Pure Water for Drinking
A Review of Essential and Toxic Metals in Health and Disease[1]

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A giant surge of research into the requirements for essential elements and their influence on health and disease has occurred in recent years. These studies have benefited by the technological advances in new methods of detection. Many are still referred to as "trace" (early investigators could barely measure them) elements, although now minute quantities can be precisely determined. These trace amounts, mammoth in their effects, act as protagonists and antagonists of many enzyme reactions, and are critical in the control of metabolic pathways. When deficient, the trace element which is readily available may step in and overreact. A vast literature has accumulated on the toxic heavy metals such as lead, cadmium and mercury and although these are recognized by all as harmful, they plague us in our environment and in our tissues. Only sporadic reports occur, however, on the deleterious effects of excess environmental copper and aluminum which are also toxic and can cause a multitude of problems not appreciated or properly recognized by the medical community at large. As such, copper and aluminum are the real villains in producing water-borne illness (sometimes irreversible) in countless numbers of people in the developed nations.

The focus of this report shall be on those elements, essential, toxic, or both, which may by their deficiencies or excesses in our drinking waters, profoundly influence our health. Data will be presented on the toxic effects known to be exerted by copper, aluminum, lead and cadmium in amounts which may be present in the water we drink. The beneficial effects of other elements in drinking water will be detailed.

Modern Man's Assault On Drinking Water

We are all too aware of the poor quality of our nation's drinking water. Whole families of pollutants include fertilizers, fungicides and herbicides, nitrite-producing nitrates, detergents, radioactive wastes, salts and other highway runoffs. Paradoxically, man has befouled his drinking water almost as much in his numerous attempts to improve it. In addition to the multitude of environmental contaminants already in the water, municipal water companies may use any of 47 different chemicals for treatment, chief among them, chlorine. We now know that chlorine interacts with the products of decaying plant matter (humus) and forms trichloromethanes which are potent carcinogens. A report from the Oak Ridge National Laboratories (1) shows that chlorine itself in pure drinking water increases plasma cholesterol in experimental animals. Thus even if the humus were separated before the addition of the chlorine we must now suspect chlorine itself and not only its reaction products. But more to the point of this presentation, two metal compounds are commonly added by many water treatment facilities, copper sulfate as an algacide and aluminum sulfate as a flocculent of particles, thus increasing the copper and aluminum content considerably.

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The potability of water cannot be properly evaluated at its source in the lake or reservoir, well or river, but only at its point of entry into our body. Water must traverse large distribution pipes which may be of lead, iron, copper, asbestos-cement, galvanized, or vinyl polymer. The water must then course through galvanized, copper or even lead home plumbing. Lead solder is used at joints and faucets. Water may be stored for long periods in copper cooking utensils or in copper coils such as in water coolers, softeners and automatic ice makers. And, again, copper sulfate may be added to precipitate algae at the water treatment plant.

A common method for the control of algae is to put 25 lbs. of bluestone (copper sulfate) in a gunny sack, tie this to the rear of a small rowboat and with an outboard motor ride around the lake or reservoir until the bluestone is dissolved. If you question this practice the employee will state that the water in the reservoir being treated is not for drinking but is only used in case of fire. If that is true, then why get rid of the algae?

The major factors which determine which elements water will pick up from the rocks, soil beds, water treatment agents and plumbing are its hardness or softness and its acidity. Water containing appreciable amounts of calcium and magnesium compounds in solution is called hard water (because of its action with soap to form an insoluble product). It is more alkaline than natural rain water which is slightly acidic, hence corrosive, because of molecules of CO_2 mixed into it in the atmosphere. Surface waters are usually soft and acidic; well waters are usually hard and loaded with calcium and magnesium salts. River waters vary considerably. Water can be artificially softened in order to allow better sudsing and to prevent boiler scale, but the process substitutes two parts sodium for every part calcium or magnesium removed. Furthermore, hard water forms a protective, beneficial coating on distribution pipes and home plumbing which prevents leaching of cadmium, lead or copper. Liming of pipes also prevents leaking, so some waterworks add lime.

Adding to the natural acidity of rainwater due to dissolved carbon dioxide from the air, are the sulfur and nitrogen oxides wafted into the air by auto exhausts. A most serious natural and global problem now is uncontrolled nitric and sulfuric oxide emission from coal and oil combustion plants in all industrial areas. Ironically, the higher smokestacks in the Ohio Valley mandated to clean the local atmosphere helped disperse pollutants hundreds of miles downwind to the Adirondacks and destroyed all fish life in hundreds of upstate New York lakes. The acid snows melting in the Adirondacks leached aluminum from clay, and the aluminum, more than the acid itself, was the major toxic entity which killed the fish (2). The problem is not confined to these few hundred lakes. The pH of rain falling in fifteen states east of the Mississippi varies from 4.8 in South Carolina to 4.1 in Massachusetts, to about 3.8 in Claron County, Pa. (3). Though dumping limestone can be effective in raising the pH, the Scandinavians with a very severe acid precipitation problem find that treatment of the lakes with limestone tends to release toxic mercury compounds normally tied up in plant tissue. Spring fed drinking water at Big Moose Lake, the setting of Dreiser's *American Tragedy* is now an American tragedy on a vaster scale, having five times the acceptable lead levels and three times the acceptable copper levels (4). The aluminum, apparently not measured at the time of the report cited, must certainly be excessive.

