Natural Mineral Waters: Chemical Characteristics and Health Effects

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Summary

Water contributes significantly to health and a daily intake of 1.5 to 2 liters of water should be guaranteed, because a good hydration is essential to maintain the body water equilibrium, although needs may vary among people. However, worldwide population is far from the Recommended Allowance for water intake.

Among the waters for human uses, there are 'waters (treated or not), intended for drinking, used for the food and beverages preparation or for other domestic purposes' and *natural mineral waters,* that are 'originated from an aquifer or underground reservoir, spring from one or more natural or bore sources and have specific hygienic features and, eventually, healthy properties'. According to the European Legislation (2009/54/EC Directive), physical and chemical characterization is used to make a classification of the different mineral waters, basing on the analysis of main parameters. Mineral composition enables to classify natural mineral waters as bicarbonate mineral waters, sulphate mineral waters, chloride mineral waters, calcic mineral waters, magnesia mineral waters, fluor urate mineral waters, ferrous mineral waters and sodium-rich mineral waters.

Although the concerns about bottled mineral waters (due to plasticizers and endocrine disruptors), many are the health effects of natural mineral waters and several studies explored their properties and their role in different physiological and pathological conditions.

Introduction

Water covers most of the earth surface and composes most of the human body; this can illustrate the critical linkages between water, health and ecosystems (1).

From outer space, the earth looks like a “blue” planet because most of its surface is covered by water. Only 2.5% of that water is fresh, and most of that lies frozen and inaccessible in the icecaps and Greenland, leaving less than 1% of fresh water accessible in lakes, river channels and underground. Only about one third of the world’s potential fresh water can be used for human needs. As pollution increases, the amount of usable water decreases.

Water contributes significantly to health and good health is the essence of development. However water’s protective role is largely unseen and taken for granted in the wealthier countries. Its contribution to health is directly within households through food and nutrition, and indirectly as a means of maintaining a healthy, diverse environment. These two precious resources — water and health — together could enhance prospects for development (2). In humans, about 60% of body weight (BW) is represented by total body water (TBW), distributed into intracellular and extracellular fluid compartments, which contain about 65 and 35% of total body water, respectively (3, 4). Water is involved in many body functions, since it serves as a carrier of nutrients and substances in the circulatory system. Furthermore, it is the vehicle to excrete products and eliminate waste and toxins and it also lubricates and provide structural supports to tissues and joints. However, there is no efficient mechanism of body’s water storage; therefore, a constant supply of fluids is needed to keep water content (4).

The water needs can be partially satisfied by an overall diet and water contained in food (5): fruit, vegetables and milk are composed for the 85% by water. Meat, fish, eggs and fresh cheese contain the 50–80% of water; and cooked pasta and rice about 60–65%. Whereas, bread and pizza contain water for 20–40% and bakery products (like biscuits, rusks and breadsticks) are composed by water only for less than 10% (6).

Nevertheless, a daily intake of 1.5 to 2 liters of water should be guaranteed, because a good hydration is essential to maintain the body water equilibrium, although needs may vary among people because of age, physical activity, personal circumstances and weather conditions (7). In Table 1 are reported the Recommended Daily Allowances for water in the difference age ranges and physiological conditions in Italy (8).

Table 1

Recommended Daily Allowance for water in Italy, LARN *(Livelli di assunzione di riferimento di nutrienti)* 2014: nd= not defined. The age groups are referred to the chronological age: i.e. 4–6 years is the period between the fourth year and the seventh year of life. The period 6–12 months correspond to the second life semester.

LARN WATER (mL/die)

	Age ranges	AI Adequate Intake
INFANTS	6–12 months	800
CHILDREN-TEENAGERS		
	1–3 years	1200
	4–6 years	1600
	7–10 years	1800
Males	11–14 years	2100
	15–17 years	2500
Females	11–14 years	1900
	15–17 years	2000
ADULTS		
Males	18–29 years	2500
	30–59 years	2500
	60–74 years	2500
	≥75 years	2500
Females	18–29 years	2000
	30–59 years	2000
	60–74 years	2000
	≥75 years	2000

LARN WATER (mL/die)

Age ranges	AI Adequate Intake
PREGNANCY	+350
BREASTFEEDING	+700

The choice of the water to drink can be variable and it depends on the personal necessity. By European Community legislation (Directive number 98/38), among the waters for human uses, there are *waters (treated or not), intended for drinking, used for the food and beverages preparation or for other domestic purposes* (in Italy, D. Leg. N. 31 of 02/02/2001). Drinking water has to be "*clear, odorless, tasteless, colorless and harmless, that is devoid of pathogenic microorganisms and harmful chemicals to humans"* and safety on the basis of microbiological, physics and chemicals parameters control (in Italy, D.M. n. 84 of 26 March 1991). Mineral waters represent a valid choice to meet the daily water intake.

