

Hair Toxic and Essential Elements

RESOURCE GUIDE

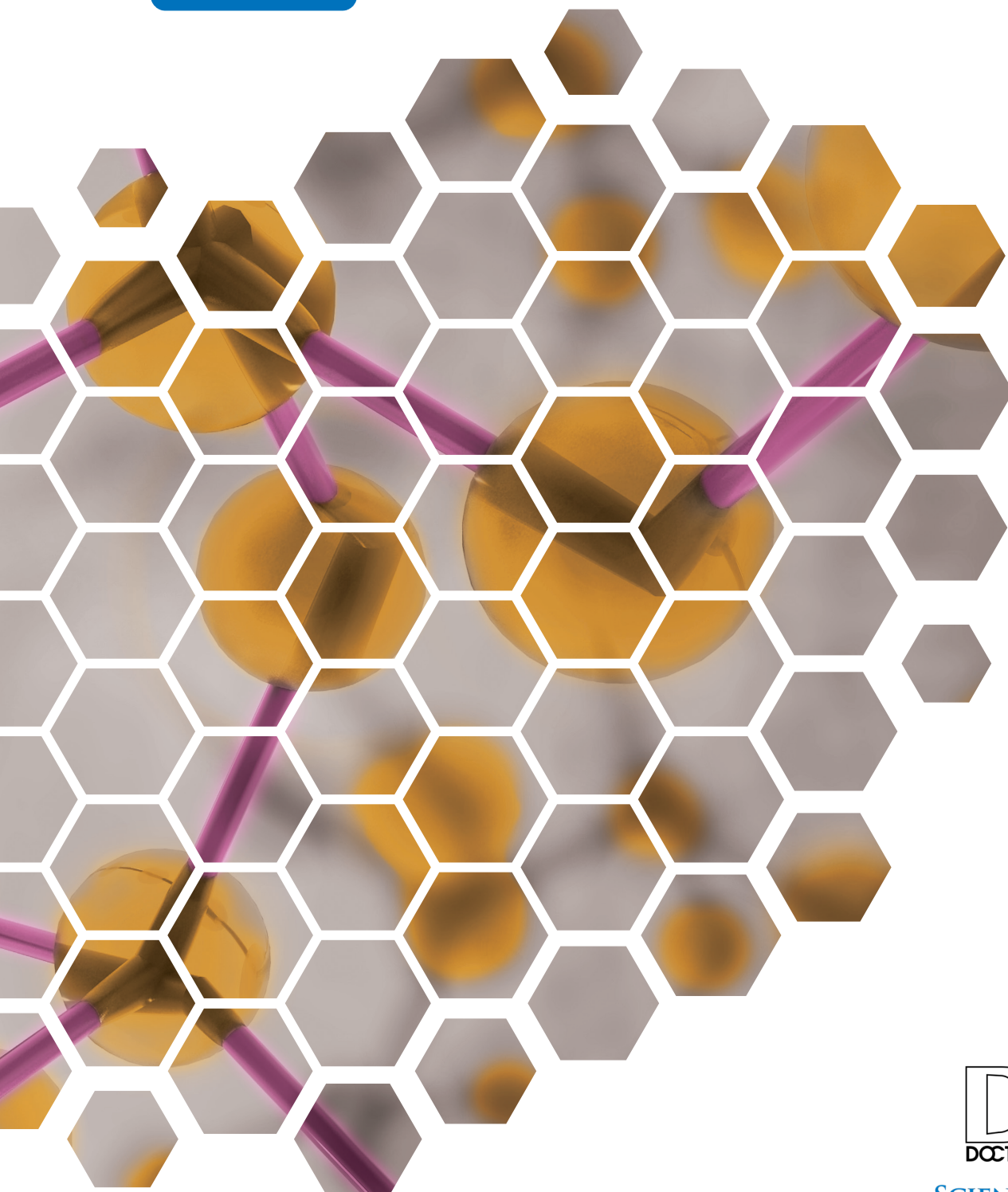


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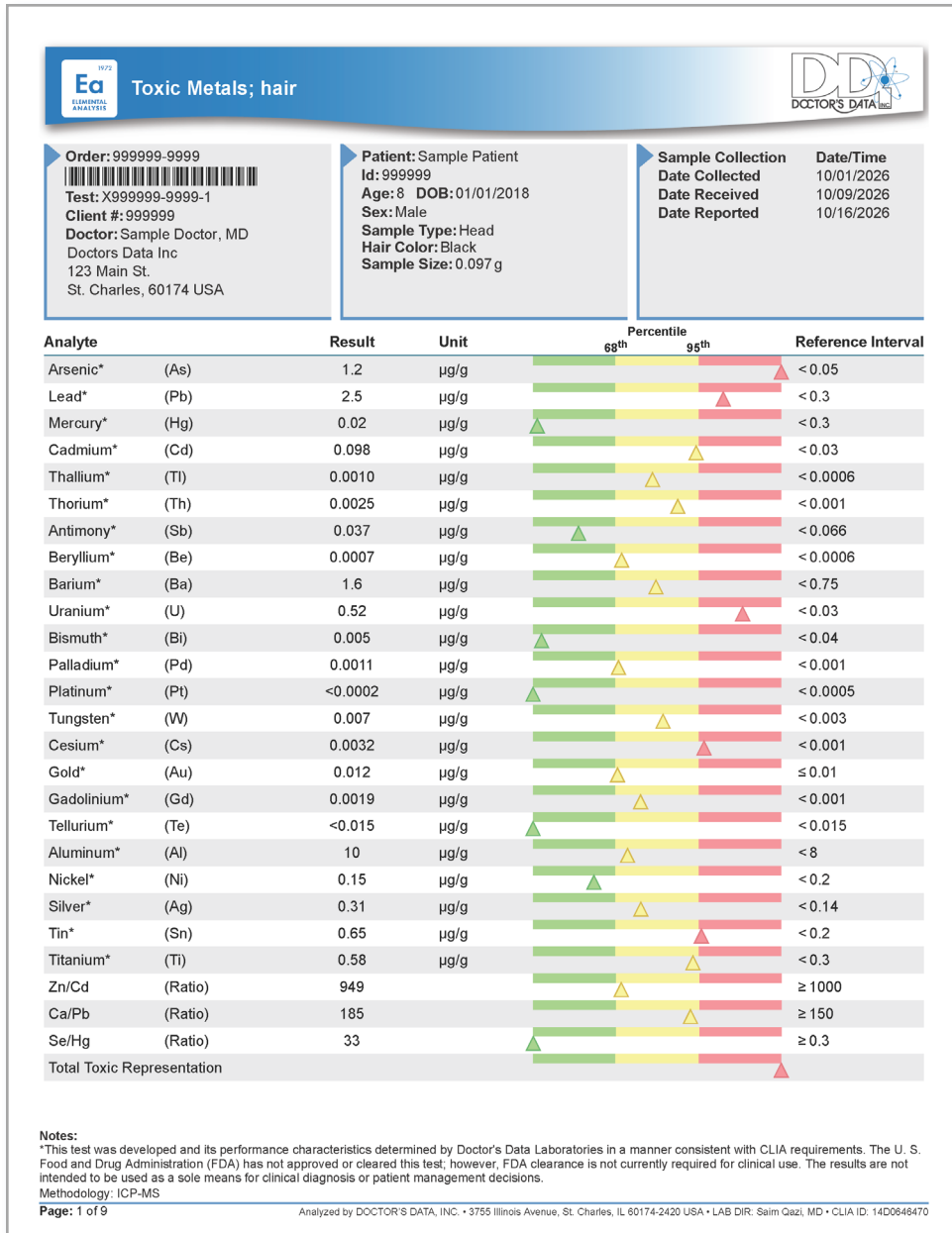
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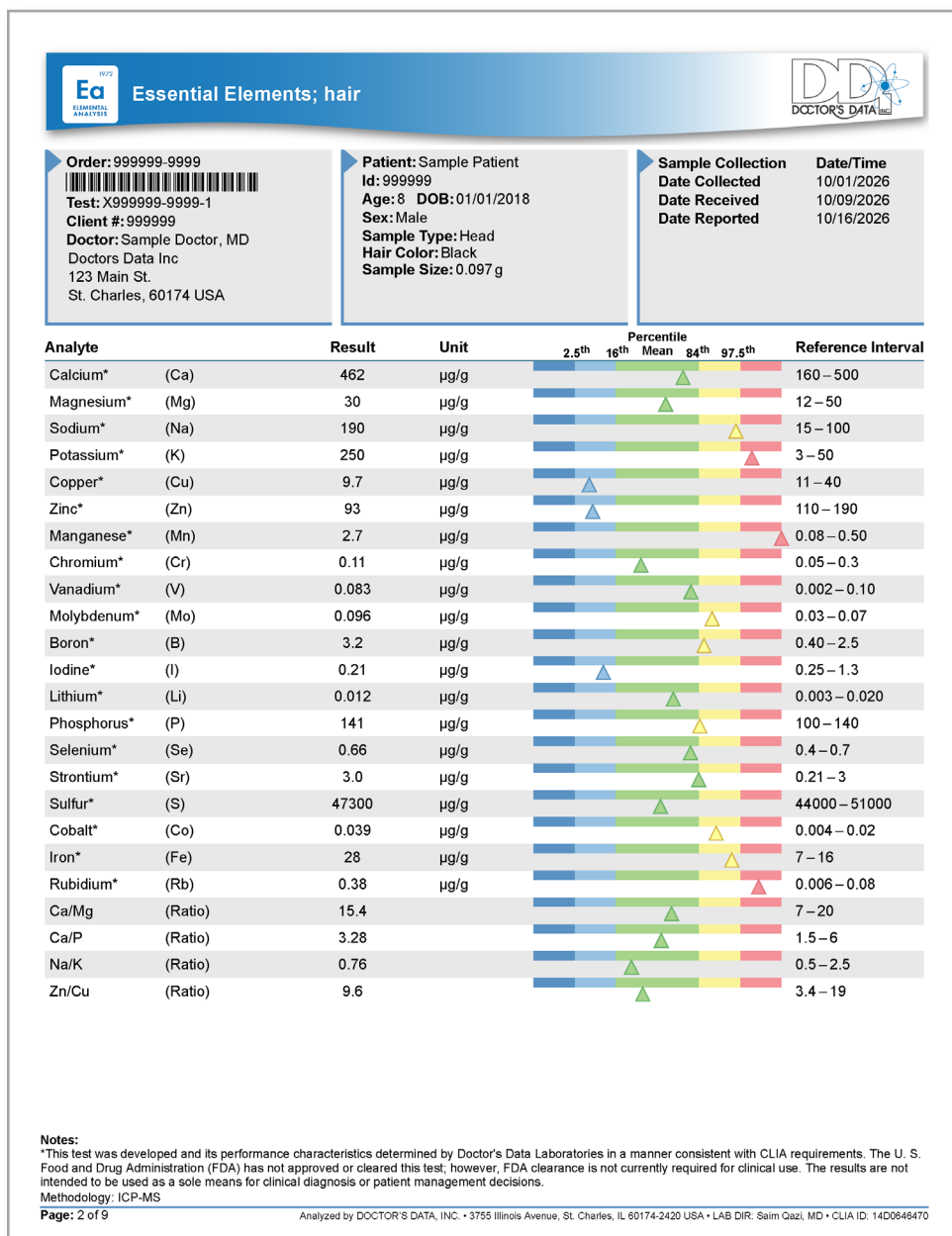
Sample Report



Hair samples are washed using a standardized 3 step wash procedure that has been validated to remove exogenous contamination, and will not affect metals derived from the body.

