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CONSUMPTION OF LOW TDS WATER

Since the beginning of time, water has been both praised and blamed for good health and human ills. We now know the real functions of water in the human body are to serve as a solvent and medium for the transport of nutrients and wastes to and from cells throughout the body, a regulator of temperature, a lubricator of joints and other tissues, and a participant in our body's biochemical reactions. It is the H_2O in water and not the dissolved and suspended minerals and other constituents that carry out these functions. Total dissolved solids (TDS) is a measure of the combined content of all inorganic and organic matter which is found in solution in water. Water low in TDS is defined in this paper as that containing between 1-100 milligrams per liter (mg/l) of TDS. This is typical of the water quality obtained from distillation, reverse osmosis, and deionization point-of-use water treatment of public or private water supplies that are generally available to consumers in the world. Worldwide, there are no agencies having scientific data to support that drinking water with low TDS will have adverse health effects. There is a recommendation regarding high TDS, which is to drink water with less than 500mg/L. Some people speculate that drinking highly purified water, treated by distillation, reverse osmosis, or deionization, "leaches" minerals from the body and thus causes mineral deficiencies with subsequent ill health effects.

An isolated report, a summary of Russian studies available through the World Health Organization, has recommended that fluid and electrolytes are better replaced with water containing a minimum of 100 mg/L of TDS. However, this may pertain more to situations in the human body during heavy exertion and sweating. This situation does not have anything to do with low TDS or demineralized water for normal drinking and cooking purposes. Even in warm weather exercise, the greatest danger is that of dehydration, and the proper advice to ward it off is to drink lots of plain water. It is the market for sports drinks which are formulated to help replace the sugar compounds, glucose in the blood and glycogen in the muscles that are burned in prolonged exercise. Sports drinks are formulated to help replace the sugar compounds - glucose in the blood, glycogen in the muscles - and electrolytes - salt, calcium, and potassium that keep cells in proper electrolytic balance - that may be burned and depleted after an hour or more of hard exercise.

The scope of this paper is limited to answering whether low TDS water contributes to the loss of minerals from body tissues, producing associated harmful side effects. The types of minerals -e.g., calcium versus sodium, or hard water versus soft water-- and the toxicity of minerals -e.g., lead, cadmium, brackish, or saline waters- are not an issue in this report. Information on the body's homeostasis mechanisms, community water supplies with natural TDS less than 50 mg/L, historic use of distilled water with less than 3 mg/L TDS on board Navy ships, the US Environmental Protection Agency's (USEPA) response to this issue, and other evidence are presented to demonstrate that the consumption of water with low levels of minerals is safe.

Established Drinking Water Standards

A review was conducted of the United States, Canadian, World Health Organization (WHO) and European Community (EC) drinking water standards. None have minimum limits or optimum levels of total dissolved solids. The US recommended maximum level is 500 mg/L, as is the Canadian guideline. In the EU, since the adoption of the new revision of the Drinking Water Directive (98/83/EC) in 2003, TDS, hardness, and alkalinity no longer have listed limits; member states are allowed to add limits if they wish. Maximum level recommendations are made for aesthetic reasons, but there is no health criteria documentation for these advisories. These levels are listed as aids to operation for water supply systems, i.e., suggested parameters for laying down a passivating film of scale in municipal distribution mains. Calcium, magnesium, hardness, and alkalinity conditions are not necessary for judging the safety of drinking water.

The Natural Control of Mineral Concentration in the Human Body

A better understanding of the effect of low TDS water on the human body requires a basic understanding of the body's mechanism in this respect. Following is a description of the relevant mechanism (Guyton 2006):