Copper: The Fourth Heavy-Metal Intoxicant

The above heading has been borrowed from the chapter on copper in our *Mental and Elemental Nutrients* (5) wherein copper is incriminated as a culpable heavy metal along with lead, mercury and cadmium. These four poisonous metals, to which we must now also add aluminum, interact with and actually displace essential elements such as zinc, manganese, magnesium and copper from enzymes in the brain and other body tissues. It is well-proven that large amounts of copper are acutely toxic but it is little known or discussed that copper in excess of the minimum adult requirement of 2 mg/day can

be at the root of a host of chronic maladies.

Copper is, of course, essential for supporting life but it is extremely unlikely that copper deficiency can occur in adults. In our investigations of thousands of serum copper levels at the Princeton Brain Bio Center, only two cases of copper deficiency have ever been noted. One was that of a twenty year old schizophrenic woman who had self-"treated" herself with an average of 2300 mg of zinc every day for four months (6). The adult requirement for copper is only 2 mg/day. Many of us may be suffering from an unhealthy accumulation by ingesting up to 5 mg or more per day, depending on what our water is laced with.

The corrosion of copper pipes by acid water can be dramatically revealed in sinks and bathtubs by blue-green deposits on the porcelain under dripping faucets. A survey of drinking waters in the Eastern United States by Pfeiffer (7) indicates that the copper levels in certain well waters are toxic or near toxic; many of the households with high copper in water had a family member with an associated psychological problem. As ruled by the United States Public Health Service, water fit to drink with respect to copper must be less than one ppm; the World Health Organization states 0.05 ppm. We recently conducted a random survey of drinking water from some local homes, schools, public buildings, supermarkets, libraries and office buildings as well as from our own relatively new BBC building (Table 1). We were particularly interested in sampling cold water drinking fountains and ice makers in which water is cooled by refrigeration in a copper coil. Standing (first morning) and running (five minutes) samples from nearby bathroom taps and ambient temperature drinking fountains were taken for comparison, as well, wherever possible. When plumbing is new and as yet un-coated with protective lime, and when the water is soft and acid as it is at our BBC building, water levels may start out as high as 7 ppm copper. One first morning sample from our cold-water drinking fountain was 5.4 ppm, where it remained until 28 oz. were dispensed ($3^1/2$ glasses) and though it was a hot summer day with peak consumption it had dropped to only 1.7 ppm by noon. Midafternoon on a cold spring day it contained 2.7 ppm. Water at our pump has no detectable copper; an initial tap water sample had 2 ppm copper and dropped to 0.08 ppm after running five minutes. The old house next door had only 0.57 ppm copper in initial morning water and 0.11 in running water. A local prep-aratory boarding school for boys contained almost 4 ppm in its copper-coil cooled drinking fountain and almost 1 ppm in its tap water. One wonders whether some extra degree of rambunctious behavior may not emanate from the fountains and foods prepared at the school. Water containing greater than 1 ppm copper has a metallic taste except to those who may have lost their sense of taste due to copper-induced zinc deficiency.

Although the main topic of this report is drinking water, it may be the first briefing for many about the dangers of excess copper and aluminum and we would be remiss in not providing information on the sources other than water to which we are unwittingly exposed. For copper, these are:

1) Copper plumbing. Acid water dissolves copper.

2) Oversalting. Loss of taste is a symp-tom of zinc deficiency. We may oversalt to compensate, then drink more copper-tainted water which further exacerbates our zinc deficiency, due to the well-known biological antagonism between zinc and copper.

3) EDTA and other sequestrants used in food processing. These are designed to prolong shelf life so a bug wouldn't eat the stuff. Green vegetables are blanched with sequestrants prior to freezing, to preserve the green color when cooked, thus removing zinc and manganese and permitting excess copper and iron to accumulate in the tissues.

4) Birth control pills. Serum copper levels rise to abnormally high levels during their use.

5) Lime and nitrate fertilizers devoid of zinc and other essential trace metals added to already depleted soils.

6) Vitamins and minerals. Squibb's popular Theragran M for years supplied 2 mg copper and only 1.5 mg zinc, typical of most vitamin and mineral preparations. This, in spite of the fact that the total content of zinc in the adult human is 10 to 15

times the body copper. Squibb finally yielded under our prodding and marketed Theragran Z for awhile with 22 mg zinc and 2 mg copper but have now reverted to a single formula. This new Theragran M contains only 15 mg zinc and 2 mg copper, still a major improvement over their original product. It is similar to Dr. Roger Williams' Life Insurance formula marketed by Bronson Lab. The optimum ratio of zinc to copper in a supplement would be 14; thus any multi-level vitamin with 2 mg copper should have 28 mg of zinc.

