DiagnosTechs™
CLINICAL & RESEARCH LABORATORY

TOXIC METALS AND ELEMENTS PANELS: UNDERSTANDING YOUR RESULTS

Contents

Introduction

Our Tandem Mass Spectrometer (ICP-MS/MS) provides DiagnosTechs the ability to perform elemental analysis in clinical specimens with unparalleled accuracy, precision, and detection. Salivary and urinary elemental analyses are provided as screening tests to evaluate a patient's exposure to potentially toxic metals, as well as deficient or higher than range levels of essential and trace elements.

POTENTIALLY TOXIC ELEMENTS

Aluminum (Al)

While aluminum exists in numerous compounds and forms, the analytical methods we use to test for aluminum do not determine the specific forms of aluminum present. This test measures total aluminum and does not distinguish between forms. Aluminum has no known biological function, and accumulation of aluminum in tissues and organs is associated with dysfunction and disease.

Aluminum is found in products most people use daily, including beverage containers, cookware, utensils, coffee pots, aluminum foil, antiperspirant, antacids, buffered aspirin, cosmetics, astringents, and toothpaste. Aluminum may be found in drinking water, processed foods, baking powder, anti-caking agents, emulsifying agents, food colors, pharmaceuticals, and dietary supplements, including certain herbs and colloidal minerals. Aluminum also is found in sunscreens and parenteral nutrition products and may be present in bone cement, surgical sutures, ceramic hips, dental implants, and internal stents. Other sources of aluminum include air pollution, flame retardants, paints, metal polish, metal alloys, and furnace linings. Additionally, aluminum may be used in the manufacture of abrasives, ceramics, electrical insulators, catalysts, paper, spark plugs, light bulbs, artificial gems, glass, and heat resistant fibers.

An average adult in the United States consumes approximately 7–9 mg of aluminum per day in their food. Unprocessed foods like fresh fruits, vegetables, and meat contain very little aluminum.

Chronic exposure to aluminum can increase the risk of developing pulmonary disease, aluminum-induced bone disease (AIBD), osteomalacia, neurotoxicity, autism spectrum disorders, ALS, and cancer. Chronic aluminum exposure also is suspected as a potential cause of Alzheimer's disease.

Acute aluminum toxicity primarily occurs in those with kidney disease who are exposed to very high levels of aluminum over a short time. Symptoms of acute aluminum toxicity include confusion, myoclonus, seizures, coma, and even death.

Antimony (Sb)

While antimony exists in various compounds and forms, the analytical methods we use to test for antimony do not determine the specific forms of antimony present. This test measures total antimony and does not distinguish between forms. Antimony has no known biological function, and exposure to antimony is associated with dysfunction and disease.

Mining and smelting operations, waste incineration, coal and petroleum combustion, polyethylene terephthalate (PET) production, battery factories, shooting ranges, and highways all are associated with elevated levels of antimony in the surrounding environment. Specific sources of antimony exposure may include bottled water, tap water, car exhaust, plastics, cosmetics, air pollution, fireworks, dirt, textiles, rubber, adhesives, pigments for fabrics, flame retardants, paints, ceramic enamels, glass, pewter, batteries, low friction metals, type metal, coal, petroleum, cable sheathing, solder, and pottery. Also, those who work in industries that process antimony ore and metal or make chemicals that contain antimony, such as antimony trioxide, may be exposed to antimony by breathing dust or via skin contact.

Exposure to antimony may cause respiratory irritation, pneumoconiosis, antimony spots on the skin, and gastrointestinal symptoms, and may increase the risk of developing sleep apnea and other sleep-related disorders, peripheral artery disease,

hypertension, insulin resistance, and gestational diabetes. Moreover, inhalation of antimony trioxide is a possible cause of cancer.

Arsenic (As)

While arsenic exists in both organic and inorganic forms in our environment, the analytical methods we use to test for arsenic do not determine the specific forms of arsenic present. This test measures total arsenic and does not distinguish between organic and inorganic forms.

Organic arsenic is considered to be virtually non-toxic and is the form primarily present in fish and shellfish. Inorganic arsenic is highly toxic and can be found in tap water, well water, bottled water, pesticides, insecticides, herbicides, foods such as rice and fruit juices, cigarette smoke, air pollution, cosmetics, wood preservatives, automobile batteries, lead alloys, asphalt, certain pigments used in glassmaking, as well as products used in the electronics, copper smelting and optical industries.

Inorganic arsenic exposure may result in respiratory and GI irritation, lymphocytopenia, anemia, anxiety, birth defects, depression, skin discoloration, and neuropathy. Chronic exposure to inorganic arsenic also can increase the risk of developing diabetes, hypertension, heart disease, stroke, COPD, lung cancer, prostate cancer, memory decline, neurological dysfunction, shingles, and other health concerns.

Acute arsenic toxicity primarily occurs in those exposed to very high levels of arsenic over a short time. Symptoms of acute arsenic toxicity include nausea, vomiting, diarrhea, gastrointestinal bleeding, cerebral edema, tachycardia, dysrhythmias, shock, coma, and even death. Acute symptoms are dose-dependent and can be delayed.

Barium (Ba)

While barium occurs in nature in many different forms and compounds, the analytical methods we use to test for barium do not determine the specific forms of barium present. This test measures total barium and does not distinguish between forms. Barium has no known biological function, and certain forms of barium exposure are associated with dysfunction and disease.

Barium may be found in drinking water as a result of contamination by industrial wastes from oil and gas drilling, metal refining, and from the erosion of natural barium deposits. Barium is used in drilling fluids, greases, sealants, boiler water treatment, paper manufacturing, sugar refining, oil refining, and to protect limestone from deterioration. Barium also is used to make shaving powders, depilatories, paints, bricks, tiles, glass, rubber, ceramics, signal flares, and fireworks, as well as insecticides and rat poisons.

