BALANCED MINERAL COMPOSITION AS AN INDICATOR OF DRINKING WATER QUALITY

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ABSTRACT

The hygienical aspect of drinking water safety and quality can be defined by the indices of epidemic safety, sanitary, chemical and radiation indices, as well as the optimal content of mineral substances. Research into the drinking waters from surface and ground water supply sources within the Odessa agglomeration has made it possible to define that the indices of balanced mineral composition of drinking water, obtained after treatment of the Dniester water, mainly meet the normative requirements, but the sodium content is higher and the fluorine content is substantially lower than the optimal value. The values of almost all indices defining the balanced mineral composition deviate from optimal value range in ground water; the concentrations of calcium, magnesium and sodium ions in the ground water decrease significantly after purification in pump-room. Fluorine deficiency in drinking water, both from surface and ground sources of water-supply, requires substantiation of the fluorination as a means of prevention of caries among public at large. Long-term consumption of drinking water with an imbalance of essential mineral components can be one of the negative impacts on public health at the Odessa agglomeration.

KEYWORDS

mineral substances, optimal content, balance of water composition

INTRODUCTION

Stability of the chemical composition of a human organism is one of the major and obligatory conditions for the normal functioning. The abnormal content of a chemical element in an organism, caused by physiographic, anthropogenic and other factors, results in disturbance of a human health. Among 92 chemical elements occurring in natural environments, 81 chemical element is found in a human organism. Regarding biological (physiological) significance, the following groups of chemical elements can be distinguished: ‘structural’ elements (C, O, H, N, Ca, Mg, Na, K, S, P, F, Cl), which form 99 percent of the element composition of an organism; essential elements (Fe, I, Cu, Zn, Co, Cr, Mo, Ni, V, Se, Mn, As, F, Si, Li); conditionally essential elements (As, B, Br, F, Li, Ni, V, Si); and the elements, which role is insufficiently explored or unknown. Essential mineral substances enter a human organism with foodstuff and drinking water. Review of the published data gives evidence that the balanced mineral composition of drinking waters is an important factor for population health (IVANOV et al., 2012; PROKOPOV – LYPOVETSKA, 2012, et al.).

The hygienical aspect of drinking water safety and quality can be defined by the indices of epidemic safety, sanitary, chemical and radiation indices, as well as the optimal content of mineral substances which determine the adequacy of its mineral composition to the physiological need of a human organism. According to the sanitary rules and regulations, which have been in force in Ukraine since 2010, namely ‘Hygienic Requirements for Drinking Water Intended for Human Consumption’, the drinking water quality indices are the following: total hardness, total alkalinity, the content of iodine, potassium, calcium, magnesium, sodium, solid residual and fluorine (Tab. 1).

Characteristics of the drinking water quality and the related impacts on public health are discussed in numerous publications and archival sources of information. Researches into the mineral composition of drinking water as regards the impact on human health will ground the contribution of this factor into the public health condition for particular cities and regions in Ukraine. Below is a brief description of some indicators of the balanced mineral composition of drinking water from surface and ground water-supply sources as a potential factor for public health formation at the Odessa agglomeration (Ukraine), which is of scientific, methodological and practical importance.

Table 1 – The indices of balanced mineral composition of drinking water

Indices	Measuring unit	The range of optimal values
Total hardness	mmol/dm^3	1.5 – 7.0
Total alkalinity	mmol/dm^3	0.5 – 6.5
Iodine (Iodide ion, I^-)	mcg/dm^3	20 – 30
Potassium (K^+)	mg/dm^3	2 – 20
Calcium (Ca^{2+})	mg/dm^3	25 – 75
Magnesium (Mg^{2+})	mg/dm^3	10 – 50
Sodium (Na^+)	mg/dm^3	2 – 20
Solid residual	mg/dm^3	200 – 500
Fluorine	mg/dm^3	0.7 – 1.2

MATERIAL AND METHODS

Assessment of the balanced mineral composition of drinking waters from surface and ground sources within the Odessa agglomeration is given on the basis of observations performed by Infoxvodokanal chemical and bacteriological laboratory. The methods of statistical and comparative data analysis were used. Average monthly values of balanced mineral composition indices for the drinking water from ground sources (2006-2007) and the tap water (2010-2014) were calculated. The research outcomes are generalized and represented in the tables built by means of the Excel program.

