,48	36,0 49,0 56,9	oxygen-containing functional groups	[91]

Table 2

Adsorption characteristics of contaminants removal using Biochar

Biochar	Pollutant		Adsorption capacity, mg/g	pH value	Reference
	Organic matter	Heavy metal			
Bamboo wood	-	Ag^{+}	584	-	[98]
Rice straw	Congo red	-	221,1	-	[99]
Microalgae (containing iron)	-	Mo As	78,5 62,5	-	[100]
Soybean straw char	-	Cu^{2+}	-	4,5	[101]
Tee waste	Antibiotic (Sulfamethazine)	-	7,12	-	[102]
Maple leaves	Tetracycline	-	40,30	6,0	[103]
Spent mushroom substrate	-	Pb^{2+}	326	-	[104]
Poplar branch	-	Zn^{2+} Pb^{2+}	227,65 363,76	-	[105]
Wheat stalk	-	Cr^{6+}	1,4833	6,0	[106]
Chlorella vulgaris	-	Ni^{2+} Co^{2+}	63,25 -	4,5 -	[107]
Seaweeds	-	Ni^{2+} Co^{2+}	20,63 18,58	4,5 4,0	
Corn stover	Methylene blue	U^{6+}	111,5/349,7	5,0/11	[108]

Contaminant removal is mainly based on the presence of functional groups and charges on the surface of the biochar [109]. The active surface functional groups of the lower-temperature biochar including the carboxyl and aliphatic C–H groups were largely consumed, while the surface of the higher-temperature biochar might absorb/deposit the infrared-active coke precursors [110]. The aromatic group from lignin gives rise to C=C asymmetric stretching at cm^{-1} as a G band corresponds to the sp^2-hybradization bonding of carbon atoms and C-H bending modes at 2927 at 796 cm^{-1}[111]. Oxidized biochars rich in carboxyl functional groups exhibited significantly greater Pb, Cu, and Zn stabilization ability compared to unoxidized biochars, especially in pH 4.9 acetate buffer (standard solution for the toxicity characteristic leaching procedure) [112]. Ion exchange and complexation between heavy metals and biochar surface functional groups such as carbonyl and hydroxyl groups were effective mechanisms for heavy metal sorption from the aqueous solution [113]. Pyrolysis temperature influences biochar's aromaticity, morphological, structural and elemental properties. Many studies showed that different pyrolytic temperatures affect the pH, carbon content, aromaticity and ash content of biochar, among other parameters, which can further impact the effectiveness of biochars in repairing metal pollutants [114].

CONCLUSION. Biochar is the low-cost adsorbent prepared from the different organic sources such as agricultural waste, plant and animal wastes. Pyrolysis (low and fast type) is the most perspective method for obtaining biochar with various functional groups. Chemical and physical activation leads to create micro-, meso-, macropores surface of biochar. From this literary review can be informed that, nowadays new type of biochars investigated such as magnetic or kind of modified. Variety ways of the application except wastewater treatment processes for instance soil remediation, gas adsorption using by biochar studied. In this review, preparation of biochar from different plants (agricultural wastes, foresty wastes and seaweeds as micro-, macroalgae, their potential and mechanism for adsorption of heavy metals, organic contaminants from the wastewater discussed in detail. Our next research works dedicated to the synthesis of biochar from maple leaves by pyrolysis and investigation of main properties.

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CHEMICAL STABILITY OF IONITE PRODUCED ON THE BASIS OF CHLORINATED POLYPROPYLENE

O.Kh. Khasanov, I.N. Khaydarov, R.I. Ismailov
Tashkent State Technical University
University st.,2 100095, Tashkent, Uzbekistan

Abstract: *This article presents studies of the chemical resistance of a new amine-containing anion exchange resin based on chlorinated polypropylene. The chemical stability of modified ion exchanger of chlorinated polypropylene (CPP) with polyethylenepolyamine (PP) and industrial ion exchanger APFC-45 (4-VP + UV-5) was studied in various aggressive environments. HPP with PP can compete with widely used ion exchangers, because resistant to strong chemicals. Also, from the obtained results it can be seen that the ion exchange resin obtained on the basis of CSP fully complies with the requirements of chemical resistance in relation to a solution of various strong oxidizing agents and alkalis and can be used in industrial enterprises. The physicochemical parameters of the synthesized ion exchanger were studied and these indicators were compared with the AN-31 anion exchanger used in industry, compared with the parameters obtained, it is almost close to the parameters of the AN-31 anion exchanger used in industry, which indicates that it can compete with this anion exchanger.*

Keywords: *polypropylene, chlorinated polypropylene, polyethylenepolyamine, ionite, chemical stability, static exchange capacity, mass*

INTRODUCTION. Water is the main raw material for various industries, agriculture and utilities. The increase in the amount of polluted water and the lack of clean water are already one of the urgent problems today, and in the future the shortage of this resource will be even more significant. Strongly basic type ion exchangers include anion exchangers containing functional ammonium quaternary groups capable of anion exchange in alkaline, neutral and acidic media. Strongly basic anion exchangers of the polycondensation type are widely used in technology. The most interesting is a strongly basic anion exchange resin containing secondary and tertiary amino groups of the aliphatic series and quaternary pyridine groups.