PECULIARITIES OF LOW-MINERALIZED DRINKING WATER CHEMICAL CONTAMINATION INFLUENCE ON HEALTH OF THE POPULATION OF THE RUSSIAN FAR EAST

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Prioritized drinking water contaminants found in water supply systems of the Russian Far East and their possible unfavorable influence on the population health have been reviewed. It is shown that drinking water natural mineral composition peculiarities have to be borne in mind when the level of somatic morbidity of the population is determined, which is essential due to intensified economic advancement of the region.

Keywords: water supply systems, drinking water, chlorinated hydrocarbons, manganese, iron, biogenic elements, disease incidence, Russian Far East

Author contributions: Koval'chuk VK made a significant contribution into the review concept and design, edited the final variant of the manuscript sent to the editorial office; Yamilova OYu made a significant contribution into literature data search and analysis, prepared the first variant of the article.

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ОСОБЕННОСТИ ВЛИЯНИЯ ХИМИЧЕСКИХ ЗАГРЯЗНИТЕЛЕЙ МАЛОМИНЕРАЛИЗОВАННОЙ ПИТЬЕВОЙ ВОДЫ НА ЗДОРОВЬЕ НАСЕЛЕНИЯ ДАЛЬНЕГО ВОСТОКА

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Представлен обзор приоритетных загрязнителей питьевой воды систем водоснабжения на Дальнем Востоке и их возможное неблагоприятное влияние на здоровье населения. Показана значимость учета особенностей природного минерального состава питьевой воды в формировании уровня соматической заболеваемости населения, что имеет особое значение в связи с интенсификацией экономического развития этого региона страны.

Ключевые слова: системы водоснабжения, питьевая вода, хлорированные углеводороды, марганец, железо, биогенные элементы, заболеваемость, Дальний Восток России

Вклад авторов: Ковальчук В. К. внес существенный вклад в концепцию и дизайн обзора, выполнил редактирование окончательного варианта рукописи, присланной в редакцию; Ямилова О. Ю. внесла существенный вклад в поиск и анализ литературных данных, подготовила первый вариант статьи.

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Drinking water is a key factor of human environment. Scarcity and poor quality of drinking water is a national problem faced by many developing countries with an arid and monsoon climate. The increased effect of anthropogenic load on sources of water supply results in its more pronounced unfavorable influence on population health, especially in urban areas.

In recent years, the rate of economic growth of the Far East of Russia has significantly outpaced the rates of water supply system upgrading. The process is very significant, as about 80% of the population take drinking water from the central water supply systems. Two- and one-step water treatment processes are commonly used to purify water at local water stations. The two-step processes still utilize the water treatment technology developed in the 50–60s years of the last century and include as follows: reactant treatment, precipitation (or clarification) of water, filtration and disinfection (chlorination or ultraviolet irradiation). Long-term observations have shown that this technology doesn't remove dissolved organic impurities of natural and human origin from water due to a rise in anthropogenic water pollution levels and systematic deficit of reagents [1]. The pollutants can react with chlorine ions to form the so-called chlorinated hydrocarbons [2]. High wear of water distribution networks can pose a challenge to drinking water quality. The networks are primarily made of metal pipes with no anticorrosive coat, which is a secondary source of water contamination with metal oxides, especially those of Fe [3].

According to scientific publications, availability of any contaminant in drinking water does not necessarily produce a negative effect on human health due to minimal levels and short-term exposure, whereas toxicity commonly depends on individual susceptibility [4,5,6,7,8]. The influence of any chemical substance on population health must be assessed during a thorough hygienic trial of many years, especially at population level.

Since the beginning of the XXth century, chlorination is the principal effective way of drinking water disinfection. Chlorinated hydrocarbons such as trihalomethanes (THM) (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) are formed in chlorination of not sufficiently clarified and discolored water at water stations. Formation of trihalomethanes is due to the interaction of active chlorine with organic substances and bromide ions in water. The first by-products of the interaction of chlorine with organic compounds were found in 1974, when trihalomethanes were discovered. At present, over 600 of different by-products of drinking water disinfection are found; many of them are not regulated yet. Trihalomethanes belong to the most common class. The process of trihalomethane formation takes up to tens of hours [9]. Increased and high levels of chlorinated organic compounds in drinking water is a risk factor for human health, leading to a rise in cases among children and overall morbidity, development of regulatory abnormalities [9,10,11,12,13,14]. Recent experimental toxicological trials have shown that the most common groups of water chlorination by-products (trihalomethanes) influence spermatogenesis, sperm mobility and morphology, decreasing fertility in male rats and rabbits. Based on the results of toxicological Chinese trials, influence of drinking water chlorination by-products can pose a threat to male health [15], has mutagenic, cytotoxic and genotoxic properties [12,16]. It is asserted that during pregnancy, the effect of THM is associated with a low length and body mass of a fetus [13]. A relation between the impaired fat and carbohydrate metabolism and the increased level of trihalomethanes in tap water is found in children from the Perm Territory [10]. Recent toxicological and epidemiological trials show an increased risk of cancer, including cancer of the urinary bladder, in people who for a long time have drinking water with THM at concentrations several times higher than those permissible for drinking water [9,11,12,17,18].