RESULTS AND DISCUSSION

The drinking water supply of Odessa agglomeration is based primarily on surface waters (the Dniester River). At the 'Dniester' wastewater treatment plant (WWTP) there is a traditional classical purification pattern, consisting of settling tanks and rapid filters. After fish-protecting constructions the river water enters a sedimentation canal intended for initial settling and deposition of suspended particles. Then, through a transversal canal, the partially clarified water is withdrawn by pumping stations for the first lifting and goes to rapid filters at the units 1-4. Water treatment at the rapid filters is performed according to a single-stage scheme on contact coagulation of water impurities (with aluminium sulfate taken as a coagulant) in the layer of filtering media. Unit 5, built in 1983-1986, includes settling tanks and rapid filters in order to provide high-quality water purification, regardless of initial condition of the river water. After filters the water goes into clean water reservoirs, where it is disinfected with a liquid chlorine (transformed into a gaseous state in the special vaporizers prior to contacting the water), in doses which provide its bacterial purity and the residual chlorine concentration at an outlet from a clean water reservoir of 0.8-1.2 mg/dm^3. At the subsequent step, the water is delivered to the city area through five flow passages to be distributed among the consumers. Since the water inflow from the 'Dniester' WWTP to the city takes from 3 to 6 hours, then prior to entering the municipal water-supply pipeline network the water is additionally disinfected with sodium hypochlorite at 8 chlorination stations in order to provide epidemiological safety of the drinking water for end-users. The 'Dniester' WWTP has been constructed according to development of the municipal water-supply system since 1873, with step-by-step expansion and increase in the purified water volumes. The major reconstruction fell on 1960-1980, when building of new rapid filter units started and a new lifting electric pump station on the Dnister River opened. The facilities are continually reconstructed, and an outdated equipment is replaced by the modern one (SAFRANOV et al., 2011).

According to the data given in the Tab. 2, the values of indices for balanced mineral composition of the influent water from the Dniester River and the tap water for the most part satisfy the established requirements. Only in one case, potassium content in the river water was registered to be below the optimal value. However, the concentrations of sodium were higher (↑) than the optimal value (opt_{max}), and the fluorine content was lower (↓) than the optimal value (opt_{min}).

Table 2 – Indices for balanced mineral composition of the water from the Dniester River and the tap water

Indices	The range of measured values		The range of optimal values
	Water from the Dniester River	Tap water	
Total hardness, $mmol/dm^3$	3.65 – 5.45	3.5 – 5.45	1.5 – 7.0
Total alkalinity, $mmol/dm^3$	2.65 – 3.90	2.7 – 4.1	0.5 – 6.5
Potassium (K^+), mg/dm^3	***1.60*↓** – 8.45	2.9 – 8.2	2 – 20
Calcium (Ca^{2+}), mg/dm^3	30.06 – 74.15	36.1 – 74.15	25 – 75
Magnesium (Mg^{2+}), mg/dm^3	12.16 – 40.74	11.55 – 35.70	10 – 50
Sodium (Na^+), mg/dm^3	6.40 – ***33.80*↑**	10.8 – ***33.00*↑**	2 – 20
Solid residual, mg/dm^3	300.0 – 440.0	301.0 – 450.0	200 – 500
Fluorine, mg/dm^3	***0.19*↓ – *0.42*↓**	***0.132*↓ – *0.42*↓**	0.7 – 1.2

