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REVIEW ARTICLE

Lithium in the natural environment and its migration in the trophic chain

O.I. Sobolev[1], B.V. Gutyj[2], L.M. Darmohray[2], S.V. Sobolieva[3], V.V. Ivanina[4], O.A. Kuzmenko[1], P.M. Karkach[1], V.F. Fesenko[1], V.V. Bilkevych[1], Y.O. Mashkin[1], A.M. Trofymchuk[1], R.V. Stavetska[1], S.V. Tkachenko[1], O.I. Babenko[1], N.I. Klopenko[1], S.V. Chernyuk[1]

[1]Bila Tserkva National Agrarian University, Bila Tserkva, 09100, Ukraine
[2]Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies Lviv, 79010, Ukraine
[3]Bila Tserkva Institute of Continuous Professional Training, Bila Tserkva, 09100, Ukraine
[4]Institute of Bioenergy Crops and Sugar Beet, NAAS, Kiev, 03141, Ukraine.
E-mail: bvh@ukr.net

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Lithium is a natural element with unique physical and chemical properties that determine its biological role in living organisms. Literary review summarizes and systematizes the results of long-term researches that have been conducted in different countries of the world in terms of lithium content in soils, water, air, plants, and foodstuffs. It has been shown that the variability of qualitative and quantitative composition of soils and water at different continents leads to significant differences in the concentration of lithium in plants. Vegetables, fruits, berries, grain crops, the products of livestock and poultry which are grown in different ecological environment are significantly differ in the content of the lithium. Lithium, being involved into the food chain, can have an impact on the human body. People with low lithium status meet slowdown in the growth of the cells, the reproductive function of the organism is impaired, there are problems in behavior, life expectancy is reduced, while high doses of this trace elements cause intoxication and can lead to pathological functional changes of individual organs or body systems at whole. Analysis of the actual consumption of the lithium with food and water indicates a low level of population provision with this trice element in most countries of the world. The data presented allow more objective assessment of the ecological and biogeochemical status of different geographical regions, and in the future to predict the level of lithium intakes with food into the human body, as well as to minimize the biological risks to human health which are associated with dangerous concentrations of this trace element.

Keywords: Lithium; concentration; soil; water; plants; foodstuffs; human deman

The history of the lithium discovery

Lithium has a special place among the trace elements that by their vital for the human body, animals and birds are attributed as conditionally essential (Levitin et al., 2017). However, for nowadays it is considered as a "serious candidate for essentiality" (Poljanskaja, 2014).

As a biotic element it has an interesting history and this story is far from over. Lithium was discovered by Swedish chemist and mineralogist Johan August Arfwedson in 1817. During a full analysis of the mineral petalite $Li[AlSi_4O_{10}]$ at Stockholm University, he isolated from it “a fire-supportive alkali of a still unknown nature” (it was lithium hydroxide). His teacher Jöns Jakob Berzelius proposed to call it lithion (Lithion), as this alkali was first discovered in the “Kingdom” of stones (with Greek. Lithos-stone). Soon after the discovery, lithium was found in other minerals, as well as in the mineral springs of Carlsbad, Marienbad and Vichy. Attempts of A. Arfwedson to isolate pure lithium were not successful at that time. In 1818, the English chemist Humphry Davy received new metal from "lition" that was called lithium (Leenson & Bankrashkov, 2017). In 1821 another English chemist William Thomas Brande allocated metallic lithium by electrolysis of its hydroxide, but in small amounts. Only in 1855, the famous German chemist Robert Wilhelm Bunsen received metallic lithium by electrolysis of lithium chloride melt, in quantities sufficient to study the properties of the metal. On an industrial scale, lithium was first produced by the German company Metallgesellschaft AG in 1923 (Mohandas & Rajmohan, 2007; Bauer & Gitlin, 2016).

In subsequent years, scientists have put more efforts and significantly advanced in study of lithium distribution in the environment, of its biological role and mechanism of its influence on living organisms.