In 1976, Cameron and Wunderlich (8) studied the phenomenon of frequent water pipe breakage and leaky pipes due to pin holes in copper plumbing in an area of New Jersey where the well water was soft and acidic and the copper content was 3.5 ppm. Hair levels of residents were extremely high in copper, cadmium and lead. Related illness reported included learning disabilities, hyperactivity, motor and behavioral problems, allergies and hypoglycemia in children; in adults, diarrhea, headaches, chest pains, fatigue and joint discomfort.

Not long after publication of *Mental and Elemental Nutrients* (5), a Superintendent of Schools from Santa Cruz, California telephoned us, very excited about the chapter on copper and the possibilities it opened concerning a strange case in his district: a child who was afraid to come to school, the mother who thought she was going crazy. They packed up and left their new home of two years. The new family who moved in began to exhibit strange symptoms as did the neighbors in this new tract of non-Victorian Haunted Houses! There were lots of redwood trees, very acid well water and new copper plumbing. A follow-up revealed that the culprit in this bizarre case was indeed copper! How many other such haunted houses remain undiscovered?

A tragic death of a 14 month old baby with all the symptoms of chronic copper intoxication occurred in Australia (9). The drinking water from the well had an acid pH of 3.8 and contained 6.75 ppm copper. The copper piping on the farm into which the family moved when he was four months *in utero* was new. The suggestion is made that the exposure to excess copper had begun *in utero* and continued as he was fed on infant formula made from the well water. This is the first known death to be reported from copper in drinking water. Undoubtedly others have occurred but were not recognized.

There have been many instances of copper intoxication reported for kidney patients undergoing hemodialysis due to tap water contamination from copper pipes but it took years before the so-called Dementia Dialytica was discovered to be due to copper poisoning and not a psychiatric illness. A comprehensive review of what Pfeiffer termed a "diagnostic dichotomy" can be found in Table 33.3 of *Mental and Elemental Nutrients* (5). Psychiatrists attributed the disease to the mental stress of dialysis, dependency on dialysis, denial of reality ... They said dependency on dialysis increases aggressive feelings and went on and on publishing such preposterous theories even into 1971, when a definitive medical diagnosis of copper intoxication had been clearly made two years prior.

What are the other risks of copper excess? We find high levels of copper and lead in hyperactive children at the PBBC in agreement with reports by many other investigators. A high copper intake increases lead toxicity (10) so children exposed to both lead and copper suffer a double whammy — or even triple — when one considers that zinc deficiency is also rampant in the lower socioeconomic groups where high blood lead is common. In 1979, Brenner (11) tested the Feingold hypothesis associating the hyperkinetic syndrome in children with ingestion of common food additives. But why didn't all children ingesting the same additive-laden diet respond to a withdrawal of additives? Brenner looked for a biochemical difference and took his clue from Pfeiffer's reported trace metal abnormalities in hyperactive children. Indeed, serum copper was found to be significantly higher in those hyperactive children who responded favorably to the Feingold additive-free diet. Salicylates, benzoates, citrate, tartrazine and some dyes may chelate heavy metals from the intestine or enhance its effects in the tissues so perhaps hyperactivity is due directly to a burden of copper and other stimulant metals. These levels may drop

when the additive agents which are chelators are removed from the diet.

Research at the PBBC has implicated excess copper and the low zinc and manganese usually accompanying it as etiological factors in some of the schizophrenias. We also find excess copper to be involved in some types of depression and that it is perhaps instrumental in postpartum and premenstrual depression, depression associated with the birth control pill and in certain periods of pregnancy. Patients with these conditions all manifest a high serum copper. And of course depression is one of the most serious emotional problems associated with chronic renal dialysis, now shown to be due to copper intoxication and not at all a psychological problem.

Excess copper has been associated with increased coronary heart disease in a study from Finland (12), and hepatic and serum copper are shown to be increased in subjects with ischaemic heart disease (13,14). Arthritics typically have serum copper levels twice normal and are low in zinc and manganese. There is also the suggestion, because of the biological antagonism of copper with anticarcinogenic molybdenum and zinc, that excess copper may be cancer promoting. Indeed copper levels do occur in patients with a variety of cancers, notably lymphoma and Hodgkins disease. Copper refinery workers show an elevated incidence of pulmonary cancer, lymphoma and leukemia (15).