As reported in the European legislation (2009/54/EC Directive) *natural mineral waters* are "originated from an aquifer or underground reservoir, spring from one or more natural or bore sources and have specific hygienic features and, eventually, healthy properties" (in Italy, D. Leg. N. 176 of 2011). They are different from drinking water because of their spring purity and conservation, for the constant level of minerals (trace elements or other constituents) and, where appropriate, for certain effects they can determine.

Food and drug administration (FDA, USA) regulates bottled water as a food and identifies *natural mineral waters* as "water containing not less than 250 parts per million (ppm) total dissolved solids (TDS), coming from a source at one or more bore holes or springs, originating from a geologically and physically protected underground water source" (Code of Federal Regulations, Title 21, Part 165 - Beverages).

The consumption of bottled mineral waters has greatly increased during the past few years, worldwide. The U.S. and International Developments and Statistics report that United States, Western European countries and several Asian nations registered an increase in bottled water markets (9) and by 2017, people all over the world are expected to consume about 391 billion liters of bottled water (10).

Many studies have focused attention on the safety of bottled mineral water, in particular on the migration of chemicals from plastic containers to water. Plasticizers (additives used to impart flexibility and handling properties to several kinds of plastics) (11) and *endocrine disruptors* (EDs - chemicals that interfere with function of the endocrine system) (12) are the main compounds involved in adverse effects on human health.

Nevertheless, natural mineral waters have intrinsic demonstrated properties and this review intends to explore them and their wide proved effects on the prevention and the treatment of different physiological and pathological status.

Characteristics of natural mineral waters

"Natural mineral water" means 'microbiologically wholesome' water, but ensures the absence of the main contamination indicators (parasites and pathogenic microorganisms, Escherichia coli and fecal streptococci, sporulated sulphite-reducing anaerobes, pseudomonas aeruginosa) both at source and during its marketing (13). The characteristics of a natural mineral water have to be proved from different points of view:

- geological and hydrological, that requires a detailed description of the catchment site, considering the nature of the terrain, the stratigraphy of the hydrogeological layer and a description of the catchment operations;
- physical, chemical and physicochemical, that implies a report about the main physical and chemical analysis to describe the final characteristics of the mineral water (i.e. rate of flow of the spring, temperature at source, dry residues at 180°, pH, anions and cations, trace elements, toxicity of certain constituent elements);

- microbiological, ensuring the absence of the main contamination indicators;
- possible pharmacological, physiological and clinical effects. The clinical researches should be conducted in order to certificate the physiological effects and benefits on human health; they should be scientific studies, conducted in long term periods and with different methodologies (13, 14).

According to the European Legislation (2009/54/EC Directive), physical and chemical characterization is used to make a classification of the different mineral waters, basing on the analysis of main parameters (3). First of all, natural mineral waters are classified by the fixed residue at 180°, that is the amount of residual mineral salts (in mg) after the evaporation of 1 L of water at 180°C (Table 2).

Table 2

Classification of natural mineral waters based on fixed residue at 180°C (14).

Fixed residue at 180°C	Definition
< 50 mg/L	Very low mineral content water (or light mineral water)
50–500 mg/L	Low mineral content water
500–1500 mg/L	Medium mineral content water
> 1500 mg/L	Rich mineral content water

By law, there is no upper or lower limits for minerals contents in natural mineral water; instead of the tap drinking water, that are strictly regulated as regards the fixed residue at 180°C.