Physical and chemical properties of lithium

It is probably impossible to get a complete scientific understanding of the features of bioaccumulation and biological action of lithium on a living organism without taking into account its physical and chemical properties and position in the periodic table

of chemical elements by D.I. Mendeleev. Lithium is the third chemical element of group I, 2-nd period (the main subgroup) of the periodic table with a relative atomic mass of 6.941, an alcali metal. Atomic and ionic radiuses become reciprocally 0.157 and 0.068 nm. Ionization energy is 5.39 EV. The Pauling electronegativity is 0.98. Melting and boiling point are 180.5 and 1340.0 °C, reciprocally. Density is 0.539 g/cm^3. Color is silver-white. The low ionic potential of lithium (1.47), due to the small size of the ion radius and ion charge, indicates its high solubility. Being a cationogenic element, lithium is most often forms simple free cations with a low charge in aqueous solutions. Lithium metal has a cubic volume-centered crystal lattice.
The lithium atom contains 3 protons and 4 neutrons. In the lithium atom there are two energy levels, on which are 3 electrons. The electronic formula of the lithium atom has the form $1s^2 2s^1$. On the outer electron orbit of the lithium atom there is 1 unpaired electron (which causes the valence equal to +1), and on the inner one are 2 electrons. The valence of lithium is constant in all known compounds (Azhazha & Gnedaja, 2006; Johanson, 2007). Numeral biological function of the lithium, scientists associate with its small ionic radius.

The distribution of lithium in the natural environment

According to the modern biogeochemical classification of the elements lithium belongs to the group of lithophilic elements which formed the earth's crust and upper mantle. Due to the high reactivity, lithium does not occur in nature in elemental form. There are more than 100 minerals (silicates, phosphates, fluorides, etc.) which include lithium, but only a few of them are of high industrial and economic importance: spodumen-$LiAl[Si_2O_6]$ (3.7% Li), lepidolit-$K_2(Li,Al)_{5-6}\{Si_{6-7}Al_{2-1}O_{20}\}(OH,F)$ (1.4-3.6% Li), petalit-$Li[AlSi_4O_{10}]$ (1.6-2.3% Li), eucryptus-$LiAl[SiO_4]$ (2.1-5.5% Li), ambligonit-LiAl $[PO_4][F,HE]$ (3.4-4.7% Li), hectorite-$Na_{0,3}(Mg,Li)_3Si_4O_{10}(OH)_2$ (0.5% Li), jadarit-$LiNaSiB_3O_7(OH)$ (7.3% Li) (Mineral profiles, 2016). They only form the industrial deposits of lithium in the granitoids, pegmatites and granites greisen. Besides, increased concentrations of lithium are attributed to such minerals as glauconite, biotite, tourmaline, phlogopite, margarite, beryl (Zhuk et al., 2010).
Natural lithium consists of two stable isotopes, with a prevalence of ^{6}Li (7.5% by weight) and ^{7}Li (92.5%). In some samples of lithium, the isotopic ratio may be impaired by natural or artificial isotope fractionation (3.75% and 96.25%, reciprocally). There are also seven other short-lived artificial radioactive lithium isotopes, with different half-lives (from ms and less), in the range of mass number from 4 to 12 (Munteanu, 2013).
Lithium belongs to the group of scattered elements. Its mass share in the earth's crust according to various estimates becomes,%: $(1.7\text{-}2.0)\cdot 10^{-3}$ (Evans, 2014); $3.0\cdot 10^{-3}$ (Shahzad et al., 2016) and $(5,0\text{-}6,5)\cdot 10^{-3}$ (Azhazha & Rajmohan, 2006; Mueller et al., 2010). Clark of lithium in the living matter according to the calculations of V.I. Vernadsky becomes $6.0\cdot 10^{-5\%}$. The low clark of lithium is associated with an abnormally high value of the atomic nucleus mass defect of the element (Belopuhov et al., 2015). The concentration of lithium in natural water varies as depends on geology, topography, hydrogeology and other variables. Thus, the range of lithium concentrations in seawater is from 0.17 to 11.7 mg/l, in fresh water-from 0.001 to 0.020 mg/l (Mohd Nani et al., 2016). The low lithium concentrations (2 ng/m^3) were detected in the air (Schäfer, 2004). In some regions of the world, the maximum values of lithium range from 2.3 to 8.9 ng/m^3 (Kabata-Pendias & Mukherjee, 2007).
It is known that the movement of chemical elements in the biosphere occurs according to the scheme: soil-water-plant-animal organisms-human. This sequential migration pathway constitutes the trophic chain, which we will consider to get a full understanding of biological functions, features of accumulation and distribution, and the value of lithium for living organisms.
According to the geochemical classification of elements by features of their migration in landscapes proposed by O.I. Perelman, lithium is referred to weakly mobile elements which slowly migrate both in gaseous state and with aqueous solutions (Belopuhov et al., 2015). The distribution of lithium in soils, water, plants, in the products of animals, poultry and human body, across different regions of the world is marked by great diversity (Shahzad et al., 2017).

