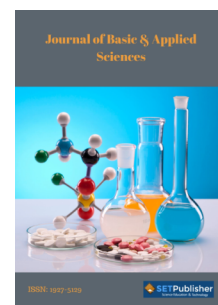




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Biologically Structured Water-A Review (Part 2): Redox Biology, Plant Resilience, SW Drinking Water Types, BSW Water and Aging, BSW Water and Immunity

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Abstract:

A review was conducted between redox biology and BSW water to link their interactions with cell bioenergetics. The exchange of electrons and protons from energized BSW water significantly contributes to recycling energy biomolecules during aerobic respiration. Plant resilience to biotic and abiotic stressors is also significantly improved by maintaining adequate levels of BSW water. The physicochemical properties of SW water are readily measured and are associated with improved human health. Natural healing water and SW water products have similar physicochemical properties. Medical literature shows a direct association between dehydration and age-related diseases. Drinking SW water enhances rehydration rates and increases intracellular water content. Research has also suggested that drinking SW water has a positive effect on certain neurological diseases and cancer types. Finally, drinking SW water improves the immunity system in humans.

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1. BSW WATER AND REDOX BIOLOGY

As Part 1 of this review mentions, BSW water has unparalleled prominence in biological redox reactions. The eminent redox properties of BSW water are due to the cold vortices of quasi-free electrons and protons within the interfacial structured water zone. The TEM images by Cardarella [1] of CD spheres show that the surfaces of the spheres were electron-dense, indicating that the spheres had cold vortex shells of quasi-free electrons (see Figure 1 in Part 1). These sub-atomic particles are donated and received for ultra-fast redox reactions to ensure redox homeostasis [1-9]. Electrons serve several functions, such as signaling particles, quenching of free radicals, or even combustion of O₂ by transferring single electrons that result in H₂O as the final product.

Redox biology is associated with cell membrane potential. Red and infrared light increases mitochondria membrane potential, increasing the energy and redox potential on mitochondrial membranes [17-20]. When the gain of electrons reduces NAD⁺, NADP⁺, and ADP, they are recycled back to NADH, NADPH, and ATP [9-11]. These biomolecules are critical in mitochondria pathways, calcium homeostasis, antioxidation, gene expression, immunological functions, aging, and cell death [9-11]. NADPH is a substrate for NADPH oxidase, which contributes to ROS signaling and hydrogen peroxide generation, which may be used to inactivate pathogens. When NAD⁺ is reduced by receiving an electron, it recycles back to NADH, and the NADH/NAD⁺ ratio increases. This NADH/NAD⁺ ratio is a key biomarker for many critical cellular functions, including metabolic pathways, DNA repair, chromatin remodeling, cellular senescence, and immune cell function [9-15].

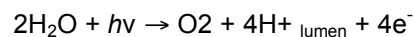
Unfortunately, the ability to maintain robust redox homeostasis with mitochondrial energy biomolecules declines with age [13-19]. Recent aging reviews reveal a causal link between declining NAD⁺ levels and increased risk in age-related diseases, including cognitive decline, cancer, metabolic disease, sarcopenia, and frailty [13]. Aging studies have shown that NAD⁺ is a vital cofactor/coenzyme and a signaling messenger that can modulate cell metabolic and transcriptional responses. Studies have shown that sirtuins are NAD⁺ dependent enzymes, and the availability of NAD⁺ regulates their activities. Sirtuins are essential enzymes in delaying cellular senescence, or the formation of 'zombie cells,' and extending longevity or lifespans. In summary, dysfunctional

mitochondria lead to increased oxidative reactions, a decline in robust redox homeostasis, and an increase in age-related disorders [13-19]. Numerous review articles suggest alternative precursor supplements to increase NAD levels or reduce ROS damage to mitochondria to extend human longevity. An alternative therapy to extend longevity that is seldom mentioned in health or aging journals is to increase BSW water levels by either replenishment by drinking SW water or exposure to red and infrared lamps to increase BSW levels with *in vivo* treatments. Both therapies will be explored further in the following sections of this review.

A study by Sohal *et al.* [20] studies the effects of redox dynamics on house fly longevity. They found that the NADH/NAD⁺ ratio decreased from 1.1 to 0.43 when flies reached 16 days old and reached 20% mortality. The decline in the ratio shows an oxidizing trend for NADH across the lifespan of flies. Also, there was a strong trend for H₂O₂ to increase across the lifespan of flies. Another house fly study by Farmer *et al.* [21] reveals that house flies with an increased rate of O₂⁻ production had shorter life spans. They state that as oxidative stress from ROS radical injury increased with age, the longevity of house flies decreased. These studies reinforce that maintaining redox homeostasis as aging occurs is critical to increasing longevity. Part 2 of this review series offers suggestions on maintaining BSW water levels as humans age, ensuring a ready supply of quasi-free electrons and protons for all redox reactions, and preserving redox health.

2. BSW WATER AND PLANT RESILIENCE TO ABIOTIC STRESSORS

Photosynthesis and BSW water are linked in a complex set of relationships. The first reaction in photosynthesis's light phase is splitting water to initiate the Electron Transfer Chain. In plant chlorophyll, Photosystem II splits water into protons (H⁺), electrons (e⁻), and molecular oxygen (O₂).



Recent research on PSII water splitting reveals that proton channels transport H⁺ from the water splitting site in PSII. Also, aquaporin channels supply PSII with water molecules [22-28]. This research shows that the proton wires, or channels, contain BSW water molecules constrained or restricted by electrostatic bonds to transport protons along delocalized H-bonds [22-28]. In addition, as BSW water levels increase, free protons (H⁺) with symmetric double-well energy profiles

can join with H_2O to form hydronium ions (H_3O^+), a carrier for H^+ [31]. Protons generated from splitting water can be removed by proton water wires or converted into hydronium ions in the presence of BSW water. Plant research also shows aquaporins supply BSW water to PSII for water splitting. However, aquaporins do not restrict water movement, so water can be transported into the PSII subunit without transporting protons simultaneously [22-28]. This research shows that BSW water, or strong H-bonded water, is crucial for PSII water-splitting activities.

Hussein *et al.* [28] investigated the water structure in PSII water channels. They state that water molecules along the aquaporin water channels are highly structured [28]. A study by Doyle *et al.* [29] also investigated water structure in PSII subsystems. They state that the Oxygen-Evolving Complex (OEC), or the water-splitting complex within PSII, contains crystallographic or crystal water. They also state that the Molecular Dynamic (MD) computer simulation shows a “higher electron density in the channel regions compared to waters in bulk, which indicates that the water structure is more ordered within the channels” [29]. The high electron density MD simulation estimates agree with the TEM images of SW water [30] mentioned in Section 1 of Part 1. SW water has delocalized electrons that circle the pentamer or hexamer water rings. This electron cloud that forms the outer shell of water spheres is electron-dense, indicating that PSII subunits contain BSW water with crystalline structures [30]. As previously mentioned in Part 1. BSW water is energized and only requires low energy input of red light to ionize water or split water without relying on high energy light frequencies that would injure chlorophyll tissue [31].

A study by Gauthier *et al.* [32] estimated that PSII subunits can generate up to $30 \mu\text{mol O}_2/\text{sq m/s}$ by splitting H_2O when exposed to a light intensity of $1,000 \mu\text{mol PAR}/\text{sq m/s}$ in French bean (*Phaseolus vulgaris*) plants. Their study shows that PSII water splitting under high-light intensity requires many water molecules (up to $3.61 \times 10^{19} \text{ H}_2\text{O}/\text{sqm/s}$) to generate the $30 \mu\text{mol O}_2/\text{sq m/s}$ in French bean plants. This estimate of water molecules is based on the fact that 12 H_2O molecules are required to be split to generate 6 O_2 molecules. The PSII research estimates that the aquaporins can supply this flux rate of water molecules. However, under full sunlight with high PAR values, the supply of BSW water could be rate-limited, thereby reducing water splitting rates and initiating

photoinhibition to protect PSII from excess free radical damage.

