REVIEW ARTICLE

A Review on Essential Minerals in Water Required for Human Health and Nutrition

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Water plays an important role in the body to perform various crucial functions which include mineral supply to the body. The relative contribution of water to the total dietary intake for selected trace elements and electrolytes lies between 1 and 20%. Minerals are inorganic supplements which are required for humans in limited quantities in the range of 1 to 4000 mg per day, depending upon the type of mineral. Requirement of minerals changes from gender to different age group, similar to that of nutrients and other basic nourishment supplements. Calcium (Ca) is essential for humans in the development of bone and proper working of nerves and muscles. Magnesium (Mg), copper (Cu), zinc (Zn) and iron (Fe) are significant co-factors which are essential in various biochemical reactions. Iodine (I) is required for the synthesis of thyroid hormones which control body's metabolism and many other body functions. Potassium (K) is significant for maintaining osmotic harmony among cells, and the interstitial liquid. Red platelets cannot work properly without iron in haemoglobin. Excessive consumption or insufficient intake of selected trace minerals can disturb the body balance and can cause various chronic effects. The paper studies the alterations in various biochemical functions when these trace minerals are consumed in disproportionate manner. This paper critically emphasizes on the controlled uptake of vital minerals such as Ca, Mg, Fe, Zn, Cu, I, K from water.

Introduction

The inorganic chemicals which are found in drinking water are mostly naturally occurring. The elements are acquired by the contact of water with rocks and soil and may be due to certain climatic changes. The chemical composition of drinking water in addition may depend on the contaminating effects of agricultural activities, industrial effects, and human settlement [**1**]. The minerals which are essential for human health are Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu), Iodine (I), Cobalt (Co), Molybdenum (Mo) and Selenium (Se). Some of these elements are found in drinking water as well, which are also considered necessary. A second group of elements that have some beneficial health effects, include Fluoride (F) and Boron (B), Manganese (Mn), Nickel (Ni) and Silicon (Si) that may be considered essential for humans [**2**].

The minerals with the largest proportion of intake from drinking water relative to that provided by food are Calcium and Magnesium. Water may provide up to 20% of the required total daily intake for these elements. For other elements daily drinking water provides less than 5 % of total intake. There may be the high contribution of fluoride and arsenic in certain geographic regions. It is assumed that the intake of secondary essential elements is mostly covered by foods, thus minimum desirable levels in drinking water are not considered necessary [**3**]. However, for populations that are on low consumption of animal flesh foods, the intake of iron (Fe), zinc (Zn) and copper (Cu) may be marginal or lower than needed, in which case the intake is expected from water.

Trace elements cannot be manufactured by human body itself, and they must be taken from the natural environment. Water is a major source of trace elements necessary for the growth of biological organisms [**4**]. The composition of trace elements in water has a serious impact on human health. Changes in drinking water and groundwater sources can result in significant changes in health risk related with trace elements. Insufficient or excessive trace elements in water can lead to the occurrence of certain effects on human health which has been discussed in subsequent section in detail.

Essential minerals and electrolytes in water and diet that are required for human health and nutrition

Calcium

Calcium is the richest mineral in the body which is required for vascular compression, muscle work, nerve transmission, intracellular signalling and hormonal discharge. Less than 1% of total body calcium is expected to support these basic metabolic functions. The remaining 99% of the body's calcium supply is kept within the bones and teeth where it supports their structure and function [**5**]. Calcium in the bones can be used as a reserve that can be discharged into the body as needed. The concentration of calcium in the body will in general decrease with the age since it is discharged from the body through sweat, skin cells, and waste [**6**]. The Recommended Dietary

Allowance (RDA) for calcium for different age-sex groups based on dietary reference intakes and dietary guidelines recommendations is listed in Table 1 [**7**].

Sources of calcium

Food

The main sources of calcium are mostly all dairy products like milk, cheese, yoghurt, buttermilk which are contributors of nutrition. The non- dairy sources include orange juice, tofu, salmon, kale, cereals, chocolate and broccoli. Fortified grains also provide certain amounts of calcium [**8, 9**].