If sodium and fluorine (Hazard class 2) are considered as the sanitary–and–chemical indices of drinking water safety and quality (DSanPiN 2.2.4–171–10), then the range of sodium concentrations meet the normative requirements (≤ 200 mg/dm^3), and fluorine concentrations do not meet the respective standard (≤ 0.7 mg/dm^3). Sodium content was observed within the optimal range only in May – September (summer season), while in other months it exceeded the maximum standard value (opt_{max}). It should be noted that the increase in natural water mineralization is accompanied by respective changes in the series of basic cations: $Ca^{2+} > Mg^{2+} > Na^+$. Consequently, such a low range of sodium content values (2 – 20 mg/dm^3) may be associated with ultra–fresh water, but in this case the drinking water standard for solid residual (mineralization) is unlikely to be maintained. Besides, under very low mineralization (< 100 mg/dm^3) the drinking water quality significantly decreases in physiological respect. As regards the fluorine content, during the whole year it was usually less than 0.2 mg/dm^3, which is much lower than the optimal range (0.7 – 1.2 mg/dm^3) and is typical of the surface water in almost all provinces of Ukraine.

The river water quality depends on environmental factors and the level of anthropogenic impact on the Dnister basin, in the bottom of which there is a water intake. Due to the increasing anthropogenic impact on the river basin the environmental status of surface drinking water has significantly deteriorated, therefore an alternative source of drinking water supply for Odessa agglomeration is the ground (artesian) water related to Upper Sarmatia Miocene aquifer. The aquifer lies on about 120-130 m depth and is protected from direct inflow of pollutants, so the waters have chemical composition, physical-chemical and microbiological parameters being stable in the course of time.

The consumers are supplied with the ground drinking water through 15 pump-room complexes located mainly in the southern parts of the agglomeration area. The technology for water treatment which is used in pump rooms consists of the following purification stages:

1) mechanic and catalytic filtering (Fe^{2+} oxidation, removal of fine-dispersed suspended particles);
2) purification of the half of water volume by reverse osmosis (removal of Ca^{2+}, Mg^{2+}, Na^+, SO_4^{2-}, Cl^-, HCO_3^-, and microorganisms);
3) mixing of the water, purified by reverse osmosis, with the water after mechanical filtration in a ratio of 1:1, leading to decrease in the values of total hardness, mineralization, Na^+, SO_4^{2-} and Cl^- content;
4) ozonation of the water, relatively balanced in mineral composition, which makes it possible to provide disinfection, deodorization, oxidation of organic and inorganic substances, degasation of water and its saturation with oxygen;
5) adsorption treatment of ozonated water at the filters with activated carbon (resulting in removal of ozon, oxidated organic and some inorganic substances);
6) secondary ozonation of the water passed through the adsorption treatment phase prior to delivering it to the end-users.

While deviation from optimal values in the surface (river) water are typical only of sodium and fluorine, nearly all the indices of balanced mineral composition estimated in the ground water from Upper Sarmatia Miocene aquifer do not fit into the range of optimal values (Tab. 3).

Table 3 – The range of indices for balanced mineral composition of drinking water from pump-room complexes within the Odessa agglomeration before (numerator) and after (denominator) treatment