Lithium in soils

Depending on the type and mineral composition of soil-forming rocks, the presence of autigene minerals which are formed in the process of hypergenesis, redox and alkaline-acid conditions, the concentration of lithium in the soil may vary considerably. Its average content in igneous rocks rarely exceeds 40-45 mg/kg, and in sedimentary rocks-60-75 mg/kg (Kabata-Pendias & Pendias, 2001; Zhuk, 2013). On the Ukrainian shield territory lithium content in igneous rocks increases from ultra-alkaline to alkaline, and in sedimentary-from limestone rocks to the rocks with a significant content of clay component (mudstone) (Zhovinskij et al., 2009).
Soils are inheriting the level of lithium content in the underlying indigenous rocks. As a result of weathering of parent rocks, lithium is relatively easily released from primary minerals, passed into moving forms and accumulated in clay minerals that are part of the granites. The accumulation and distribution of lithium in soils is influenced by the humus content and composition of clay minerals. The content of lithium in different soils and their genetic horizons can vary widely, according to one data-from 0,01 to 160 mg/kg (Kabata-Pendias & Pendias, 2001), others ranging from 7 to 200 mg/kg (Schrauzer, 2002). The average content of lithium in soils is usually 25-30 mg/kg. The level of lithium in the soil also depends on the acid-alkaline conditions. Scientists believe that acidic soils contribute to the solubility of the lithium. Therefore, the content of lithium in acidic soils is higher than in alkaline one (Aral & Vecchio-Sadus, 2008).
The monitoring of lithium content in different soil types carried out by Ukrainian scientists defines that in the upper horizon (0-10 cm) of dark chestnut soils its gross content is 6-9 mg/kg (Cvej et al., 2001), sod-carbonate soils-10-15, sod-podzolic soils-15-35, podzolic black soils-25-35, typical black soils-40-50 mg/kg (Zhuk et al., 2010). The distribution of lithium throughout the

soil profile is uneven. Its content in the lower soil horizons increases (Ammari et al., 2011; Zhuk, 2013). While determining lithium content of the soils, it was also found that its mobile forms account for 4 to 8% of the gross content.

Lithium in natural waters

The studying of ecological-hydro geochemical features of trace elements distribution showed that lithium present in surface and groundwater worldwide. It usually easily passes into natural water from the solid fraction. In the water lithium is both in the form of simple ions Li^+, and in complex compounds with different agenda of natural water. With increasing water mineralization, there is a tendency to reduce the proportion of simple Li^+ ions and increase the share of complex compounds. Lithium in natural water is considered primarily as one of the scarce rare metals (Gaillardet et al., 2003).