Water

Calcium is present in water naturally. It is present in earth's crust. Seawater may contain approximately 400 mg/l and river water may contain 1-2 mg/l of calcium, yet in lime zones, waterways may contain calcium concentrations as high as 100 mg/l [**8,10**]. Calcium is significant determinant of water harness, and it likewise works as a pH stabilizer, due to its buffering qualities. The presence of Calcium in water gives it a better taste. Water should provide up to 10-15% of the recommended total daily intake of calcium.

Calcium deficiency

Lack of calcium consumption for a long term can cause osteopenia which if untreated can prompt osteoporosis. The danger of bone fractures also increases, especially in older individuals. Calcium deficiency can also cause rickets which is related to nutrient D inadequacy [**11**]. Hypocalcaemia results in numbness and tingling in the fingers, muscle cramps, seizures, lethargy, poor appetite, and abnormal heart rhythms. High consumption of calcium can cause constipation. In adults, too much calcium mostly from dietary supplements but not food might increase the risk of kidney stones [**12**]. People who consume high amounts of calcium may increase risks of prostate cancer and heart disease.

Magnesium

Magnesium is the most abundant mineral present in the human body which is required for production of energy, oxidative phosphorylation, and glycolysis. It is important for the structural development of bone in the body and is also required for the synthesis of DNA and RNA. Magnesium is a cofactor for hundreds of enzyme reactions within the body [**13**]. These enzymes are important for a variety of key processes taking place within the body such as conversion of energy from carbohydrates, fats and protein, blood sugar balance and bone health. Approximately 25g magnesium is present in an adult human body of which 50% to 60% present in the bones and the rest in soft tissues. Magnesium is also present in blood serum [**14**]. The RDA for magnesium for different age groups is given in **Table 1**.

Sources of magnesium

Food

Magnesium is found in a variety of foods, but the best sources tend to be green leafy vegetables, raw cacao, nuts, dark chocolate, tofu, legumes and whole grains. Green leafy vegetables, such as spinach, chives, basil, spearmint, kale are good sources. The foods containing dietary fibre provide certain amount of magnesium [**8,15**].

Water

Magnesium is present in water bodies which is essential for the human being. About 1300 mg/l magnesium is present in seawater. It is the most commonly found cation in oceans after sodium. River water contains approximately 4 mg/l of magnesium, marine algae 6000-20,000 mg/l, and oysters 1200 mg/l [**4**]. Water should provide magnesium in the range of 15-20% of the recommended total daily intake.

Magnesium deficiency

Magnesium inadequacy causes loss of appetite, nausea, vomiting, fatigue, and weakness. As magnesium inadequacy declines numbness, tingling, muscle compressions and cramps, seizures, personality changes, abnormal heart rhythms, and coronary fits can occur [**14, 16**]. Extreme magnesium deficiency can result in hypocalcaemia or hypokalaemia (low serum calcium or potassium levels, respectively) on the grounds that mineral homeostasis is disrupted [**13**].

Potassium

Potassium is present in all body tissues and is required for normal cell function because of its role in maintaining

Table 1. Recommended Dietary Allowances (RDA's) for Calcium (Ca), Magnesium (Mg) and Potassium (K)

Minerals	Ca		Mg		K	
Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
0-6 m	200 mg*	200 mg	30 mg*	30 mg*	400 mg*	400 mg
6-12 m	260 mg*	260 mg	75 mg*	75 mg*	860 mg*	860 mg
1-3y	700 mg	700 mg	80 mg	80 mg	2000 mg	2000 mg
4-8y	1000 mg	1000 mg	130 mg	130 mg	2300 mg	2300 mg
9-13y	1300 mg	1300 mg	240 mg	240 mg	2500 mg	2300 mg
13-18y	1300 mg	1300 mg	410 mg	360 mg	3000 mg	2300 mg
19-30y	1000 mg	1000 mg	400 mg	310 mg	3400 mg	2600 mg
31-50y	1000 mg	1200 mg	420 mg	320 mg	3400 mg	2600 mg
51-70+y	1200 mg	1200 mg	420 mg	320 mg	3400 mg	2600 mg