This test addresses exposure to potentially toxic elements over a greater window of time compared to blood levels of metals.

Toxic element ratios in hair, such as Zn/Cd, Ca/Pb, and Se/Hg, evaluate the protective relationship between essential and toxic elements.



Essential elements in hair provide a stable long-term view, reflecting incorporation of elements over several weeks.

Hair provides a simple, non-invasive matrix for assessing essential mineral patterns.

Beyond individual element levels, ratios, such as Ca/Mg, Na/K, and Zn/Cu, highlight functional patterns that single element values cannot capture.

Introduction

Hair is an excretory tissue for essential, nonessential, and potentially toxic elements since elements are irreversibly incorporated into growing hair. Therefore, hair element analysis provides an indirect screening test for exposure, physiological excess, deficiency, or maldistribution of elements in the body. Clinical research indicates that hair levels of specific elements, particularly toxic elements such as cadmium, mercury, lead, and arsenic are highly correlated with pathological disorders. For such elements, levels in hair provide a longer temporal window of exposure than levels in blood or urine.

Hair provides a noninvasive estimation of ongoing/recent exposure to elements but cannot provide a definitive estimate of the extent of long-term net retention or body burden, nor toxic effects. All screening tests have limitations that must be taken into account. The correlation between hair element levels and physiological disorders is influenced by numerous factors. Individual variability and compensatory mechanisms are major factors that affect the relationship between the distribution of elements in hair and symptoms or pathological conditions.

It is also very important to keep in mind that scalp hair is vulnerable to external contamination by exposure to hair treatments and products. Likewise, some hair treatments (e.g., permanent solutions, dyes, bleach) can strip hair of endogenously acquired elements and result in falsely low values. Careful consideration of these limitations must be made when interpreting hair analysis results. The data provided should be evaluated in conjunction with symptomatology, diet analysis, occupation and lifestyle, physical examination, and other analytical laboratory tests.

Caution: The contents of this report are not intended to be diagnostic, and the physician using this information is cautioned against treatment based solely on the results of this screening test. For example, copper supplementation based on a result of low hair copper is contraindicated in patients with Wilson's Disease.

Pubic Hair Specimens

Pubic hair and scalp hair are very different tissues with respect to protein and chemical composition, and rate of growth. The levels of most nutrient elements in pubic and scalp hair for a given individual are typically quite different. Although we do have reference ranges for nutrient elements in pubic hair specimens, there is a lack of clinical data to support sound interpretation at this time. For the potentially toxic elements, however, there appears to be a good correlation between scalp and pubic hair. Some clinicians utilize pubic hair for toxic element analysis, (a) to confirm results from scalp hair, and/or (b) when scalp hair has been recently treated with dye or permanent and bleaching reagents.

Total Toxic Element Indication

The potentially toxic elements vary considerably with respect to their relative toxicities. The accumulation of more than one of the most toxic elements may have synergistic adverse effects, even if the level of each individual element is not strikingly high. Therefore, we present a total toxic element "score" which is estimated using a weighted average based upon relative toxicity using information from ATSDR (Agency for Toxic Substances and Disease Registry). For example, the combined presence of lead and mercury will give a higher total score than that of the combination of silver and beryllium.

Silver High

Hair Silver (Ag) levels have been found to reflect environmental exposure to the element. However, hair is commonly contaminated with Ag from hair treatments such as permanents, dyes, and bleaches.

Ag is not an essential element and is of relatively low toxicity. However, some Ag salts are very toxic.

Sources of Ag include seafood, metal and chemical processing industries, photographic processes, jewelry making (especially soldering), effluents from coal fired power plants, and colloidal silver products.

The bacteriostatic properties of Ag have been long recognized, and Ag has been used extensively for medicinal purposes; particularly in the treatment of burns. There is much controversy over the long-term safety of consumption of colloidal silver. Very high intake of colloidal silver has been reported to give rise to tumors in the liver and spleen of animals (Metals in Clinical and Analytical Chemistry, eds. Seiler, Segel and Segel, 1994). However, this data may not have relevance to the effects of chronic, low-level consumption by humans.

Aluminum High

The Aluminum (Al) level in hair may be an indicator of exposure and assimilation of this element, provided that hair preparations have not added exogenous Al. Al is a nonessential element that can be toxic if excessively assimilated into cells. Excess Al can inhibit the formation of alpha-ketoglutarate and result in toxic levels of ammonia in tissues. Al can bond to phosphorylated bases on DNA and disrupt protein synthesis and catabolism. Al excess should be considered when symptoms of presenile dementia or Alzheimer's disease are observed. Hair Al is commonly elevated in children and adults with low zinc and behavioral/learning disorders such as ADD, ADHD and autism. Individuals with renal problems or on renal dialysis may have elevated Al. Everyday exposure is mainly from inorganic Al salts and oxides found in food additives, cookware, antacids, antiperspirants, and water treatment. Antiperspirants commonly contain Al chlorohydrate or zirconium compounds, while municipal water supplies may include trace Al from natural sources or alum used in treatment. Inorganic Al compounds are found in skin tanning solutions, cosmetics, mordants, and coagulating agents. Additional sources include sodium Al phosphate in baking powder, processed cheese, cake mixes, and other foods, as well as certain vaccines. Al foil may also contribute, as small amounts can leach into food, particularly when acidic foods such as tomato sauce or citrus are prepared in Al pots or wrapped in foil. Over-the-counter antacids and buffered aspirin often contain Al compounds. Consumer products such as paints, packaging, electronics, and building materials also contribute indirectly to exposure. Analyses performed at Doctor's Data indicate extremely high levels of Al in many "colloidal mineral" products. Al has neurotoxic effects at high levels, but low levels of accumulation may not elicit immediate symptoms. Early symptoms of Al burden may include: fatigue, headache, and symptoms of phosphate depletion. Chronic high exposure can contribute to neurological effects (studied in Alzheimer's disease (M. Dey. Pharmacol. Rep., 74(3): 439–50, 2022.). A urine elements test can be used to corroborate Al exposure.

Arsenic High

Hair Arsenic (As) is an excellent marker to assess chronic exposure to inorganic As. Inorganic As is highly toxic, whereas organic As is largely harmless and rapidly excreted. Inorganic As accumulates in hair, nails, skin, thyroid gland, bone and the gastrointestinal tract. Organic As, such as arsenobetaine found in shellfish, is rapidly excreted in the urine and as such is not primarily represented in hair.

Arsenic has been included in certain historical lice treatment formulations. As can cause malaise, muscle weakness, vomiting, diarrhea, dermatitis, and skin cancer. Long-term exposure may affect the peripheral nervous, cardiovascular, and hematopoietic systems. As is a major biological antagonist to selenium.

Common sources of As found in hair include drinking water (well), dietary sources (including rice), insecticides (calcium and lead arsenate), smog, industrial exposure, particularly in the manufacture of electronic components (gallium arsenide) and shellfish (arsenobetaine). Rice and rice products are the most significant dietary source of inorganic As worldwide, with brown rice containing higher levels than white rice due to retention in the bran layer. Rice-based foods such as cereals, milk, flour, snacks, and syrups can all contain measurable inorganic As, particularly when grown in regions with high-As groundwater such as Bangladesh, India, parts of China, and the U.S. South-Central states. Infant rice cereals and snacks are of special concern, prompting FDA guidance levels of ≤ 100 ppb inorganic As.

Other dietary sources include fruit juices, sweeteners like organic brown rice syrup, and certain cereal grains, though wheat, barley, oats, and corn generally contain much lower levels. Vegetables grown in contaminated soil, such as carrots, beets, spinach, lettuce, and potatoes, may accumulate As, and hijiki seaweed is a known outlier with extremely high inorganic As content. Please note that hair can be contaminated externally with As from water. Health agencies recommend varying grains, rinsing rice before cooking, using excess water to reduce As content, limiting hijiki consumption, and testing private wells for As.

Confirmatory tests for acute, recent exposure to As are whole blood or urine.

Gold

Gold (Au) salts (chrysotherapy) were historically utilized to reduce joint inflammation and slow progression of joint damage, though their exact pharmacodynamics remain poorly understood. Toxicity occurs in 30–50% of patients, with ~10% experiencing severe reactions requiring discontinuation. Patients with the HLA-DR3 genotype are more susceptible to Au-induced toxicity. Kean, W.F., Lock, C.J.L., Buchanan, W.W., Howard-Lock, H., Hogan, M.G. (1992). Gold toxicity: chemical, structural, biological, and clinical experimental issues. In: Rainsford, K.D., Velo, G.P. (eds) Side-Effects of Anti-Inflammatory Drugs 3. Inflammation and Drug Therapy Series, vol 5. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-2982-4_37

Boron High

Boron (B) is normally found in hair but the correlations among B absorption, and tissue and hair levels of B have yet to be determined. B has a low order of toxicity, but excessive intake induces riboflavinuria. Exogenous contamination of hair with B is possible since B is present in some soaps. B is also present in some cleaners, cement, ceramics, and glass.

Boron Low

Boron (B) is normally found in hair, but the correlations among dietary B intake, and tissue and hair levels of B have yet to be established. Recent studies clearly indicate that B has an important role in normal bone metabolism/density and may be needed for normal membrane function. In post-menopausal women consuming a very low B diet, B supplementation significantly lowered urinary excretion of calcium and magnesium and increased serum levels of estrogen (Environ. Health Perspect.; 102 Supl.7: 59-63, 1994). Further research is in process to determine the clinical significance of hair B levels.

Barium High

Hair may be used for biological monitoring of barium (Ba) exposure. Exogenous contamination has been observed from bath water containing Ba. Elevated levels of hair Ba are often observed as a result of exposure to Ba for diagnostic medical tests.

Elevated levels of Ba may interfere with calcium metabolism and displace potassium. Very high retention of Ba can result in increased stress hormone levels (e.g. catecholamines), and may cause ventricular fibrillation, bronchoconstriction, and swelling of the brain and testis. Chronic ingestion of Ba at elevated levels may be manifested by muscular and myocardial stimulation, tingling in the extremities, and loss of tendon reflexes.

Undesirable exposure to Ba may be associated with contaminated water, air or soil. Ba has been used in rodenticides and insecticides and is used for medical testing (barium enemas). Mining and refining coal and combustion of coal and oil emit Ba. Mine tailings and masonry products made from such can be a significant source of Ba to individuals producing or working with them (e.g. reconstruction, demolition). Arc-welding, metal fabrication, and occupational work with fireworks can be associated with abnormal exposure to Ba.

The main dietary sources of Ba are peanuts/peanut butter, milk, flour, potatoes, and some types of nuts.

A confirmatory test for elevated Ba is measurement of blood electrolytes; hypokalemia may be associated with elevated Ba. Sweat analysis indicates that sauna therapy may increase excretion of Ba (Doctor's Data, unpublished.)

Beryllium High

Beryllium (Be) has been found in the hair, but documentation correlating exposure, tissue levels and hair levels is lacking. Therefore, Be is measured in hair primarily for investigational purposes. Be can be toxic to humans and animals. Be is a biological antagonist of magnesium. Be has a long-term effect of inducing abnormal activity in T lymphocytes, causing immune dysregulation and hypersensitivity reactions. In animals, Be has been shown to induce rickets and to damage the liver, kidney, lungs, and skin. Be is poorly absorbed in the gastrointestinal tract but is readily absorbed through the lungs and respiratory tract. Inhalation is the primary route of exposure to Be and chronic uptake results in dyspnea, cough and pulmonary distress. (Am. Rev. Respir. Dis.; 173:464-473, 1988).