Mineral waters are also classified by other physical parameters, like pH, temperature and hardness. With regard to pH, mineral waters are classified as acid water (pH<7) or alkaline water (pH>7). By temperature, mineral waters may be cold (< 20°C at source), hypotermal (20–30°C at source), mesothermal waters (30–40°C at source) and hyperthermal waters (> 40°C at source). Hardness indicates the presence of alkaline earth metals and mineral

waters may be very soft (0–100 mg/L of CaCO3), soft (100–200 mg/L of CaCO3), hard (200–300 mg/L of CaCO3) or very hard (> 300 mg/L of CaCO3) (15).

The effect of the water in many metabolic pathways is associated, in many cases, to its role of suppling and transporting different minerals. Minerals are inorganic compounds with biological essential functions, as bone and teeth mineralization, regulation of hydrosaline balance at the basis of cellular exchanges, activation of various metabolic pathways (Table 3).

Table 3

Minerals present in some mineral waters and examples of their biological functions in human body.

Category	Mineral	Some biological functions
Macronutrients present in the human body in modest quantities	**Calcium**	Bone development, regulation of muscle contraction and myocardium activity, blood clotting, nerve impulses transmission, regulation of cell permeability.
	Chlorine (Cloruri)	Hydrochloric acid formation (digestive juices for digestion process).
	Phosphorus	Protein synthesis, ATP synthesis and transport of energy in biological systems.
	Magnesium	Bone formation, nervous and muscular activities, lipid metabolism and protein synthesis, CVD protection.
	Potassium	Muscles and myocardium activities, neuromuscular excitability, acid-base balance, water retention and osmotic pressure.
	Sodium	Fundamental regulation of cell permeability and body fluids; defency is rare, but an excessive intake may be associated with high blood pressure.
	Sulphur (Solphate)	Essential amino acids, cartilage, hair and nails formation, enzyme activity in redox processes and cellular respiration, intestinal peristalsis.
Micro-nutrients trace elements, essential for some biological functions	**Cobalt**	Constituent of vitamin B12: growth factor, nucleic acid synthesis, hematopoiesis.
	Chromium	Enzymatic reactions involved in the metabolism of carbohydrates, lipids and proteins.

Category	Mineral	Some biological functions
	Iron	Blood and muscle tissues: hemoglobin, myoglobin.
	Flourine (Fluoride)	Protection and prevention of tooth decay, bone development; diseases related to excess.
	Iodium (Iodide)	Essential for the synthesis of hormones that are involved in the growth process and body development.
	Manganese	Synthesis of several enzymes involved in the metabolism of proteins and sugars, bone development.
	Molybdenum	Production of enzymes associated to uric acid.
	Copper	Functionality of several enzymes in blood and muscles.
	Selenium	Protection of the muscle membrane integrity, antioxidant.

They are essential for humans because the organism cannot produce them, so it's necessary a regular intake from foods and water. The availability of minerals from food is less than mineral water, because in foods minerals are bound to complex molecules that can limit their absorbability, instead in water they are present as free ions (16).

On the basis of minerals content, waters have been classified in several ways: Marotta and Sica classification (1933) represents in Italy the first reference and it takes into consideration temperature, fixed residue and chemical composition, according to a scheme that includes classes and subclasses. They gave a name to each mineral water considering, firstly, the prevalent anion and secondly, the cation; they classified waters as salt waters, salty-sulfate waters, bicarbonate-sulfate waters, salt-bromine-iodine waters, etc. (3). Although in Europe and in United States there are many categorizations of mineral waters (17, 18), nowadays the 2009/54/EC Directive is the European reference to classify them. As reported in the EC Directive, mineral waters can be:

- "Water with bicarbonate", if bicarbonate content is >600 mg/L
- "Water with sulfate", if sulfate content is >200 mg/L
- "Water with chloride", if chloride content is >200 mg/L

- “Water with calcium”, if calcium content is >150 mg/L
- “Water with magnesium”, if magnesium content is >50 mg/L
- “Water with fluoride”, if fluoride content is >1 mg/L (More than 1,5 mg/L of fluoride is unsuitable for children below the age of 7)
- “Acid water”, if the CO_2 content is >250 mg/L
- “Water with sodium”, if sodium content is >200 mg/L. The lettering “indicate for low sodium diet” can be added to labels if sodium content is <20 mg/L.