*adequate intake, m-months, y-years, mg-milligrams.

intracellular fluid volume and transmembrane electrochemical gradients. The total amount of potassium in the adult body is about 145 millimole (mmol)/l of intercellular fluid. Potassium is absorbed via passive diffusion, primarily in the small intestine. About 90% of ingested potassium is absorbed and used to maintain its normal intracellular and extracellular concentrations [**14**]. Potassium is excreted primarily in the urine, some is excreted in the stool, and a very small amount is lost in sweat. The kidneys control potassium discharge in response to changes in dietary intakes, and potassium discharge increases rapidly in healthy people after potassium utilization, except if body stores are exhausted [**17**]. The RDA for potassium for different age groups is enlisted in Table 1.

Sources of potassium

Food

Potassium is found in a wide variety of plant and animal foods and in beverages. Many fruits and vegetables are excellent sources, as are some legumes (e.g., soybeans) and potatoes. Meats, poultry, fish and yogurt also contain potassium. Among starchy foods, whole-wheat flour and brown rice are much higher in potassium than their refined counterparts, white wheat flour and white rice. Milk, coffee, tea, other non-alcoholic beverages, and potatoes are the top sources of potassium in the diet [**2,8**]. The body absorbs about 85% – 90% of dietary potassium. The forms of potassium in fruits and vegetables include potassium phosphate, sulphate, and citrate.

Water

Seawater contains about 400 mg/l potassium. It settles, so mostly it is found in sediments. Rivers contain about 2-3 mg/l potassium. This difference is caused due to large potassium concentration in oceanic basalts. Granite which is rich in Calcium contains up to 2.5% potassium. It is found in water in the form of K^+ (aq) ions [**17**]. So for an adult, the amount of potassium needed from water should be in the range of 6-8 % of the required daily intake.

Potassium deficiency

Insufficient potassium intakes can increase blood pressure, kidney stone risk, bone turnover, urinary calcium excretion, and salt sensitivity. Severe potassium deficiency can cause hypokalaemia, (serum potassium level less than about 3.6 mmol/l). Mild hypokalaemia is characterized by constipation, fatigue, muscle weakness, and malaise. Moderate to severe hypokalaemia (serum potassium level less than about 2.5 mmol/l) can cause polyuria (large volume of dilute urine), encephalopathy in patients with kidney disease, glucose intolerance, muscular paralysis, poor respiration, and cardiac arrhythmias, especially in individuals with underlying heart disease [**11**]. Severe hypokalaemia can be life threatening because of its effects on muscle contraction and, hence, cardiac function.

Iron

Iron is an important component of haemoglobin, a red blood cell that is useful to transfer oxygen from the lungs to the tissues. Iron supports muscle metabolism and healthy connective tissue. It is additionally important for physical development, neurological improvement, cell working, and blend of hormones. In the range of 3 to 4 grams of elemental iron in adults, is in haemoglobin [**3**]. A significant part of iron is stored in the form of ferritin or hemosiderin in the liver, spleen, and bone marrow or is located in myoglobin in muscle tissue [**18**]. Transferrin is the primary protein in blood that ties to iron and transports it all through the body. Humans ordinarily lose only small amounts of iron in urine, faeces, the gastrointestinal tract and skin. The RDA for iron based on dietary reference intake is given in **Table 2**.

Sources of Iron

Food

Dietary sources of Iron are meat, seafood, cashew nuts, beans, vegetables, legumes, fortified grain products, chocolate, tofu, bread, rice, raisins, spaghetti, broccoli, cheese, milk. The iron in animal-based foods is easier to absorb than the iron in plant-based foods [**8**].

Water

Seawater contains approximately 1-3 mcg/l of iron. Rivers contain approximately 0.5-1 mg/l of iron, and groundwater contains 100 mg/l. Drinking water may not contain more than 200 mcg/l of iron. Most algae contain between 20 and 200 mg/l of iron, and some brown algae may accumulate up to 4000 mg/l [**11**]. The bio concentration factor of algae in seawater is approximately 10^4 - 10^5. Sea fish contain approximately 10-90 mg/l and oyster tissue contains approximately 195 mg/l of iron (all are dry mass). An average adult should get approximately 3-5 % of Fe from drinking water.