As mentioned above, magnetic fields increase SW water levels depending on static magnetic strength and exposure time [33-36]. Tu *et al.* [37] investigated the effect of magnetic fields on oxygen (O_2) production in an algal-bacterium symbiotic complex in a wastewater treatment study. They found a 24.6% increase in O_2 production when the algal-bacterium complex was exposed to a static magnetic field of 100 mT. Yang *et al.* [38] also investigated the effect of magnetic fields on *Chlorella vulgaris* on O_2 production. They found that O_2 production increased by about 100% after two h exposure to a static magnet field (250 mT). These studies indicate that static magnetic fields increased SW water in the culture solution, increasing the rate of water splitting in the bacteria PSII subsystem with a subsequent increase in O_2 production. These bacteria studies provide indirect evidence that increased levels of BSW water within chlorophyll optimize PSII water splitting rates. In other words, any rate-limiting restrictions due to a limited supply of energized BSW water in excess nutrient solutions are overcome by magnetic fields that increase SW water levels in the solution.

The terms tightly bound water and BSW interfacial water are synonymous in crop research involving drought tolerance. These terms refer to the strongly bound, interfacial water layer covering cell membranes or about 60-70% of the intracellular water content in plant tissue. Bound water in plant tissue is generally estimated using an instrument that measures water activity. These instruments measure free water in plant tissue in a sealed, temperature-controlled chamber [39]. As the free water evaporates in plant tissue and reaches equilibrium with the air vapor, the relative humidity of the air in the chamber is measured to estimate the water activity value. The amount of bound water can be estimated by subtracting the free water content from the total water content of the plant tissue.

Another method of measuring BSW water in plant tissue is Differential Scanning Calorimetry (DSC) [40]. This calorimeter method measures the temperature and heat flow associated with a material based on glass transition temperature values [41]. A stepwise change in the heat flow indicates when plant tissue's interfacial or intracellular water transitions from a liquid state to a “glassy state” [41]. When plant tissue water content is reduced to 0.1 g H_2O dry weight, the tissue enters a “glassy state” [41]. BSW water had liquid

crystalline properties, while a glassy state in plant cell cytoplasm has an amorphous mixture of biomolecules and water with extremely high viscosity.

The glass transition temperature marks the threshold when the rubbery stage in plant cytoplasm transforms into the glassy stage, and all the free water has been vaporized [42]. Kunzek *et al.* [43] found that the viscosity of glassy state water in plant tissue can reach 1,013 Pa s. This level of extreme dehydration can only be achieved by high temperature drying in ovens. When the intracellular water content is reduced from about 0.5 to 0.1 g H₂O/g tissue, the plant tissue is beyond rehydration and revival, even for desiccation-resistant plant species. The glass transition temperature (T_g) can be used as a biomarker to compare drought and desiccation tolerance in plant and crop species [44-45]. Exothermic peaks in the DSC data may indicate the degree of crystallization of the test material [46]. DSC software is programmable to test for T_g values in plant material. Given the assumption that BSW levels in plant foliage are correlated with drought tolerance, DSC tests for water properties in foliage would provide valuable insight into drought tolerance testing of crop varieties.

Numerous articles have correlated bound water levels in plants with increased drought tolerance [47-48]. Rascio *et al.* [47] investigated two wheat genotypes (*Triticum durum*) grown under water stress conditions. The first wheat genotype had a regular cell affinity for bound water or BSW water, and the second wheat genotype was a mutant genotype with a higher affinity for bound water. They found that the mutant wheat genotype with higher levels of bound, or BSW water, had significantly lower leaf temperature than the non-mutant genotype even as the air temperature increased to 35 °C. They also found that the mutant genotype had about 66% lower transpiration rates than the non-mutant genotype. Another genotype study by Rascio *et al.* [48] found that the drought-tolerant wheat genotype had a higher level of bound water in the wheat foliage.

Drought tolerance studies involving cotton by Ergashovich *et al.* [50] and Singh *et al.* [51] show a correlation between bound water levels in the foliage and increased tolerance to water stress. Jecmenica *et al.* [52] found that bound water in common bean foliage increased root length when bean plants were grown at 30 °C. Zhang *et al.* [53] found that the ratio of bound water to free water increased in water-stressed sugar cane that had a foliage chemical treatment. Wang *et al.* [54] studied the effects of hot, dry summers on a

drought resistant C4 tussock grass (*Heteropogon contortus*) used for grazing in China. They found that the bound water to free water ratio (BW: FW ratio) was the most sensitive parameter for measuring water stress sensitivity. Also, they found that the BW: FW ratio was 152% higher in the drought-resistant tussock grass grown at 4 % soil moisture compared to the control treatment grown at 10%. An ecological study by Yukui *et al.* [55] found that the BW: FW ratio was correlated with drought resistance in desert shrubs. Other studies show more indirect findings involving correlations between bound water in plants and their ability to increase drought tolerance or resistance. It is evident from this literature that the ability of a plant genotype or species to increase its BSW water levels also increases its drought tolerance and ability to minimize environmental abiotic stressors such as water stress.

Several reviews were published on the effects of watering plants with structured water [56-58]. However, very few studies have measured the properties of their structured water and the crop responses to their SW water treatments. A deficit irrigation study by Ramsey [59] investigated the effects of magnetized seeds and SW irrigation water on velvet beans (*Mucuna pruriens*) grown under water stress or reduced irrigation conditions. A complete description of the study methods and plant responses is described in Ramsey [59]. The combined effect of magnetized seeds and watering with SW water minimized kidney bean plant water stress levels based on the gas exchange responses. Also, the combined treatments resulted in a water saving of 29 to 49% for the optimum treatments. Correlation analysis among the gas exchange and soil moisture data revealed several plant responses were unlinked from their typical responses to increased water stress conditions for the optimum treatments.

In the two years following the publication of this article by Ramsey [59], a more in-depth data analysis revealed new findings to explain these improvements in drought tolerance due to the combined treatments. The data was reanalyzed to correlate unexplored gas exchange responses with the magnetized seed and SW irrigation water treatments (see this article in this special issue). The new findings show that the magnetized seed and SW water treatments altered foliage water properties and deactivated a large suite of plant defense responses intended to minimize plant injury to intense water stress conditions. Crop irrigation with SW water and magnetized seed treatments is

time-consuming and increases crop input costs. However, if irrigation water savings could approach even 30 or 40%, the additional input expenses may be cost-effective enough to evaluate in farm-scale studies. This study also indicates that plants are quantum coherent due to their ability to deactivate many critical plant defense activities in spite of soil moisture reaching about 2% (v/v) for the optimal seed and water treatment under the high water stress treatment. Despite the low soil moisture, the optimal treatment had an average daily water saving of about 50% that started about 30 days after planting into the 60-day study.

3. PHYSICOCHEMICAL PROPERTIES OF STRUCTURED WATER

There are many polymeric water structures and maybe hundreds of supramolecular water structures [30]. Analyzing the structure of water is a difficult task. However, SW water can be indirectly quantified and qualified by its water properties. Measuring the physicochemical properties of SW water is an inexpensive method of quantifying proton concentrations and potential for electron exchange rates. SW water's physicochemical properties differ from tap water, indicating the potential functional properties when SW water is converted into BSW water. Three physicochemical water properties are readily measured and are directly related to the ability of SW water to exchange electrons and protons in redox reactions. These properties are pH, oxidation-reduction potential (ORP), and electrical conductivity (EC), which directly or indirectly measure the concentrations of protons (H^+) or electron potential (e^-) in a water sample.