Based on the IARC (International Agency for Research on Cancer) classification, trichloroethylene belongs to group 2A (probably carcinogenic to humans), whereas chloroform belongs to group 2B (possibly carcinogenic to humans). It has been established that in the countryside of the Primorsky Territory (Ussurian lowlands), the individual carcinogenic risk of trichloroethylene contained in well water can be equal to $1.54 \cdot 10^{-6}$, which corresponds to 1.54 of additional cases of cancer per million of exposed people [17]. In chronic experimental trials it has been shown that peroral chloroform induces malignant hepatomas, renal adenomas and adenocarcinomas in mice and rats [15]. Based on hazard indices, the central nervous system, kidneys, liver, skin and mucous membranes, blood, bones and immune systems, hormonal exchange, digestive and blood circulation organs are unfavorably affected by contaminating chemical substances [4,6,7,9,17].

It should be noted that carcinogenic properties of many water chlorination by-products are manifested through a chronic influence of increased and high carcinogenic doses on a body. This occurs most frequently when the technological process of water handling is disturbed or in an extreme effect on the water regimen of a water supply source (flood, sewage emergency release). Under these conditions, a causal effect between contamination of water with chlorinated hydrocarbons and cancer occurrences is seen during a shorter period. It's more difficult to confirm the leading role of these substances in the development of cancer in population if the level of chlorinated organic compounds in drinking water is low. Moreover, water can contain compounds with carcinogenic activity of another origin [4,9], hampering assessment of a potential risk for human health, when a found in water cancer-causing chemical produces an effect.

In the largest part of the Russian Far East, water in sources is soft and low-mineralized (based on a medical classification) and ultra-fresh (based on a technical classification), the latter explaining its high corrosive activity towards water-bearing fittings [3]. According to the literature, long-term use of drinking water with increased levels of Fe up to 5 mg/L can result in dryness and pruritis of skin, pathological changes in the mucous membranes, blood and immune system, and siderosis (over 37.8 mg/L) [3,19,20]. It is believed that a very high level of iron in drinking water is a reason for iron accumulation in a body and development of ecologically dependent pathologies [21]. Siderosis, resulting from iron accumulation, is commonly transformed into hepatic and pancreatic cancer. A higher iron level makes proliferation of tumor cells more intense. However, unlike chelated iron, ions of Fe can initiate mutagenesis [19,21]. Data from different sources indicate at the causal effect between a higher iron entry into the body and incidence of colorectal cancer or occurrence of premalignant polyps (adenomas). However, the process mechanisms are under investigated now [22,23]. However, increased body saturation with iron impairs the body resistance and can lead to a higher overall morbidity, neoplasms, cardiomyopathies, arthropathies, and an increased number of endocrine and neurogenerative disorders [21]. Excess of iron can result in an intensified oxidative stress, which is currently considered as a link of such pathological processes as Alzheimer disease and Parkinson's disease [21,24]. Disbalance of iron in a body promotes excessive accumulation of toxic metals in the central nervous system (manganese, copper, cobalt, cadmium, aluminum, etc.) [25].

Manganese is also a top-priority drinking water contaminant in ore-bearing regions of the Russian Far East, primarily, on water pipes with underground sources. It is mainly of a natural origin, though it is also formed in water pipes due to water microflora activity or industrial soil contamination (for instance, improper removal of dry-charged batteries or other toxic substances [26]. Just like with iron, high levels of manganese in drinking water can alter health of adults and children. Manganese is a mineral element, which is both essential, and potentially toxic. This depends on the dose level. It is important in a number of physiological processes, and can be a powerful neurotoxicant, when in excess [25,27,28,29].