Iron deficiency

The fundamental impact of iron deficiency is anaemia, different signs of iron deficiency include impaired mental and motor development and altered behaviour [**9**]. Different indications that might be seen with iron insufficiency are delayed nerve conduction affecting the sound-related and visual frameworks, decreased capacity for physical work, increased spontaneous motor activity, impaired hindered cell-intervened insusceptibility and bactericidal limit of neutrophils, weakened thermoregulation, functional and histologic abnormalities of the gastrointestinal tract, defective mobilisation of liver, increased risk of premature birth. Iron deficiency is the single most common nutritional disorder worldwide and the main cause of anaemia in infancy, childhood and pregnancy [**11,14**].

Zinc

Zinc is engaged in various aspects of cellular metabolism. It is required for the catalytic activity of more than hundreds of enzymes and it plays a role in immune function, protein synthesis, wound healing, DNA synthesis, and cell division. Zinc supports normal growth and development during pregnancy, childhood, and adolescence and is required for proper sense of taste and smell [**3**]. A daily intake of zinc is required to maintain a gradual state because the body has no specialized zinc storage system. It is also used for boosting the immune system, improving growth and heath in zinc deficient infants and children, for treating the common cold and recurrent ear infections, the flu, upper respiratory tract infections, preventing and treating lower respiratory infections, swine flu, bladder infections, ringing in the ears, and severe head injuries. It is also used for the treatment of malaria and other diseases caused by parasites. The RDA for zinc for different age and sex groups is enlisted in **Table 2**.

Sources of Zinc

Food

Protein rich foods, such as meat and marine organisms, contain high concentrations of zinc (10–50 mg/kg wet weight), whereas grains, vegetables and fruit are low in zinc (usually < 5mg/kg) [**19,20**].

Water

Zinc is naturally present in water. The average zinc concentration in seawater is 0.6-5 mcg/l. Rivers generally contain between 5 and 10 mcg/l zinc. Algae contain 20-700 mg/l, sea fish and shells contain 3-25 mg/l, oysters contain 100-900 mg/l and lobsters contain 7-50 mg/l. Water should provide up to 0.5% of the recommended total daily intake of zinc.

Zinc deficiency

Zinc deficiency may manifest as acne, eczema, xerosis, non-specific oral ulceration, stomatitis, may disturb the sense of taste and smell. Severe zinc deficiency may cause night blindness. Impaired immune function in people with zinc deficiency can lead to the development of respiratory, gastrointestinal, or other infections. Zinc deficiency contributes to an increased incidence and severity of diarrhoea [**11**].

Copper

Copper is likewise engaged with numerous physiologic procedures, for example, angiogenesis, neurohormone homeostasis, and guideline of quality articulation, mental health, pigmentation, and insusceptible framework working. Human body contains small amount of copper content, an average adult has a total body content of 50–120 mg copper. Most of the copper is discharged in bile, and a limited quantity is discharged in urine [3, 20]. It is a cofactor for hundreds of enzyme reactions which are involved in production of energy, iron metabolism, activation of neuropeptide, synthesis of connective tissues, and neurotransmitter synthesis. The RDA for copper based on different age-sex groups is given in **Table 2**.

Sources of Copper

Food

The richest dietary copper sources include shellfish, seeds and nuts, organ meats, wheat-bran cereals, whole-grain products and chocolate. The absorption of copper is strongly influenced by the amount of copper in the diet, bioavailability ranges from 75% of dietary copper when the diet contains only 400 mcg/day to 12% when the diet contains 7.5 mg/day [**8**].

Water

Copper is found in surface water, groundwater, seawater and drinking-water, yet it is fundamentally present in complexes or as particulate matter. Copper concentration in drinking-water changes generally because of variations in water characteristics such as pH, hardness and copper availability in the distribution system. In an unpolluted zone of the River Periyar in India, copper concentrations in drinking water ranged from 0.0008 to 0.010 mg/l. In USA concentrations in surface waters ranged from 0.0005 to 1 mg/l. In the United Kingdom, the mean concentration of copper in the River Stour was found 0.006 mg/l [**11**]. Water should provide up to 12% of the recommended total daily intake of copper.

