Vol. 3, No. 1, 2018

SORPTION PURIFICATION OF NATURAL WATER FROM MICRO-MIXTURES OF HARD METALS

Lidiia Kupchyk[1], Oksana Salavor[2], Oksana Nychyk[2]

[1]Institute for Sorption and Problems of Endoecology
National Academy of Sciences of Ukraine
03164, 13, General Naumov Str., Kyiv, Ukraine
[2]National University of Food Technologies
01033, 68, Volodymyrska Str., Kyiv, Ukraine
saloksamir@ukr.net

Received: 30.11.2017

Abstract. The research determines the efficiency of the use of activated carbon in the process of water purification from heavy-metal ions for technological purposes in the food industry. Comparative studies of the use of sorbents of various types of activated carbon have been carried out. The study determines the factors that influence the efficiency of drinking water purification from heavy metal ions through activated carbon. It also proves the highest efficiency of oxidized form of activated carbon

Key words: water purification, activated carbon, sorbent, heavy metals, purification efficiency.

The food industry is one of the most developed branches of material production in Ukraine. It is also one of the largest consumers of freshwater, with its annual requirement of more than 2 billion m^3. The deterioration of the quality of natural water in industrially developed regions under the influence of man-made factors, in particular heavy metal ions, makes it problematic for its further use in the technological processes of food production [1].

Much of the water in the food industry is used as raw material and solvent as well as for washing raw materials and equipment, which results in high water quality requirements [2]. In this regard, the crucial task is to determine the possibilities of ensuring the quality of technological water in food industry based on the use of advanced water treatment technologies. Sources of drinking water supply, i.e. natural water, are characterized (especially in the industrial regions of Ukraine) by high amount of heavy-metal ions, which can be 1-5 times higher than maximum allowable concentration. Such an increased concentration of heavy-metal ions in water can be caused both by natural factors (geochemical characteristics of water supply sources) and by man-made factors [3].

The risk from heavy metals is caused by the stability of their ions in the external environment, solubility in the water, sorption by soil and later by plants. This leads to accumulation of heavy metals in hazardous concentrations in food products and the emergence of a number of so-called ecologically dependent diseases (toxicodermia, allergies, cancer, and etc.) [4].

The purpose of the research is to determine the effectiveness of using different types of activated carbon in the process of water purification from heavy-metal ions for technological purposes in the food industry. Table 1 presents physical and chemical indicators of four categories of natural water used in the studies.

Table 1

Physical and chemical indicators of natural water

№	Indicators and unit of measure	River-water	Artesian Water	Tap water	Pond Water
1	Hydrogen index (pH)	5,86	7,49	7,41	6,5
2	General stiffness, mmol/dm^3	7,0	10,2	8,2	7, 5
3	Permanganate oxidation, mgO/dm^3	8,3	1,84	4,38	9,8

Table 2 indicates the concentration of micro-impurities in the studied natural water of the four categories.

The following types of activated carbon were used in the capacity of sorbents: bituminous coal Filtrasorb-300 (produced in Belgium), activated anthracite CWZ-3 (produced in Poland), activated fruit-stone carbon and its oxidized form, obtained from the experimental production at the Institute for Sorption and Problems of Endoecology, National Academy of Sciences of Ukraine. The fractional composition of various types of coal was practically the same and amounted to 0.5–2.5 mm. Table. 3 presents physical and chemical and structural-porous characteristics of the studied types of coal.

Table 2

Concentration of micro-impurities in investigated natural water

№	Concentration of micro-impurities, mg/l	River-water	Artesian Water	Tap water	Pond Water	MAC of Micro-impurities, mg/l
1	zinc	1.84	3.38	5.62	2.03	5
2	copper	0.52	0.63	0.46	0.7	1
3	aluminum	0.32	0.46	0.35	0. 5	0.5
4	iron	0.29	0.24	0.2	0.25	0.3
5	nickel	0.07	0.09	0.09	0.07	0.1
6	manganese	0.08	0.08	0.09	0.06	0.1
7	lead	0.01	0.01	0.01	0.01	0.03
8	cadmium	0.003	0.003	0.004	0.002	0.005

Table 3

Characteristics of activated carbon used in experiments

№	Indicator and unit of measurement	Activated carbon			
		F-300	CWZ-3	activated fruit-stone carbon	oxidized form of activated fruit-stone carbon
1	Bulk density, g/cm^3	0.56	0.47	0.45	0.46
2	Adsorption activity on methylene blue, mg/g	230	200	220	210
3	Adsorption activity on iodine, mg/g	95	80	75	70
4	Total volume of sorption pores (V_{mi}+V_{me}), cm^3/g	0.40	0.56	0.52	0.48
5	Specific surface area (in BET), m^2/g	1000	1080	960	920
6	Static exchange capacity in Na^+-cation, mg-eq/g	0.2	0.15	0.2	0.9

The experimental procedure was as follows: the model solutions containing micro-impurities of heavy metal salts (concentration 5 MAC) were prepared from natural and tap water. Sorption experiments were conducted within dynamic conditions (column tests). After a certain amount of water passed through the water column (column volume CV), samples were taken for analysis on the content of ions of the investigated metals by atomic absorption spectroscopy [5] and pH.