The concentration of H^+ in an aqueous solution is measured as the $-\log[H^+]$, otherwise known as pH [22-23]. When the covalent bonds for H_2O are broken, then H^+ or OH^- are the common ionic forms resulting from the half-reactions that form the basis for all biological acid-base reactions. The relative concentration of H^+ , or hydronium ion (H_3O^+) in solutions, supports much of the cell's needs for proton signaling and recycling of several biomolecules back to their non-reduced state. As mentioned in Part 1, as water becomes more structured, some protons have low energy barriers and, with negligible energy inputs, can join with H_2O to form hydronium ions (H_3O^+). In addition, hydronium ions are excluded from the EZ water zone, increasing membrane potential and the energy levels available for cells. Also, hydronium ions resonate at 7.85 Hz,

increasing the EZ water level on cell membranes. These findings show that increasing the pH levels within physiological limits also increases cell membrane potential and the EZ water zone in living organisms.

The status of electron concentration in an aqueous solution or cells is measured as the oxidation-reduction potential (ORP). A simple definition for ORP is a solution's capacity for electron transfer. ORP is an indicator of the oxidation-reduction status based on the collective electron activity within the solution [60-64]. Meters measure ORP as the voltage potential reading between the measuring and reference electrodes. A positive ORP indicates the ability to accept electrons as an oxidizing agent. A negative ORP indicates the ability to donate electrons as a reducing agent. Depending on the solution being measured, the ORP electrodes will serve as either an electron donor or an electron acceptor. Redox reactions that generate a negatively charged ion could include a wide range of molecules; thus, it is impossible to identify all the ionic species contributing to a cell's collective electron-based redox conditions. Because the ion species are difficult to identify in solution, ORP measures the collective electron concentration measured by electron flux or ORP in millivolts (mV), a numerical index of the intensity of oxidizing or reducing conditions within a system [60-64].

Most mineral and municipal tap water sources have a positive ORP of + 200 to + 400 mV (Table 1). The water sources in Table 1 also have a wide range of ORP values, indicating that humans can tolerate a wide range of ORP values, including negative and positive values, without any harmful health effects. Most drinking water sources have a positive ORP with pro-oxidant properties, i.e., the water receives electrons. In contrast, BSW water has a negative ORP; thus, the water can donate electrons and has tremendous antioxidant properties due to the ubiquitous presence of water in cells [65].

The scales for ORP and pH are similar in that they both have a neutral center point with negative and positive readings extending from the center point. The physiological range for pH in humans is tightly controlled, with a narrow range between 7.35 to 7.45. The physiological range for ORP is much higher, including + 150 mV in the stomach, -110 mV in the throat, and -250 mV in the large intestine [59]. Typical ORP values for cells range from approximately -10 to -90 mV, depending on the cell type [60-61].

Table 1: Typical Oxidation Reduction Potential (ORP) Values for Liquids, Drinking Water, or Biological Tissue for both Negative and Positive ORP Ranges [65]

Aqueous liquid	Redox potential (negative mV)	Aqueous liquid	Redox potential (positive mV)
Organic-rich saline	-400	Degassed pure water	+200
Euxinic water (H ₂ S)	-250	Distilled water	+250
Healthy human cells	-170 ~ -290	Groundwater	+250
Anaerobic yeast fermentation	-180	Mineral water	+200 ~ +400
Green tea	-100	Tap water	+220 ~ +380
Vegetable juice	-70	Surface seawater	≈ +400
Mother's milk	-70	Swimming pool	+400 ~ +475
Ave. human environment	-70	Rainwater	+600

Research was conducted on physicochemical water properties during the generation of SW water (Ramsey unpublished data). The physicochemical data shows a negative, linear relationship between ORP and pH (Figure 1). The regression equation in Figure 1 shows that a pH of 9.0 has an ORP value of -89 mV. This is a loose relationship because pH and ORP varies when measured in water samples with widely different properties. Also, the negative relationship shows that the concentration of hydroxide ions (OH⁻) or alkalinity of water and negative electron activity (negative ORP) are directly related to one another. This relationship also has implications for SW drinking water and overall health status and resilience to environmental stressors.

ORP is generally buffered in plants and animals to meet the cell type or organ functional needs. While pH

value can be measured within seconds, a stable ORP measurement can take up to several minutes, if not hours, to reach a stable value due to the type of reactions and their reaction rates. The ORP measurement is strongly influenced by metal surfaces and the cleanness of the electrode [61-62, 64]. Structured drinking water studies have not yet evaluated whether drinking water with high negative ORP values (> -250 mV) may be buffered as absorbed into the body, minimizing any potential health benefits of lowering overall ORP levels. Numerous drinking water studies, however, have correlated the physicochemical properties of structured water with any health effects [65-73]. The physicochemical properties of different water types or sources are listed in Tables 2, 3, and 4.

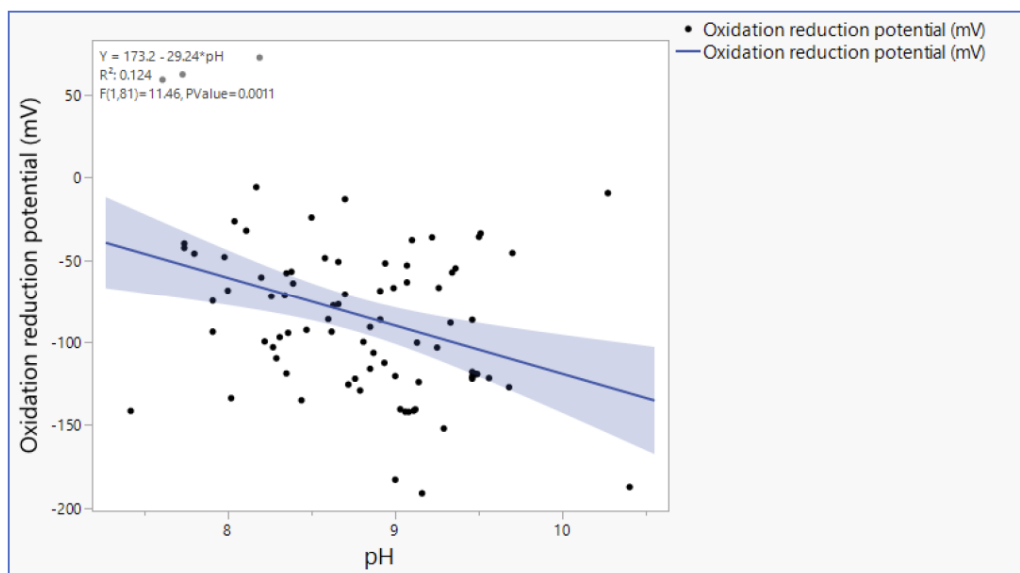
**Figure 1: Linear regression between ORP and pH for custom-generated SW water (unpublished data).**

Table 2: Comparison of Physicochemical Water Properties between Seawater and Several Types of Drinking Water. The Drinking Water Samples were Measured for the Four Water Properties by this Author

Water Description	Electrical Conductivity (uS/cm)	Oxidation Reduction Potential (mV)	pH	Total dissolved solids (ppm)
Sea water	50,000	+450	7.9	-
Charcoal Filtered tap water	397-418	-70 to -71	8.0-8.2	202-209
Unfiltered tap water	301.7	-76.6	8.315	-
Distilled water	4.22	-59.6	8.22	2.13
Mineral water	378.5	-178.0	8.33	189
Filtered bottled water	192	-136.1	6.42	96.1
Reverse osmosis water	69.7	-94	7.0	22
Commercial alkaline drinking water	195.7	+33.2	9.27	97.82