Indices	The range of measured values		The range of optimal values
	2006-2007	2010-2014	
Total hardness, mmol/dm^3	1.80 – ***9.20***↑ ***0.10***↓ – 3.60	1.90 – ***8.50***↑ ***0.50***↓ – 3.40	1.5 – 7.0
Total alkalinity, mmol/dm^3	*3.20* – ***8.50***↑ ***0.10***↓ – 4.00	3.00 – 6.00 0.80 – 4.70	0.5 – 6.5
Potassium (K^+), mg/dm^3	– ***0.30***↓ – ***42.23***↑	4.60 – 12.00 ***1.00***↓– 7.80	2 – 20
Calcium (Ca^{2+}), mg/dm^3	– ***1.00***↓ – ***24.04***↓	***13.0***↓ – 54.0 ***3.00***↓ – 32.00	25 – 75
Magnesium (Mg^{2+}), mg/dm^3	– ***0.61***↓ – 29.19	13.4 – ***69.0***↑ ***4.30***↓ – 27.10	10 – 50
Sodium (Na^+), mg/dm^3	– ***0.50***↓– ***198.76***↑	***125.0***↑ – ***300.0***↑ ***49.80***↑– ***175.00***↑	2 – 20
Solid residual, mg/dm^3	363.60 – ***4096.60***↑ ***21.80***↓– ***742.00***↑	***652.3***↑ – ***1214***↑ ***141.0***↓– ***858.0***↑	200 – 500
Fluorine, mg/dm^3	– ***0.03***↓ – ***0.61***↓	– ***0.05***↓ – ***0.64***↓	0.7 – 1.2

As one can see from Tab. 3, the values of all the indices for balanced mineral composition of drinking water from Upper Sarmatia aquifer decrease significantly after treatment. Further purification of the water from artesian wells at the water treatment complexes is merely partial solution to the problem of balance between physiologically significant mineral components of drinking water and, in some cases, this may even aggravate the problem.

Average monthly values of the indices for balanced mineral composition of the drinking water from pump rooms within Odessa agglomeration show a more complex distribution compared to the tap water. It is possible that distribution of the values for balanced mineral composition of the water from ground water-supply sources depends to a large extent on the data array components, i.e. the data on a specific indicator for various pump rooms. Herewith, the natural hydrodynamic and hydrogeochemical zoning of ground water, operation conditions and other factors need to be considered. In this regard, the data on the average values of some indices for balanced mineral composition of the drinking water before and after treatment in particular pump-room complexes are of interest (SAFRANOV et al., 2013).

At all pump rooms the average values of *total hardness* for the waters before treatment were within the optimal range, except for the pump room located at the northern part of Odessa, where total hardness was slightly higher than the optimal value (opt_{max}). After treatment of ground waters, the average value of total hardness was below the optimal range (opt_{min}) almost in all pump-room complexes. These data indirectly show the Ca^{2+} and Mg^{2+} deficiency (but not their ratio) in the ground waters used for drinking purposes in the majority of pump rooms. It is known that under consumption of hard drinking waters the intestinal uptake of fats is disturbed, owing to fat saponification and formation of calcium-magnesium insoluble soaps. In the regions with a hot climate the clinical course of urolithiasis becomes worse under water hardness of over 10 mmol/dm^3. Hard water contributes to appearance of dermatitis, because calcium magnesium soaps have an irritable effect. For drinking purposes, it is preferable to have water of medium hardness with low magnesium content, because magnesium sulfates disturb absorption processes and motion activity of intestines. Therefore, if SO_4^{2-} content in water is below 250 mg/dm^3, then Mg^{2+} content must not exceed 30-50 mg/dm^3. It is advisable that calcium content comprised 75-100 mg/dm^3, or up to 150 mg/dm^3, at the most. Sometimes, high natural content of sodium is typical of soft drinking water; however, sodium excess serves as an additional factor for development of some forms of hypertension. The hightened hardness of drinking water contributes to development of cardiovascular diseases (AKULOV et al., 1986). According to the World Health Organization (WHO) materials, the epidemiological researches, having been conducted in various countries during the last 50 years, indicated that there is a connection between the increased number of cardiovascular diseases with subsequent lethal outcome and the consumption of soft ground water (RUDKO et al., 2010), nevertheless there is a number of papers in which the point is that such groundwater indices as hardness, Ca^{2+} and Mg^{2+} content have no effect on the cardiovascular disease incidence (IVANOV et al., 2012).

Average values of *total alkalinity* in the drinking water from all pump-room complexes both before and after treatment are within the standard range that is a positive factor for the public health. The use of alkaline drinking water is known to make for the rise of population life expectancy index by 20-30%.