Natural mineral waters and administration

The classification of natural mineral waters on the basis of the mineral content is also useful to identify the health properties of each type. The *Italian Geothermal Union* has largely investigated the roles and the effects of the natural mineral waters (19) and have periodically diffused news about the usage of the different type of natural mineral waters for specific upsets (Table 4).

Table 4

Characteristics of the main natural mineral waters and their respective general therapeutic indications (22).

Type of Natural mineral water	Content of the main mineral (mg/L)	Applications
BICARBONATE	>600 mg/L	Promote digestion, because neutralizes gastric acidity.
SULPHATE	>200 mg/L	Lightly laxative; it is suggested for hepatobiliary diseases.
CHLORIDE	>200 mg/L	Balance of intestine, bile ducts and liver; laxative effect.
CALCIC	>150 mg/L	It is suggested for adolescents, pregnant women, subjects who don’t consume dairy products, elderly men; contributes to prevent osteoporosis and hypertension.
MAGNESIAC	>50 mg/L	Promote digestion.
FLUORURATE	>1 mg/L	Strengthen teeth structure and prevent dental decay; helps in osteoporosis.

Type of Natural mineral water	Content of the main mineral (mg/L)	Applications
FERROUS	>1 mg/L	It is suggested for anemia and iron deficiency.
SODIUM-RICH	>200 mg/L	It is suggested for intense physical activity (to replenish the salts leaked through sweating).
LOW-SODIUM	<20 mg/L	It is suggested in case of hypertension.

Nevertheless, many are the clinical studies and researches that have been developed to demonstrate healthy properties of natural mineral waters.

"Bicarbonate mineral waters"

Bicarbonate natural mineral waters are cold and alkaline mineral waters with low mineral content and diuretic properties. Several studies have demonstrated the positive effects of bicarbonate mineral waters on digestive tract. Studies on crenotherapy treatments (20) and on patients with functional dyspepsia show that the consumption of bicarbonate mineral water may neutralize acid secretion, increase the pH level in the gastric lumen, accelerate gastric emptying and stimulate the release of digestive hormones (known to have pivotal roles in the regulation of gastric function) (21).

The alkali load of this mineral water seems to be important for the decrease of bone resorption. Few studies investigated the properties of bicarbonate-rich mineral water, especially waters with a strongly negative potential renal acid load. They proved to create an alkaline environment and decrease bone resorption and bone resorption markers (C-telopeptides) (23). This effect is demonstrated in subjects with adequate calcium intake and in comparison with acid calcium-rich mineral waters (sulphate calcium-rich mineral waters) (24).

Many studies show the health effects of bicarbonate mineral water on cardiometabolic risk biomarkers (reducing especially total-cholesterol, fasting glucose and LDL-cholesterol) (25) and in the prevention of Cardiovascular Diseases (CVD). In particular, sodium-bicarbonate

waters demonstrated to significantly decrease serum total cholesterol and LDL-cholesterol, to increase HDL-cholesterol and, moreover, produce a significant reduction in soluble intercellular adhesion molecule (26, 27). Moreover, compared to low mineral waters, sodium-bicarbonate waters decrease post-prandial lipaemia and aldosterone levels (28). The capacity of reducing lipaemia after meals may be associated to the capacity of lowering increase in cholecystokinin concentration and lowering gallbladder emptying, which may limit the release of biliary salts into the duodenum and therefore reduce postprandial lipaemia (29), especially the plasma triglyceride (VLDL triglyceride and chylomicron triglyceride) (30).

"Sulphate mineral waters"

Sulphate mineral water is characterized by the presence of sulphate anion, with different cations (4). The presence of specific cations combined with sulphate enhance the properties of these waters: magnesium sulphate and sodium sulphate mineral waters demonstrated to be really efficient for functional constipation conditions (31). Drinking mineral water rich in magnesium sulphate and sodium sulphate can confer significant benefits for healthy digestion, in terms of improvement of constipation symptoms, overall bowel movements and stool consistency (32).

A more complex mineral system, as the sulphate-bicarbonate-calcium-magnesiac mineral water, has a therapeutic activity in the functional disorders of the biliary tract: this water is particularly efficient thanks to elective anions that exert choleresis and cholagogue actions, helping to remove the gallbladder hypomotility and to correct the tendency to biliary sludge (33).