As it is known, the microelements composition of natural water correlates with its content in the rocks over which they circulate. Therefore, the lithium content in the water depends on physical and chemical conditions of the environment and its ability to migrate from rock to solution, as a result of the solubility of many lithium compounds. The concentration of lithium in surface and groundwater may be higher than the natural fond in places where lithium-rich brines and minerals are found, as well as in places where lithium batteries are recycled (Aral & Vecchio-Sadus, 2008).

Lithium concentration in surface water is usually low. In the largest rivers of the USA, the average lithium content is about 2 µg/l (Kszos et al., 2003[b]) and varies from 0.26 to 4.16 µg/l (Anderson et al., 1988). However, these scientists note that the average concentration of lithium in surface water may equate 40 µg/l or even higher (Kszos & Stewart, 2003[a]). The results obtained in the study the concentration of this trace element in the surface water of South-East Ireland support this conclusion. Scientists have defined lithium level variability through a year in the range from 20 to 91 µg/l (Kavanagh et al., 2017).

There are areas in the world whose surface water contain high level of lithium. Natural high-lithium brines are found in Northern Chile (1400-1500 mg/l) (Ogawa et al., 2014), in China (560-1300 mg/l) (Song et al., 2017), Bolivia (700-900 mg/l) (An et al., 2012) and Argentina (520-620 mg/l) (Warren, 2016). Lakes which brines contain lower concentrations of lithium (200 mg/l) are located in the United States (Kesler et al., 2012).

Surface water of technogenic-polluted territories is also characterized by high content of lithium (Udalov, 2014). In particular, as a result of significant volumes of mine waste water entering the river ecosystems in Donbass (Ukraine), the maximum concentrations of lithium in the rivers can reach of 11.8-13.7 mg/l (Onyshhenko, 2006). According to the conclusions of scientists, the chemical composition of surface water under technogenic load does not contribute to their safe use as sources of drinking water supply.

In groundwater, the concentration of lithium is higher than in surface water and typically range from 0.05 to 150 µg/l (Liaugaudaite et al., 2017). However, in some geographical regions of Austria, Argentina and Chile high concentrations of lithium (more than 1000 µg/l) have been recorded in the groundwater (Kapusta et al., 2011; Concha et al., 2010). There is a notice in the literature that groundwater in temperate wet areas contains less lithium than in the hot arid areas (Kabata-Pendias & Stewart, 2007).

The data obtained by scientists in different countries allow suggesting that the concentration of lithium in drinking water is different. The content of lithium in the drinking water of some regions of Austria ranges 4.0-16.0 µg/l (median of 11.3 µg/l) (Helbich et al., 2013); Greece-0.1-121.0 (median 11.10) (Giotakos et al., 2013); Denmark-0.6-30.7 (median 11.6) (Knudsen et al., 2017); Italy-0.11-60.80 (median 11.10) (Pompili et al., 2015); China-0.03-14.83 (Soldatova et al., 2015); Lithuania-0.48-35.53 (median 3.60) (Liaugaudaite et al., 2017); Macedonia-0.11-5.20 (median 1.21) (Kostik et al., 2014); Northern England-1.0-21.0 (Kabacs et al., 2011); Russia-3.0-160.0 (Golicyn & Shvec, 2012); Texas-2.8-219.0 (Blüml et al., 2013); Ukraine-0-50.0 (Pribilova, 2015); Japan-0-59.0 µg/l (Ishii et al., 2017; Sugawara et al., 2013; Ohgami et al., 2009). It should also be noted that nowadays national standards of many countries worldwide do not contain maximum permissible thresholds of lithium concentrations in drinking water.

Monitoring of lithium in bottled drinking water has shown that its concentration is ranging widely, with deviations of four to five orders. Thus, the study of 132 brands of bottled water in 28 countries worldwide showed that lithium content in the samples ranged from 0.057 to 5460 µg/l (median 4.8 µg/l). The highest concentration of lithium (5460 µg/l) was found in bottle of water from France. Some lower concentrations of this trace element were found in water that was bottled in Germany and Yugoslavia, reciprocally-1.4 and 1.3 mg/l (Krachler & Shotyk, 2009).