Possible sources of Be are: electronic components, metal alloys used in aircraft and aerospace applications (especially aluminum-copper-beryllium alloys), bearing sleeves, optical lens coatings, and some phosphors in fluorescent lights. Tobacco contains Be, and smoking immediately increases the Be levels in the blood and urine.

A confirming test for Be exposure is urine elements analysis. Be is slowly excreted in urine and may be found elevated many months after the exposure.

Bismuth High

No published studies correlate Bismuth (Bi) exposure with hair Bi levels; therefore, hair Bi levels are measured primarily for investigational purposes. Bi is a non-essential element of low toxicity. However, excessive intake of insoluble, inorganic Bi-containing compounds can cause nephrotoxicity and encephalopathy. Absorption is dependent upon solubility of the Bi compound, with insoluble Bi excreted in the feces while soluble forms are excreted in the urine. Sources of Bi include: cosmetics (lipstick), Bi containing medications such as ranitidine Bi-citrate, antacids (Pepto Bismol), pigments used in colored glass and ceramics, dental cement, and dry cell battery electrodes.

Symptoms of moderate Bi toxicity include: constipation or bowel irregularity, foul breath, blue/black gum line, and malaise. High levels of Bi accumulation can result in nephrotoxicity (nephrosis, proteinuria) and neurotoxicity (tremor, memory loss, myoclonic jerks, dysarthria, dementia).

Urine elements analysis can be used to corroborate Bi absorption for a period of days or a few weeks after exposure. (J. Lab. Clin. Med.; 119:529-537,1992).

Calcium High

Hair Calcium (Ca) levels have been correlated with nutritional intake, several disease syndromes, and metabolic disorders. However, hair Ca is sensitive to contamination by permanent solutions, dyes or bleaching. If hair has been treated, the reported level of Ca is likely to be artifactually high and not indicative of Ca status or metabolism.

When external contamination is ruled out, elevated Ca is most often interpreted as a maldistribution of Ca. Rarely is elevated hair Ca indicative of excess dietary Ca. However, overzealous supplementation is possible. A high result for hair Ca is more likely to be indicative of an inappropriately low ratio of dietary Ca to phosphorus. Conditions associated with elevated hair Ca include but are not limited to: hyperparathyroidism, osteoporosis, excess dietary Ca or protein, excess vitamins A and/or D, phosphorus/magnesium/calcium imbalance (assessed by whole blood element analysis), hypoglycemia, hormonal imbalances, and metabolic disorders.

Hair analysis is not the preferred way to assess body Ca stores. Ca status should be assessed through: dietary analysis, whole blood or serum Ca level, vitamin A and D levels, blood concentrations of other electrolytes (sodium, magnesium, potassium), parathyroid hormone determinations, and bone density measurement.

Calcium Low

Hair Calcium (Ca) levels have been correlated with nutritional intake, several disease syndromes, and metabolic disorders. Interpretation of low hair Ca levels is difficult, and other variables need to be considered.

Ca is the most abundant element in the body. Although most Ca is contained in the skeletal system, Ca is actively involved in muscle contraction, the nervous system, hormone secretion, and immunological responses.

Causes of Ca deficiency includes, but are not limited to inadequate dietary Ca, protein or vitamin D, excess dietary phosphorus and malabsorption. Malabsorption is likely if other essential elements such as magnesium, cobalt, manganese, and chromium are also at low levels in hair. Other factors associated with poor Ca status include physical inactivity, chronic stress, hormonal imbalance, aluminum containing antacids, chronic use of diuretics or laxatives, high alcohol intake, and exposure to toxic elements (e.g. lead, cadmium).

Symptoms of Ca deficiency include: muscle cramps or tetany, myalgia, and skeletal pain. Chronic Ca deficiency (or negative balance) results in osteoporosis.

Hair is vulnerable to external contamination by Ca as a result of hair treatments (permanent solutions, dyes, bleach). Other means to assess Ca status include: dietary assessment, whole blood elements analysis, and measurement of bone density, serum vitamin D-3, and parathyroid hormone.

Cadmium High

Hair Cadmium (Cd) levels provide an excellent indication of exposure to Cd. Cd is a toxic heavy metal that has no metabolic function in the body. Moderately high Cd levels, about 4-8 µg/g, may be associated with hypertension, while very severe Cd toxicity may cause hypotension. Cd adversely affects the kidneys, lungs, testes, arterial walls, and bones and interferes with many enzymatic reactions. Chronic Cd excess can lead to microcytic, hypochromic anemia and proteinuria with loss of beta-2-microglobulin, and functional zinc deficiency. Cd excess is also commonly associated with fatigue, weight loss, osteomalacia, and lumbar pain.

Cd absorption is reduced by zinc, calcium, and selenium. Cd is found in varying amounts in foods, from .04 µg/g for some fruits to 3-5 µg/g in some oysters and anchovies. The use of tobacco products significantly increases Cd intake. Refined carbohydrates have very little zinc in relation to the Cd. West coast oysters are notoriously high in Cd.

If hair zinc is not abnormal, external contamination may have caused the elevated hair Cd level. Exogenous contamination may come from permanent solutions, dyes, bleach, and some hair spray. Confirmatory tests for Cd are whole blood or urine.

Cesium

Cesium (Cs) is a naturally-occurring element found in rocks, soil, and dust at low concentrations. It is present in the environment only in the stable form of Cs133; the radioactive isotopes 134Cs and 137Cs are not measured or reported by Doctor's Data. Natural deposits of Cs ores occur in Maine, South Dakota and Manitoba (Bernic Lake), Canada. Cesium may bio-accumulate in aquatic food chains.

Cesium may be used in high-density drilling fluids (oil and gas industry) and may contaminate local water and vegetation. Cesium may occur naturally in mineral waters; one study analyzed the Cs concentration in 163 mineral and thermal waters and found the level ranged from 4.5 to 148 µg per liter. Cs has been found in cow milk.

Cesium can be absorbed after oral ingestion, upon breathing contaminated air and through contact with the skin. Cesium is readily absorbed across the brush border of the intestines in a manner similar to potassium, and most is eventually excreted through the urine and feces. The biological half-life of Cs in humans ranges from 15 days in infants to 100–150 days in adults.

The cesium-137 isotope is used in cancer treatments, for ventricular function and pulmonary imaging studies, industrial radiology, and for food and instrument sterilization; Cs137 agents may contain amounts of Cs133. Again, it is emphasized that Cs measured at Doctor's Data is Cs133, not Cs137.

Cobalt High

Hair may be used for monitoring excess exposure to cobalt (Co). However, hair is occasionally contaminated by external Co from some hair treatments. If an individual's hair has been treated with permanent solutions, dyes, or bleach, the Co levels may not be indicative of body Co accumulation.

Humans absorb Co both as inorganic Co and as vitamin B-12; the body pools of each fluctuate independently. Humans cannot convert inorganic Co to vitamin B-12, and vitamin B-12 provides the only documented function of Co in humans. Thus, a high hair Co level does not mean that vitamin B-12 levels are high or even adequate.

Co is utilized in the manufacture of metal alloys with high melting point, strength and resistance to oxidation. Alloys with chromium, nickel, molybdenum, and copper are utilized in the electrical, aeronautical, and automobile industries. Co salts and oxides are used in the glass industry, for paints and colored pottery. They are also used as fertilizers, catalysts in chemical reactions, and in some dental amalgams. Co salts are no longer utilized as foam stabilizers in the brewing of malt beverages due to cardiovascular diseases that the metal induced.

The primary clinical manifestations of chronic Co toxicity include weight loss, pulmonary syndrome, allergy, nausea, cardiomyopathy, electrolyte imbalance, hematological disorders, and thyroid lesion.

The dietary content of Co is highly variable and depends upon types of foods eaten, geographical location, and type of soil. Toxicity has been noted with ingestion of 250-400 mg/day. Recent animal studies indicate that excess Co can cause marked impairment of myocardial metabolism that results in metabolic acidosis. (Clin. Chem.; 43(6): 5192, 1997).

Hair analysis cannot be used to assess vitamin B-12 status. Appropriate tests for determination of B-12 status are the measurement of urine levels of methylmalonic acid (elevated with B-12 coenzyme deficiency/dysfunction), quantitative blood assay for vitamin B-12, and urine amino acids analysis (several metabolic steps require vitamin B-12).

Cobalt Low

One cannot determine vitamin B-12 status by using hair analysis, and the clinical significance of low hair Cobalt (Co) levels is not known. Hair is analyzed for Co primarily for detection of excessive intake of the potentially toxic element.

There is little evidence that Co has an essential function in humans other than as an obligatory constituent of the vitamin B-12 molecule. Humans absorb Co as inorganic Co and as vitamin B-12; the body pools of each fluctuate independently. Humans cannot convert inorganic Co to vitamin B-12.

The dietary content of Co is highly variable, depending upon types of foods eaten, geographical location, and type of soil. Vegetarians often have lower levels of Co than meat eaters.

Appropriate tests for determination of vitamin B-12 status are the measurement of urine levels of methylmalonic acid (elevated with vitamin B-12 coenzyme deficiency/dysfunction), a quantitative blood assay for vitamin B-12, a urine amino acids analysis (several metabolic steps require vitamin B-12), and diet analysis.

Chromium High

A high hair chromium (Cr) level is likely to indicate excess exposure to Cr. Hair Cr levels do not appear to be affected by permanent solutions, dyes, or bleaches, but external contamination is possible. Trivalent Cr is considered to be an essential trace element with a low order of toxicity. Cr toxicity via oral ingestion is not likely. However, it is noteworthy that excessive self-supplementation has been reported to be associated with insomnia and increased unpleasant dream activity in some individuals (J. Nutr. Med.; 3(43), 1992).

Phytates decrease oral assimilation of Cr+3, whereas nicotinic acid and vitamin C increase absorption of Cr+3, zinc, vanadium and iron compete with Cr for absorption.

In contrast, hexavalent Cr compounds are considerably more toxic and are primarily absorbed via inhalation as a result of industrial exposure. Industrial exposure to high amounts of Cr has been reported to be associated with allergic dermatitis, skin ulcers, bronchitis, and lung and nasal carcinoma. Elevated hair Cr levels have also been observed in patients with cerebral thrombosis and cerebral hemorrhage.

Sources of exposure to hexavalent Cr include: manufacture and use of ferrochromium and stainless steel, chromium plating (plumbing, electrical appliances, automotive parts), welding, commercial spray painting, wood finishing and leather tanning industries, and handling of cement. Extensive mining of Cr and disposal of spent ore presents a serious environmental problem in certain regions.

Tests to confirm excess exposure to Cr include analysis of Cr in plasma (trivalent) versus packed red blood cells (hexavalent); both analyses are more indicative of recent exposure than of body burden. A urine elements analysis will confirm recent exposure and serum hyaluronidase activity is reported to be elevated with excessive exposure to Cr.

Chromium Low

Hair Chromium (Cr) is a good indicator of tissue levels and may provide a better indication of status than do urine or blood plasma/serum (Nielsen, F.H. In Modern Nutrition on Health and Disease; 8th Edition, 1994. Ed. Shils, Olson and Shike. Lea and Febiger, Philadelphia). Hair Cr is seldom affected by permanent solutions, dyes, and bleaches.

Cr (trivalent) is generally accepted as an essential trace element that is required for maintenance of normal glucose and cholesterol levels; it potentiates insulin function, i.e., as a part of "glucose tolerance factor". Deficiency conditions may include hyperglycemia, transient hyper/hypoglycemia, fatigue, accelerated atherosclerogenesis, elevated LDL cholesterol, increased need for insulin and diabetes-like symptoms, and impaired stress responses. Marginal or insufficient Cr is common in the U.S., where average tissue levels are low compared to those found in many other countries. Low hair Cr appears to be associated with increased risk of cardiovascular disease and an atherogenic lipoprotein profile (low HDL, high LDL). Common causes of deficiency are ingestion of highly processed foods, inadequate soil levels of Cr, gastrointestinal dysfunction, and insufficient vitamin B-6. Cr status is also compromised in patients with iron overload/high transferrin saturation because transferrin is a major transport protein for Cr.