Sulphate is an obligate nutrient for numerous metabolic and cellular processes, particularly in foetal growth and development. For this reason sulphate mineral waters demonstrate to be an alternative choice for diet of pregnant women (34).

"Chloride mineral waters"

Chloride mineral waters are composed by chloride as predominant element and the most abundant cations are sodium, calcium and magnesium. Although studies about their health effects are scarce, chloride mineral water may exert their properties for bowel functions: they may stimulate intestinal peristalsis and intestinal secretion of water and electrolytes (3). Moreover, they may have a choleretic and cholagoge action by increasing biliary secretion and bile inflow into duodenum (4).

Chloride is often present in combination with sodium and they are the main constituents of "Salt mineral waters". They may be used for hydropinic therapy and can be either hypo-, hyso- or hyperthermal waters inducing different biological effects, such as a stimulating effect on both gastric emptying and interdigestive cyclic motor activity of the gastro-duodenal tract (15). Their use is in particular indicated for hydropinic therapy for disease of the gastrointestinal system (35).

The salt-bromine-iodine waters are characterized by the combination of chloride and sodium with iodine and bromine. They are well known for their anti-inflammatory activity and are used in a variety of pathological conditions, such as diseases of the gastrointestinal system (36).

"Calcic mineral waters"

Calcium is the main mineral of the calcic mineral waters. It is generally recognized that calcium intake is important for skeletal health and that it may be beneficial to several non-skeletal body systems, as nervous system, muscle and blood system (37). Calcium is a cation that can be associated with different anions, that give to calcium mineral waters specific properties. The main anions are bicarbonate and sulphate. Some studies investigated the potential role of bicarbonate calcium-rich water in maintaining an alkaline environment and in improving acid-base balance in the body (38, 39). In fact, diet components (and also mineral waters) may have basic or acid effects and their role on bone mineral density,

especially in elderly, have been largely studied (40). The study conducted by Wynn et al. on European and North American commercial waters reveals that bicarbonate calcium-rich water has an alkalizing power and may increase serum and urinary pH, creating an optimal environment for bone mineralization (39). A French study shows that in post-menopausal women, with low calcium intake, the consumption of high calcium mineral water lowers indices of bone remodeling (41). A systematic review and a meta-analysis on five studies shows that, although only a few studies with a relatively small number of subjects are available, the calcium bioavailability of mineral waters is at least comparable to, and possibly better than, that from dairy products or pharmaceutical preparations (42). Because of calcium bioavailability, high-calcium mineral waters represent an important dietary source of calcium and should be recognized as good low-calorie nutritional calcium supplements (43). The beneficial effects of calcium-rich mineral water on bone mineralization is widely demonstrated. A study conducted by Costi et al. on 255 women shows that using regularly water rich in calcium improves the average spine mineral density (44). Similar results was shown in the study of Aptel that included 4434 women over 75 years of age. An increase of 100 mg/day in calcium from drinking water was associated to a 0.5% increase in femoral bone density (45).

European Food Safety Agency (EFSA) recognized the Health claim on calcium '*is important for the development of bones'* and in this prospective calcium-rich mineral waters may be consumed as '*functional foods'* (46).

"Magnesiac mineral waters"

Magnesiac mineral waters are characterized by magnesium as the essential component. This water may be useful in obstetric-gynecologic pathologies: pre-menstrual syndrome, climaterium and postmenopausal osteoporosis (3).

Magnesium may be combined with other minerals. Magnesium sulphate mineral waters improves bowel function, in terms of reduction of constipation, improvement in the constipation symptoms and overall bowel movements (32). *In vitro* studies demonstrated

that magnesium sulphate may act as a cathartic by increasing the aquaporin 3 (AQP3) expression level and by changing osmotic pressure in the colon (47).

Sulphate-bicarbonate-calcium-magnesiac mineral waters proved to have therapeutic activity in the functional disorders of the biliary tract. High magnesium content favors the Oddi sphincter relaxation and allows the bile flowing, improving biliary ducts activity (33).

Results from a recent meta-analysis demonstrate that in European population, (in particular in Scandinavian population), high levels of magnesium in drinking water may reduce the risk of Coronary Heart Disease (CHD) mortality (48).

