



Proceeding Paper

Evaluating Methods to Enhance the Taste and Health Benefits of Alternative Potable Waters [†]

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Abstract: As conventional sources of freshwater continue to be impacted, the use of alternatively produced drinking waters, such as desalinated seawater or condensed atmospheric water, are being increasingly consumed. Lacking the minerals and other natural properties of surface and ground waters, alternative waters are often modified or amended to address taste and health issues. This presentation explores some of those treatments in terms of the proposed taste and health benefits, the water quality issues addressed, and the pertinent research on bottled or specialty waters that could assist in identifying how alternative waters might be best amended or modified.

Keywords: water; alternative sources; health; additives; taste

1. Introduction

The combination of climate change and environmental pollution has impacted the quality and quantity of drinking water available from conventional freshwater sources. In response to these dwindling potable water resources, a growing number of alternative water sources have emerged in the form of technologies that were introduced or markedly improved during the last two decades. These technologies include desalinated ocean or brackish waters, condensed atmospheric water, recycled wastewater, and captured cloud or fog water, all of which produce potable waters that often lack the minerals and other natural properties of ground and surface waters [1]. Hence, alternative waters are increasingly amended with salts or mineral solutions, adjusted for pH or ORP, and treated in other ways to improve taste or enhance human health.

The primary emphasis of water quality has traditionally been identifying and remediating contaminants in potable sources in order to reduce human health risks; however, characterizing quality solely by the absence of toxins overlooks water's potential health benefits in other ways. Public drinking waters have historically been treated to address taste, odor and/or clarity issues [1], but how these treatments may have influenced the nutritional value or health attributes of water (other than providing hydration) has received only limited attention. One exception is fluoride that, while present at detectable levels in some natural waters, remains a controversial additive to potable waters because of the perceived tradeoffs between preventing dental caries and impacting systemic health [2]. Moreover, fluoride is not designated as an essential human nutrient.

A review of the ways in which alternative waters are amended or altered suggests that some are more common, more extensively researched, or potentially more effective than others are. Recent insights into the physics and chemistry of water, combined with an improved understanding of the factors that influence human taste and health, provide a framework for exploring potential enhancements to alternative waters. Many of these enhancements were initially introduced in the form of specialized bottled waters that were marketed as a healthier option than tap water [3].



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2. Minerals and Organics

Potential healthful benefits of drinking water have focused predominantly on minerals, also known as electrolytes, that are essential to the optimal functioning of the human body and are sometimes present at sufficient concentrations in source waters to be consequential. Major minerals typically include calcium, magnesium, sodium, chloride, and potassium. At least some trace minerals are normally present in source waters (e.g., selenium, chromium, iodine, phosphorus), whereas others may either be present in source waters or released from storage and conveyance materials comprising water distribution systems (e.g., iron, manganese, copper, zinc). While many of these trace minerals are essential nutrients at low concentrations, elevated levels in drinking water can pose toxicity problems. By contrast, elevated levels of major minerals are usually not a toxicity issue but can adversely affect the water's taste.

Minerals are normally dissolved in water as inorganic ions (positively or negatively charged), although minerals can also be complexed with organic compounds. The nutritional value of minerals in water is highly dependent on a number of variables, including their valence state or electrical charge, the presence of other minerals (especially as ions), a person's particular gut flora, the volume of water normally ingested, and any foods that may be consumed with the water. Phytochemicals or biochemicals present in a variety of different foods can increase or, more commonly, decrease the bioavailability of minerals dissolved in drinking waters. As such, most essential minerals in the human diet are provided by food [4], within which they are typically complexed by organic molecules such as amino acids and carbohydrates.

Drinking water generally supplies less than 5% of the recommended intake of most minerals, with the exception of calcium and magnesium that could account for as much as 20% of the recommended intake under unusual circumstances [4]. A number of epidemiological studies have reported a reduced incidence of cardiovascular disease and hypertension in communities where the tap water is at least moderately hard [5,6], meaning that the combined calcium and magnesium levels are a minimum of 60 to 120 parts-per-million (ppm), reported as calcium carbonate.