Confirmatory tests for Cr adequacy include glucose tolerance and packed red blood cell elements analysis.

Copper High

An elevated level of copper (Cu) in hair may be indicative of excess Cu in the body. However, it is important first to rule out exogenous contamination sources: permanent solutions, dyes, bleaches, swimming pool/hot tub water (very common), and washing hair in acidic water carried through Cu pipes. In the case of contamination from hair treatments, other elements (aluminum, silver, nickel, titanium) may also be elevated.

Copper is used extensively in sanitation and in the production of kitchen utensils, and thermal and electric conductors. Copper solutions are used in industrial processes such as electroplating, printed circuit production, textile production, and catalysts in chemical processes. Albeit reduced, Cu-sulfate is sometimes used in agriculture (vineyards, orchards). Other sources of Cu exposure include contaminated food or drinking water, and excessive Cu supplementation, particularly in combination with low intake of zinc or molybdenum. Insufficient intake of competitively absorbed elements such as zinc or molybdenum can lead to or worsen Cu excess. Cu toxicity significantly compromises zinc homeostasis.

Medical conditions that may be associated with excess Cu include: biliary obstruction (reduced ability to excrete Cu), liver disease (hepatitis or cirrhosis), and renal dysfunction. Symptoms associated with excess Cu accumulation are muscle and joint pain, depression, irritability, tremor, hemolytic anemia, learning disabilities, and behavioral disorders.

Copper Low

Hair Copper (Cu) levels are usually indicative of body status with two exceptions: (1) addition of exogenous Cu (occasionally found in hair preparations or algacides in swimming pools/hot tubs), and (2) low hair Cu in Wilson's or Menkes' diseases. In Wilson's disease, Cu transport is defective and Cu accumulates, sometimes to toxic levels, in intestinal mucosa, liver and kidneys. At the same time, it is low in hair and deficient in other peripheral tissues. In Menkes' disease, the activity of Cu-dependent enzymes is very low. Cu supplementation is contraindicated in these diseases.

Cu is an essential element that is required for the activity of certain enzymes. Erythrocyte superoxide dismutase (SOD) is a Cu (and zinc) dependent enzyme; lysyl oxidase (LOX) which catalyzes crosslinking of collagen is another Cu dependent enzyme. Adrenal catecholamine synthesis is Cu dependent, because the enzyme dopamine beta-hydroxylase, which catalyzes formation of norepinephrine from dopamine, requires Cu.

Symptoms of Cu deficiency include: elevated cholesterol, increased inflammatory responses, anemia, bone and collagen disorders, reproductive failure, and impaired immunity. Possible reasons for a Cu deficiency include: intestinal malabsorption, insufficient dietary intake, molybdenum excess, zinc excess, and chelation therapy. Cu status is adversely affected by excess of antagonistic metals such as mercury, lead, cadmium, and manganese.

Confirmatory tests for Cu deficiency are serum ceruloplasmin to rule out Wilson's disease (ceruloplasmin is deficient in Wilson's disease), a whole blood or packed red blood cell elements analysis, and a functional test for Cu (barring zinc deficiency) is measurement of erythrocytes SOD activity. Erythrocyte SOD activity is subnormal with Cu deficiency.

Copper Normal

Hair Copper (Cu) levels are usually indicative of body status, except that exogenous contamination may occur, giving a false normal (or false high). Common sources of contamination include: permanent solutions, dyes, bleaches, and swimming pools/hot tubs in which Cu compounds have been used as algaecides.

Cu is an essential element that activates specific enzymes. Erythrocyte superoxide dismutase (SOD) is a Cu (and zinc) dependent enzyme; lysyl oxidase which catalyzes crosslinking of collagen is another Cu dependent enzyme. Adrenal catecholamine synthesis is Cu dependent, because the enzyme dopamine beta-hydroxylase, which catalyzes formation of norepinephrine from dopamine, requires Cu.

If hair Cu is in the normal range, this usually means tissue levels are in the normal range. However, under circumstances of contamination, a real Cu deficit could appear as a (false) normal. If symptoms of Cu deficiency are present, a whole blood or red blood cell elements analysis can be performed for confirmation of Cu status.

Gadolinium

The level of gadolinium (Gd) in hair provides an indication of recent or ongoing exposure to the metal, and decorporation from the body. Gd has no known biological role in humans. Toxicity from oral or environmental exposure is rare due to poor gastrointestinal absorption (<0.05%). The single greatest direct source of exposure is Gd-based contrast agents (GBCAs) used with magnetic resonance imaging (MRI), and Gd would be expected to be variably high for all individuals if hair is collected within six months after administration. Concern has been raised regarding unstable linear GBCAs, especially for patients with moderate to severe kidney dysfunction. The vast majority of medically administered Gd is normally cleared in patients with good kidney function (glomerular filtration rate; GFR), but clearance may be markedly slowed with compromised GFR.

While Gd levels normally decrease rather rapidly in urine and feces, some Gd is retained in the body for a long time. Equivocal concern exists regarding Gd deposition in the brain, which is correlated with the number of GBCA-enhanced MRI procedures. Gd is also found in the environment in geographically variable amounts, usually at very low levels. Direct exposure from industrial and household sources (alloys, television tube phosphors, radar technologies, compact discs, microwaves) is not a concern, though disposal of Gd-containing devices contributes to greater potential for environmental exposure.

"Gadolinium deposition disease" has been described in the literature and may be associated with pain, headache, skin thickening, muscle weakness, arthralgia, and persistent clouded mentation. If such new symptoms appear 2-8 weeks after Gd-enhanced MRI, it has been suggested that urine Gd (1st AM void or 24-hour collection) be determined. Unpublished observations at Doctor's Data indicate that variably high levels of Gd are detected in stool metal specimens in association with administration of GBCAs for imaging purposes.

Iron High

Hair Iron (Fe) levels do not correlate with Fe assimilation as determined by serum ferritin, Fe binding capacity, or transferrin saturation. Hair Fe is not indicative of liver Fe loading disease, and hair Fe is not necessarily elevated with hemochromatosis.

Elevated hair Fe should be viewed only as a screening test result that may warrant further investigation to confirm or rule out Fe overload. Hair Fe levels may also be elevated from bathing or washing in well water containing high levels of Fe.

Laboratory tests that are useful in assessing Fe status include: serum Fe level, serum ferritin level, percent saturation of ferritin, and total Fe binding capacity ("TIBC").

Iron Low

Hair Iron (Fe) levels do not correlate with Fe assimilation as determined by serum ferritin, Fe binding capacity, or transferrin saturation. A very low hair Fe result should be viewed only as possible indication for further tests because hair is only a screening test for this element. Fe supplementation is not indicated nor recommended solely on the basis of the measured hair Fe level. Unwarranted Fe supplementation, particularly in combination with ascorbic acid, can result in Fe overload. A large body of scientific literature indicates significant relationships between dietary Fe overload and heart disease, cancer, diabetes, osteoporosis, and arthritis. (Biochem. Mol. Med.; 54(1):1-11, 1995).

Mercury High

Hair mercury (Hg) is an excellent indicator of exposure to methylmercury from fish. Mercury is toxic to humans and animals. Individuals vary greatly in sensitivity and tolerance to Hg burden.

Hg can suppress biological selenium function and may cause or contribute to immune dysregulation in sensitive individuals. Hallmark symptoms of excess Hg include: loss of appetite, decreased senses of touch, hearing, and vision, fatigue, depression, emotional instability, peripheral numbness and tremors, poor memory and cognitive dysfunction, and neuromuscular disorders. Hair Hg has been reported to correlate with acute myocardial infarction and on average each 1 µg/g of hair Hg was found to correlate with a 9% increase in AML risk. (Circulation 1995; 91:645-655).

Sources of Hg include dental amalgams, fish, water supplies, some hemorrhoidal preparations, skin lightening agents, instruments (thermometers, electrodes, batteries), and combustion of fossil fuels, Ayurvedic herbs, some fertilizers, and the paper/pulp and gold industries. After dental amalgams are installed or removed, a transient (several months) increase in hair Hg is observed. Also, "baseline" hair Hg levels for individuals with dental amalgams are higher (about 1 to 2 µg/g) than are baseline levels for those without (below 1 µg/g).

Confirmatory tests for elevated Hg are measurement of whole blood as an indication of recent/ongoing exposure of organic methylmercury or measurement of urine Hg to assess elemental or inorganic Hg.

Iodine High

Hair Iodine (I) levels have been noted to vary according to I status levels and dietary intake. I is nutritionally essential for humans and is used in the formation of thyroid hormones. I is bound to the tyrosine residue in thyroglobulin to form triiodothyronine (T-3) and thyroxine (T-4). However, there is no scientific support indicating that high hair I levels, per se, are diagnostic of thyroid function.

External contamination of hair with I from hair treatments is possible. Contamination is often accompanied by elevated aluminum, silver, nickel, and titanium if there is exogenous I contamination from hair preparations.

Conditions that may be associated with excessive I include: hypersensitivity reactions, hypothyroidism, thyroiditis, and iodide goiter. Hypersensitivity reactions can be immunologic or nonimmunologic, but usually include dermatological irritation or contact dermatoses. Other possible hypersensitivity reactions include: angio-edema, burning or soreness of mouth and throat, and nausea/diarrhea. Autonomous thyrotoxicosis (Plummer's disease) and autoimmune thyrotoxicosis (Graves' disease) may occur in I excess if thyroid function is poorly controlled by hypothalamic-pituitary action. If questionable, thyroid function should be assessed by measurement of TSH, T-4, and T-3.

Iodine Low

Hair Iodine (I) levels have been noted to vary according to I status and dietary intake. I is an essential element and is required for synthesis of thyroid hormones. I is bound to the tyrosine residue in thyroglobulin to form triiodothyronine (T-3) and thyroxine (T-4). However, there is no scientific support linking low levels of I in hair to hypothyroidism.

Symptoms associated with confirmed I deficiency include: fatigue, weight gain, and reduced metabolic rate and cellular respiration, and goiter. Severe and chronic I deficiency may result in intellectual disability and congenital hypothyroidism or iodine deficiency-related developmental delay. Breast dysplasia and cancer have been correlated with I deficiency.

I is readily absorbed in organic and inorganic forms. Although it is absorbed in the stomach, most absorption occurs in the small intestine. Good dietary sources of I include: seafood, kelp, sunflower seeds, mushrooms, eggs, beef liver, cheddar cheese, and peanuts as well as iodized salt.

If hair I is low, and thyroid function is questionable, thyroid parameters should be checked (TSH, T-3 and T-4).

Palladium

The relationship between the levels of palladium (Pd) in hair and exposure to the metal has yet to be determined. Pd compounds are rarely encountered by most people. Most palladium compounds should be regarded as toxic and carcinogenic. There have been numerous reports of allergic contact dermatitis to Pd. The main contact sources are jewelry and dental materials (gold alloys). The characteristics of Pd (ductile, malleable, resistant to corrosion, easily fused and welded) make it an acceptable material for jewelry making and dentistry. Palladium is used in the field of communications in facing electrical contacts in automatic switch gear. The nonmagnetic springs in clocks and watches as well as special coatings for mirrors are also made of Pd. The chemicals industry uses Pd as a catalyst. Palladium is often found associated with platinum in Australia, Brazil, Russia, Ethiopia, and North and South America, as well as with nickel and copper deposits in Canada and South Africa.