Unfortunately, there are almost no data for *iodine* content in the drinking water, but it should be recalled that nearly the entire population of Ukraine experiences the iodine deficiency (RUDKO et al., 2010). Iodine belongs to the microelements of a vital importance. A person gets the major amount of iodine through daily food allowance: approximately 70 mcg with plant food, 40 mcg with animal food, 10 mcg with drinking water and the atmospheric air (ROZEN, 1970). The locality, where I^- content in drinking water is less than 10 mcg/dm^3 and where the thyroid gland disorder is observed for more than 10 percent of the population, is considered to be iodine deficient. The biological value of iodine is related to the endemic goitre development, and the physical and mental development delay for children.

Potassium concentration did not go beyond the optimal range. Potassium regulates the acid-base balance of blood. It participates in the neurotransmission, activates a number of enzymes, intensifies a cardiac muscular work, salutarily influences on the skin condition and functioning of kidneys. Potassium is a protector against the unwanted impact of sodium excess, and normalizes the blood pressure.

Calcium concentration was within the optimal range. The widespread opinion that Ca^{2+} availability in ground water contributes to induration of the arteries, lithogenesis, formation of kidney stones and hepatic diseases was not corroborated by factual evidence. Having a high physiological activity, calcium performs various functions in an organism, e.g. bone tissue formation, teeth mineralization, regulation of the intracellular processes, control of nerve conduction processes and muscular contractions, maintenance of stable cardiac activity. Excess calcium in an organism may cause arthritis, osteodystrophy, osteofibrosis, muscular asthenia etc. Calcium deficiency is the reason for 147 disease types (osteoporosis, tachycardia, arrhythmia, albication of hands and feet, renal and hepatic colics, overirritation etc.). E.g., an osteoporosis, a disease ranking 10th by a death rate among the adult population, is caused by the scarcity of calcium in an organism (RUDKO et al., 2010).

Magnesium content (similarly to the value of total hardness) in November-December and January-March of some years was slightly lower than a minimum optimal value (opt_{min}). Magnesium is a main intracellular element. The normal level of magnesium concentration in an organism is necessary for many of the processes essential for life; magnesium reinforces the immune system. An excessive amount of magnesium causes a cathartic action. With the decline in magnesium concentration in blood, the symptoms of nervous excitation and even convulsive disorder are observed. Decreased magnesium content in an organism results in the increased calcium content, and an excess of magnesium leads to calcium and phosphorus deficiency. Since the major part of magnesium gets into the human organism with foodstuff, then a question on the significance of magnesium concentration in drinking water is debatable. However, such form of magnesium has a higher bioaccumulation factor, than magnesium contained in foodstuff. Magnesium content in drinking water is assumed to be a decisive factor for those people who consume it in negligible quantities with foodstuff, but drink the magnesium-rich water. A connection between magnesium content in water and Mg in a myocardium, a skeletal muscle and coronary arteries is revealed (RUDKO et al., 2010).

As regards *sodium* concentration, an apparent excess of the optimal value (opt_{max}) is traced during the whole period of observations. Sodium is known to be an essential intercellular and intracellular element, which participates in creation of the necessary buffer capacity of blood, control of blood pressure and water metabolism, activation of digestive enzymes, regulation of nerve and muscular tissues. Water-retaining ability of tissues is also associated with sodium content. Under high sodium concentration (and the simultaneous deficit of calcium) a specific alkaline phosphatase, which is the biochemical marker of such diseases as an osteoporosis and osteomalacia, is formed (RUDKO et al., 2010).