> “Homeostasis is the maintenance of static or constant conditions in the internal body environment. This natural process controls the mineral (ion) and the water concentrations in the body fluids within narrow limits inside and outside all the cells in all the organs and tissues of the body. The kidneys are most important in maintaining constant ion concentrations (including sodium, potassium, calcium, etc.) through elimination and reabsorption. In homeostasis, three body fluids are involved: plasma (approximately 3/5 of the blood volume); interstitial fluid (the fluid between cells); and intracellular (fluid inside the cells). The concentration of sodium ions is highest outside the cell and that of potassium ions is highest inside the cell. When the osmotic pressure is high on one side of the cell membrane (high concentration of ions) and low on the other side, water moves across the cell membrane from the dilute side toward the other side to equalize the osmotic pressure. This phenomenon is known as osmosis. This is unlike reverse osmosis which occurs when outside pressure is applied to the concentrated side, pushing the water back to the dilute side. The normal osmolality (concentration of ions) of all these fluids is about 300 milliosmoles per liter (mOsm/L), or 9,000 mg/L.
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> Any changes from normal in ion concentration across the cell membrane is corrected in one minute or less because water moves quickly through cell membranes. Thus, small changes in osmolality from drinking purified water (0-100 mg/L TDS) are quickly brought to equilibrium.
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> The kidneys control the overall concentration of the constituents of body fluids. It filters about 180 liters (165 quarts) of water per day, but over 99% is reabsorbed and only 1.0-1.5 liters are eliminated as urine. If the osmolality of the fluid to be filtered by the kidney is lower than normal (low solute concentration - such as low TDS water) nervous and hormonal feedback mechanisms cause the kidney to excrete more water than normal and thus maintain the ion concentration in the body fluid to normal values. The opposite is true if the ion concentration of the fluid to be filtered is higher than normal. This kidney homeostatic mechanism keeps the body fluid osmolality normal. The osmolality of the fluid to be filtered by the kidney is controlled to ± 3% to maintain it at the normal level of 300 mOsm/L. The three basic hormonal and nervous control systems triggered by abnormal ion concentration in the body fluids to be filtered by the kidney are antidiuretic hormone (ADH) from the pituitary gland, aldosterone from the adrenal glands, and thirst (as osmolality rise of about 1% causes thirst).
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> Because of these kidney control mechanisms, drinking one liter of water would cause the urine output to increase about nine times after about 45 minutes (due to absorption of water in the gut) and continue for about two hours. Thus, the concentrations of solutes in the blood and other body fluids are quickly maintained by the kidney through homeostasis. These control mechanisms keep the sodium concentration at ± 7%. Calcium secretion is controlled by

parathyroid hormone to ± a few percent in the extracellular body fluid. Also, saliva increases the ion concentrations during water intake. The concentration of sodium chloride in saliva is typically 15 milliequivalents per liter (mEq/L) or 877 mg/L; that of potassium ion is about 30 mEq/L (1170 mg/L). As low TDS water is consumed, it is combined with saliva which increases the TDS before it reaches the gut to be absorbed, (e.g., each one mL of saliva can increase the TDS level in eight ounces of water consumed by about 10 mg/L).

Therefore, it is evident that consumption by a healthy person of low TDS water alone cannot cause unhealthy systems. 'Healthy person' means free of disease, hormonal problems, etc., and not necessarily a healthy diet. Homeostasis is maintained by diet as are other body functions. If homeostasis is not maintained because of major diet deficiencies, disease, or hormonal dysfunction, consuming low TDS water would be a minor (if any) factor in any observed symptoms. It is apparent that disease, physiological dysfunction, or major nutritional deficiencies may cause a "leaching" problem, but not consuming one to two liters of low TDS water on a daily basis."[1]

Literature Search and Review

A review of the literature has shown that there is very little information published in western scientific literature that relates the consumption of low TDS water to physiological effects on the human body. A report submitted to the World Health Organization in 1980 contained an annex reviewing work that had been reported in Russian literature. Current literature searches do not uncover any official translation of any of the articles cited in that annex. The annex concludes that consumption of water with less than 100 mg/L disturbs the body's water/salt balance, promoting the release of sodium, potassium, chloride, and calcium ions from the body of animals or humans, imposing a stress on the mechanism of homeostasis, promoting changes in the gastrointestinal muscles and mucosa, and reducing the thirst quenching capacity of the water. This annex has been intensively reviewed by many scientific experts, including Dr. Lee Rozelle and Dr. Ronald L. Wathen (see Appendix A for the complete reviews).

US EPA's Dr. Edward V. Ohanian, Chief of Human Risk Assessment Branch wrote, "Drinking water supplies a number of minerals that are important to human health. However, drinking water is normally a minor source of these minerals. Typically, the diet is the major source of these beneficial minerals. I am not aware of any data adequate to support the conclusion that water with low levels of minerals is unsafe."

An additional search performed in 2014 reviewed a WHO publication on Nutrients in Drinking Water, which includes the meeting notes and related articles discussed in a 2003 meeting.[2,5,9] There are chapters in this paper discussing consumption of demineralized water, which suggest that more research may be necessary to determine if guidelines should be established for minimum drinking water TDS limits, but the overall symposium conclusions are silent on the matter. The most recent WHO Guidelines for Drinking Water Quality (4th edition, 2011) discusses palatability and scaling issues at high TDS, but does not discuss low TDS. It also states that no health-based guideline value for TDS has been proposed.