A study of bottled mineral water, both sparkling and non-sparkling, purchased in various regions of Italy, by random sampling, allowed to define that average concentration of lithium in the water was 3.4 µg/l, with maximum value in individual samples-241.0 µg/l (Cicchella et al., 2010).

Interesting data were obtained while exploring the concentration of lithium in mineral water that has been purchased in supermarkets of 40 European countries. The average lithium content in bottled water was 10.0 µg/l. The highest value of this indicator (9860 µg/l) was recorded in mineral water from Slovakia (Demetriades et al., 2012).

Lithium in plants and plant products

The variability of qualitative and quantitative composition of soils and water of different continents leads to significant differences in terms of lithium concentration in the plants. In plants lithium concentration is about 0.0001% (by weight) (Shaposhnikova & Bolgova, 2012). A few literature data on the content of lithium in the plants indicate that its level can range from 0.1 to 2680 mg/kg of dry matter. The lithium content in the plants is influenced by several factors: the type of soil and its pH, the total content of trace elements in the soil, the value of its mobile form, season, type of plant, place of growing, weather and climatic conditions. The amount of lithium entering from the soil nutrient environment into the plants have often due to the presence of barrier mechanisms in the last (Kashin & Ivanov, 2007; Kalinowska et al., 2013).

Although lithium does not belong to the major nutrition elements of the plants, there is evidence in the scientific literature about its role in many physiological and biochemical processes. Thus, it is reliably established that lithium in small quantities has a positive effect on the growth and development of plants, increases their resistance to diseases, improves water-salt metabolism and transportation of potassium, enhances the photochemical activity of chloroplasts, the synthesis and translocation of sugars, nitrogen metabolism, activates enzymatic processes, regulates biosynthesis and accumulation of alkaloids and their predecessors, increases the intensity of respiration, the absorption and accumulation of a number of mineral elements. With deficiency of lithium in plants, the synthesis of vitamin B_{12} is slowing down. High concentrations of lithium disrupt the metabolism of nucleic acids, the expression of some genes, the development of pollen, damage cell organelles and macromolecules, slow down the growth of plants, cause the appearance of chlorotic and necrotic spots on the leaves. However, scientists note that the exact mechanisms of lithium action at low and high concentrations on plant morphogenesis have not yet been fully clarified (Hawrylak-Nowak et al., 2012; Shahzad et al., 2016).

By the ability to accumulate lithium, all plants can be divided into two groups: plants-concentrators and non-concentrator plants. The first group includes plants of the families *Rosáles, Caryophylláceae, Solanaceae, Ranunculáceae, Asteraceae*, as well as some species of plants which belong to the group of halophytes. Ultra-high concentrations of lithium (up to 4.0 mg/kg of dry matter) are typical for aloe tree, black henbane, cassia colic, belladonna, scotch cotton thistle, marsh cinquefoil, etc. The second group includes all other plants, including most agricultural crops (Shaposhnikova & Bolgova, 2012; Kalinowska et al., 2013). According to scientists, for lithiophiles (some species of plants of families solanaceae and ranunculaceae), lithium is vital.

The content of lithium in plants does not always correlate with its concentration in the nutrient environment. It has been determined that lithium absorption depends on the biological characteristics of plants, their age, and, first of all, on the cation exchange capacity of the roots and their biochemical composition, as well as on the strength of ion bonds with cell membranes (Ohrimenko et al., 1988). Besides it, the degree of lithium absorption by plants may be influenced by the concentration of ions Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- in the soil (Ammari et al., 2011).

Aboveground vegetative parts of plants contain more lithium than roots. Even less lithium in the seeds (Tomascak et al., 2016). Usually, the average content of lithium in plants is estimated to be 0.15-0.42 mg/kg dry matter (Shahzad et al., 2016).