Copper Excess Promotes Zinc Deficiency

Some of the symptoms of excess copper may be identical with those of zinc deficiency since excess copper displaces zinc from its active sites. Serum zinc deficiency and copper excess have become evident only since the change from galvanized water pipes to copper plumbing. Before that, man obtained some of his needed supply of zinc (and unfortunately cadmium) by drinking-water which coursed through zine-lined or galvanized pipes or from galvanized food processing vessels. Now with copper piping and the slight or even high acidity of most water, we are getting an excess of copper which is antagonizing the little zinc we do obtain from our food. The average

American ingests only 8.5 mg of the needed 15 mg recommended daily allowance of zinc. Twenty are needed in pregnancy and 25 in lactation. No wonder there is such a high incidence of still-births, birth defects and mental retardation in impoverished neighborhoods where the protein foods (zinc-rich) are even scarcer. Our low intake can be blamed on food processing, junk foods and soil deficiency. The U.S. Dept. of Agriculture states that in some western states zinc deficiency of the soil is now second only to nitrogen deficiency. The usual fertilizers are only rated for their calcium, potassium and nitrate content.

Zinc deficiency in humans is associated with amnesia, irritability, depression and paranoia. In children, insufficient zinc levels have been associated with lowered learning ability, apathy, lethargy and mental retardation. Common are stretch marks in the skin, thin or balding hair, and white spots in fingernails (16). Hair may lack pigment and change to a normal deeper color with zinc therapy. Severe acne, delayed menses, impotence in men, joint pain, and loss of taste are further symptoms (5). Although the essentiality of zinc for mammalian life was established in 1934, zinc deficiency had never been observed in man until 1962 when Ananda Prasad found that a lack of zinc caused stunting of growth, dwarfing, lack of mental acuity and sexual immaturity in young Iranian males (17). The normal diet of the Iranian villagers consisted in large part of unleavened bread containing phytate, a compound which prevents the absorption of zinc. Strain and Pories, well-known for discovering that zinc promotes healing of wounds and leg ulcers also noted that low zinc levels in hair and serum have been found in patients with atherosclerosis (18). Oral zinc promoted renewed blood circulation in cramping calf muscles.

Zinc deficiency in mothers has been associated with congenital anomalies of the nervous system (19). Zinc together with manganese has reduced symptoms of schizophrenia (20). A 30% deficit of zinc content in brain tissue was found in early onset schizophrenia and chronic alcoholism (21). In another study, schizophrenics had about one-half the zinc content of the brain in normal subjects (22).

Zinc deficiency is associated with thymus gland involution and loss of T-cell immunity (23) and the literature of late, including some from Sloan Kettering (24) is replete with evidence that zinc, needed by every aspect of the immune surveillance system, plays a key role in our susceptibility to cancer and even AIDS.

Two diseases affecting millions with no known treatment heretofore may yield to zinc. Schistosomiasis, contracted from the waters and trypanosomiasis (African Sleeping Sickness), both parasitic infections indigenous to Africa, South America and Asia, countries where zinc deficiency is also indigenous, could not be contracted by rats with adequate zinc nutriture (25,26).

We have discussed zinc at length in this report, not merely because it occupies a lot of PBBC attention and not because its presence or absence per *se* in our drinking waters is of great significance. What is significant is that the excess copper from our drinking water exerts a profound effect on our already deficient zinc levels.

Aluminum: Light Metal, Heavy Intoxicant

Aluminum is the commonest element in the earth's crust and has long been thought to have a relatively low toxicity, at least in the quantities ingested by man. Aluminum is not now considered to be a health hazard by the U.S. Public Health Service and there is no recommended upper limit for aluminum in drinking water. At the Princeton BBC, however, aluminum as a toxic element has been occupying our attention since 1978 when we first determined blood levels. As indicated previously, alum is frequently employed as a flocculating agent in water purification, but with the relatively new global problem of acid rain, responsible for dead lakes all over the world, aluminum is being leached more and more from our clay soil. Even if we were not concerned with aluminum per *se* in our drinking water, results of a recent study indicate that the neurotoxic effect of aluminum is dependent on our intake of copper, zinc, iron and magnesium. Hence, levels of other pertinent elements in water can affect aluminum uptake from drinking water and other sources.

Such other environmental sources of aluminum (BBC Handout), obvious to all of us, are aluminum foil, pots and pans, soda and beer cans, bottle caps, and some food containers. Aluminum is leached from such vessels with acid and salty foods. Less obvious sources are foods such as non-dairy creamers, free-flowing table salt and other powdered foods which may contain aluminum calcium silicate as an anti-caking agent. Alum or sodium aluminum phosphate or sulfate is found in baking powder and all baked goods and mixes likely to contain baking powder as well as in some processed cheeses and pickled fruits and vegetables. Aluminum in some form which may or may not appear on the label as an ingredient is common in most toothpastes and antiperspirants, and in some chewing gums and cosmetics. Many pharmaceuticals contain aluminum; examine labels of antidiarrheals, vaginal douches, hemorrhoidal preparations, analgesics, particularly buffered aspirin and most antacids. Many calcium supplements such as Dolomite and Os-Cal may also be naturally contaminated from clay. In England, the hot water heater cathode is commonly made of aluminum which eventually dissolves, thus finding its way into the food of those who use hot water for tea or cooking. A magnesium cathode is used in the U.S.