As people have a relatively wide range of taste sensitivities for water, assessing subtle changes in the levels of major minerals based on taste alone is difficult. Nonetheless, waters possessing major minerals, which comprise most of the total dissolved solids (TDS), in excess of 500 to 600 ppm are not palatable to many people due to their salty taste. Conversely, waters containing less than 25 ppm of major minerals often have a flat or bitter taste that can be unpleasant. Even at slightly elevated concentrations, many of the trace minerals can impart a metallic taste to water that is considered objectionable.

In addition to the electrolytes (minerals) that may enhance human health, there are usually organic compounds present in natural waters that could do the same. The most notable of the organics are fulvic acids, which are produced from the microbial decomposition of plants and contain various vitamins, amino acids, carbohydrates and lipids that might be beneficial to human health, depending on their purity (i.e., absence of toxins) and bioavailability [7]. Besides potentially harboring contaminants, some organic compounds can also impart an unpleasant taste to water and, consequently, are normally removed using routine water treatment techniques.

3. ORP and pH

In addition to substances dissolved in drinking water, various physical properties of water have been correlated with both taste and human health. Two properties frequently cited are potential hydrogen (pH) and redox potential (measured as an oxidation-reduction potential or ORP), which indicate the water's relative acidity or basicity and oxidative or reductive capacity, respectively. Adjusting the pH of potable water to prevent metals leaching from pipes or to improve taste and disinfection, has long been an accepted water treatment practice. Acidic drinking water can taste bitter or metallic, while basic water often tastes soda-like. Increasing the pH of water specifically to enhance human health, as

is the case with various bottled or specialty waters, is a more recent trend that has been applied to alternative waters only to a limited extent.

Artificially adjusted waters with a pH greater than 8.0 are generally referred to as “alkaline”, although true alkaline waters have a basic pH resulting from the dissolution of alkali minerals containing sodium or potassium, rather than from modifications via neutralizing filters or electric ionizers. Alkaline water can reportedly act as an antioxidant, hydration enhancer, acid neutralizer, and reducer of blood viscosity [8,9], although some of these health claims are disputed on the basis of their lack of adequate supporting research. Questions surrounding the health claims for alkaline water often relate to the body’s efficient systems for tightly regulating the pH of extracellular body fluids [10], regardless of a drinking water’s pH unless it is hazardously acidic or basic.

Water with a relatively high pH normally has a correspondingly low ORP, accounting for alkaline water’s designation as an antioxidant. Most natural freshwaters have a moderately high or positive ORP value (i.e., oxidizing), rather than a lower or negative ORP value (i.e., reducing), but this depends largely upon the extent to which the waters are oxygenated—either naturally or artificially. Reducing conditions in potable water are often considered to be beneficial inasmuch as they can neutralize free radicals and, thus, minimize the damaging effects. A more recent trend in lowering ORP is the infusion of water with hydrogen gas, produced by electrolysis or dissolving tablets, for purposes of enhancing its antioxidant, anti-inflammatory and metabolic benefits [11,12].

The most common methods for raising the pH and lowering the ORP of alternative drinking water include passing it through a neutralizing media containing calcium carbonate or magnesium oxide and injecting it with sodium hydroxide or sodium carbonate. Sodium-containing additives are sometimes considered less desirable from a health perspective due to excess sodium’s role in hypertension. Electrolysis and molecular hydrogen infusion (using elemental magnesium and an organic acid) are more expensive methods of pH/ORP adjustment, and the former technique generates an acidic waste stream.