Table 2. Recommended Dietary Allowances (RDA's) for Zinc (Zn), Iron (Fe), Copper (Cu), Iodine (I).

Minerals	Zn		Fe		Cu		I	
Age	Male	Female	Male	Female	Male	Female	Male	Female
0-6 m	2 mg*	2 mg	0.27 mg*	0.27 mg	200 mcg*	200 mcg	110 mcg*	110 mcg
6-12 m	3 mg*	3 mg	11 mg*	11 mg	200 mcg*	200 mcg	130 mcg*	130 mcg
1-3y	3 mg	3 mg	7 mg	7 mg	340 mcg	340 mcg	90 mcg	90 mcg
4-8y	5 mg	5 mg	10 mg	10 mg	440 mcg	440 mcg	90 mcg	90 mcg
9-13y	8 mg	8 mg	8 mg	8 mg	700 mcg	700 mcg	120 mcg	120 mcg
13-18y	11 mg	9 mg	11 mg	15 mg	890 mcg	890 mcg	150 mcg	150 mcg
19-30y	11 mg	8 mg	8 mg	18 mg	900 mcg	900 mcg	150 mcg	150 mcg
31-50y	11 mg	8 mg	8 mg	18 mg	900 mcg	900 mcg	150 mcg	150 mcg
51-70+y	11 mg	8 mg	8 mg	8 mg	900 mcg	900 mcg	150 mcg	150 mcg

*adequate intake, m-months, y-years, mg-milligrams, mcg-micrograms.

Copper deficiency

Copper deficiency is not common in humans. Low copper levels can affect a person's immune system and energy levels. The effects of copper deficiency include spasticity, muscle weakness, anaemia, connective tissue disorders, osteoporosis, and low white blood count [**21**].

Iodine

Thyroid function is primarily regulated by thyroid-stimulating hormone (TSH), also known as thyrotropin. TSH secretion increases thyroidal uptake of iodine and stimulates the synthesis and release of T3 and T4. In the absence of sufficient iodine, TSH levels remain elevated, leading to goitre, an enlargement of the thyroid gland that reflects the body's attempt to trap more iodine from the circulation and produce thyroid hormones [**22**]. Iodine in food and iodized salt is present in several chemical forms including sodium and potassium salts, inorganic iodine (I_2), iodate, and iodide, the reduced form of iodine [**24**]. Iodine rarely occurs as the element, but rather as a salt, so it is referred to as iodide and not iodine. The RDA of iodine for different age groups is given in **Table 2**.

Sources of iodine

Food

The good sources of Iodine include seafood, dairy products, grain products, iodized salt and eggs. Dairy products and grain products are the major contributors of iodine to the diet. Iodine is also present in human breast milk and infant formulas [**10**].

Water

Iodine is present in water bodies naturally. The average concentration of iodine in seawater is up to 60 µg/l. Rivers usually contain about 5 mcg/l of iodine. Corals, sea shells and fishes contains high concentrations of iodine, mostly in the shape of thyroxin or tri-iodine thyroxin. So an average adult body should get about 5-7 % of iodine from drinking water of the recommended total daily intake.

Iodine deficiency

Iodine deficiency has various adverse effects on growth and development, and is the most common cause of preventable mental retardation in the world. If consumption of iodine for an average adult falls below approximately 10–20 mcg/day, hypothyroidism occurs, a condition that is frequently accompanied by goitre [**28**]. Goitre is generally the earliest clinical sign of iodine deficiency. Chronic iodine deficiency may be related with an increased risk of the follicular type of thyroid cancer. Consuming high levels of iodine can cause some of the symptoms as iodine deficiency, including goitre [**30**].