Potassium High

High hair Potassium (K) is not necessarily reflective of dietary intake or nutrient status. However, elevated K may be reflective of metabolic disorders associated with exposure to potentially toxic elements.

K is an electrolyte and a potentiator of enzyme functions, but neither of these functions take place in hair. Elevated K in hair may reflect overall retention of K by the body or maldistribution of this element. In adrenocortical insufficiency, K is increased in blood, while it is decreased in urine; cellular K may or may not be increased. Also, hair is occasionally contaminated with K from some shampoos. Observations at Doctor's Data indicate that K and sodium levels in hair are commonly high in association with toxic element burden. The elevated K and sodium levels are often concomitant with low levels of calcium and magnesium in hair. This apparent phenomenon requires further investigation.

Elevated hair potassium should be viewed as a screening test. Appropriate tests for excess body K include measurements of packed red blood cell K; serum or whole blood K and sodium/K ratio, measurement of urine K and sodium/K ratio; and an assessment of adrenocortical function.

Potassium Low

The level of Potassium (K) in hair does not reflect nutritional status or dietary intake. However, hair K levels may provide clinically relevant information pertaining to adrenal function and/or electrolyte balance.

K is an electrolyte and a potentiator of enzyme functions in cells, but neither of these functions takes place in hair. K can be low in the body as the result of gastrointestinal or renal dysfunction, or as a side effect of some diuretics. In adrenocortical hyperactivity, blood levels of K are depressed, while urinary K is increased. Low hair K should be viewed as a screening test. Observations at Doctor's Data indicate that hair levels of sodium and K are commonly low in association with emotional stress. The low levels of sodium and K are frequently concomitant with high levels of calcium and magnesium in hair. This apparent "emotional stress pattern" requires further investigation.

Symptoms of true K deficiency include: muscle weakness, fatigue, and tachycardia. Diabetic acidosis can result in severe K loss.

Confirmatory tests for K deficiency include measurements of packed red blood cell K; whole blood K and the sodium/K ratio; urine K and the sodium/K ratio. An electrocardiogram may show abnormalities when K is low in serum/plasma or whole blood.

Lithium High

Lithium (Li) is normally found in the hair at very low levels. Hair Li levels correlate with high dosage of Li carbonate in patients treated for Affective Disorders. Li occurs almost universally at low concentrations in water and in plant and animal food products. Li is used in the manufacture of lightweight metal alloys, glass, lubrication greases, and batteries.

Li at low levels may have essential functions in humans. Intracellularly, it slows the conversion of phosphorylated inositol to free inositol. In the nervous system, this moderates neuronal excitability. Li also influences monoamine neurotransmitter concentrations at the synapse (this function is increased when Li is used therapeutically for mania or bipolar illness).

Li, when ingested in excessive quantities, may cause dermatitis, nausea, confusion, edema, or hypotension. Li toxicity may be more pronounced with low sodium intake. Li may compete for calcium and magnesium binding sites on biological ligands. Li at levels above two standard deviations does not necessarily constitute Li toxicity. Confirmation of excess Li levels may be obtained from blood plasma/serum levels if the uptake/exposure is recent or chronic. Point-in-time Li doses are rapidly excreted in urine, and blood analysis may not be indicative after 5 to 7 days.

Lithium Low

Lithium (Li) is normally found in hair at very low levels. Hair Li correlates with high dosage of Li carbonate in patients treated for Affective Disorders. However, the clinical significance of low hair Li levels is not certain at this time. Thus, hair Li is measured primarily for research purposes. Anecdotally, clinical feedback to Doctor's Data consultants suggests that low level Li supplementation may have some beneficial effects in patients with behavioral/emotional disorders. Li occurs almost universally in water and in the diet; excess Li is rapidly excreted in urine.

Li at low levels may have essential functions in humans. Intracellularly, Li inhibits the conversion of phosphorylated inositol to free inositol. In the nervous system, this moderates neuronal excitability. Li also influences monoamine neurotransmitter concentrations at the synapse (this function is increased when Li is used therapeutically for mania or bipolar illness).

A confirmatory test for low Li is measurement of Li in blood serum/plasma.

Magnesium High

Magnesium (Mg) is an essential element with both electrolyte and enzyme-activator functions. However, neither of these functions takes place in hair. Body excess of Mg is rare but may occur from excessive oral or parenteral supplementation or as a result of renal damage or insufficiency.

If one rules out external contamination of hair as a result of recent hair treatment, elevated hair Mg is more likely to indicate maldistribution of the element. Physiological Mg dysfunction may or may not be present. Maldistribution of Mg can occur as a result of chronic emotional or physical stress, toxic metal or chemical exposure, physiological imbalance of calcium and phosphorus, bone mineral depletion, and renal insufficiency with poor clearance of Mg (and other metabolites). Elevated hair Mg has been correlated with hypoglycemia and an inappropriately low ratio of dietary calcium to phosphorus.

Mg status can be difficult to assess; whole blood and packed blood red cell Mg levels are more indicative than serum/plasma levels. Amino acid analysis can be helpful in showing rate-limited steps that are Mg-dependent (e.g. phosphorylation).

Magnesium Low

Low hair Magnesium (Mg) levels may be indicative of Mg deficiency, but this has not been unequivocally demonstrated. When hair Mg is low, dietary intake and malabsorption should be considered. Mg is an essential element/electrolyte that is necessary for the activity of many important enzymes. Low hair Mg may or may not be associated with physiological dysfunction.

Causes of Mg deficiency include: consumption of a "junk food" diet or Mg-deficient foods, intestinal malabsorption, hypocalcemia with decreased Mg retention, chemical toxicity with renal wasting, alcoholism, alkalosis, prolonged diarrhea/laxative abuse, and iatrogenic causes (digoxin therapy, occasionally from oral contraceptives, hypercalcemic drugs, gentamicin, neomycin).

Symptoms of Mg deficiency include: muscle twitching, cramps, tremor or muscle spasms, paresthesia, and mental depression. Low Mg status is associated with arrhythmias and increased cardiovascular risk.

Mg status can be difficult to assess; whole blood and packed red cell levels are more indicative than serum/plasma levels. Amino acid analysis can be helpful in showing rate-limited steps that are Mg-dependent, such as phosphorylation. Taurine deficiency is often associated with urinary loss of Mg. The Mg challenge method may be indicative: baseline 24-hour urine Mg measurement, followed by 0.2 mEq/Kg intravenous mg, followed by 24-hour Mg measurement. A deficiency is judged to be present if less than 80% of the administered Mg is excreted in the urine.

Manganese High

Hair manganese (Mn) levels generally reflect actual body stores, but external contamination can influence hair Mn. Since particulate manganese-containing dust is the most common source of Mn toxicity, hair is considered to be an excellent tissue for the assessment of Mn exposure. However, high hair Mn can be an artifact of contamination from hair treatments/products or well water (containing high Mn). These possibilities should definitely be considered and ruled out before proceeding with therapies to alleviate an apparent excess of Mn.

Mn is an essential element which is involved in the activation of many important enzymes. However, Mn excess is postulated to result in glutathionyl radical formation, reduction of the free glutathione pool, and increased exposure of adrenal catecholamines (e.g. dopamine) to free radical damage. Excess Mn causes degeneration of myelin pigmented dopaminergic neurons which results in abnormally low levels of serotonin and dopamine in the brain. This is hypothesized to be a reason behind the neurotoxic effects attributed to Mn overload.

The brain is particularly affected by Mn excess. Symptoms or conditions consistent with excessive Mn include: lethargy, disorientation, memory loss, anxiety, emotional instability, and bipolar-like behaviors (laughing and crying), aberrant or violent behaviors, and tremor or Parkinson-like symptoms.

Occupationally, the greatest sources of exposure to Mn dust and fumes occur in mining of the element, and in the production and fabrication of iron and steel. In addition, various Mn compounds are widely used in fertilizers, animal feeds, pharmaceutical products, dyes, paint dryers, catalysts, wood preservatives, and ceramic production. Mn is also an air pollutant derived from the gasoline additive MMT.

Other sources of exposure include contaminated teas, contaminated drinking water, some street drugs, and smoking. Conditions predisposing to Mn excess are: iron or calcium deficiency, chronic infection, and impaired liver function. Mn excess is occasionally associated with alcoholism (hepatic dysfunction), and biliary cirrhosis/obstruction.

A confirmatory test for Mn excess is Whole Blood Elements.

Manganese Low

Hair Manganese (Mn) levels correlate well with Mn levels in other body tissues. Hair Mn levels are commonly low, in part due to low dietary Mn intake and the interaction of Mn with phosphates in the gut. Intestinal malabsorption also limits Mn uptake.

Mn is an essential element that is involved in energy metabolism, and bone and cartilage formation. Mn is an activator of many important enzymes including: mitochondrial superoxide dismutase, arginase, and pyruvate carboxylase.

Symptoms associated with Mn deficiency include: fatigue, lack of physical endurance, slow growth of fingernails and hair, impaired metabolism of bone and cartilage, dermatitis, weight loss, and reduced fertility. Increased allergic sensitivities and inflammation are often associated with low Mn. Seizures are occasionally reported to be associated with severe Mn deficiency.

An appropriate laboratory test to confirm Mn deficiency is whole blood elements analysis.

Molybdenum High

Hair is a tissue that accurately reflects exposure to excess Molybdenum (Mo), and hair is not often subject to external contamination of Mo.

Mo is an essential and relatively non-toxic element. Therefore, Mo excess may not feature symptoms. Possible manifestations of Mo excess are; loss of appetite, anemia, and arthritic symptoms. These are also signs of copper deficiency which can be a result of Mo excess.

Excess Mo is uncommon but can be the result of occupational exposures. Lubricants, catalysts, pigments, organic glazes, steel alloys are sources of Mo. Copper deficiency can predispose to Mo retention and excess.

Confirmatory tests for excess Mo include a 24-hour urine elements analysis and measurement of whole blood or packed red blood cell copper (may be depressed in Mo excess).

Molybdenum Low

Low Molybdenum (Mo) in hair is a possible indication of Mo deficiency. Hair is very rarely contaminated with exogenous Mo.

Mo is an essential trace element that is an activator of specific enzymes such as: xanthine oxidase (catalyzes formation of uric acid), sulfite oxidase (catalyzes oxidation of sulfite to sulfate), and aldehyde dehydrogenase (catalyzes oxidation of aldehydes). Possible effects or symptoms consistent with Mo deficiency are: subnormal uric acid in blood and urine, sensitivity or reactivity to sulfites, protein intolerance (specifically to sulfur-bearing amino acids), and sensitivity or reactivity to aldehydes.

True Mo deficiency is uncommon but may result from: a poor-quality diet, gastrointestinal dysfunctions, or tungsten exposure. Tungsten (from "TIG" welding) can be a powerful antagonist of Mo retention in the body. Copper overload can also reduce Mo retention.

Because normal blood and blood cell Mo levels are very low (a few parts per billion), blood measurement is not an appropriate tissue for confirmation of subnormal molybdenum.

Confirmatory tests for Mo deficiency include measurement of urine sulfite concentration (increased in Mo deficiency), measurement of blood/urine uric acid level (decreased in Mo deficiency), and measurement of urinary Mo content.