Reported health benefits for drinking low ORP water, such as its antioxidant effects [13], differ from those posited for drinking highly oxygenated (higher ORP) water, which include improved exercise recovery and liver function [14]. Oxygenated water generally has a fresher taste, particularly when cold, than flatter-tasting waters with less dissolved oxygen or other gases. Oxygenating alternative waters is one of the simplest methods to improve its taste and can be achieved by injecting oxygen or ozone gases. Whereas the reported health benefits of low ORP waters (including hydrogen-infused) and oxygenated waters (including ozone-infused) are plentiful in the popular literature, they too are controversial. Questions focus on the fate of these modified waters following ingestion and on the biochemical mechanisms by which they are presumed to function [15,16].

4. Molecular Nuances

Water’s potential health effects may also include nuances of the water molecules themselves. Liquid water is actually a complex and dynamic network of molecules that connect to one another via connections known as hydrogen bonds, which can switch trillions of times per second. This switching among neighboring molecules permits water to flow as a liquid and yet possess much of the molecular structure of a solid (i.e., ice). Besides the bulk liquid network, water molecules can combine to form a variety of geometric assemblages or clusters within which the intermolecular connections persist somewhat longer. Water containing such clusters is sometimes referred to as structured, as it appears to have greater order or more regular clusters than the bulk liquid.

Natural waters are structured as a result of geological, hydrological, fluvial, and other processes. Artificially structured waters are usually produced by introducing various solutes or specific materials into the water or exposing it to an array of fields and energies (e.g., electric, magnetic, vortical, thermal). Drinking structured water has been associated with health benefits such as reducing inflammation and oxidative stresses [17,18]. As a result of the aforementioned hydrogen bond dynamics (even within clusters) and the restructuring

of ingested water upon contact with biological molecules or surfaces, questions persist about the mechanisms proposed for structured water's reported health benefits. Unlike pH and ORP that are easily measured in water, molecular structure is often inferred from physical properties such as density, viscosity, and surface tension. A lower surface tension has been associated with a smoother taste and texture of water.

Intracellular water that is structured inside living cells has been hypothesized to behave as a kind of gel in facilitating many cellular functions [19], thus prompting the question of how intracellular water might be influenced by ingesting externally structured water. Theories range from externally structured water's requirement of less metabolic energy for internal restructuring, to its provision of optimum hydration and removal of toxins from the body. Since water molecules enter living cells primarily through small channels (i.e., aquaporins) in a single-file manner [20], any extracellular water structuring is probably lost while transiting the cell membrane. At present, the molecular structuring of alternative waters is performed almost exclusively by consumers. If structuring were to be used for alternative waters on a larger scale, magnetic and vortical methods might be the most likely candidates as they have been applied to various non-potable waters.

Approximately 0.02% of water's hydrogen atoms consist of a heavier isotope (i.e., deuterium), the resulting concentration of which depends on the latitude, elevation, and precipitation temperature of natural waters. So-called deuterium depleted water (DDW) has a concentration that is less than the global average of approximately 150 ppm and is theorized to be healthful because the body's biological processes and structures generally favor hydrogen over deuterium due to the associated water's chemical and physical properties [21]. The mechanisms responsible for DDW's health benefits (e.g., correcting metabolic or genetic processes, inhibiting cancer proliferation), have been more extensively investigated than those for structured waters. DDW is artificially produced via a continuous distillation process that is expensive and, thus, unlikely to be applied routinely to alternative waters.

5. Remineralization

Drinking water produced via reverse osmosis (RO), including that obtained from household systems, water vending machines, and almost all bottled waters, is sometimes remineralized in order to improve taste or nutrition, as well as to achieve specific goals for pH and ORP. Without the remineralization of alternative waters, TDS concentrations are typically less than 20 to 30 ppm. Whereas, the remineralization of low TDS waters is designed to address taste and potential deficiencies of major minerals, there are some interesting questions related to how and why the waters are remineralized.

Perhaps most controversial is whether routinely consuming low TDS water poses a risk to people by osmotically extracting minerals from the body's structures or extracellular fluids that possess higher mineral contents. Whereas mineral leaching has been identified for foods that are cooked or prepared in low TDS water, a similar leaching process has not been demonstrated in human bodies [22,23]. Healthy bodies possess an array of integrated control systems (e.g., sensory, hormonal, excretory) for retaining or expelling specific minerals to maintain the ionic composition of extracellular fluids.