Aluminum in drinking water had been linked to congenital malformations of the central nervous system in South Wales, Australia (27), where aluminum sulfate is added to the drinking water. Excess aluminum can cause phosphate depletion due to formation of insoluble phosphate in the gut. Phosphate depletion leads to an increased excretion of calcium, probably from dissolution of bone, and this leads to osteomalacia and osteoporosis. Indeed osteomalacia and osteodystrophy were very common in dialysis patients in two towns in England where aluminum is added to remove natural color and taste from the water supply (28). The disease is rare in Birmingham where aluminum is not used for purification and where the water content of aluminum is less than 50 ppb.

Dialysis patients are excellent though inadvertent harbingers of the potential

danger lurking in our water supply. The symptoms they manifest acutely should post a severe warning that chronic diseases with like symptoms may have a similar causation. The Dementia Dialytica due to copper, for example, gave us a full blown picture of copper intoxication including psychosis at its worst in a very short time frame. We should not forget that slow motion, seemingly imperceptible changes, may lead to the same end result, psychosis.

Dialysis may, in fact, have provided us with a clue to one of the worst diseases of modern times, Alzheimer's disease. Aluminum intoxication has now been found to be responsible for the encephalopathy syndrome observed in patients on chronic dialysis (29). Alfrey and the Denver group first implicated the aluminum phosphate binding gels given dialysis patients as the source of the aluminum (30). But in England and in other dialysis centers in the U.S., cases began appearing where high tap-water aluminum in the dialysate (50-400 ug/L) occurred. The aluminum was found to be poorly removed by softeners, and deionization is necessary. The clinical features of aluminum intoxication are speech difficulties, muscle jerking, dementia, loss of memory, hallucinations and paranoia, seizures and abnormal EEG, and finally, death. Symptoms are not too different from those exhibited in Alzheimer's disease.

Critical regions of the brain in Alzheimer's disease do show 1.5 times normal aluminum levels. At the PBBC we have some data which support the link between aluminum intoxication and memory loss as shown by elevated levels of aluminum in blood in patients with memory loss (31). Dr. Elizabeth Lodge Rees found that delinquent and psychotic boys had extraordinarily high hair aluminum levels. Their hair lead and iron were also very high. We also have found elevated hair aluminum in a group of hyperactive boys and in a group with behavioral disorders or learning disabilities. Lead levels were also higher but not significantly so. The role of lead, copper and aluminum in childhood disorders such as hyperactivity and other behavioral and learning problems warrant routine assay in every disabled child.

Recommended treatment found effective in reducing blood aluminum levels at the PBBC is dietary supplementation with magnesium, zinc, manganese and vitamin C.

Lead: Plumbism and Plumbing

Plumbism is lead poisoning, after the Latin word for lead, "plumbum". Many scholars have attributed the fall of Rome to the extensive use of lead aqueducts, lead in drinking vessels, and lead acetate to sweeten wines. There is now no doubt that chronic lead poisoning causes physical brain damage, yet lead piping in old water distribution systems and in old homes remains in use today. Lead solder is still applied to new plumbing, so that lead in drinking water continues to be a problem in some soft water areas. Lead in gasoline has polluted not only our air but our reservoirs and waterways. In 1974, the White House Council on Environmental Quality stated that rainwater runoff from streets carries more heavy metals from auto exhaust such as lead, mercury and copper into our waterways than do discharges from most major industries. Lead levels in the blood of Americans dropped 37% in four years after use of lead-free gasoline was begun in the U.S.; yet it has been a continuing battle with industry for the Environmental Protection Agency to maintain the ban on lead.

There are now massive data from researchers in the U.S. and Scotland that lead exposure is associated with mental retardation in children. The 1975 study in Glasgow showed a clear relationship between lead levels in tap water and retardation (32). The retarded children had higher blood lead levels than matched controls. The soft water was to be treated with calcium salts to decrease the acidity and leaching of lead. An added benefit would be that dietary calcium prevents the accumulation of lead in body tissues. In another American study even "slightly elevated" levels of lead in children's blood have been associated with lowered scores in intelligence tests (33).

Research in our laboratory shows serum copper and blood lead to be high in hyperactive, autistic and learning disabled children. Exposure to lead has been

implicated strongly in neonatal deaths and birth defects and is thought to be the causative factor in a study linking infant mortality and soft water (34,35). It has been shown that a blood lead level of 15 mcg% (the Center for Disease Control allows 25 mcg% as safe!) causes persistent changes in electrical activity of the brains of young children. These investigators stress that there is no threshold and no safe level for lead (36). We maintain that any lead level over the age of the child can cause impairment.