^aAverage value for surface seawater.^bCommercial water from the Colorado aquifer.^cWater generated from electrolysis using the cathode probe to collect alkaline water.**Table 3: Comparison of Physicochemical Water Properties between Structured Water Samples and Natural Springs, Wells, or Rivers known for Healing Powers or Promoting Good Health**

Water Description	Electrical conductivity (uS/cm)	Oxidation Reduction Potential (mV)	pH	Total dissolved solids (ppm)
Commercial structured water	860	+106.4	7.8-8.2	34
Custom Generated Structured Water - concentrated	8,000-10,000	-24	8-9	205
Custom Generated Structured Water - diluted	872-1,000	-13	7-8	697
Brandholz at Nordenau slate cave water ^b	Na	-250	8.01	Na
Water from Hunza river ^c	30.37 to 113.5 for river samples	-50 to -450	8.32 to 7.13 for river samples	22.61
Zamzam natural well water ^d	976-1390	Na	7.73	798-1000

^a<https://kaqun.hu/>.^bHenry M, Chambron J. Physico-chemical, biological and therapeutic characteristics of electrolyzed reduced alkaline water (ERAW). Water. 2013 Dec;5(4):2094-115.^cAli A. Hussain Z. Khan Z. Hussain A. An Assessment of Physico-Chemical and Microbiological Parameters of Water from Hunza and Gilgit Rivers, Gilgit-Baltistan Pakistan 2015 (www.jcbasc.org).^dAbdullatif BM, Baeshen AA. Assessment of Different Water supplies in Jeddah as an indicator of water quality and their impact on seed germination. Life Science Journal. 2013 Jan 1;1:10.**Table 4: Water Properties for Structured and Unstructured Tap Water**

Water Property	Structured water	Unstructured tap water
Density (g/ml)	0.97	1.0
Specific heat (cal/mol)	1.25 (18-20 cal/mol)	1.0 (15-18 cal/mol)
Viscosity (mPa.s at 25 C)	2-10 times tap water	0.89
H-bond energy (kcal/mol) ^a	24	2.4 to 12 (ave. 5.6)

^aMandumpal JB. A Journey Through Water: A Scientific Exploration of The Most Anomalous Liquid on Earth. Bentham Science Publishers; 2017 Mar 1.

4. EFFECTS OF DRINKING SW WATER ON HEALTH AND LONGEVITY

The human body has an average water volume of 3.71 l and 2.71 for males and females, respectively [74]. A

concept article by Messori *et al.* [75] estimates that the percentage of BSW interfacial water in a human adult ranges from 20 to 30%. Based on these two water volume estimates, the average volume of BSW interfacial water would range from 740 to 1,110 ml for

males and 542 to 813 ml for females in humans, or about 2.47 to 3.71×10^{25} and 1.81 to 2.72×10^{25} molecules of SW water in males and females, respectively. Other estimates of extracellular (ECW) and intracellular water (ICW) state that the average adult human should have an ICW: ECW ratio of about 75% ICW and 25% ECW water content [76-79]. Shi *et al.* [80] conducted a Raman microscopic study of BSW water in HeLa cells, revealing that BSW water was 64% of the total water in the cytoplasm of a human cell, and the other 36% was free water, i.e., ICW water consists of 64% BSW and 36% free water. These estimates for ECW and ICW water content in humans indicate the importance of BSW water, whether covering cell membranes (ECW water) or inside cells (ICW water). Guo *et al.* [81] investigated the heat of vaporization of bound water using NMR and DSC methods in radiata pine tissue. They found that 30% of the total water content in the wood tissue was bound water.

Several health studies involving hydration, human longevity, and age-related diseases have concluded that “free biological water” decreases with age [22, 82-84]. As dehydration accelerates during aging, it becomes critical to replenish BSW water levels for everyone over 50 or 60 years old [85-88]. One review on aging and dehydration states that the total water content in a 45-year-old adult ranges from 65-70 %, which decreases to about 45-50% in a 70-year-old man [89]. Another dehydration review by Lavizzo-Mourey [90] states that the total percent body water decreases to 50.8 percent in men aged 61 to 74 years and to 43.4 percent in women aged 61 to 74 years. A third dehydration review by Hooper *et al.* [91] states that the percentage of body water content decreases from 70 to 60 to 50%, respectively, in newborn babies, childhood, and older adults. These human dehydration reviews generally agree about a 10 to 20% loss in water content as young adults mature into their sixties and seventies. An abundance of medical literature has shown that even a conservative loss of 10 to 15% water content due to aging has proven to be strongly correlated to many age-related diseases [85-87]. No medical research has yet evaluated the effects of SW drinking water on age-related diseases. However, a few water drinking studies have shown that SW water is associated with human longevity and that rehydration at the cell level can be enhanced.

The challenge of water replenishment therapy is whether drinking non-structured or structured water

enhances BSW water levels. The drinking water market offers so many confusing claims for improving health status that a review of the clinical evidence is needed to distinguish which water products work best for enhancing BSW water levels. Drinking water products can generally be separated into water products with various compositions, such as alkaline or H₂-infused water and structured water products. Alkaline drinking water is treated with minerals or electrolysis to raise the pH of the water. These water products increase the water's hydroxide ion concentration or alkalinity. A recent venture in changing water composition is infusing hydrogen gas (H₂) into the water. The claims for hydrogen water include antioxidant properties with increased energy and longevity and improved muscle recovery after a workout [92]. As mentioned above, increasing the pH level within physiological limits, which is 7.35 to 7.45 in humans, also increases cell membrane potential and BSW water levels. Therefore, alkaline water and H₂-infused water products can slightly raise blood pH levels and increase cell energy levels.

A hydrogen water study by Matsiyevska [93] reveals that H₂ gas changes physicochemical water properties, modifying human blood parameters. His findings state that human blood varies in ORP from -100 to -200 mV. Also, his study found that mineral water treated with H₂ gas reduced the ORP to -103 mV, with a pH of 6.84 and rh of 16.9 for the mineral water. When they infused H₂ gas into tap water, the ORP was -210 mV, with a pH of 7.4. These physicochemical water properties do not match the linear regression results in Figure 1, i.e., water with an ORP of -130 mV should have a higher pH. Generally, H₂-infused water products on the market have a pH ≥ 9 . The addition of H₂ gas in mineral water results in hydronium and hydroxide ions, resulting in a significant reduction in ORP. The subjects that drank the hydrogen-saturated mineral water had oxygen-rich blood, and all the white and red blood cells returned to normal shape. Their findings show that H₂-saturated water reversed age-related blood cell aggregation and excess clotting, and the blood parameters were close to ideal [93].

More recent drinking water studies with H₂-infused water reveal the effects on blood pH. Ostojic [94] found that blood pH increased by ~6% in adult men who drank two l/day of H₂-infused water for seven days. Another study by Ostojic *et al.* [94] found that blood pH increased by 0.04 (negative log H⁺) for men who drank two l/day of H₂-infused water for 14 days. Drid *et al.*

[95] found that female athletes' blood pH raised from 7.39 to 7.47 after drinking 300 ml of H₂-infused water. As previously mentioned, increasing pH increases hydronium ions (H₃O⁺), increasing cell energy levels. These drinking water studies provide real world evidence that drinking water with enhanced physicochemical properties can alter blood properties and ultimately improve overall health. The advantage of drinking SW water properties is that the water is already structured and has alkaline properties with a pH range from 8 to 10.

A website for a commercial hydrogen water product [97] reports that electrolysis is used to generate drinking water with an ORP of -850 mV. Drinking water with a negative ORP has reductive properties, and as the absolute value of ORP increases, the reductive or antioxidant properties increase [97]. BSW interfacial water always has a negative ORP value (Table 1). Any drinking water products with reductive properties or a negative ORP have inherent antioxidant properties that match the cell membrane potential's negative redox properties.