The water from Upper Sarmatia aquifer on the prevalent part of Odessa agglomeration are fresh and light saltish. Fresh water of the sulfate hydrocarbonate sodium type is widespread in the southern part of the area, fresh and light saltish water of the sulfate chloride sodium type – in the central part, and saltish and salt water of the chloride sodium type – in the northern part. The most mineralized water relates to the areas, located at the northern part of the urban area, where the content of *solid residual* exceeds 4000 mg/dm^3. In addition to high mineralization, the heightened values of hardness, alkalinity, potassium and sodium are typical of such ground waters. That is why they can be used for drinking purposes only after additional treatment. The treated ground water in all studied pump-room complexes is characterized by the average content of solid residual within the optimal range. The drinking water with heightened mineralization affects gastric secretion and disturbs a water-salt balance that leads to various adverse physiological abnormalities in an organism (heat exhaustion under hot weather, disturbed sense of quenching the thirst, increased hydrophily of tissues, change in gastric secretion, reinforced motor functions of the stomach and intestinal peristalsis etc.). On the other hand, a long-term consumption of low-mineral water may bring to some adverse physiological disturbances in an organism, particularly, to decreased chloride content in tissues etc. (AKULOV et al., 1986). Consumption of the ground water being too low in minerals has a negative impact on the homoeostasis mechanisms, mineral and water metabolism (a fluid output, diuresis, intensifies) due to elution of intra- and extra-cellular ions from biological fluids, i.e. their negative balance. The demineralized ground water has not only inadequate organoleptic indices, but also exerts a negative impact on the human organism. The probable consequences of consuming the mineral-poor ground water are divided into the following categories: a direct impact on mucous membrane of the stomach, metabolism, mineral homeostasis and other functions of an organism; a minor inflow of calcium and magnesium; a small inflow of other macro- and microelements; losses of calcium, magnesium and other macronutrient elements in the course of cooking; a potentially increased inflow of toxic metals into an organism.

The *fluorine* content both in pump-room water and tapwater (SAFRANOV et al., 2011, 2013) does not reach an optimal level (opt_{min}). Some papers dealing with drinking water quality for children in their first year (infants) give the following data: fluorine content must be no more than 0.3 mg/dm^3 to prevent fluorosis. Drinking water is considered as a source of calcium (24-56 percent of the daily need), which content must comprise from 50.0 to 100.0 mg/dm^3, and the basic source of fluorine inflow into an organism with 90-97 percent assimilation. The WHO report entitled 'Fluoride in Drinking Water' represents the latest scientific data on fluorine abundance and the health impact. Under insufficient inflow of fluorine into an organism, the resistance of enamel to sour food and bacterial decomposition products decreases, leading to caries. The excessive intake of fluorine results in a fluorosis. The changing colour and erosion of enamel are characteristic for the clinical dental fluorosis. The whole enamel can be damaged in harder cases. Under the skeletal fluorosis, fluorine gradually accumulates in bones over the years that causes impairment in suppleness and pain in the joints (PROKOPOV – LYPOVETSKA, 2012). Fluorine is a microelement with a relatively abrupt transition from the physiologically beneficial concentrations to the concentrations provoking a toxicosis; therefore convincing arguments both from supporters and opponents of drinking-water fluorination are offered in Ukrainian and foreign publications (KUZUBOVA - KOBRINA, 1996; RUDKO et al., 2010). A regional principle for standardization of fluorine content in drinking water is adopted in many countries. According to it, the optimal concentration is determined by the maximum daily air temperature, on which the amount of water consumed per person depends. The average monthly values of the air temperature (°C) in Odessa for the case of 2014 (at 12.00) make up: 0.39 in January; 3.4 in February; 7.89 in March; 11.83 in April; 17.4 in May; 24.2 in June; 25.5 in July; 27.69 in August; 19.52 in September; 15.65 in October; 8.87 in November; 3.45 in December. With regard to the data, fluorine content in drinking water during the period from January to April and from November to December may comprise 1.2 mg/dm^3, in May and September – 0.9 mg/dm^3, in June and July – 0.8 mg/dm^3 and in August – 0.7 mg/dm^3.