"Fluorurate mineral waters"

Mineral waters with fluoride may be indicated for children, because they can reduce the incidence of decay and promote bone mineralization. However, fluorurate mineral water consumption has to be maintained low (49). The concerns about high fluoride intake are related to their possible carcinogenic effect, but actually the results of epidemiological and animal models studies show that fluorurate mineral water is not directly associated to cancer risk (50, 51).

High fluorurate mineral water consumption may have some toxic effects: from dental fluorosis to skeletal fluorosis, if fluoride intake is above than 10 mg/L (49). For this reason, the European Food Safety Agency (EFSA) established fluoride upper limit of exposure to 1,5 mg/L/die (52). This value limit is confirmed also by World Health Organization (53).

“Ferrous mineral waters”

There are two principal types of ferrous waters: sulphate-ferrous/ferric waters and bicarbonate ferrous waters. The sulphate-ferrous/ferric waters are very concentrated and are arsenic-rich. The pH is very low for the presence of sulphate and phosphate acids. The bicarbonate-ferrous waters are arsenic-poor, the pH is of about 6 and they have important haemopoietic properties (15). They are indicated in iron-deficiency anemia and they are also recommended for pregnant women, specifically in the treatment of anemia (54). In fact, the bioavailability of iron in this water is very high due to the presence of other trace elements: copper, zinc, manganese, lithium and aluminum (4). Moreover, they demonstrated beneficial therapeutic effects on specific chronic phloglosis of the upper respiratory tract (55).

“Sodium-rich mineral waters”

Sodium-rich mineral waters are characterized by the presence of sodium as the main cation, that can be associated to different anions.

The concern about the consumption of this water and the association with hypertension is reasonable when sodium is bound to chloride. In this case, they are not recommended to subjects suffering for cardiovascular diseases (CVD) (4).

Although few are the studies that investigate bicarbonate sodium-rich mineral water properties, some report health effects of this water. Schoppen et al. report that in post-menopausal women bicarbonate sodium-rich mineral water may be protective against CVD risk (26) and may increase insulin sensitivity (56). An animal study investigated the potential role of hypersaline sodium-rich naturally sparkling mineral water in the protection against Metabolic Syndrome (MS): in an environmental model for MS, the intake of sodium-rich water demonstrated to maintain low some parameters normally involved in the MS development (as insulin, leptin, aldosterone, melatonine) (57).

Conclusions

The concerns about bottled mineral water are related to the release of chemicals from bottles to water. Among these are the plasticizers, like the Di(2-ethylexyl)phthalate (DEHP) that is widely used as plasticizer and is also present in PET bottles (11). Polyethylene terephthalate (PET) is a material chemical inactive, but some *in vitro* studies proved that storage conditions (like exposure to sunlight and high temperature) may contribute to the release of chemicals from bottles to water (32, 58, 59).

The EDs represent another important issue for bottled water. Some *in vitro* studies investigated the exposure to chemicals with estrogen-like activity in bottled mineral water. Pinto et al. analyzed 30 samples of nine Italian mineral waters, stored in PET bottles, and the results show that 90% of samples elicited an estrogenic activity lower than 10% of the activity induced by the reference model (12). On the contrary, analysis on German mineral water, stored in PET, glass and TetraPak bottles, demonstrate a significantly elevated estrogenic activity in 12 of 20 brands (60). In an updated study, bioanalytical techniques and *in vivo* experiments with molluskan model are used to determine the estrogenicity of bottled water. The estrogenic activity of bottled water form PET containers is approximately twice compared to products from glass bottles (61). The release of estrogenic compounds from plastic material has been investigated also for tap water, that is distributed through plastic pipes. The summarized results show that the migration of 2,4-di-tert-butylphenol (2,4-d-t-BP) from plastic pipes could result in chronic exposure and the migration levels varied greatly among different plastic pipe materials and manufacturing brands (62).

It is not demonstrated if the concerns about bottled water influence water intake. However, nowadays, Mediterranean countries population, as Italy, Spain and France prove to be below the EFSA Allowance Intake (AI) for Total Water Intake (TWI) (63–65). Also US population is far from the Recommended Allowance for water intake, both in males and in females (66). Studies prove that socio-economic status influence the consumption of water as a beverage: adults with higher incomes consumed more water as a beverage than adults with lower incomes (65, 66).