Currently, there are no published drinking water studies involving structured water and its effects on age-related diseases. However, a few water drinking studies have shown that structured water is associated with human longevity, and rehydration at the cell level can be enhanced [97-111]. Two drinking studies with human subjects showed that intracellular water content improved after drinking different forms of structured water. Fisher *et al.* [98] evaluated the effects of drinking structured water (0.5 l/person) using an MRET water generator that adds structure with a resonance device oscillating at 7.8 Hz. Using a bioimpedance meter, they found a 4.2% increase in intracellular water. They state that the ratio of extracellular to intracellular water in humans is approximately 20:40 and that an average 75 kg male has a total water volume of 45 l with 30 l of intracellular water. A drinking water study by Smirnov [99] also evaluated the effects of MRET-structured water and found that intracellular water uptake increased three-fold. A third drinking water study by Johansson and Sukhotskya [100] found that structured water improved the resiliency and auto-stabilization of human heart rates within 15 min. of drinking 100 ml of water.

Replenishing BSW water with drinking SW water or using infrared lamp treatments to increase EZ water “*in vivo*” can improve neurological health. A case study by Smirnov [101] found that a man suffering from cerebral

palsy had exceptional recovery after drinking SW water for twelve months. The MRET water generator was also used in this case study. In another study, Smirnov [102] tested the MRET water generator on transgenic mice that expressed an amyloid gene that increased amyloid plaque production. The brain area in the mice that drank the MRET water increased their total brain area by 15% compared with the control mice. Also, the transgenic mice predisposed to amyloid plaque production that drank tap water had a mortality rate of 33%, which is comparable to the 25 to 40% mortality expected from this type of transgenic mice. In comparison, the transgenic mice that drank the MRET water had a mortality rate of 9% or a 75% decrease in mortality due to drinking the MRET water.

Another independent study by Saltmarche *et al.* [112] indirectly validated the transgenic mouse study by Smirnov. The Saltmarche study tested mild to moderately severe dementia or Alzheimer's patients with a near-infrared (NIR) photo-biomodulation light attached to their heads with a 41 mW/cm² power density. The use of infrared pulsed radiation in these patients also increased the EZ water zone in their brain tissue, as Chai *et al.* [113] found that far-infrared light increased the EZ water zone to 600 µm after just 10 min. Exposure. The NIR treatment used in the Saltmarche study likely increased the BSW water levels in the patients' brains over the 12-week study. The patients had significantly improved test scores and personality profiles after 12 weeks of NIR brain treatments. In addition, the study results were comparable to those from a large dementia study that tested a dementia drug (donepezil). In other words, the NIR study improved the neurological health of dementia patients and had comparable results to a dementia drug study. Other clinical studies that tested NIR photo-biomodulation treatments on dementia and Alzheimer's patients found similar improvements in neurological recovery [114-116]. These research findings with either MRET water generator or NIR lamp treatments provide evidence that increasing BSW levels in transgenic mice or dementia patients can improve longevity and increase neurological recovery rates.

A study by Wang *et al.* [117] evaluated “micro-clustered water (MC),” or structured drinking water, on the hydration status in humans. They found that diabetes patients who drank micro-clustered water had improved cell water distribution (ICW/ECW), basal metabolism rate (BMR), phase angle (PA), and cell capacitance

(CP) during the four-week study. Liguori *et al.* [118] investigated the effects of Ion Cyclotron Resonance (ICR) treatments in a human clinical trial (See Part 1 Section 3). The ICR treatment included the Schumann Resonance (7.88 Hz), hydronium ion (H_3O^+) resonance, and several mineral ion frequencies in sequential wavelength treatments. They found that the intracellular water content, based on bio-impedance meter readings, increased for the ICR treatment. In addition, the ICR treatment increased the IWC water structure, indicating that ICR treatments increase BSW levels in humans [118].

An unpublished study by Jhon [110] investigated the effects of SW water on the longevity of beagle dogs. The study evaluated the survival rate for 32 beagle dogs for over a decade-long test. The study showed that more than half of the dogs that drank SW water survived over 13 years. However, half of the beagles that drank the unstructured water survived less than seven years [110].

Magnetized water research has the most extended history and the most published studies. However, few drinking water articles have published any details related to SW water properties. Research on the effects of magnetic fields on water properties reveals that bulk water becomes more structured depending on the strength and duration of the magnetic fields [119-124]. The health benefits of drinking magnetized water have been widely researched [125-133]. The evidence is compelling that magnetized drinking water improves animal health, but the same literature offers few links between magnetized water and SW water properties.

Many case studies investigated the effects of drinking natural water with SW properties that have increased health and longevity [134-140]. Over a dozen research and case studies by Ignatov evaluated the effects of SW properties of natural water sources on human health and longevity have been published [141-150]. He measured the physicochemical water properties from high-elevation streams (1,000 to 1,500 m) in Bulgaria in a region containing shungite minerals and zeolite clays [144-145]. Shungite is an ancient rock containing non-crystallized fullerene-like carbon (30 %), silica (45 %), and silicate mica (about 20 %). Shungite alters physicochemical water properties such as oxidation-reduction processes, sorption, catalytic, biological activity, and electrical conductivity, improving its health benefits as a drinking water [144-145]. Ignatov used the evaporation angle of water droplets to estimate the energy of hydrogen bonds of shungite and

zeolite solutions in water [141-150]. He found a significant relationship between the H-bond energy of the mountain drinking water and extended life spans for the villagers drinking the mountain water. Ignatov states that the average number of centenarians in Russia and Bulgaria is 8 and 47 per million, respectively. However, the average number of centenarians in the Bulgarian mountains around the Teteven Municipality jumps to 139 per 1 million, or a 1.96-fold increase in centenarians, significantly associated with the water source they drink [141-142]. His research focused on the SW water properties, including electrical conductivity, mineral content, and H-bond strength in several natural drinking water sources. His studies reveal a strong relationship between the SW water properties in high-elevation shungite-filtered water sources and human health and longevity.

Other age-related hydration research indirectly confirms Ignatov's findings. Lorenzo [151] investigated the effects of hydration on aging. He states that hydration declines with age, suggesting BSW water also decreases with age. Kerch *et al.* investigated the effects of bound and free water on age-related diseases [152-153]. He states that the ratio of bound water to free water decreases with age, i.e., bound water gradually converts to a higher percentage of free water as humans age, which is correlated with a host of age-related diseases. These age-related hydration studies confirm that drinking SW water improves health and longevity, and conversely, the loss of BSW water, or bound water, is associated with age-related diseases.

As mentioned, drinking SW water with negative ORP values matches the BSW interfacial water properties with the negative cell membrane potential. The reviews by Yang and Brackenbury [68-69] state that malignant cells have lower negative cell membrane potentials. Their review states that the average membrane potential for nine malignant (tumor) cell types was ~24 mV. They also state that the average resting membrane potential for eight types of non-tumor cells was ~-72 mV. A concept article on the causes of cancer by Szigeti *et al.* [154] states that malignant cells have a lower membrane potential. They also conclude that cells undergoing division into daughter cells require tremendous energy, and healthy cells with negative membrane potentials can enter mitosis and remain non-malignant. These research findings indicate that cells' risk of becoming malignant or

cancerous increases as membrane potentials decrease. In other words, as cell membrane potentials decrease from approximately -72 mV to -22 mV, the risk of cells becoming malignant substantially increases. Membrane potential is directly related to the depth of the BSW water zone, i.e., the deeper the EZ water zone or BSW interfacial water zone, the higher the negative membrane potential.