CONCLUSION

The indices of balanced mineral composition of drinking water, obtained after treatment of the Dniester water, mainly meet the normative requirements, but the sodium content is higher and the fluorine content is substantially lower than the optimal value. The values of almost all indices defining the balanced mineral composition deviate from optimal value range in ground water. The concentrations of calcium, magnesium and sodium ions in the ground water decrease by 40-50% after purification in pump-room. This further leads to the development of diseases due to deficiency of the essential cations. Fluorine deficiency in drinking water, both from surface and ground sources of water-supply for the agglomeration, requires substantiation of the fluorination as a means of prevention of caries among public at large. Long-term consumption of drinking water with an imbalance of essential mineral components can be one of the negative impacts on public health at the Odessa agglomeration, so there is a need for further special studies.

LITERATURE

IVANOV, A.V. – TAFEEVA, E.A. – DAVLETOVA, N.KH. – VAVASHKIN, K.V., 2012. Sovremennȳe predstavleniya o vliyanii pit'evoĭ vodȳ na sostoyanie zdorov'ya naseleniya [Present-day views on drinking water impact on the population health status.]. In: Voda: khimiya i ékologiya, 3: 48-53.

PROKOPOV, V.O. – LYPOVETSKA, O.B., 2012. Vplyv mineral'noho skladu pytnoyi vody na stan zdorov''ya naselennya (ohlyad literatury) [Influence of the drinking water mineral composition on public health (literature review)]. Hihiyena naselenykh mists', 3: 63-73.

STATE COMMITTEE OF UKRAINE FOR TECHNICAL REGULATION AND CONSUMER POLICY, 2010. Derzhavni sanitarni normy ta pravyla «Hihiyenichni vymohy do vody pytnoyi, pryznachenoyi dlya spozhyvannya lyudynoyu» [State sanitary rules and regulations ‘Hygienic requirements for drinking water intended for human consumption’]: DSanPiN 2.2.4-171-10, Kyiv, 25 pp.

SAFRANOV, T.A. - HUSIEVA, K.D. - POLISHCHUK, A.A., et al., 2011. Yakist' dzherela tsentralizovanoho vodopostachannya Odes'koyi promyslovo-mis'koyi ahlomeratsiyi [Quality of the centralized water supply source for the Odessa industrial–and–urban agglomeration]. Vìsnik Odesʹkogo deržavnogo ekologìčnogo unìversitetu, Odessa, 11: 3-16.

SAFRANOV, T.A. - POLISHCHUK, A.A. - HUSIEVA, K.D., 2013. Fiziologicheskaya polnotsennost' mineral'nogo sostava pit'evȳkh vod Odesskoĭ aglomeratsii [Physiological adequacy of the mineral composition of drinking water at Odessa agglomeration]. Vìsnik Odesʹkogo deržavnogo ekologìčnogo unìversitetu, Odessa, 15: 5-16.

AKULOV K.I. - BUSHTUEVA K.A. - GONCHARUK E.I., 1986. Kommunal'naya gigiena. [Municipal Hygiene]. Meditsina, Moskva, 608 pp.

RUDKO H.I. - ADAMENKO O.M. (eds.), 2010. Vstup do medychnoyi heolohiyi [Basics of Medical Geology]. Akadempres, Kyiv. In 2 volumes. vol.1: 736 pp., vol.2: 448 pp.

ROZEN, B.YA., 1970. Geokhimiya broma i ĭoda [Bromine and Iodine Geochemistry]. Nedra, Moskva, 142 pp.

KUZUBOVA, L.I. – KOBRINA, V.N., 1996. Khimicheskie metodȳ podgotovki vodȳ (khlorirovanie, ozonirovanie, ftorirovanie): Analiticheskiĭ obzor [Chemical methods of water treatment (chlorination, ozonation, fluorination): Analytical review]. SO RAN [Siberian Branch of the Russian Academy of Sciences], NIOKh [N.N. Vorozhtsov Novosibirsk Institute of Organic Chemistry], Series on Ecology, Issue 2, Novosibirsk, 132 pp.