Column parameters: diameter – 2.8 cm; overall height – 40.3 cm; height of the sorbent layer – 16.8 cm; the volume of sorbent – 103.4 cm^3. Speed of water passing: volume velocity – 1l/hour; linear velocity 1.62 m / hour.

The influence of contact of water with activated carbon on its hydrogen index is of great importance in purification. It is known that water contains many dissolved electrolytes, which can significantly affect its pH [6]. Fig. 1 shows the results of measurements of pH of artesian water after contact with activated carbon of various types.

It is evident that at the initial stages of contact of water with coal there is a certain change in the pH of water in such a way that F-300 and CWZ-3 coal somewhat alkalifies water, activated fruit-stone carbon practically does not change the pH, and oxidized form of activated fruit-stone carbon acidifies it. These phenomena are observed when pumping through the sorbent of the first 200–300 column volumes. During further pumping of water through coal, its pH remains virtually unchanged and cannot affect the sorption of metal ions.

Table 4 shows the results of sorption extraction of ions of some heavy and transition metals by carbon sorbents of various types, in percentage of the micro-impurities from its initial concentration, after pumping a volume equal to 200 column volumes.

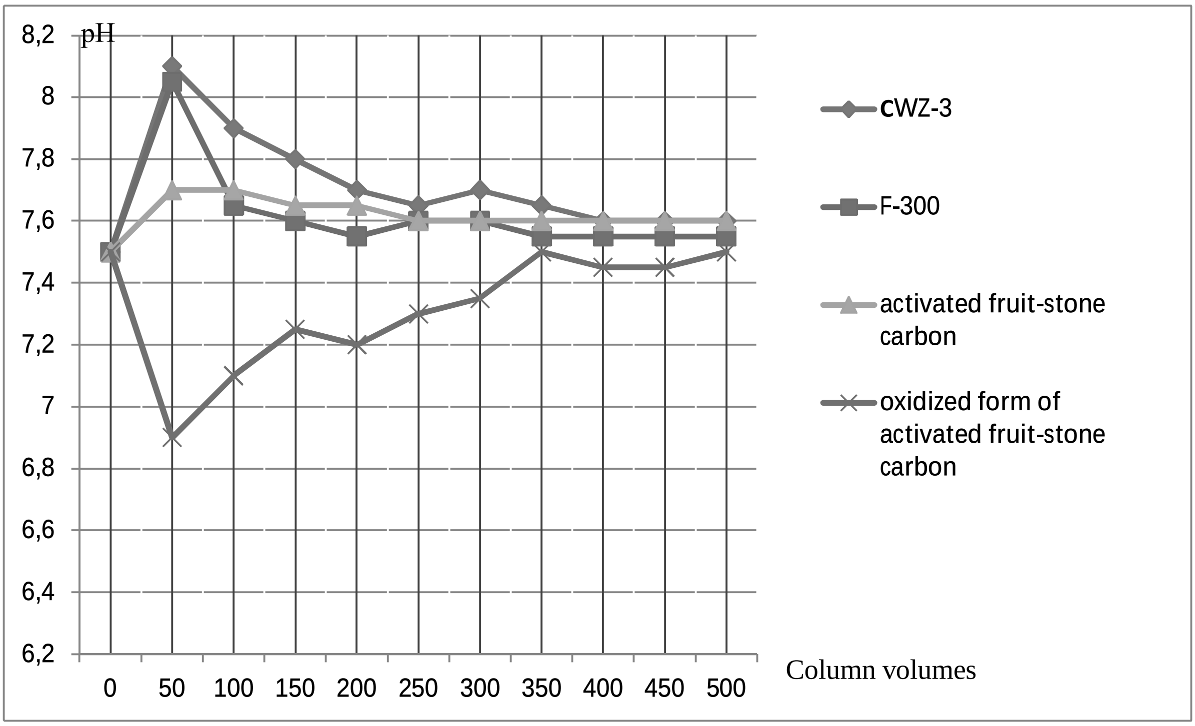

Fig. 1. Dynamics of pH changes of artesian water due to interaction with different types of activated carbon