Adequate water intake, and especially drinking natural mineral water, is associated with higher diet quality: in France, women with the largest consumption of drinking water intake had higher diet quality and less energy dense diets, also thanks to healthier food choices (e.g., more fruits and vegetables and fewer sweets). Moreover, the study in French population demonstrated that micronutrients intake is positively associated to the water intake (65). The National Health and Nutrition Examination Study in US also documented a positive association of total water, plain water and moisture in foods with dietary and serum minerals, vitamins and carotenoids (67).

Natural mineral waters are characterized by specific mineral content and are classified on the basis of the main elements that compose them. Several Authors explored the properties and health effects of mineral waters, sometimes through not updated studies or with low number of subjects.

Gastrointestinal system results to be stimulated by natural mineral waters. In particular, bicarbonate and chloride mineral waters proved to have positive effects for gastric function. Animal and *in vivo* studies on an Italian bicarbonate mineral water show its role in neutralising acid secretion, increasing pH level in the gastric lumen and stimulating the release of digestive hormones (21). Chloride mineral waters are mainly used for hydropinic therapy, stimulating gastric emptying and gastro-duodenal peristalsis (35). Bowel function results to be promoted by sulphate and magnesium mineral waters, in terms of reduction of constipation, improvement in the constipation symptoms and overall bowel movements (31, 32).

Biliary tract functionality is favored by a more complex mineral system, as the sulphate-bicarbonate-calcium-magnesiac mineral water, that is particularly efficient thanks to elective anions that exert choleresis and cholagogue actions, helping to remove the gall-bladder hypomotility and to correct the tendency to biliary sludge. High magnesium content favors the Oddi sphincter relaxation and allows the bile flowing, improving biliary ducts activity (33).

In iron-deficiency anemia and in the treatment of anemia for pregnant woman, ferrous waters are highly recommended (54). Mineral waters with fluoride may be indicated for children, because they can reduce the incidence of decay and promote bone mineralization. However, fluorurate mineral water consumption has to be maintained low (49).

Skeletal health and bone mineralization need a regular calcium intake and calcic mineral waters represent an important dietary source of calcium and should be recognized as good low-calorie nutritional calcium supplements (43). The calcium bioavailability of mineral waters has been investigated by different Authors and it is demonstrated that calcium from mineral waters is bioavailable as dairy products, sometimes also more than milk (37, 42). Moreover, calcium-rich mineral waters increase bone mineralization, considering both femoral and spinal bone mineral density after calcic waters intake (44, 45). EFSA identified calcium with the health claim 'is important for the development of bones' and calcium-rich mineral waters may be recognised as 'functional foods' (46).

Emerging studies on CVD report that bicarbonate mineral water may have health effects on cardiometabolic risk biomarkers (reducing especially total-cholesterol, fasting glucose and LDL-cholesterol) (25) and, compared to low mineral waters, sodium-bicarbonate waters decrease post-prandial lipaemia and aldosterone levels (28). The capacity of reducing lipaemia after meals may be associated to the capacity of lowering increase in cholecystokinin concentration and lowering gallbladder emptying, which may limit the release of biliary salts into the duodenum and therefore reduce postprandial lipaemia (29), especially the plasma triglyceride (VLDL triglyceride and chylomicron triglyceride) (30). Moreover, Schoppen et al. report that in post-menopausal women bicarbonate sodium-rich mineral water may be protective against CVD risk (26) and may increase insulin sensitivity (56). A recent meta-analysis, instead, demonstrated that in European population, (in particular in Scandinavian population) high levels of magnesium in drinking water may reduce the risk of Coronary Heart Disease (CHD) mortality (48).

Metabolic Syndrome (MS) is an increasing burden and the consumption mineral waters may help to prevent it. An animal study investigated the potential role of hypersaline sodium-rich naturally sparkling mineral water in the protection against MS: in an environmental

model for MS, the intake of sodium-rich water demonstrated to maintain low some parameters normally involved in the MS development (as insulin, leptin, aldosterone, melatonine) (57).

In conclusion, natural mineral waters represent a valid choice in everyday life to satisfy water needs of body and, because of their documented characteristics (about mineral composition and health benefits), they may be consume in different physiological and pathological conditions. However, other studies could be useful to understand the biochemical pathways involved in health effects of natural mineral waters.

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