Several drinking water studies evaluated the effects of SW water on cancer cells or cancer patients. Ignatov *et al.* [154] investigated the effects of infrared light and high-frequency EMF field (2.3×10^7 MHz) treatments on water structures. They found that the water treatments increased H-bond strength in water and increased water structure. In a related study, Toshkova *et al.* [156] investigated the effects of the same infrared and EMF-treated water in a drinking water study with tumor-infected hamsters. They found that the infrared and EMF-treated water increased the H-bond strength in the blood plasma of mice with cancer. Also, they state that the infrared and EMF-treated water increased mitochondrial polarity or membrane potential. Finally, they stated that infrared and EMF-treated water increased the life span and decreased tumor growth in mice with cancer.

In collaboration with Dr. Pollack, a study by Hang *et al.* [157] they investigated the effects of a hydrophilic ceramic powder (QELBY powder) mixed with water to create SW water with EZ water properties. They found that QELBY powder increased the water structure. After mixing water with QELBY powder (1% or 9,988 mg/l) and water for 0.5 h, the ORP of the water rose to -75 mV. Another study by Hang *et al.* [158] investigated the effects of water treatment using QELBY powder (10,000 mg/l) with an approximate ORP of -75 mV on Natural Killer (NK) cells and phagocytic activity in media cultures. The same QELBY water was also tested on viability for breast cancer cells (MCF-7 cell line). They found that NK cell activity increased from 8% (control) to 25% for the QELBY SW water treatments. Also, they found that phagocytic activity increased twofold for the QELBY water treatment. In addition, they show that breast cancer cell viability decreased by approximately 20% for the QELBY water treatment. Finally, they found that the mitochondrial membrane potential increased 1.36-fold with the QELBY treatment, indicating a deepening of the EZ zone that covers the mitochondria membrane [158].

A concept article by Mojica *et al.* [159] proposes that SW drinking water could be used as a hydration

therapy for cancer patients. The underlying concept of this SW water research is that cells with adequate levels of BSW water and healthy negative ORP values reduce the risk for several types of cancer. This cell hydration concept was indirectly confirmed by a clinical study conducted by Mayrovitz [160]. He monitored breast cancer patients using non-invasive measurements to correlate water content in arm tissue with the risk of relapse for patients in cancer remission. He evaluated the ability of two portable medical devices to measure intracellular water content (IWC) in healthy patients and patients in remission from Breast Cancer-Related Lymphedema (BCRL). One device measured IWC using bioimpedance spectroscopy (BIS). The second device measured IWC using a Tissue Dielectric Constant (TDC) monitor to measure the dielectric properties of tissue. He found that both devices accurately measured IWC levels in patients with and without BCRL. He concluded that the non-invasive devices could reliably screen patients for BCRL symptoms based on their IWC levels from arm measurements. The findings from this study show that the level of intracellular water content could be used to predict or screen patients for their risk of relapse into cancer. The overall implications of this study suggest that the level of IWC water in human tissue could reliably correlate with certain cancer risks. As mentioned, ICW water comprises 64% BSW and 36% free water [80]. These findings agree with the concept paper by Mojica *et al.* [159] that adequate levels of BSW water would reduce the risk for several types of cancer. Mojica *et al.* suggest that cell membrane potential near -60 to -70 mV is a reliable biomarker for maintaining adequate BSW levels in humans. Yang and Brackenbury [68 -69] also agree that membrane potentials should be maintained near -70 mV, significantly decreasing cancer risk. These findings show that IWC water content and BSW interfacial water zone should be maintained at healthy levels to minimize cancer risks.

Aquaporins are protein-based water channels in cell and organelle membranes that allow rapid transfer of water and other low molecular weight molecules across the membranes. The aquaporin identified in mitochondria membranes is called AQP8. The AQP8 aquaporin assists with the transport of H_2O and H_2O_2 across the mitochondria's inner membrane. Ikaga *et al.* [161] found that "knocking out" the ability of AQP8 to function contributes to mitochondrial dysfunction. He also states that mitochondrial AQP8 contributes to mitochondrial respiratory function by maintaining water

homeostasis [161]. This study highlights the importance of water transport across membranes and maintaining water and redox homeostasis for both intra and extracellular environments. Kozumi and Kitagawa [162] state that three different aquaporins preferentially transported SW water generated from a ceramic device. The increase in permeability for the aquaporins ranged from 21% to 26% when SW water was compared to non-structured water. Also, Ali *et al.* [163] found that four aquaporin types exhibited increased transport of natural healing spring water that had physicochemical properties comparable to structured water. Both studies suggest that human aquaporins are more permeable for SW and BSW water. The ability of a single aquaporin to rapidly transport water into cell organelles at rates up to 3×10^9 H₂O/s indicates how crucial aquaporins and structured water are for maintaining water homeostasis across both intra and cellular membranes. Maintaining the IWC: EWC ratio in cells as humans age is important so that BSW levels are at optimum levels for ultra-fast exchange of electrons and protons to preserve redox homeostasis at the cell and higher biological scales [1-9].

This review of the health benefits of drinking man-made or naturally sourced SW water reveals several impressive benefits. There are many more case studies for drinking naturally sourced SW than drinking man-made water products. Several other generation methods for drinking water have properties similar to SW water, including magnetized, electrolyzed, or hydrogen water. This article did not extensively review these methods of generating drinking water due to their

limited information on their possible SW water properties.

5. EFFECTS OF INFRARED RADIATION ON BSW ZONE DYNAMICS

Energy from infrared radiation temporarily increases the thickness of the BSW interfacial water zone in plant or animal tissue when directly exposed to the radiation, according to Pollack [155]. This spectrum covers near, mid, and far ranges with associated wavelengths (Figure 2). When a surface absorbs infrared radiation, radiative heat transfer occurs, and the temperature rises in that surface material. Water molecules readily absorb infrared radiation, especially in the far infrared spectrum. Near-infrared (NIR) has higher energy, penetrating deeper into tissue and raising tissue temperature faster than far infrared. As tissue absorbs NIR energy, it rises the temperature and is re-emitted at lower FIR energies that can be detected with thermal IR scans. Wein's law can be used to convert the temperature of an object into the infrared wavelength emitted from the object. For example, the average temperature of humans is 98 F, which converts to a FIR wavelength of 9,343 nm, based on Wein's law. Human mitochondria have an average temperature of 53-54 C, which converts to a FIR wavelength of 10,174 nm. Radiant heat from a temperature rise is constantly emitted in FIR wavelengths, but organic tissue can absorb a wide range of wavelengths in the EMF spectrum.

Pollack proposes that infrared radiation causes free water molecules to self-assemble into BSW water

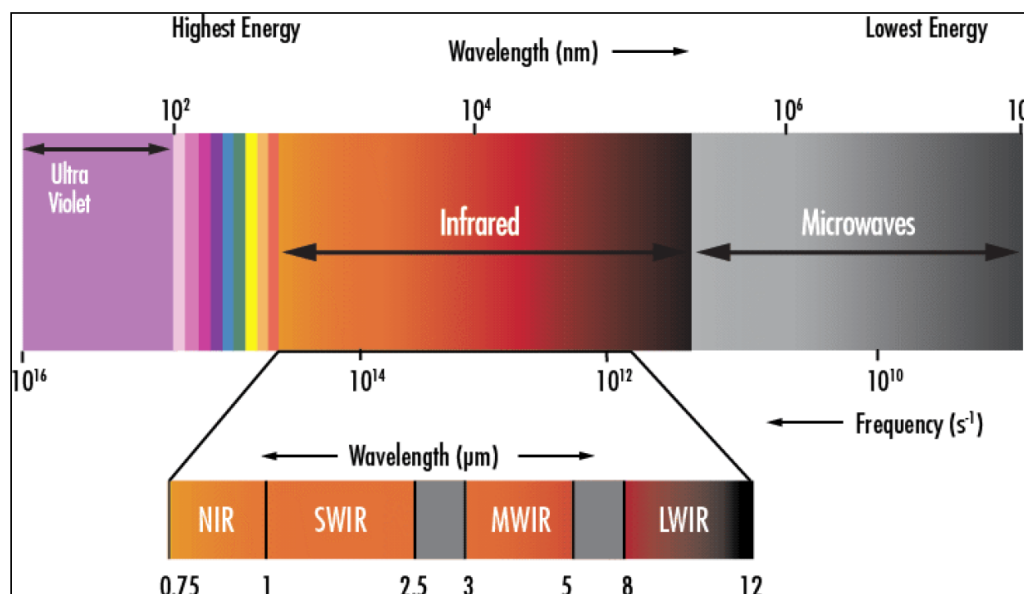


Figure 2: Infrared wavelength spectrum and associated wavelengths (open access image).