Other questions about water remineralization relate to both the actual salts that are utilized and the ratio of major minerals in added solutions. The most common additives to low TDS waters are calcium carbonate and magnesium oxide, which have limited bioavailability but raise the pH and provide a buffering effect. Other sources of mineralization include various salts, concentrated mineral liquids, and even seawater, most of which are dominated by sodium and chloride. Though seawater has a mineral composition similar to that of blood plasma, it has an ORP higher than most natural freshwaters and often contains organic compounds derived from marine organisms. While some of these compounds have potential health benefits, their addition to alternative waters is unlikely to be implemented.

Some drinking water additives claim to have an ideal ratio of major minerals or a suite of important trace minerals. However, most trace minerals are provided by food and,

although drinking waters may emulate the ratio of major minerals in extracellular fluids, there are numerous factors that can result in the differential absorption of those minerals. Consequently, minerals are not necessarily absorbed in proportion to the ratios reflected in liquids, salts, or other additives, requiring the body's homeostatic processes to maintain the precise suite and concentration of minerals comprising those fluids.

When remineralizing alternative waters with a low TDS, an important consideration is taste. Taste is a function of the minerals dissolved within it, as well as its temperature, oxygen content, pH, and organic carbon content. Palatability is also influenced by people's own taste sensitivity and by any materials or chemicals that contact the water during its treatment, storage, or transport [24]. Perhaps as important, from a nutritional perspective, is the presence of calcium and magnesium, the latter of which is a common mineral deficiency due to its relatively low concentration in most foods. The bioavailability of magnesium from mineralized waters is similar to that from foods, and its levels in bodily fluids are stringently controlled by the kidney's excretion and retention processes [25].

6. Conclusions

Much of the evidence (both scientific and anecdotal) presented for the health benefits of amended, modified, or specialty waters is based on one of several types of inquiries. The first includes animal studies and *in vitro* laboratory investigations that are valuable and represent an essential step in researching health effects, but alone are not definitive. Another is the study of people whose drinking water has one or more of the specified attributes and who appear to be either healthier or longer-lived than most others. These studies frequently represent small or regional populations that are geographically and/or socially isolated and, thus, may possess diets and lifestyles that differ appreciably from those of most postmodern populations.

Another line of evidence for the reported benefits of ingesting modified or specialty waters pertains to the treatment of specific diseases or chronic health problems. Fewer research studies have focused on whether, or how, these waters may improve or sustain wellness among relatively healthy people and, therefore, the routine or prolonged consumption of some modified or specialty waters has been questioned. Additionally, at least some of the hypothesized health benefits are based on product-sponsored research, which may be legitimate but would benefit from corroborating studies by funders who have no financial stake in the findings. Finally, anecdotal observations and customer testimonials can be quite useful, but are not definitive, in evaluating actual health benefits.

Nonetheless, results from all of the aforementioned types of investigations and observations collectively suggest that water's quality is not limited to its simply being free of contaminants. Whereas accepted scientific mechanisms for the efficacy of some of the purported health benefits of water modifications or additives do not currently exist, it does not mean that such benefits are without merit. Research into human nutrition has revealed unexpected, but generally accepted, influences on processes ranging from gene expression to brain plasticity for which the mechanisms are not yet fully understood.

Research studies that investigate both the health effects of modified or amended alternative waters, and mechanisms for their doing so, would be valuable in evaluating whether relatively healthy people might benefit from routinely drinking them. Research into the health benefits of high-quality natural waters [26], which could serve as a model for amending alternative waters, may also be a productive endeavor. Given the likelihood that alternative drinking waters (e.g., recycled, desalinated, atmospheric, cloud captured) will be increasingly consumed as a result of the ongoing depletion and pollution of traditional surface and ground water sources, it would seemingly be worthwhile to better understand how these alternative waters could be optimally modified to improve taste and to potentially promote human health.

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