High concentrations of lithium are toxic to plants. For most plant species, toxic levels of lithium range between 5 and 50 mg/kg, except for concentrator plants. Citrus trees (avocados, oranges) are extremely sensitive to high lithium content (Kalinowska et al., 2013; Shahzad et al., 2016).

Among the agriculture crops which constitute a significant proportion of the daily human diet, the lowest content of lithium in fruits and berries, notably in lemon-0.103 mg/kg; pumpkin and melon-0.060; banana -0.033; ivy and apricot-0.300; apple-0.008; blueberries-0.060; strawberries-0.030 mg/kg.

In vegetables the concentration of lithium is an order of magnitude higher. There is evidence that the content of this trace element in spinach is 4.60 mg/kg; green onions-1.80; peppers-0.87; potatoes-0.77; salads-0.30; tomatoes-0.29 mg/kg.

Among grain crops, cereals contain less lithium than legumes. The general regularity for cereal crops is that the content of lithium in their grains decreases in the following sequence: barley > corn > rice > flinty wheat > millet > oats > corn > soft wheat that becomes reciprocally: 0.231; 0.149; 0.120; 0.110; 0.072; 0.060; 0.050 and 0.020 mg/kg. The removal of lithium from the soil with a grain of lentil, soy, peas and beans becomes reciprocally 0.748; 0.670; 0.031 and 0.021 mg/kg (Anke et al., 2003; Thagapsu, 2005; Suttle, 2010; Konovalova et al., 2012; Shahzad et al., 2016).

It should also be noted that the same species of plants, in the same phase of vegetation (flowering), but in different environmental conditions, differ significantly in lithium content. The difference by this indicator in some plant species can range from 1.5 to 8.9 times (Kashin & Ivanov, 2007).

Data on the natural content of lithium in mushrooms are limited. Scientists, having analyzed 171 samples of 38 species of edible wild mushrooms collected in Hungary, defined that the average content of lithium in them is 0.189 mg/kg. The highest average concentration of lithium was determined in fungi species such as *Craterellus cornucopioides* (0.609 mg/kg), *Amanita strobiliformis* (0.520 mg/kg) and *Psathyrella candolleana* (0.390 mg/kg) (Vetter, 2005). A low concentration of lithium (0.25 mg/kg) were stated in mushrooms collected in Tuscany (Italy) (Giannaccini et al., 2012).

The limited number of publications is regarding the content of lithium in tea. There are notes in the scientific literature that the concentration of lithium in 29 types of tea consumed in China was low and ranged from 0.02 to 0.60 mg/kg. A high concentration of lithium (greater than 11 mg/kg) was found only in one type of tea-Luobuma (*Apocynum venetum*) (Wang et al., 2014).

Lithium in food products of animal origin

By the opinion of many scientists, the main factors are determining the concentration of lithium in food of animal origin (meat, milk, eggs, fish, etc.) are its level in soils, water and forage plants. It is known that lithium in small amounts is contained in all organs and tissues, but distributes across them too unevenly, moreover it varies in different species of farm animals and poultry. High concentrations of endogenous lithium are observed in the spleen, lungs, kidneys, brain and blood of almost all species of animals, lower in the liver and muscles. It was found that the average content of lithium in the liver and kidneys of cattle is 5 mg/kg of dry matter. The concentration of lithium in the meat of different species of farm animals increases in this order: poultry meat < beef < lamb. This is due to the fact that green fodder and silage, which are the basis of the diet of cattle and sheep, contain more lithium than feed grain, which is fed to poultry as part of the mixed feed. Fish of lithium content is virtually identical to poultry meat (about 3 mg/kg of dry matter). The eggs and milk are characterized by a higher concentration of lithium which in average of 7.4 and 7.5 mg/kg of dry matter, reciprocally. Unlike the milk, dairy products (soft and hard cheeses) contain only 20-55% of lithium of its concentration in the ascending raw material. The concentration of