Conclusion and future prospective

The paper delivers the overall data of the nutritional value of minerals and their recommended dietary allowance, its sources from food and most importantly from water. Water provides Ca and Mg in highest proportion, but an average adult doesn't get these minerals in required amount. This is because of the use of reverse osmosis (RO) technology. RO rejects essential minerals from the water which are required for the healthy body. RO removes Ca and Mg from water which are essential for bones, thus consuming water with less proportion of these minerals disturbs the body balance and causes various chronic effects. The minerals like Cu, Zn and I are present in lowest proportion in water, but they are essential for human health. So it is necessary to get these minerals from water or from food in small proportions. The paper pulls the attention of the readers from all the domains to wisely choose the treatment method for potable water. The RO technology should be used for drinking water purpose by checking the parameters like pressure, composition, flow of water in such a way that the minerals are retained in the water and the human body should get those essential minerals from water.

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Conflicts of interest

There are no conflicts to declare

Keywords

Minerals, health, supplements, deficiency.

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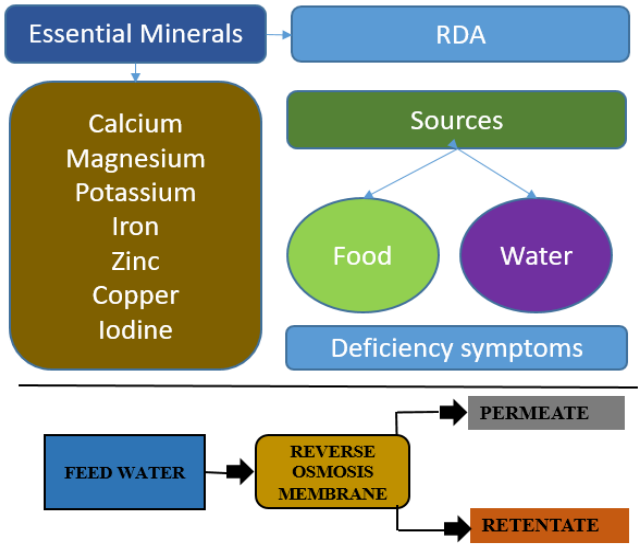
Graphical abstract

The paper summarizes the essential minerals present in the water required for human health and nutrition, their recommended dietary allowance (RDA), sources and deficiency symptoms. The use of Reverse Osmosis membrane rejects these minerals, which disturbs the body balance and can cause various chronic effects. The paper pulls the attention of the readers from all the domains to wisely choose the treatment method for potable water.



SUPPORTING INFORMATION

Table 3. Comparative data for essential minerals

Minerals	Sources in food	Concentration in water in mg/l (Sources)		Deficiency effects/Symptoms	References
		River water	Sea water		
Calcium	All milk products, orange juice, tofu, salmon, and kale	1-2	400	Tingling in the fingers, muscle cramps, seizures, lethargy and abnormal heart rhythms	5-12
Magnesium	Green leafy vegetables, raw cacao, nuts, dark chocolate, tofu, legumes and whole grains	4	1300	Loss of appetite, nausea, vomiting, fatigue, weakness and coronary fits	4, 8, 13-15
Potassium	Soybeans, milk, coffee, tea, other non-alcoholic beverages and potatoes	2-3	400	Increased blood pressure, kidney stone risk, bone turnover constipation, fatigue and muscle weakness	2,8,11,14,17
Iron	Nuts, beans, vegetables, legumes, fortified grain products, chocolate, tofu, bread, rice, raisins, spaghetti, broccoli	0.5-1	< 0.1	Delayed nerve conduction, decreased capacity for physical work.	3,8,9,11,18
Zinc	Protein rich foods, meat and marine organisms	< 0.1	< 0.1	Acne, eczema, xerosis, non-specific oral ulceration, stomatitis.	3,11,19,20
Copper	Shellfish, seeds and nuts, organ meats, wheat-bran cereals, whole-grain products and chocolate	< 0.1	< 0.1	Muscle weakness, anaemia, connective tissue disorders, osteoporosis, and low white blood count	8,11,20,21
Iodine	Dairy products, grain products, iodized salt and eggs	< 0.1	< 0.1	Goitre, hypothyroidism	10,22,28,30