Discussion of Field Experiences

There are no known scientific data which clearly demonstrate that the consumption of low TDS water by humans will or will not lead to harmful effects on the human body. However, a number of field experiences can be cited which support the premise that the consumption of such water by humans does not cause such harmful effects. There are no known documented experiences which show that consuming low TDS water will create any long-term health effects.

The US Navy has used distilled sea water for human consumption for approximately 40 years.[3] TDS levels below 3 mg/L have been reported and consumption of this water for months at a time is common on submarines. No health problems have been reported by the Navy. The US Army uses reverse osmosis units to provide drinking water for soldiers in the field. The USEPA conducted a project in San Ysidro, New Mexico in which the TDS was dropped from 800 mg/L to a range of 40 to 70 mg/L. No health effects were observed. NASA has reported no ill effects from the consumption of approximately 0.05 mg/L TDS water on board space craft.

Possibly the largest field study of human consumption of low TDS water is within the United States where municipal systems are delivering water in this category. Millions of people currently consume such water, and this practice has gone on for decades. Exact data are difficult to obtain due to seasonal changes, use of blended water from multiple sources, and changes of sources. In addition, thousands of private wells, as well as numerous small municipal systems in the US produce low TDS water. No known health effects or problems have been reported as a result of this widespread practice. Thousands of TDS reduction devices have been sold residentially in the United States for decades. No reports of mineral depletion or health effects are known as a result of the consumption of this water. In a field test in Boulder, Colorado with about 50 families, an experimental, zero discharge water system provided drinking water containing about. 0.05 ppm TDS. No ill health effects were caused as a result of drinking this water. In conclusion, the field experiences cited suggest that there are no long-term ill health effects, specifically the mineral leaching from human tissue, due to the consumption of low TDS water.

Conclusion

It has been concluded that the consumption of low TDS water, naturally occurring or received from a treatment process, does not result in harmful effects to the human body. This is based upon the following points:

- No public health organization with authority over the drinking water quality anywhere in the world has enacted or even proposed a minimum requirement for total dissolved minerals in drinking water.
- The human body's own control mechanism (homeostasis) regulates the mineral content of the body fluids and the discharge of different types of ions from the body of normal health individuals drinking water with low or high mineral content.
- Several types of scientific literature searches have found no harmful effects to the human body attributable to the consumption of low TDS water.
- Review of the Soviet report has shown that the scientific methods used are questionable and the conclusions are either vague or unsupported by the data.
- Many examples of real-world situations in which large populations have been and continue to be provided exclusively with low TDS water without any reported unusual or ill health effects, establishes the safety of consuming such waters by human beings.

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Appendix A

Dr. Rozelle review:

"The data for their conclusions are not very convincing from a scientific viewpoint. The volume of water consumed per day was not indicated and the length of time of the experiment for the human "volunteers" was not indicated (one year fpr rats). The physiological changes reported apparently were based on rat and dog studies. For dogs, the same physiological changes were observed for water containing *50* mg/L and 1, 000 mg/L. The conclusion of a minimum TDS of 100 mg/L is confusing and thus not very convincing. In the human studies, diuresis was observed particularly on the second day of the study (the increase in urine output reported to be 18%). The volume of water in the body from the "distillate" was reported to be 50-100% higher than the "other groups." They also reported increased elimination of sodium, potassium, chloride, calcium, and magnesium in the urine, and the specific gravity was reduced. In the blood serum, the sodium was increased and the potassium decreased. Then it was reported that the "tendency" for similar changes were observed after consumption of 100 mg/L TDS and 1,00 mg/LTDS. The water intake (based on thirst) of various TDS waters was not clearly reported. In some cases it was difficult to determine if the data were from animals or humans. In summary, the Russian studies, as reported in Annex 8 of the WHO document appeared not to be rigorously scientific."

Dr. Wathen review:

"The annex of the report is an alleged "review" of water and salt balance under the influence of a variety of water and salt intakes, in a variety of animals, including humans, exposed to a variety of conditions. The review is long on deductions, but very short on (re) presentation of solid data. Moreover, probably only a handful of references cited in this review (assuming they are cited correctly) may be from creditable scientific journals, that is, journals which demand proper scientific methodology and peer review of all work, prior to publication. Many of the cited articles may be from journals of "personal opinion": being versed only in English, it is impossible for me to establish the credibility of the cited work. This review cited observations on the organoleptic features of water (i.e., consumer appreciation of taste, odor, and color qualities) to underscore precise, physiologic thirst slaking with specific levels of TDS -- containing water in response to volume depletion. To begin with, the quoted electroencephalographic studies probably indicate only that a maximum number of receptor sites (taste buds) have to be recruited through stimulation to provide a maximum brain (alpha) wave response and that the TDS level in water providing the maximum response was between 200-600 mg/L of salt. One would expect such a response; one might also imagine that receptor response (sensitivity) is considerably tempered by prior salt and mineral exposure for the individual. Organoleptic features are very, very unlikely to define whether a given water source is healthful on non-healthful or that the amount imbibed is appropriate to need. Moreover, taste receptor electrical activity, being unlikely to reveal preference by the consumer, means the consumer must be asked whether he or she prefers a given type of water. More often than not, preference reflects prior experience (learned behavior).