lithium in the butter, which is made from animal fats (milk) is 1.2 mg/kg of dry matter. The oil made from vegetable fats contains less lithium (Anke et al., 2003; Mueller et al., 2010).
The Lithium in the honey is presented in a small amount. The concentration of this trace element is highly varying and depends on the botanical and geographical origin of honey, as well as on the conditions of the area where it is obtained (the coastal and mountain areas, rural or urban). Thus, the research results on mono-and multicolored honey obtained in different countries worldwide showed that the honey from France has a lithium content ranging from 0.0 to 0.24 μg/kg (Devillers et al., 2002), Turkey-from 0.30 to 1.50 (Bağci et al., 2007), Spain-from 0.0 to 110.0 (Terrab et al., 2005) and Poland from-0.4 to 5.3 μg/kg of natural product (Stecka & Pohl, 2011).
If the natural fond of lithium is low, its concentration in animal products is also low, for example, in milk and dairy products it ranges from 0.01 to 0.50 mg/kg, fish-from 0.00 to 0.58 mg/kg (Nabrzyski & Gajewska, 2002), soft and hard cheeses-from 0.015 to 0.028 mg/kg, butter-from 0.0075 mg/kg (Bilandžić et al., 2014). At the same time, more recent researches by French scientists have shown that the level of lithium in fish may be even lower, notably in eel and salmon-less than 0,01 mg/kg, sardines, herring and grenadier-0.031-0.045 mg/kg, anchovy and pilchard-0.105 and 0.093 mg/kg, reciprocally (Guerin et al., 2011).
A completely different picture is observed in regions where soils and surface water have a high content of trace elements. As a result, food of animal and plant origin received in this area contains higher levels of lithium than elsewhere. One of such regions is the Northern part of Chile. The lithium content in fish of different species caught in this region varies from 18.2 to 103.2 mg/kg. Livestock products also contain very high levels of lithium, notably the meat of different animal species-from 10.2 to 99.3 mg/kg, cow's milk-from 4379 to 4996 mg/l. The lithium concentration in goat's milk is of a wider ranging-from 3129 to 4997 mg per 1 liter of natural product (Figueroa et al., 2013).

The consumption of lithium with food and human demand for it

The data presented on the content of lithium in water and foods suggest that lithium, being in the food chain, can have an impact on humans. Most people today (except some regions) consume less lithium than necessary. Analysis of the actual consumption of lithium with food products indicates an insufficient (or even low) level of the human body's provision with this trace element.
Specialists from the US Environmental Protection Agency have estimated that daily consumption of lithium by an adult weighing 70 kg ranges from 0.65 to 3.10 mg. People are living in geographic regions such as Northern Argentina and Northern Chile according to their estimates consumes lithium from 2 to 30 mg/day (Marshall, 2015).
A significant number of countries worldwide are characterized by moderate and low rates of lithium consumption by the population. In different countries of the world the level of lithium consumption with food becomes, mg/day: China-1.560; Mexico -1.485; Sweden-1.090; Denmark-1.009; USA-0.429-0.821; Japan-0.812; Germany-0.182-0.546; Austria-0.348; England-0.107; Spain-0.011-0.105; Turkey-0.029-0.051; France-0.048; Italy-0.016- 0.045; Finland-0.035; Canada-0.022; Belgium-0.001-0.015 (Van Cauwenberg et al., 1999; Schrauzer, 2002; Kalonji et al., 2015). People with low lithium status have reduced growth rates, impaired reproductive function, which can lead to infertility; life expectancy reduces due to premature aging, aggressiveness increases, problems in behavior appears. The researchers are using statistical analysis methods have determined an inverse highly probable relationship between the level of lithium intake in the human body and the level of suicide among the population, as well as correlation between the level of violent crimes such as murder, rape and robbery.
For today there are no official recommendations of the FAO/WHO experts on dietary standards for human consumption of lithium. In this regard, some countries have offered their citizens an adequate and upper permissible (safe) level of lithium consumption. For example, in Russia, they are reciprocally 0.1 and 0.3 mg/day (Rekomenduemye, 2004). The existing research results suggest that the recommended rate of lithium consumption for an adult of 70 kg weight is 1.0 mg/day (Schrauzer, 2002). As a result, a dose of daily consumption of this trace elements was proposed 14.3 μg per 1 kg of human body weight (Aral & Vecchio-Sadus, 2008). Extrapolation of this value taking into account the body weight of children and teenagers allows calculating their approximate physiological need for lithium.
At the same time, the threshold of toxic lithium dose for humans has been established. It depends on the gender, body weight and age of the person and ranges from 90 to 200 mg/day (Shaposhnikova & Bolgova, 2012). With mild lithium intoxication the symptoms include: weakness, hands trembling, dizziness, nausea or vomiting, blurred vision, weak concentration of attention and diarrhea.
Correction of the body's lithium status is best to do by consumption of natural foods rich in lithium as well as mineral water or water from artesian wells. When people consume only food and drinking water, cases of acute poisoning and intoxication of the body by lithium are unlikely. Another way is using lithium preparations (organic or inorganic lithium salts) in microdoses.