Sodium High

Sodium (Na) is an essential element with extracellular electrolyte functions. However, these functions do not occur in hair. Hair Na measurement should be considered a screening test only; blood testing for Na and electrolyte levels is much more diagnostic and indicative of status. High hair Na may have no clinical significance, or it may be the result of an electrolyte imbalance. A possible imbalance for which high hair Na is a consistent finding is adrenocortical hyperactivity. In this condition, blood Na is elevated while

potassium is low. Potassium is elevated (wasted) in the urine. Observations at Doctor's Data indicate that Na and potassium levels in hair are commonly high in association with elevated levels of potentially toxic elements. The elevated Na and potassium levels are frequently concomitant with low levels of calcium and magnesium in hair. This apparent phenomenon requires further investigation.

Appropriate tests for Na status as an electrolyte are measurements of Na in whole blood and urine, and measurements of adrenocortical function.

Sodium Low

The level of Sodium (Na) in hair has not been documented to be indicative of dietary adequacy or nutritional status. Na is an essential element with extracellular electrolyte functions, but these functions do not occur in hair. Low hair Na may have no clinical significance, or it may be consistent with electrolyte imbalance associated with adrenal insufficiency. In this condition, blood Na would be low, blood potassium would be high, and urinary levels of Na would be expected to be high. Observations at Doctor's Data indicate that Na and potassium levels in hair are commonly low in association with emotional stress. The low levels of Na and potassium are frequently concomitant with high levels of calcium and magnesium in hair. This apparent "emotional stress pattern" requires further investigation.

Appropriate tests for Na status as an electrolyte are measurements of Na in whole blood and urine, and measurements of adrenocortical function.

Nickel High

Hair is a reasonable tissue for monitoring exposure to Nickel (Ni). However, hair is commonly contaminated with Ni from hair treatments and dyes. When hair Ni is measured at more than .6 ppm, the possible use of hair dyes or colorings should be investigated before concluding that excessive Ni is present. Nickel is present in a surprisingly large number of foods and food products, including: black tea, nuts and seeds, soy milk and chocolate milk, chocolate and cocoa powders, certain canned and processed foods, including meat and fish, certain grains, including: oats, buckwheat, whole wheat and wheat germ.

There is substantial evidence that Ni is an essential element which is required in extremely low amounts. However, excess Ni has been well established to be nephrotoxic, and carcinogenic. Elevated Ni is often found in individuals who work in the electronic and plating, mining, and steel manufacturing industries. A cigarette typically contains 2 to 6 mcg of Ni; Ni is absorbed more efficiently in the lungs than in the gastrointestinal tract. Symptoms of chronic Ni exposure include dermatitis, chronic rhinitis, and hypersensitivity reactions. Ni can hypersensitize the immune system, subsequently causing hyperallergenic responses to many different substances.

Symptoms of Ni toxicity are dermatitis and pulmonary inflammation (following exposure to Ni dust, smoke). Long term or chronic Ni toxicity may lead to liver necrosis and carcinoma.

Phosphorus High

Hair Phosphorus (P) levels do not accurately reflect the adequacy of the biochemical functions of P. Further, hair P concentration does not correlate with dietary intake of P. However, hair P levels may be affected by abnormal calcium, P or vitamin D metabolism and possibly by abnormal magnesium levels. Hair P levels are measured primarily for research purposes.

P is a major component of mineralized tissue such as bone and teeth. Along with calcium, P assimilation is regulated by vitamin D. Phosphates also are present in every cell of the body where they are involved in chemical energy transfer and enzyme regulation. Phosphorylation chemistry is part of carbohydrates, amino acids, and lipid metabolism.

Appropriate tests for assessing P status are measurements of whole blood (total) P level; serum vitamin D-3 and/or 25-OH vitamin D-3 level; and 24-hour urinary P level (together with those of calcium and magnesium).

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Appropriate tests for assessing P status are measurements of whole blood (total) P level; serum vitamin D-3 and/or 25-OH vitamin D-3 level; and 24-hour urinary P level (together with measurements of calcium and magnesium).

Lead High

This individual's hair Lead (Pb) level is considered to be moderately elevated. Generally, hair is an excellent indicator of exposure to Pb. However, elevated levels of Pb in head hair can be an artifact of hair darkening agents, or dyes, e.g. lead acetate. Although these agents can cause exogenous contamination, some transdermal absorption does occur.

Pb has neurotoxic and nephrotoxic effects in humans as well as interfering with heme biosynthesis. Pb may also affect the body's ability to utilize the essential elements calcium, magnesium, and zinc. At moderate levels of body burden, Pb may have adverse effects on memory, cognitive function, nerve conduction, and metabolism of vitamin D. Children with hair Pb levels greater than 1 µg/g have been reported to have a higher incidence of hyperactivity than those with less than 1 µg/g. Children with hair Pb levels above 3 µg/g have been reported to have more learning problems than those with less than 3 µg/g.

Symptoms associated with excess Pb are somewhat nonspecific, but include: anemia, headaches, fatigue, weight loss, cognitive dysfunction, and decreased coordination.

Sources of exposure to Pb include: welding, old leaded paint (chips/dust), drinking water, some fertilizers, industrial pollution, lead-glazed pottery, Ayurvedic herbs, and use of firearms. Confirmatory tests for Pb include urine and whole blood.

Lead Extremely High

This individual's hair Lead (Pb) level is considered to be extremely elevated and is consistent with significant prolonged exposure to Pb. Hair is an excellent indicator of exposure to Pb. However, elevated levels of Pb in head hair can be an artifact of hair darkening agents, or dyes, e.g., lead acetate. Although these agents can cause exogenous contamination, transdermal absorption can contribute to body burden.

Pb has neurotoxic and nephrotoxic effects and interferes with heme biosynthesis. Pb may also affect the body's ability to utilize the essential elements calcium, magnesium, and zinc. At high levels of body burden, Pb may have adverse effects on memory and cognitive abilities, nerve conduction, and metabolism of vitamin D. Impaired erythropoiesis and anemia may be present. Children with hair Pb levels above 3 µg/g have been reported to have more learning problems than those with less than 3 µg/g. (Arch. Environ. Hlth. 51: 214-220, 1996).

Symptoms associated with excess Pb are vague, but include: loss of appetite and body weight, poor memory, fatigue, constipation, headaches, inability to concentrate, and decreased coordination.

Sources of exposure to Pb include: welding, old leaded paint (dust/chips), drinking water, some fertilizers, industrial waste, lead-glazed pottery, manufacture of stained glass, Ayurvedic herbs and use of firearms.

Confirmatory tests for Pb include urine and whole blood.

Platinum High

Platinum (Pt) is a nonessential element that is sometimes detected in hair. However, the clinical significance of hair Pt has not been well studied. Hair treatments commonly contribute to artifactual contamination of hair.

Pt is poorly absorbed in the gut but may be absorbed via inhalation. Since it is a relatively rare element, most Pt exposures are of occupational origin. In recent years, there may have been a slight increase in environmental Pt due to the use of Pt as a catalyst in automobile exhaust converters. Pt is a byproduct of copper refining and used as an alloy in dental and orthopedic materials. Symptoms of excess exposure to Pt include: dermatitis, irritation of mucus membranes, dyspnea and wheezing (for inhaled Pt dusts or salts), development of chronic allergic reactions ("platinosis"), nephrosis, and immunosuppression (from Pt diamine salts).

Pt containing drugs, such as cisplatin and carboplatin, are used as chemotherapeutic agents. Such drugs are extremely toxic and cause nephrotoxicity with associated magnesium wasting and hypomagnesemia, myelosuppression, ototoxicity, and neurotoxicity.

Rubidium High

Hair Rubidium (Rb) levels may correlate with exposure and with Rb levels in other tissues. Rb is chemically very similar to potassium and competes with potassium in some enzymatic reactions; substitution for potassium by Rb may or may not result in inhibition. (Comp. Biochem. Physiol.; 73: 223, 1982, Haematologica 75: 27, 1990). Rubidium is not considered to have a biological function; due to its chemical similarity to potassium, it may be taken up by plants and animals.

The low toxicity of Rb is illustrated by the fact that no symptoms of toxicity were observed in nine men in which 10 - 15% of their total body potassium was replaced by Rb (Horm. Metab. Res., 13:175,1980). Earlier studies with rats demonstrated that on a potassium-deficient diet, death occurred when 50% of muscle tissue was replaced with rubidium (Follis AJP 1943 Jan; Vol. 138 no. 246-250). Rb82 is used in medical tests such as positron emission tomography (PET) scans, myocardial perfusion scans, and brain scans. Rb may have antidepressant activity, particularly in patients with kidney disease (Canavese, Blood Purif 2008;26:311–314). Although Rb toxicity is exceedingly rare, excessive Rb intake may result in inhibition of I uptake by the thyroid gland and interfere with cardiac muscle contraction. It is considered moderately toxic at high levels of ingestion and may result in symptoms of failure to gain weight, ataxia, hyper irritation, skin ulcers, and anxiety or nervousness. Rubidium exposure may exacerbate pre-existing heart conditions, kidney conditions, or potassium imbalance.

Rb is used in electron tubes, light-sensitive cathodes, and other electrical equipment. The metal is used in the manufacture of photocells and in the removal of residual gases from vacuum tubes. Rubidium salts are used in glasses and ceramics and in fireworks. Plants, such as sugar beets, may use rubidium in potassium-deficient soils. Soybeans, beef, tomatoes, and ground coffee are food sources containing relatively high levels of Rb (~ 90 - 200 ppm). Daily intake varies from 1-5 mg depending on geography and diet.

Rubidium Low

Hair Rubidium (Rb) levels may correlate with exposure and with Rb levels in other tissues. Rubidium is not considered to have a biological function; due to its chemical similarity to potassium, it may be taken up by plants and animals (Comp. Biochem. Physiol.; 73: 223, 1982, Haematologica 75: 27, 1990). Daily intake varies from 1-5 mg depending on geography and diet.

Sulfur High

Sulfur (S) in hair is covalently bound within the cysteinyl residues of hair protein. On average, cysteine constitutes about sixteen percent of the total amino acid content of hair. Although not well documented, hair S levels may vary with S-containing amino acid status in the body. Interpretation of hair S levels is confounded by the fact that some hair conditioners and permanent treatments increase hair S while straighteners can significantly lower hair S levels.

Although not documented in the literature, elevated hair S might be associated with increased body burden or with disordered metabolism of S. Theoretically, supplementation of inordinately high levels of S-bearing amino acids (taurine, cystine, methionine) might raise tissue S levels. If hair S is significantly and consistently elevated, and hair treatment is ruled out, then sulfate-sulfite disorders, cystinosis, biliary dysfunction, renal disease, diet, and supplementation habits should be investigated.

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Observations at Doctor's Data indicate that hair S and urine sulfhydryl amino acid levels are often low in Hg burdened patients.

Appropriate tests to determine sulfhydryl amino acid status are plasma or urine amino acid analyses.

Antimony High

Hair is a preferred tissue for analysis of Antimony (Sb) exposure and body burden. Elevated hair Sb levels have been noted as long as a year after exposure. Sb is a nonessential element that is chemically similar to but less toxic than arsenic. Food and smoking are the usual sources of Sb. Sb is released during metal smelting and refining, and its largest industrial use is in flame retardant manufacturing, where antimony trioxide is incorporated into plastics, textiles, and electronics. Sb is utilized in battery production, glass and ceramics, paints, solder, metal alloys, gunpowder, petroleum refining, and electronics such as circuit boards and semiconductors. PET plastic bottles and food containers are manufactured using Sb trioxide as a catalyst, and small amounts can leach into bottled water or beverages, especially when exposed to heat or sunlight, and the EPA has published hazard summaries on Sb compounds. Textiles, upholstery, and carpets treated with fire retardants may contain Sb compounds, and Sb trioxide acts synergistically with

halogenated flame retardants in treated materials, including furniture and electronics that burn during wildfires (U.S. EPA, Antimony Compounds Hazard Summary, Office of Health & Environ. Assessment, 2000.). Other possible sources are some anthelmintic and antiprotozoal drugs. Like arsenic, Sb has a high affinity for sulfhydryl groups on many enzymes. Sb is conjugated with glutathione and excreted in urine and feces. Therefore, excessive exposure to Sb has the potential to deplete intracellular glutathione pools. Early signs of Sb excess include fatigue, muscle weakness, myopathy, nausea, low back pain, headache, and metallic taste. Later symptoms include hemolytic anemia, myoglobinuria, hematuria, and renal failure. Transdermal absorption can lead to "antimony spots" which resemble chicken pox. Respiratory tissue irritation may result from inhalation of Sb particles or dust. A confirmatory test for recent or current exposure is the measurement of Sb in the urine or whole blood.