Although there is much public awareness of the dangers of lead and although we have scored some measure of success in reducing lead in our environment, significant exposure is still unavoidable. What is not known is that excess dietary copper — and we are all likely to be exposed to it in our plumbing — exaggerates the severity of lead toxicity. Studies show that with a fixed amount of lead in the diet increasing amounts of lead accumulate in the organs as dietary copper increases (37). Zinc is a powerful antidote for lead, copper and cadmium poisoning (38) but, unhappily, excess copper also exacerbates our already borderline zinc deficiency. Thus a dietary deficiency of zinc or copper-induced deficiency of zinc makes us sitting ducks for the toxic metals around us.

At the PBBC, we have always considered that blood levels greater than the age of the child or greater than 15 mcg% in adults were unacceptable. We treat all such patients who are high in lead with supplements of zinc and vitamin C. The lead levels always come down. Dramatizing the efficacy of the zinc and vitamin C regimen is a study we did on a group of 22 battery workers with high levels of lead in their blood (39). After 12 weeks of treatment, lead levels of virtually all the workers dropped significantly (at the 1 in 1000 level of confidence) even though they were on the job and exposed to lead throughout the course of treatment.

Other Relevant Metals in Drinking Water

We shall briefly touch upon other metals whose deficiencies or excesses in our water supply may influence our health:

Lithium. The fifth century physician Aurelianus recommended mineral waters for the treatment of manic insanity and melancholia. Mineral waters of the spa at Wiesbaden, used during Roman times, as well as of other European springs have high quantities of lithium (4 mg per liter) (40). Lithium is approved for use today for the control of manic episodes in manic-depressive psychosis. It has been found to lower cholesterol levels, which rise under conditions of mental stress (41). Other researchers, including doctors at the PBBC, have found lithium to be effective in depressive illness and at lower doses than indicated for mania. Recent reports confirm that lithium may be useful in the treatment of alcoholics (42,43).

Lithium intake from foods is extremely low, but there are some areas even in this country where lithium in water averages 0.1 mg per liter and can be a significant contribution to our daily intake — as much as 0.2 mg per day in 8 glasses of water. Dawson at the University of Texas has found that admissions to state mental hospitals and homicide and suicide rates correlated inversely with the lithium content of drinking water (40). He espouses the extremely controversial view that it be added to the drinking water up to the level of that occurring naturally in other waters with a high lithium content.

We tested the lithium content of a variety of bottled natural spring and mineral waters which were most popular and available at our local supermarket, including some European sources such as Perrier from France and Rambosa from Sweden. The only samples with detectable levels of lithium were from Saratoga, New York. The Natural Saratoga Sparkling Water contained 0.17 mg/L but the Original Saratoga Geyser brand contained 2.3 mg/L, approaching levels at European spas reported as having at least anecdotal efficacy. Consumption of two liters (roughly 8 glasses) per day would provide 46 mg elemental lithium. One 330 mg tablet of lithium carbonate, about $^{1}/3$ the dose recommended for long-term control of mania, contains 56.4 mg of elemental lithium. It is not an altogether implausible suggestion that low levels of lithium may produce some calming effect on the normal population

— that our moods may hinge on the water we drink.

Molybdenum. The U.S. Dept. of the Interior found molybdenum in about one-third of all samples surveyed at a mean concentration of 68 ug/L. It sets no limits for molybdenum in drinking water. A daily consumption of 2 L averaging about 136 ug would represent a considerable portion of the average dietary intake estimated to vary between 120 and 240 ug. Therefore, natural waters low in this metal could compromise our molybdenum status when diets are wanting. Tissue levels of important molybdenum flavin enzymes have been shown to be a function of dietary intake. Furthermore — enter again our arch villain copper — copper and molybdenum are biochemical antagonists; thus copper from plumbing can exacerbate molybdenum as well as zinc deficiency. Biochemical abnormalities of impaired sulfite and xanthine oxidase activities have been noted both in inborn metabolic error diseases (44,45) and in stark molybdenum deficiency due to total parenteral nutrition (46). We have submitted that sulfite sensitivity, a new-found cause of severe and often fatal reactions in allergic and asthmatic individuals, may be due to widespread molybdenum deficiency (47). Since molybdenum deficiency causes an elevated plasma methionine, implicated in McCully's cogent homocysteine theory of arteriosclerosis (48), we have postulated that molybdenum deficiency may be one more risk factor for arteriosclerosis (49).

In China, a deficiency of molybdenum in soil and waters has been cited as a possible factor in the causation of the high esophageal cancer rates. Molybdenum probably exerts its anticancer effect in oxidation-reduction of enzymes of bacteria and algae, enabling them to convert dangerous nitrogen compounds, namely nitro-samine precursors, to ammonia in the soil. Molybdenum fertilizers also increase the ascorbic acid content of grains and vegetables, a known effective measure in cancer protection. Molybdenum enriched fertilizers are now applied to the soil in China.

Manganese. Manganese is another of the generally overlooked essential trace metals in which deficiency, particularly in diabetes, may be common. It has been found at a mean concentration of 0.06 mg/ L in about half of the waters surveyed, not a significant dietary source since the amount required by the healthy individual to replace excreted manganese is approximately 4 mg. It is mentioned here only because reports of ugly, dirty-looking brown drinking water due to manganese contamination appear from time *to* time in the news reports. There is no danger in such water, however, and a limit of 50 ug/ L has been recommended officially only because of the unpleasant coloration and not because of its toxicity.