Lithium and human health

For a long time lithium has successfully been used in medicine as an effective and safe means for the treatment and prevention of many diseases (Bourgeois & Masson, 2017). Lithium therapy is used for the treatment of affective bipolar disorders in manic and depressive phases, as well as for the prevention of relapses. It is an effective tool in suicide prevention (Machado-Vieira et al., 2009; Severus et al., 2014; Malhi et al., 2017).
Preparations of lithium are used to reduce the risk of developing dementia (amentia) and have a significant neuroprotective effect in low and even very low doses (Mauer et al., 2014; Gerhard et al., 2015).

Lithium has been proven to be highly effective in treating patients with Alzheimer's disease and mild cognitive impairment. Long-term use of lithium microdoses prevents the development of Alzheimer's disease and cognitive impairment, improves overall condition, and serves as a prevention of their further progress (Matsunaga et al., 2015; Nunes et al., 2015). Lithium is considered as a possible therapeutic agent for the treatment of other chronic neurodegenerative diseases such as Parkinson's and Huntington's diseases (Lazzara & Kim, 2015).
Clinical and experimental researches have shown that lithium has an anticarcinogen effect and is able to prevent and treat some types of cancer (Li et al., 2015; Berk et al., 2017).
Preparations of lithium stimulate osteogenesis, increase bone density and bone mass and are used as supportive therapy in the treatment of osteoporosis (Zamani et al., 2009; Tang et al., 2015). Low doses of lithium reduce total mortality and promote to the prolongation of human life (Zarse et al., 2011).

Conclusion

Lithium was detected in the atmosphere, lithosphere, hydrosphere and biosphere. The movement of lithium in the natural environment is determined by a combination of mechanical, physical-chemical, biogenic and technogenic migration processes. Migration of lithium in the natural environment occurs mainly in ionic form. The low energy coefficient of lithium ions indicates their high migration ability. The content of lithium in soils and natural water varies widely and depends mainly on the landscape and geochemical features of different geographical regions. The major factor that determines the concentration of lithium in vegetables, fruits, berries, mushrooms, cereals, food of animal origin (meat, milk, eggs, fish) is its level in the soils, water and forage plants. Besides it, a significant role in the bioaccumulation of lithium plays species features of plants and animals. Today, the level of lithium intake with food and water in the human body is considered to be low, despite the absence of recommended norms of consumption of this trace element. Despite the fact that there is a significant amount of scientific evidences regarding the distribution and migration of lithium in the major components of the natural environment, some issues have not been fully studied yet and some literature data are contradictory and require further explanation or clarification.

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