Selenium High

Selenium (Se) is a nutritionally essential element, but it is also one of the most toxic essential elements when exposure is excessive (Modern Nutrition in Health and Disease, ed. Shils, Olson and Shike, 1994). Barring exogenous contamination (which is frequent for Se), hair Se levels accurately reflect tissue levels. Hair is subject to considerable Se contamination by some antidandruff shampoos. Elevated hair Se is almost always from external contamination. One exposure to a Se containing antidandruff shampoo will elevate the Se levels. Similarly, sulfur containing shampoos are often contaminated with Se and can also cause artifactually high hair Se levels. Se toxicity usually results from industrial exposure. Se is utilized in the electronics and related industries. Se is utilized in xerography, semiconductors, photoelectric cells, and infrared optic materials. Se is also utilized in the manufacture of pink and red glasses, and for head-resistant red pigments in plastics, enamels, paints, and inks. Se can be toxic when ingested at levels exceeding 15 times that needed for essential functions. Dietary sources include Brazil nuts, whole grains, cereals, fish, and eggs provide smaller amounts. Se toxicity (selenosis) can result in: interference with the metabolism of sulfur-bearing amino acids, structural changes and red pigmentation in hair and nails, garlic breath, metallic taste in the mouth, discoloration of teeth and skin, gastroenteritis, and neurological disorders. Some Se compounds have been reported to have carcinogenic activity and promote the carcinogenic effects of certain chemicals. Confirmatory tests for Se excess are measurements of Se level in whole blood or packed red blood cells.

Selenium Low

Selenium (Se) is normally found in hair at very low levels, and several studies provide evidence that low hair Se is reflective of dietary intake and associated with cardiovascular disorders. Utilization of hair Se levels to assess nutritional status, however, is complicated by the fact that use of Se- or sulfur-containing shampoo markedly increases hair Se (externally) and can give a false high value.

Se is an extremely important essential element due to its antioxidative function as an obligatory component of the enzyme glutathione peroxidase. Se is also protective in its capacity to bind and "inactivate" mercury, and Se is an essential cofactor in the deiodination of T-4 to active T-3 (thyroid hormone). Some conditions of functional hypothyroidism therefore may be due to Se deficiency (Nature; 349:438-440, 1991); this is of particular concern with mercury exposure. Studies have also indicated significant inverse correlations between Se and heart disease, cancer, and asthma.

Selenium deficiency is common and can result from low dietary intake of Se or vitamin E, and exposure to toxic metals, pesticides/herbicides and chemical solvents.

Symptoms of Se deficiency are similar to that of vitamin E deficiency and include muscle aches, increased inflammatory response, loss of body weight, alopecia, listlessness, skeletal and muscular degeneration, growth stunting, and depressed immune function.

Confirmatory tests for Se deficiency are Se content of packed red blood cells, and activity of glutathione peroxidase in red blood cells.

Tin High

Hair Tin (Sn) levels have been found to correlate with environmental exposure. Depending on the chemical form, Sn can be a potentially toxic element. Inorganic Sn has a low degree of toxicity, while organic Sn has appreciable toxicity. The main source of Sn is food. Other possible sources are: dental amalgams, cosmetics, preservatives, food and beverage containers, pewter, bronze, and anticorrosive plating. Sn exposure correlates with canned food consumption, with concentrations depending on whether cans are lacquered. Symptoms of excess Sn include: skin, eye, and GI tract irritation, muscle weakness, anemia, and testicular degeneration.

Confirmatory tests for recent Sn exposure are whole blood or urine.

Strontium Low

Strontium (Sr) is normally found in hair, and hair Sr levels are correlated with hair calcium levels. Strontium appears to be essential for growth, but it has not been proven that Sr is essential for adults. Strontium is chemically similar to calcium and boron, and Sr can replace calcium in many biological processes. The clinical significance of low hair Sr levels is not well established.

Brazil nuts are rich in Sr; other sources of Sr include: cereals, grains, dairy products, and seafood.

Other tests indicative of Sr status are measurements of Sr in whole blood, Sr/calcium ratio in blood, and Sr in urine.

Strontium High

Hair usually reflects the body burden of Strontium (Sr), and Sr levels usually correlate with calcium levels in body tissue. However, hair levels of Sr can be raised by external contamination, usually from hair treatment products. Elevated Sr in hair treated with permanent solutions, dyes, or bleaches is likely to be an artifact of hair treatment and probably does not reflect the level of Sr in other tissues.

Diseases of excess Sr have not been reported, except for Sr rickets. In general, Sr excess is not of clinical concern in the U.S. Its bad reputation comes from its radioactive isotopes, which were widespread in the western U.S. as a result of nuclear testing in the 1950's. Stable Sr (not radioactive Sr) is measured and reported by Doctor's Data.

Other tests indicative of Sr status or excess are measurements of Sr in whole blood, Sr/calcium ratio in blood, and Sr in urine.

Tellurium

Little is known about the toxicity of tellurium (Te) and the relationship between the levels of Te in hair. There have been reports of humans occupationally exposed to as little as 0.01 mg/m³ of air or less developing "tellurium breath," which has a garlic-like odor. Te deposits are found in Mexico, South America, Western Australia, Ontario, Canada, and in the U.S. (small rock deposits are found in Colorado and

California); however, Te rarely occurs in its native state. Te is usually associated with gold, silver, copper, lead, mercury, and bismuth. Commercial sources of Te are found as by-products in lead and copper refineries. The alloying of Te with copper and stainless steel improves the machinability of metals (improves strength/hardness, decreases corrosive action of sulfuric acid on lead). Other uses of Te include the manufacturing of rectifiers, thermoelectric devices, semiconductor research, and anti-knock compounds for gas. Te is also responsible for the blue color in glass. Colloidal Te has been used as an insecticide, germicide, and fungicide.

Thorium High

Correlations among the levels of Thorium (Th) in hair and other tissues have yet to be established.

Th is a radioactive element with 13 known isotopes; Th-232 constitutes 99% of the naturally-occurring Th. Th-232 is the isotope measured at Doctor's Data and reported for this sample. Th-232 has a half-life of 1.4×10^{10} years. It decays by alpha-emission to produce radium, Ra-228. In turn, Ra-228 (half-life 6.7 years) decays to other radioactive isotopes and eventually converts to lead. This radioactive decay process produces alpha, beta, and gamma emissions.

Th is considered mildly toxic for two reasons, the low-level radioactivity and slight biochemical toxicity. Th salts at high levels may inhibit amylase and phosphatase enzymes. Most orally ingested thorium, if not excreted in urine, binds to bone tissue where it has a long biological half-life (years).

Th has about the same abundance in the earth as does lead and is encountered in mining for titanium and rare earth elements. Commercially, Th is used in incandescent gas lantern mantles, refractory materials, and as a coating for tungsten in electronic applications. Th may also be present in tungsten-inert-gas (TIG) welding electrodes.

A urine elements analysis can be performed to assess further the extent of Th exposure.

Titanium High

Titanium (Ti) is measured in hair to assist in the identification of external contamination of hair by treatments and products. Shampoos, dyes, and "highlighting" are the primary sources of Ti, which binds tenaciously to hair.

Ti dioxide is the most common form of Ti used for industrial purposes; e.g. coating of welding rods and white pigment in paints, dyes, and paper fillers. Ti dioxide and other Ti-containing compounds have extremely low toxicity. The elevated level of Ti in the hair sample is most likely without clinical significance unless Ti implants (orthopedic, dental) are in place.

Thallium High

Thallium (Tl) is a highly toxic element which, like lead and mercury, accumulates in many body tissues. Hair levels reflect exposure to Tl. Common sources of Tl are: foods (marine organisms concentrate Tl up to 700 times), rodenticides/pesticides tobacco, contaminated water, electronics components, fly ash, cement dust, and some fertilizers. Tl is rapidly and completely absorbed when ingested, inhaled or brought into contact with skin. Spinacia and Brassica group vegetables, such as kale, cabbage, spinach and lettuce, efficiently assimilate Tl from soil. Alarmingly, this has made dark green leafy vegetables one of the most common sources of Tl exposure. Observations are suggestive that Spinacia and Brassica group vegetables may be contaminated with Tl, and high consumption of brassica vegetables may be clinically problematic. Tl has been detected in prenatal vitamins, and clinicians should be aware that the neurotoxic metal readily crosses the placenta to the developing fetus (Schwalfenberg, et al. Heavy metal contamination

of prenatal vitamins. Toxicology Reports. March 2018. DOI: 10.1016/j.toxrep.2018.02.015). Symptoms of TI excess include: sleep disturbances, cardiac, optical, dermatological, liver, GI, and kidney dysfunctions. Albuminuria and alopecia are consistent with TI excess. Potassium, selenium, and sulfhydryl compounds (e.g. glutathione) diminish TI retention and toxicity. TI toxicity can have a long latency period before clinical symptoms become apparent.

Uranium High

The levels of Uranium (U) in hair usually reflect levels of U in other tissues. However, hair may be externally contaminated by shampoos or hair products that contain U. U is a nonessential element that is very abundant in rock, particularly granite, lignite, monazite sands, and phosphate rocks. U is present at widely varying levels in drinking water, root vegetables, and present in high phosphate fertilizers. High levels of U detected may be due to water sourced from a rock shale, which can indicate the potential for radon gas release, as U naturally decays into radon, a radioactive gas that can migrate through soil and accumulate indoors. A radon test for the home may be considered to assess potential exposure risk. Other sources of U include: ceramics, some colored glass, many household products and tailings from U mines. Spent U rods have been milled into armor piercing bullets and missile heads. Uranyl cations bind tenaciously to protein, phosphate, nucleotides, and bone, where it substitutes for Ca. Published data are sparse, but there appears to be a correlation between U exposure, nephrotoxicity and cancer. Kidney and bone are the primary sites of U accumulation. All isotopes of U are radioactive; ²³⁸U is the most abundant and lowest energy emitter. It is important to note that the measured result, which is ²³⁸U, does NOT necessarily indicate or imply exposure to highly enriched ²³⁵U, which is used in nuclear power and weaponry. Chronic fatigue is often reported in association with hair U levels >0.5 µg/g (Doctor's Data observations). U is rapidly cleared from blood and deposited in tissues. Currently, DTPA is the only effective chelating agent for ACUTE U poisoning. However, it must be administered immediately and is not effective once U has transferred from blood to tissues. Currently there are no available chelators or complexing agents that have been established to be effective for ameliorating U retention associated with long-term, low-level exposure to U. Urine or fecal elements analysis can be performed to confirm recent or ongoing exposure to U. Because U is such a potent nephrotoxin, one might test for urinary wasting of amino acids and low molecular weight proteins (B-2-microglobulin) in patients with markedly elevated hair U levels.

Vanadium High

High levels of vanadium (V) in hair may be indicative of excess absorption of the element. It is well established that excess V may have toxic effects on humans depending on the chemical form. Although it appears that V may have essential functions, overzealous supplementation should be considered with caution.