Though certain mechanisms of manganese absorption and transportation are not fully examined yet, some articles state that iron and manganese can have common absorption and transport pathways. When Mn and Fe compete for the same transport systems, iron-deficiency anemia is developed in case the arrival of Fe is normal [30,31]. On the contrary, consumption of manganese from food is decreased when the nutritional level of Fe is increased. Moreover, the biological availability of manganese can be influenced by the level of Fe. Intestinal absorption of manganese is increased when there is not enough Fe; increased Fe stores (ferritin levels) are associated with a lower consumption of manganese. Men commonly consume less manganese than women. This can be explained by the fact that men usually have higher Fe stores. Besides, iron deficiency increases the risk of manganese accumulation in the brain [25,30].

Manganese can commonly be found in underground waters when manganese minerals are weathering and leaching from geological materials into water beds. Its water concentration can vary greatly. However, we have not enough articles devoted to the effect produced by manganese found in water on population health. In has been found out that in research studies of adults and children, high levels of manganese in water can produce a neurotoxic effect [32,33]. In Bangladesh, increased manganese concentration in water (mean concentration of 800 μg/l) is related to the decreased intelligence quotient (IQ) for 142 children not elder than 10 years old [34]. In Canada, a medical examination of 362 children aged 6 to 13 years has shown that high manganese concentrations can trigger more hyperactive and oppositional behavior in children [35]. This is supplemented by a Canadian trial, where an interrelation between impaired memory, motor functions and long-term consumption of manganese with water (exceeding 100 and 180 μg/l, respectively) was found [36]. In other words, the central nervous system is a target organ for excess exposure to manganese in an ionic form [32,29].

It has been shown that, apart from a negative effect on the central nervous system, chronic consumption of drinking water with a high level of manganese can trigger diseases of genitourinary system, skin and subcutaneous fat, stress of thyroid sphere, complications of pregnancies and deliveries, allergic reactions, disturbances of cellular immunity and non-specific resistance, and mutagenic activity [27,30,31,37]. Currently, a reference dose of manganese, which goes with drinking water, is equal to 0.14 mg/kg. This is the dose used to assess the risk for human health during exposure to chemical substances.

The Russian Far East is known to be a part of an extensive biogeochemical province with a marked deficiency of some biogenic elements in the environmental objects. In particular, laboratory research performed in the Sakha Republic, Jewish Autonomous Region, Magadan Region and Primorsky Territory has shown that water taken from the potable water distribution systems contains low levels of calcium, magnesium, fluorine and other micronutrients [38,39,40,41,42]. By total dissolved solids, the water can be classified as ultra-fresh (0.5 g/l), and as very soft (up to 1.5 mg-equ/L) or soft (1.5–3 mg-equ/L) when classified by hardness. Very low mineralization of drinking water is important for human health.

Over the last decade, a number of scientific publications that point at the relation between some pathological conditions and long-term use of too soft drinking water with low levels of carbonates, calcium and magnesium hydrocarbonates, needed for a normal human life, has risen considerably [40,43,44,45]. Moreover, long stay on the territories with a pronounced disbalance of calcium and magnesium in drinking water is one of pathogenic risk factors of urolithiasis in urinary organs [42,46]. A causal relationship between a high incidence of cardiovascular morbidity, including hypertensive disease and ischemic heart disease, and long-term use of low-mineralized drinking water has been proven earlier [44,47]. In the Russian Far East, territories with high cardiovascular risk mainly include a seaboard of the northwest part of the Pacific Ocean, especially its southern part, located to the east from the Sikhote-Alin in the Primorsky Territory. Water from water supply systems is mineralized the least and has the largest possible deficiency of magnesium and calcium [1,40,46]. The value of water found biogenic elements for a human body is based on their almost 100% bioavailability; in food products, the same value is equal to 25–40% only and can be found mainly in milk and milk products.

In conclusion of a review of scientific publications, it's necessary to mention reports about a higher toxicity of lead, arsenic, contained in very soft, low-mineralized drinking tap water [44,45,48]. This phenomenon can also be typical of drinking water chlorates. However, available literature lacks publications on that issue. A probability of changing the toxicity of drinking water anthropogenic contaminants depending on its mineralization level requires a shift from traditional approaches limiting only upper and maximum allowable concentrations of certain substances in drinking water by organoleptic and toxicological signs of harmfulness, to the optimization approach, regulating the minimum levels of biogenic elements, responsible for total hardness of water. This approach that has been implemented in a setting of environmental standards for the quality of pre-packed drinking water definitely reflects the most progressive tendencies in the doctrine of drinking waters and is actual for the Russian Far East.

The presented analysis of scientific literature makes it possible to compile a research program to provide a rationale for a set of preventive activities. The activities are aimed at the weakening of an unfavorable effect of drinking water quality in water supply systems produced on the health of inhabitants of the Far East, which is essential due to expected intensified economic advancement of the region.

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