based on the absorption of IR energy by water molecules and altered electrostatic charges in the water molecules [155]. However, Pollack also states that the expanded EZ water zone is temporary and returns to its original size within about 10 min. He also states that the EZ zone maintains its new thickness if there is a continuous supply of IR energy from any source. All warm-blooded animals generate far infrared radiation during aerobic respiration in the hundreds of mitochondria in each cell. This infrared radiation emitted by mitochondria is absorbed by BSW interfacial water. Recycling and partial storage of heat generated by the mitochondria in BSW water improves overall metabolic efficiency, reduces energy demands, and supplies supplemental energy in the form of increased thickness of the EZ water zone. There is an intricate interplay between external and internal sources of IR radiation in creating and maintaining an adequate thickness for BSW water zones.

The interaction between IR energy and the electrostatics of energized water moles proposed by Pollack may also hint at the temporary nature of EZ water zone thickness [153]. The energy from IR radiation may be enough to split SW water that has been energized. However, the energy of IR radiation is too low to alter hydrogen bond strength in free or unstructured water. As mentioned in Part 1, when H-bonds are shortened, free water molecules increase in polymeric structures with much longer stability and duration dynamics. The shelf life of structured drinking water products is evidence of the stability of generated SW water. This author has custom-generated SW water that has maintained its physicochemical water properties for well over 12 months. Also, this author conducted a plant watering study using generated SW water [59]. The SW water was added to potting soil, which is highly reactive, and was then taken up into the roots of water-stressed plants. The study results indicate that the generated water maintained its SW water properties when transported in the soil matrix and the plant vascular system. Biological research is still uncertain whether BSW interfacial water has weaker H-bond strengths, less stability, and cyclic water zone dynamics than generated SW water using energy sources high enough to break the covalent bonds in water molecules. However, the bioenergy fields needed to maintain or increase BSW levels “*in vivo*” are probably too weak to shorten the H-bonds that ensure stable polymeric structures. It remains an open question whether drinking SW water with strong H-bonds would convert into BSW interfacial water with

increased stability and prolonged duration spans. Also, it is still unclear if drinking high quality, generated SW water with strong H-bonds negatively impacts metabolic activities. The large volume of case studies for drinking natural or spring water with SW water properties and extending human longevity suggests only positive effects of drinking SW water. Part 3 of this review will describe several methods of generating SW water that produce shorter H-bonds and ensure stable SW water structures using energy sources strong enough to break the covalent bonds in water.

6. BIOMARKER MONITORING TO QUANTIFY EFFECTS OF DRINKING SW WATER ON HEALTH

The effects of SW water on human health can be monitored using home digital devices to measure four biomarkers. The biomarkers were heart rate, percent blood oxygen, body temperature, and Resting Energy Expenditure (REE). Personal biomarkers should be monitored after a prolonged rest period, as the biomarkers are also robustly synchronized to physical activity. In other words, these biomarkers are highly variable depending on any physical activity. Therefore, monitoring biomarkers while the body is at full rest provides more accurate results with less variation in averaging the results.

Essential biomarkers can be monitored with inexpensive devices. The heart pulse rate is measured with a finger oximeter that collects beats per minute (BPM). The oximeter also measures the percentage of blood oxygen. Digital thermometers measure body temperature when placed under the tongue. Also, indirect calorimeters measure Resting Energy Expenditure data [164]. The calorimeter data included volumetric oxygen consumption and estimates of calorie burn rates (kcal/day) while at rest and total calories per day.

Biomarkers for heart pulse rate and body temperature are easy to monitor daily over long periods. These biomarkers have taken on a new health monitoring status due to new research correlating the two biomarkers to a person's overall health status. Recent research has shown a direct, linear relationship between heart pulse rate and body temperature. Broman *et al.* [165] found that the heart rate increased by 8.35 BPM for every 1°C increase in body temperature between 32.0°C and 42.0°C in critically ill patients. Also, Neal *et al.* [166] found that in children under 16 years of age, the heart rate increased by 12.3 BPM for every 1 C increase in temperature after

accounting for oxygen saturation, location of attendance, and age. Medical literature confirms that life spans are shortened as body temperature increases with increasing respiration rates [167-170]. Monitoring personal temperatures before and after drinking SW water should indicate a trend in reduced body temperature over time.

Research on aging shows a negative relationship between heart rates and longevity [171-173]. In a review by Jensen [174], he states that a reduction of 19% in resting heart rates (65 versus 80 bpm) was associated with 4.6 years longer life expectancy in men and 3.6 years in women. An earlier study by Jensen *et al.* [175] analyzed a large cohort study to estimate any associations between heart rates and longevity. A similar study was published by Woodward *et al.* [176]. They found that the health risk ratio was 1.0 for both sexes, with a resting heart rate of less than 60 BPM for heart failure and total mortality. Another meta-analysis study on heart rate and longevity by Quer *et al.* [177] involved a 92,000-person cohort study. They found that men's average resting heart rate at 70 years old was about 62 BPM. Again, personal monitoring with an oximeter before and after drinking SW water should show a trend in reducing heart pulse rates over time.

A portable indirect calorimeter measures aerobic respiration rates, i.e., the meter measures calories burned (kcal/day) when data is collected after different activities. In Part 1 of this review, the Water Respiration (WR) theory was presented as a cell energy source. If the WR energy cycle theory is ultimately proven valid, then total cell energy is a product of aerobic (AR) and water respiration (WR), along with secondary sources previously mentioned in Part 1. Water-based WR respiration is directly proportional to the level of BSW water available to initiate the WR cycle. In contrast, AR respiration requires a carbon-based energy source and O_2 to initiate the AR cycle within the mitochondria. As the AR respiration decreases and WR respiration increases, there is a reduction in REE and O_2 for aerobic respiration needs. Aerobic respiration consumes O_2 ; therefore, the percentage of blood oxygen is a direct biomarker for respiration status. Personal monitoring of REE rates requires collecting data before physical activity first thing in the morning. Monitoring REE rates before and after drinking SW water should show a trend in reduced REE rates over time.

Personal medical devices have been developed to monitor water content in body tissue remotely. Two

types of portable meters have been designed to measure extracellular and intracellular water content remotely. One device uses bioimpedance spectroscopy (BIS). The BIS device sends a small electrical current into the body tissue over a range of frequencies and measures the impedance of the current. Algorithms convert the impedance values into biomarker estimates of body composition, including extracellular and intracellular water content. The accuracy of the BIS meters has been evaluated in several tests [178-180]. The second uses electrical current to measure the tissue's Tissue Dielectric Constant (TDC). The dielectric properties of tissue are directly proportional to its water content [181-182]. A comparison between BIS and TDC medical meters was conducted by Lahtinen *et al.* [183]. These meters allow daily monitoring of hydration levels and test for any enhancement of IWC levels due to drinking SW water.