Excess levels of V in the body can also result from chronic consumption of fish, shrimp, crabs, and oysters derived from water near offshore oil rigs. Industrial/environmental sources of V include: processing of mineral ores, phosphate fertilizers, combustion of oil and coal, production of steel, and chemicals used in the fixation of dyes and print (Metals in Clinical and Analytical Chemistry, 1994). V is used in producing rust resistant, spring and high-speed tool steels. Vanadium pentoxide and other vanadates are used as catalysts in the production of sulfuric acid and formaldehyde. Urban airsheds in industrialized areas have been reported to have high levels of V.

Symptoms of V toxicity vary with chemical form and route of absorption. Inhalation of excess V may produce respiratory irritation and bronchitis. Excess ingestion of V can result in decreased appetite, depressed growth, diarrhea/gastrointestinal disturbances, nephrotoxic and hematotoxic effects. Pallor, diarrhea, and green tongue are early signs of excess V and have been reported in human subjects consuming about 20 mg V/day. (Modern Nutrition in Health and Disease, 8th edition, eds. Shils, M., Olson, J., and Mosha, S., 1994).

Confirmatory tests for excess V are whole blood, and urine V which reflects very recent or ongoing exposure.

Vanadium Low

Vanadium (V) is typically found at low levels in hair, and the clinical significance of the measured result of lower-than-average hair V is not known. V is measured in hair for research purposes because it has been postulated to be an essential microtrace element. Indirect data to support this postulate have been derived from experimental models. Suggested functions for V include: regulation of sodium-potassium-ATPase, intracellular glutathione metabolism, thyroid metabolism, and insulin mimetic effects at pharmacological doses.

Average dietary V intake varies considerably between 20 mcg to 2 mg. Food sources of V include: liver, fish, radishes, grains, nuts, and vegetable oils.

Tungsten

The relationship between the levels of tungsten (W) in hair and exposure has yet to be established. W has no known physiological role. Long-term chronic exposures have been associated with lung disease (pneumoconiosis or "hard metal lung disease") and lung cancer. Skin contact with W may produce contact eczema, pruritis, folliculitis, and neurodermatitis. Tungsten appears to have an antagonistic relationship to Mo, decreasing hepatic Mo concentration and reducing the effectiveness of sulfite and xanthine oxidases. High levels of tungsten block essential molybdoenzymes (like sulfite oxidase and xanthine dehydrogenase). This disruption can lead to an inability to convert toxic sulfites into essential sulfates, resulting in sulfite sensitivities or abnormally low levels of uric acid in the blood. Tungsten is a silvery-white lustrous element usually obtained as a grey powder and is mainly utilized as tungsten carbide in metallurgy, mining, and petroleum industries. Calcium and magnesium tungstates are widely used as filaments for electric lamps, electron tubes, and television tubes. Since tungsten has the highest melting point of all metals, it is used for high-speed and hot-worked steel. Other sources of W include catalysts and reagents in biological analysis, fire and waterproof materials, and industrial lubrications. Acute environmental exposures have been detected in hair up to two months after ingestion of a tungsten-contaminated beverage. Intestinal absorption of tungsten is rapid and apparently significant. W is rapidly transported to the blood and then to the kidneys for filtration and eventual excretion from the body. Pulmonary absorption of W-tungstic oxide has been studied in dogs. Sixty percent of W is rapidly deposited in the respiratory tract, and thirty-three percent of that fraction reaches systemic circulation. Tungsten is also readily transferred from mother to fetus, usually later in gestation.

Zinc High

Zinc (Zn) is an essential element that is required in many very important biological processes. However, Zn can be toxic if exposure is excessive. Although uncommon, high hair Zn might be indicative of Zn overload which could result from Zn contaminated water (galvanized pipes), welding or gross, chronic over-supplementation (100 mg/day). Other sources of Zn exposure include: manufacture of brass, bronze, white paint, pesticide production, galvanization of steel and iron products, dry cell batteries, and use in rubber, textile, and ceramic industries. Symptoms of Zn excess include: gastrointestinal disorders, decreased heme synthesis (copper deficiency), tachycardia, blurred vision, and hypothermia.

Paradoxically, a moderately elevated level of Zn in hair may be associated with Zn wasting, and a low level of Zn in cells. Zn may be displaced from proteins such as intracellular metallothionein by other metals, especially cadmium and copper. Zn may also be high in hair in association with chronic use of Zn-containing anti-dandruff shampoo. Rough or dry, flaky skin is a symptom of Zn deficiency, so it is not uncommon for Zn deficient patients to use an anti-dandruff/anti-itch shampoo. A result of high hair Zn warrants further testing to assess Zn status.

Confirmatory tests for Zn status include whole blood or RBC Zn tests.

Zinc Low

A result of low hair Zinc (Zn) may be indicative of low Zn in whole blood, red blood cells, and other tissues. Hair analysis is a good screen for Zn deficiency provided that the hair sample has not been chemically treated (permanent solutions, dyes, and bleaches); such hair treatments can significantly lower the level of Zn in hair. Other laboratory tests to confirm Zn status are whole blood or packed red blood cell elements analysis.

Zn is an essential element that is required in numerous biochemical processes including protein, nucleic acid, and energy metabolism. Zn is an obligatory co-factor for numerous enzymes including alcohol dehydrogenase, carbonic anhydrase, and superoxide dismutase.

Zn competes for absorption with copper and iron. Cadmium, lead and mercury are potent Zn antagonists. Zn deficiency can be caused by malabsorption, chelating agents, poor diet, excessive use of alcohol or diuretics, metabolic disorder of metallothionein metabolism, surgery, and burns. Hair levels of Zn (copper and selenium) were decreased in human subjects after switching from a mixed to a lactovegetarian diet. (Am. J. Clin. Nutr.; 55:885-90,1992).

Hair Zn is commonly low in diabetics, and in association with ADD/ADHD and autism (Doctor's Data observation). Reported symptoms of Zn deficiency include: fatigue, apathy, hypochlorhydria, decreased vision and dysgeusia, anorexia, anemia, dermatitis, weak/brittle nails and hair, white spots on nails, alopecia, impaired wound healing, sexual dysfunction (males), and hypogonadism.

Ratios

Zn/Cd

The zinc (Zn) to cadmium (Cd) ratio reflects how much protective Zn is present relative to Cd in the hair sample, since Zn and Cd compete for shared transporters and binding sites, including metallothionein, and adequate Zn status induces metallothionein production that sequesters Cd and limits its absorption and tissue accumulation.

A low ratio indicates that Cd exposure may be outpacing the body's Zn-dependent protective capacity while a high ratio suggests Zn reserves are adequate to help buffer Cd's toxic effects. That said, the ratio is a relative measure, a favorable Zn/Cd ratio can still coexist with a genuinely elevated absolute Cd level, therefore it should be read alongside clinical history and, when applicable, blood or urine Cd and serum Zn levels rather than in isolation. When evaluating ratios, always look at both individual values for both elements.

Ca/Pb

The calcium (Ca) to lead (Pb) ratio reflects how much Ca is present relative to Pb in the hair sample, since Ca and Pb compete for the same absorption pathways, and adequate Ca can blunt Pb uptake and retention. A low ratio indicates that Pb exposure may be outpacing Ca while a high ratio suggests Ca is doing a reasonable job limiting Pb absorption. That said, the ratio is a relative measure, a favorable Ca/Pb ratio can still coexist with a genuinely elevated absolute Pb level, therefore it should be read alongside clinical history and, when applicable, blood Pb and serum Ca levels rather than in isolation. When evaluating ratios, always look at both individual values for both elements.

Se/Hg

The selenium (Se) to mercury (Hg) ratio captures whether there's enough Se on board to help neutralize mercury's toxicity, since Se binds mercury and helps protect enzyme and antioxidant function from mercury interference. A higher ratio is reassuring in the sense that selenium reserves appear adequate relative to the Hg exposure, supporting thyroid and antioxidant pathways that Hg may otherwise disrupt. A ratio within normal limits doesn't rule out Hg exposure; both Hg toxicity and Se excess (selenosis) are possible even when the ratio looks favorable, particularly if Hg exposure is ongoing (fish, seafood, environmental sources). When evaluating ratios, always look at individual values for both elements.

Ca/Mg

The calcium (Ca) to magnesium (Mg) ratio reflects how much Ca is present relative to Mg in the hair sample, since Ca and Mg share intestinal transport pathways and compete for absorption, and Mg also serves as a required cofactor for the parathyroid hormone secretion and vitamin D activation that govern Ca regulation.

A low ratio may indicate Mg is comparatively high relative to Ca, or that Ca intake and absorption are lagging, while a high ratio suggests Ca is accumulating relative to Mg, a pattern population studies have linked to altered cardiometabolic risk markers. That said, the ratio is a relative measure, a favorable Ca/Mg ratio can still coexist with a genuinely low absolute level of either mineral, therefore it should be read alongside clinical history and, when applicable, serum or RBC magnesium and calcium levels rather than in isolation. When evaluating ratios, always look at both individual values for both elements.

Ca/P

The calcium (Ca) to phosphorus (P) ratio reflects the balance between these two closely linked minerals, since Ca and P are co-regulated by parathyroid hormone (PTH), vitamin D, and renal handling, and together drive bone mineralization. A habitually low Ca/P ratio, relatively high P intake relative to Ca, which is common with heavy consumption of phosphate-containing food additives, colas, and processed foods, has been associated with a sustained rise in serum PTH and increased bone turnover, even in individuals whose absolute calcium intake is otherwise adequate.

A high Ca/P ratio is generally favorable for bone mineral balance; markedly elevated ratios driven by very low phosphorus intake are uncommon, since phosphorus is itself an essential nutrient. As with other ratios, this value should be interpreted alongside the individual Ca and P levels, and, when clinically indicated, alongside dietary phosphorus intake (including food additive sources), serum PTH, vitamin D status, and renal function. When evaluating ratios, always look at both individual values for both elements.

Na/K

The sodium (Na) to potassium (K) ratio reflects how much Na is present relative to K in the hair sample, since Na and K act antagonistically on vascular tone and renal fluid handling, and adequate K intake promotes natriuresis and helps offset the blood-pressure-raising effects of Na.

A low ratio (relatively more K to Na) is generally considered favorable for cardiovascular health while a high ratio has been associated with elevated blood pressure and greater cardiovascular risk in population studies. That said, the ratio is a relative measure, a favorable Na/K ratio can still coexist with a genuinely high absolute Na level or an underlying condition affecting electrolyte handling, therefore it should be read alongside clinical history and, when applicable, blood pressure and serum electrolyte levels rather than in isolation. When evaluating ratios, always look at both individual values for both elements.

Zn/Cu

The zinc (Zn) to copper (Cu) ratio reflects how much Zn is present relative to Cu in the hair sample, since Zn and Cu compete for absorption at the level of intestinal metallothionein, a binding protein that zinc strongly induces and that preferentially sequesters copper, limiting its absorption and increasing its loss with shed intestinal cells.

A low ratio indicates that Cu may be accumulating relative to Zn status while a high ratio suggests Zn is suppressing Cu absorption more aggressively; the same mechanism exploited therapeutically with high-dose zinc in Wilson's disease. That said, the ratio is a relative measure, a favorable Zn/Cu ratio can still coexist with a genuinely elevated absolute Cu level, or conversely a very high ratio can signal an emerging zinc-induced copper deficiency, therefore it should be read alongside clinical history and, when applicable, serum copper, ceruloplasmin, and serum zinc levels rather than in isolation. When evaluating ratios, always look at both individual values for both elements.



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