Chromium. A safe and adequate daily dietary intake of chromium is considered to be 50 - 200 ug for adults but the average intake has been determined at only 33 ug for males and 25 ug for females. Moreover, increased consumption of refined sugar stimulates urinary chromium losses. Chromium deficiency should therefore be of serious concern in our sugar and junk food-ridden society. Chromium was found in slightly more than half the water samples surveyed at a mean concentration of 14 ug/L, therefore the 28 ug per day one might derive from eight glasses of water would represent a significant contribution. According to Merz, chromium in water which is in the hexavalent state is better absorbed by the organism than the tri-valent form in foods (50). A recent study demonstrated that both inorganic chromium and brewer's yeast supplementation had an equivalent favorable effect on the glucose metabolism of subjects with elevated serum glucose (51).

Long term effects of a suboptimum chromium intake are thought to be related to the increase in diabetes and atherosclerosis. Chromium is essential for maintaining glucose tolerance; it has been found to prevent experimentally induced atherosclerosis in animals and to lower blood cholesterol levels. High chromium levels, associated with a very low incidence of heart disease, are noted in Africans and Orientals and probably result from their low consumption of refined sugar.

Selenium. The amount of selenium in drinking water is generally thought to be too low by comparison with the dietary intake to be of much significance but there

are, in fact, states such as Colorado, North and South Dakota and Utah which have the lowest rate of hypertension and have large amounts of selenium in drinking water. There are studies correlating the selenium content of various forage crops with cardiovascular-renal, cerebrovascular, coronary and hypertensive heart disease as well as with a low cancer rate (52). Selenium can inhibit virally or chemically induced tumour formation and will also lower the incidence of spontaneous mammary adenocarcinoma (53). The dramatic therapeutic effect of selenium on the outcome of Keshan's disease, a type of congestive heart failure common in Keshan province of China, emphasizes its importance as a significant factor in heart disease (54). There is a well-known antagonism between selenium and other heavy metals and it has been demonstrated that selenium, like zinc, protects animals against the acute and toxic effects of such metals. Once more, there is a selenium-copper antagonism so that the benefits of dietary selenium may be offset and a borderline diet may become a deficient one because of high copper in the water.

The Water Factor: Nutrient or Poison?

In 1960, the late Henry Schroeder reported on an inverse correlation between drinking water hardness and cardiovascular disease (55). This followed on the heels of a report from Japan of a positive correlation between fatal strokes and acidity of river water (56). These reports sent everyone all over the world scurrying for the so-called "water factor", a protective factor in hard and missing in soft, or an adverse factor in soft water. The relationship between water hardness and lessened cardiac fatalities was definitely a global finding.

Schroeder was a principal proponent of cadmium as the toxic factor which can dissolve in soft water from galvanized pipes (57). He has shown that cadmium concentrated in the kidney and caused hypertension and large ugly plaques in the arteries of rats. Further supporting this view is the twin Kansas Cities story where the correlation between cardiovascular disease and soft water was now inverse, conflicting with worldwide reports favoring hard water (58). Kansas City, Kansas and Kansas City, Mo. draw their water from the same source but the Missouri city's water is artificially softened and has a 30% lower cardiovascular mortality rate. The investigators here felt that their results, though opposite to the worldwide trend, helped answer why hard water ordinarily protects people against heart attacks. The hard water Kansas City had a three fold higher level of cadmium in water and its residents had a 13 times higher cadmium level in serum than the soft water side. In the soft water Kansas City, zinc was higher in water and three times higher in the serum of its residents. The reason why these results were opposite to those worldwide was probably that the source water, the Missouri River, is very high in cadmium. This cadmium is removed in the water softening process in Missouri. Soft water, as it courses through distribution and home piping, will leach zinc (which is good) from galvanized (coated with zinc) pipes and would pick up cadmium only if it is present as a contaminant. These investigators then named zinc as the protective water factor and cadmium as the villain. Indeed cadmium-induced hypertension can be reversed by zinc in laboratory animals.

Another study assailed barium as the water factor culprit in heart disease. Selenium, silicon and vanadium have been variously hailed as the protective water factor by other researchers.

The most obvious elements to consider first when searching for a "water factor" in cardiovascular disease are calcium and magnesium, which confer the very property of hardness. Many dismiss these as candidates, for it is said that the contribution of calcium and magnesium from the water is small compared with the dietary intake and that their only role is, besides neutralizing the acidity, that they lime pipes and prevent corrosion, hence leaching of toxic metals. Other investigators dispute this and feel that magnesium is the most likely candidate, the strongest correlate and that hard water can in fact contribute 10-20% of our intake. Surveys in this country show that self-selected diets contain 200-250 mg/day of magnesium,

considerably below the recommended 300-400 mg/day. Furthermore, stress (physical, as in exercise or from trauma) or psychological (anger, overwork) results in a heightened magnesium requirement due to secretion of adrenalin and corticosteroids. Overly high dietary levels of protein, vitamin D, sugar, alcohol and phosphate (exceedingly common in our soda-pop culture) all increase the need for magnesium.