The review refers to exposure to desert and exercise conditions for humans and how water lost in sweating should be replaced, not with purified water but with salt water. Who would disagree with this conclusion? With GatoradeR, for example, selling to extremely large US and world markets, one hardly needs to be reminded in this day and age that volume and salt losses encumbered with the sweating of heavy exercise are best replaced with a fluid whose constituents are more aligned with extracellular fluid in the human. GatoradeR, though billed a being "low sodium" on its label, is in fact rather high in salt content (both sodium and potassium) and it provides a rapid, convenient, and safe way to promptly reconstitute vascular volume after heavy exercise. Dizziness, even syncope (passing out), from volume depletion are thereby avoided and strength of the individual is better sustained, due both to volume replacement and the glucose contained within Gatorade.

Gatorade is a water source to be taken only to replace severe fluid losses accompanying sweating; it generally averts the need for supplemental salt tablets. Gatorade, in an opinion which may not be shared by the Gatorade Company (Chicago, IL), is not a source which should be used to replace normal fluid and electrolyte losses any more so than pure water should be used to accommodate severe volume losses. In the presence of salt accompanying usual dietary food intake (4-8 gm/day of sodium in US), Gatorade might conceivably lead to volume excess. A 64 oz. serving of Gatorade contains: 880 mg of sodium; 200 mg of potassium; and about 400 calories, as carbohydrate (112 grams). There is no magical solution; one should drink what's appropriate to the circumstance. Replacement of the large fluid losses accompanying heavy exercise or thermal exposure, therefore, has nothing to do with using purified water for normal drinking and cooking purposes, the latter being paired with normal food intake to meet salt and mineral needs. In normal day-to-day activity not associated with extremes in sweat loss, the salt and minerals accompanying normal food intake more than meet daily dietary needs of such elements, whether consuming potable water (e.g., TDS of up to 500 mg/L) or purified water (e.g., TDS 100 mg/L) or pure water (e.g., 0.111 mg/L TDS).

Salts and minerals are not "leached" from the human body; they are preferentially retained or excreted, either of these events occurring relative to whether or not one is surfeit in water or salt or both. In short, the human body is not a lead or copper pipe which "leaches" in the presence of purified water. The Annex VIII review is very misleading in this regard.

I also think it is incredible to suggest that, in the absence of abnormal water loading experiments, consumption of demineralized water will cause distortion of the mucosal cells lining the GI tract. Besides, in the normal human setting, such water is often combined with other elements (e.g., coffee, tea, fruit juices, soft drinks, etc.) which raises its TDS prior to consumption. But, even if the TDS is not raised by some external means, through the additions of saliva, gastric secretions, and small intestine secretions beyond the stomach, there is an internal elevation in TDS of any dilute fluid one might drink. It would be my opinion that the adsorptive portion of the GI tract, that is, the small intestine, in the absence of extreme water loading, never sees a hypotonic solution sufficient to cause the mucosal cells to swell or to appear damaged. There is a tendency in this review to draw conclusions from observations in anhidrotic (nonsweating) laboratory animals (dogs, rats, and rabbits) and apply them to the very hidrotic (sweating) human. That is, the review often draws conclusions from fluid, electrolyte, and acid-base studies in "non-sweaters" and seems to transfer these conclusions to the "sweaters." It is imprudent physiologically, if not scientifically erroneous, to do so. I found the reported physiological data to be very confusing, often at right-angles to prior knowledge. One wonders if the responses to various levels of salt in water were confused when citing data from the actual papers used in the review.

I personally have never heard of osmorceptors being present in the gut which might serve to regulate fluid adsorption. And certainly, I have never heard of the liver being a repository of salt to be released to reconstitute salt levels in the vascular compartment. This statement, I think, is borderline preposterous. The literature cited here has been misconstrued or is comprised of essentially factitious observations. Salt in all body fluid compartments redistributes bidirectionally in attempts to off-set excesses or insufficiencies in extracellular fluid constituents, particularly in the vascular (blood volume) compartment.”