7. ALTERNATIVE TREATMENTS FOR MAINTAINING BSW WATER LEVELS DURING AGING

The second part of this review focused on drinking SW water to maintain BSW water levels in humans or irrigated plants. However, research also reveals that two other treatments, including infrared light and magnetic fields, can increase BSW levels in organisms. These treatments for increasing BSW levels rely on exposing the body to energy fields that penetrate the tissue and induce self-assembly of free water into BSW water.

Additional research studies confirmed Pollack's assertion that red and infrared light increases the EZ zone on membranes, which increases membrane potential [184-188]. Sommer *et al.* [189-190] state that the bound water on mitochondria absorbs red to near-infrared radiation (R-NIR light) in Low-Level Light Therapy (LLLT) treatments. Medical treatments based on biophotomodulation or LLLT use red to near-infrared light to treat wound healing, stroke, traumatic brain injury, neurodegenerative conditions, cancer, *in vitro* fertilization, and pain management [190]. A review by Ravera *et al.* [191] states that biophotomodulation LLLT treatments positively affect cell-based bioenergetics. They also state that bound water, or EZ water, absorbs red to near-infrared light, which increases mitochondrial membrane potential. Passarella *et al.* [192] found that rat liver mitochondria had increased membrane potential and a 70% increase in ATP levels when the cells were exposed to red light (647 nm). Alexandratou *et al.* [193] showed a 30% increase in mitochondrial membrane potential with 15 s

exposure to red light EMF (647 nm). A third study by Hu *et al.* [194] revealed a 34.5% increase in mitochondrial membrane potential when exposed to red light (633 nm). Yu *et al.* [195] found that photo modulation with NIR (660 nm) increased oxygen consumption twofold and increased membrane potential by 33% in rat liver mitochondria. A review by Yang and Youngblood [196] also states that biophotomodulation with red and near-infrared radiation can increase mitochondrial membrane potential and partially alleviate mitochondria dysfunction.

Research on the effects of static magnetic fields on water structure also shows some promise. Konovalov *et al.* [197] and Sidorenko *et al.* [198] collaborated on studies involving generating structured water with electromagnetic fields. They were able to form “nano-sized water assemblies” or water clusters up to 400 nm in size. These water clusters were estimated to contain up to 500 million H₂O molecules. Their findings suggest that electromagnetic fields can generate coherent domains, fully described in Part 1 of this review. Chang *et al.* [199] investigated the effects of static magnetic fields on water structure using molecular simulation models. They found that external magnetic fields from 0 to 10 T increased the number of hydrogen bonds in water, resulting in the formation of larger water clusters. Other studies by Cai *et al.* [200], Pang *et al.* [201], Jung *et al.* [202], and Ghauri *et al.* [203] found that magnetic fields increase water structure based on the enhancement of several SW water properties. A study by Shalatonin and Pollack [204] found that a neodymium bar magnet (1,440 mT) increased the EZ water zone on microspheres.

These studies were conducted under laboratory conditions, so one can only conjecture whether magnetic fields can increase BSW water levels by placing static magnets on the organism's surface. Mohamed and Hanafy [205] found that water exposed to static magnetic field (2 mT) for 1 h exhibited SW water properties by increasing pH by 11.6%, viscosity by 10%, and electrical conductivity by 10%. They used the same magnetized water to irrigate common beans (*Phaseolus vulgaris*), resulting in a 7.9% increase in plant height and a 13% increase in weight of 100 seeds compared to the control plants. Despite the low magnetic field strength (2 mT), their irrigation study showed increased plant responses based on plant, seed, and chlorophyll variables. Magnetic fields increase the hydrogen bond numbers in water, which increases water structure, depending on the magnetic

field strength and duration of exposure [206-207]. The effects of different energy fields, including the strength and duration of exposure to different fields, on altering H-bond strength in liquid water will be briefly discussed in Part 3.

8. BSW WATER EFFECTS ON INNATE IMMUNITY AND VIRUS ATTACHMENT TO MEMBRANES

BSW water can boost human immunity via two different processes. The first process boosts the redox activities within the innate immune system. The innate immune system is the “first responder” immunity system that goes into action immediately. The innate immunity cells surround and engulf the invader or produce free radicals that chemically inactivate the pathogens. Innate immunity is non-specific and includes responses such as phagocytosis, killing of pathogens or cells, and cytokine production. The second process involves the ability of BSW water to increase cell membrane rigidity by the semi-flexible liquid crystalline coating on membrane surfaces.

The innate system includes leukocytes, such as neutrophils, that generate free radical oxygen species [208-209]. When the immune system signals are sent to neutrophils, the enzyme NADPH oxidase is activated to produce free radicals [210-212]. NADPH oxidase can generate a respiratory burst that can increase oxygen consumption by 10-15-fold [210-212]. The innate immune system uses this rapid increase in Radical Oxygen Species (ROS) to inactivate pathogens through a series of redox reactions [213-215]. Hang *et al.* [158] found that Natural Killer cell activity increased from 8% to 25% for the control and SW water treatments, respectively. Also, they found that phagocytic activity increased twofold for the SW water treatment. As mentioned in Part 1, excess ROS radicals can be rapidly quenched when adequate BSW water levels are present due to their excellent antioxidant properties.

Pollack *et al.* [184-187] conclude that the EZ zone, a.k.a. BSW interfacial layer, excludes virtually all ions, solutes, and pathogens. Shalatonin [216] states that a long-range EMF interaction between the EZ water and SARS-CoV-2 glycosylated spikes creates a “glass-like” hydration layer that covers the cell membrane. Many research phrases are vague descriptions such as “glass-like,” but this phrase suggests that the glass-like hydration layer is synonymous with a liquid crystalline lattice of H-bonded water molecules hydration layer. This glass-like hydration layer inhibits the entry of the

SARS-CoV virus into a host cell. She concludes that viral interactions with EZ water may also be able to exclude human immunodeficiency viruses, influenza viruses, and possibly other enveloped viruses. A concept paper by Messori [217] states that viruses such as SARS-CoV-2 seek host cells via long-range emission of ULF-EMF signals. These EMF signals are the electromagnetaxis principle that viruses use to seek out and find host cells. The EMF signals also alert the host cells to initiate a cascade of redox reactions to generate ROS radicals. The same ULF-EMF signals also create a glass-like stabilizing EZ zone that inhibits viral attachment to host cells [217].

Chen *et al.* [218] investigated the strength of the exclusion force in the EZ water zone. They found that negatively charged microspheres were repelled from an EZ zone on a Nafion surface with a force increasing from 0 to 3 pN as the microsphere distance decreased from 60 to 0 μm from the surface. The SARS-CoV-2 virus is negatively charged on its outside surface. Therefore, SARS-CoV-2 should be repelled from negatively charged EZ water zones that also repelled the negatively charged microspheres in the study by Chen *et al.* [218]. Cheng and Moraru [219] evaluated the effects of long-range interactions between structured water generated as an EZ water zone on a Nafion surface and bacteria. They found that an EZ water zone excluded *Staphylococcus aureus*, *Escherichia coli* O157:H7, and *Listeria monocytogenes* from 40-60 μm from the surface, with an additional transition zone of 40-80 μm for bacteria suspended in tryptic soy broth. Kowacz and Pollack [220] evaluated the ability of propolis (bee glue) to create an EZ water zone. They state that Propolis created an EZ zone over 40 min., approximately 200-300 μm thick, and was stable for about two h before diminishing in depth. They state that the propolis-generated EZ zone created an effective exclusion zone that prevented the attachment of viruses or entry of pathogen bacteria.

These research findings indicate that viral entry into host cells is associated with the depth of BSW interfacial water covering the host cell membrane. Further research is needed to investigate the effects of maintaining and enhancing BSW interfacial water on inhibiting virus entry into host cells. Additional research is required to investigate the interplay between BSW water levels, ROS generation and quenching, ROS inactivation of pathogens, and boosting overall cell immunity.

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