In a symposium on magnesium, soft water and heart disease, magnesium deficiency was implicated in heart attacks following disturbances of heart rhythm, a frequent cause of sudden death from heart attacks (59). Such deaths are directly associated with a deficiency of magnesium in heart muscle itself. One of the manifestations of magnesium deficiency in experimental animals is an increased tendency to cardiac arrhythmias. Magnesium supplements are therapeutic in human cardiac arrhythmia, acute hypertension and ischaemic heart disease.

Industrialized countries, characterized by high death rates from cardiovascular diseases, are also characterized by a high consumption of refined and processed food — the so-called empty calorie foods which have lost most of their trace element content. A study which dramatizes the role of water as an important source of essential trace elements is one reported from London (60). A substantial drop in the death rate of babies occurred, paradoxically, during a drought. The residents were forced to turn to hard water sources which alone made the difference between life and death for some infants. The investigation attributed the decrease in the death rate among the very small children to the presence of trace elements in some surface reservoir water supplies.

What We Can Do?

The poor quality of our nation's drinking water has been well covered in the popular press. This has spurred the public, if not governmental protection agencies, to take various measures in their homes to improve the drinking water. The popularity of bottled water has soared and this is expensive. Furthermore, bottled water isn't regularly monitored for synthetic chemicals or metals, except in states like New York which require it. A study by the Suffolk County Health Dept. found the average bottled water to be no better or no worse than the average tap water. None had undesirable levels of copper or other toxic metals; therefore bottled water is a prudent alternative to water known to be contaminated with chemicals or in homes where very soft and acid water is attacking the copper plumbing. Many have installed various filter units containing activated charcoal, effective in removing chlorine, sediment, sulfur, detergent, odors and organic chemicals from tap water, but not very effective in removing copper and other toxic metals. Water softeners (ion exchange) do remove them, but this process unhappily substitutes two parts sodium for every part calcium and magnesium removed, thus further aggravating hypertension in our oversalted society, while denying us the calcium and magnesium we need. Minerals can only be removed by distillation, deionization or reverse osmosis. These are expensive systems and leave water with a bland, insipid taste, devoid of calcium or magnesium. Since copper usually enters water at the home distribution system, one could bottle one's own drinking water at the pump or point of entry into the house. Companies such as Culligan may lime the acid water before it enters the copper house plumbing. In most cases, however, it suffices to let the water run for five minutes when is has been standing in the pipes overnight.

Given the present state of our nation's waters, of our copper plumbing, copper-coil water coolers and ice makers, there is a need for developing a simple method which can effectively remove harmful metals from the drinking water in our homes without also removing calcium and magnesium. We must also assume an active role in supplementing our diet with the missing trace minerals.

We are no longer concerned with the short-term, the acute water-borne infectious diseases. The past three decades have revealed insidious long-term effects of our seemingly pristine waters; links between the chemicals and minerals in our drinking water and chronic ailments such as heart disease and cancer are no longer

Table 1

Copper Content of Some Drinking Waters in the Vicinity of the Brain Bio Center (ppm)

Brain Bio Center	Kitchen or Bathroom	Drinking Fountains Tap	Drinking Fountains Refrigerated
Standing, Many Days	4.2		
Standing, Many Hours	2.0		
Running	0.08		
At Pump	0		
Hot Summer Day — 1st A.M. Sample			5.4
Noon			1.7
Cold Spring Day — Midafternoon			2.7
Laboratory Ice Machine			1.8
Blue Ice Chips at Bottom			12.9
Old House, Adjacent to BBC			
Standing	.6		
Running	.1		
Princeton University			
Library	.6		.6
Chemistry Dept.	.1		1.5
Chemistry Dept. Running			.9
The Lawrenceville School	.6	.8	3.8
The Mercer County Community College	.2	—	.8
Burnt Hill Road Grammar School			
Early Morning	.17	.2	—
Late Afternoon	.17	.2	
Montgomery Township Municipal Bldg.			.5
Rocky Hill Library	.3		.2
Foodtown Supermarket Rocky Hill			.3
E. R. Squibb Worldwide Headquarters			
Standing	.4		.7
Running	.2		.6

speculation. Imbalances of trace metals and the presence of toxic materials in drinking water undoubtedly play a large role we have yet to fully elucidate.

A sequel to this paper, "Pure Water for Useful Longevity", presented in part before the Princeton Brain Bio Center 5th Scientific Symposium: Lother Burgerstein Conference on Useful Longevity, Lawrenceville, N.J., May 14,1985, will be submitted for publication in a forthcoming issue of Orthomolecular Medicine.

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