Table 4

Efficiency of sorption extraction of heavy metals and aluminum ions by carbon sorbents of various types

№	Metal ion	Water type	Type of coal			
			F-300	CWZ-3	activated fruit-stone carbon	oxidized form of activated fruit-stone carbon
1	2	3	4	5	6	7
1	Zn	artesian	26	29	20	29
		river	97	97	97	98
		tap	31	37	28	47
		pond	74	56	82	80
2	Cu	artesian	7	23	64	91
		river	82	98	86	93
		tap	45	56	78	86
		pond	96	96	96	98
3	Al	artesian	81	83	86	85
		river	90	84	86	93
		tap	80	55	81	80
		pond	99	98	98	100
4	Fe	artesian	67	73	78	87
		river	81	84	83	90
		tap	36	64	38	53
		pond	100	100	100	100
5	Ni	artesian	37	42	42	56
		river	100	100	100	100
		tap	78	78	69	100
		pond	82	75	63	85
6	Mn	artesian	45	46	35	35
		river	57	48	48	57
		tap	22	22	18	24
		pond	36	30	46	54

Continuation of table 4

1	2	3	4	5	6	7
7	Pb	artesian	100	100	100	100
		river	100	100	100	100
		tap	100	100	100	100
		pond	100	100	100	100
8	Cd	artesian	0	2	10	10
		river	90	90	90	90
		tap	61	43	5	5
		pond	90	90	90	90

Many factors influence the efficiency of potable water purification by activated carbon. In particular, the content of humic substances and chemistry of the surface of carbon material in the water play a critical role. The selectivity of the adsorption of various metal ions is proportional to the surface of the carbon material and the concentration of active functional groups on its surface [6]. Ions can be divided into 3 groups, according to the efficiency of their extraction:

– ions, the extraction of which depends on the content of organic impurities in the water (zinc, copper, nickel and cadmium). During adsorptive copper removal, F-300 and CWZ-3 coal successfully operate only for river and pond water. At the same time, activated fruit-stone carbon can essentially bind copper in all the investigated types of water (up to a level below 0.3 MAC, and activated fruit-stone carbon – up to 2 MAC). Apparently, chemistry of the coal surface plays a decisive role when using the oxidized form of activated fruit-stone carbon to bind copper ions;

– ions that are badly removed from different types of water and are little dependent on the content of organic impurities (manganese);

– ions, which are almost completely removed from water, regardless of impurities of organic impurities in the water (lead, aluminum, iron).

Thus, the most expedient way to clean water is to use oxidized coal. The known types of coal, namely, F300, CWZ and activated fruit-stone carbon have similar values of the efficiency of water purification from metal ions, while the oxidized form of activated fruit-stone carbon has considerably higher rates. It is likely that the complex formation on the surface of oxidized coal greatly contributes to the removal of ions from their aqueous solutions.

Therefore, the comparative characteristic of the effectiveness of various types of carbon sorbents in relation to heavy metal ions during their sorption from water of various categories indicates the benefits of oxidized form of activated fruit-stone carbon in achieving maximum removal of heavy metal ions. The use of other types of activated coal can be justified for the purpose of extracting one or another ion taking into account the degree of purity of the source water and the requirements for the quality of technological water during the processes of food enterprises.

References

[1] Shevchenko O., Sokolenko A, Poddubnyj V. Produkty pitanija. Kiev: PP Ljuksar, 2011, 390. (in Russian)

[2] Domaretskyi V, Shyian P.: Zahalna tekhnolohiia kharchovykh vyrobnytstv. Kyiv: Un-t “Ukraina”, 2011, 814. (in Ukrainian)

[3] Arkhipova H., Mudrak T, Zavertana D. Visnyk Natsionalnoho aviatsiinoho universytetu, 2010, 1, 232. (in Ukrainian): http://dspace.nuft.edu.ua/jspui/bitstream/123456789/2004/7/Arhipova.pdf

[4] Dubinina A. Toksychni rechovyny i metody yikh vyznachennia. Kharkiv : KhDUKhT, 2016,106. (in Ukrainian)

[5] GOST 30178-96:1996. Syr'e i produkty pishhevye. Atomno-absorbcionnyj metod opredelenija toksichnyh jelementov. (in Russian)

[6] Zapolskyi A. Vodopostachannia, vodovidvedennia ta yakist vody. Kyiv: Vyshcha shkola, 2005, 671. (in Ukrainian)