Barium sulfate is considered to be safe because of its low solubility and is utilized as a contrast agent in gastrointestinal imaging.

Exposure to barium in its soluble forms may cause weakness, abdominal pain, cramping, vomiting, diarrhea, constipation, ringing in the ears, sweating, confusion, paralysis, changes in blood pressure, tachycardia, numbness, and difficulty breathing. Chronic barium exposure can lead to insulin resistance and kidney damage.

Beryllium (Be)

While beryllium exists in numerous compounds and forms, the analytical methods we use to test for beryllium do not determine the specific forms of beryllium present. This test measures total beryllium and does not distinguish between forms. Beryllium has no known biological function, and exposure to beryllium is associated with dysfunction and disease.

Beryllium is used as an alloying agent in producing beryllium copper, which is extensively used for springs, electrical contacts, spot-welding electrodes, and non-sparking tools. It is applied as a structural material for high-speed aircraft, missiles, spacecraft, and communication satellites, and is used in manufacturing automotive parts, computers, electronics, ceramics, dental crowns and bridges, golf clubs, and bicycles.

When exposed to particles, fumes, mists, and solutions from beryllium-containing materials, individuals may develop beryllium sensitization or chronic beryllium disease, a potentially disabling or even fatal respiratory disease. Significant beryllium exposure also can cause heart disease, lung cancer, liver disease, kidney stones, ulcers, dermatitis, and other skin conditions.

Cadmium (Cd)

While cadmium exists in numerous compounds and forms, the analytical methods we use to test for cadmium do not determine the specific forms of cadmium present. This test measures total cadmium and does not distinguish between forms. Cadmium has no known biological function, and accumulation of cadmium in tissues and organs is associated with dysfunction and disease.

Overall, the greatest non-occupational exposure to cadmium is due to cigarette smoking since tobacco leaves naturally accumulate high amounts of cadmium. Exposure to second-hand smoke, electronic cigarettes (e-cigarettes), and vaping devices also increase cadmium levels. In the United States, the largest source of cadmium exposure for non-smoking adults and children is through food. In general, lettuce, spinach, potatoes, grains, peanuts, soybeans, sunflower seeds, shellfish, and organ meats (liver and kidney) have relatively high cadmium content.

Other sources of cadmium exposure include asphalt, pigments, plastics, paints, rechargeable batteries, metal soldering, metal plating, municipal waste incinerators, coal-burning facilities, colored glass manufacturing, semiconductors, smelting facilities, printing, textiles, fertilizer, rubber, and fungicides.

Excessive exposure to cadmium may result in gastrointestinal irritation, hypertension, insulin resistance, diabetes, osteoporosis, kidney damage, liver disease, anemia, anxiety, prostate cancer, learning disabilities, endometriosis, psoriasis, autoimmune disorders, heart disease, stroke, lung disease, periodontal disease, immunosuppression, birth defects, and infertility.

Cesium (Cs)

This test measures total cesium in its stable (non-radioactive) forms. Exposure to stable cesium from the environment has no known adverse health effects.

Non-radioactive, stable cesium occurs naturally, mostly from the erosion and weathering of rocks and minerals. The mining of certain ores also can release stable cesium into the air, soil, and water. Unstable, or radioactive, cesium is not natural and may be released into the environment during the operation of nuclear power plants, the explosion of nuclear weapons, and from accidents involving nuclear power plants or nuclear-powered satellites or submarines.

Stable cesium compounds are used commercially in vacuum tubes, tungsten filaments and cathodes, hydrogenation reactions, and petroleum drilling fluids. Cesium is used also in manufacturing photoelectric cells, scintillation counters, and atomic clocks. While the level of stable cesium in air, food, and water is generally very low, the amount of radioactive cesium present is highly dependent upon whether or not there has been recent fallout from a nuclear explosion such as a weapons test or an accident at a nuclear power plant. Those who work in an industry that processes or uses natural cesium, radioactive cesium, or cesium compounds are more likely to be exposed to cesium.

Exposure to stable cesium from common environmental sources is not associated with adverse health effects. Exposure to radioactive cesium is much more concerning and can cause acute radiation syndrome, which includes symptoms such as nausea, vomiting, diarrhea, bleeding, coma, and even death.

Gadolinium (Gd)

While gadolinium exists in various compounds and forms, the analytical methods we use to test for gadolinium do not determine the specific forms of gadolinium present. This test measures total gadolinium and does not distinguish between forms. Exposure to gadolinium may be associated with dysfunction and disease.

Gadolinium is used in neutron shielding, microwave filtration, manufacture of color televisions, and titanium production. Various gadolinium complexes also are used as magnetic resonance imaging (MRI) contrast agents to improve the quality of the MRI image, and this is the most common source of gadolinium exposure.

Symptoms of gadolinium toxicity include persistent headache; severe pain in the bones, joints, arms, and legs; and sensations of sharp pins and needles, cutting, or burning. Other symptoms include cognitive impairment, clouded mentation (“brain fog”), nausea and vomiting, thickening of soft tissues such as tendons and ligaments, and tightness in the hands and feet. Also, exposure to gadolinium-containing contrast agents may increase the risk of a rare but serious disease called nephrogenic systemic fibrosis in individuals with severe kidney disease.

Lead (Pb)

While lead exists in numerous compounds and forms, the analytical methods we use to test for lead do not determine the specific forms of lead present. This test measures total lead and does not distinguish between forms. Lead has no known biological function, and accumulation of lead in tissues and organs is associated with dysfunction and disease. This test is not a substitute for the whole blood lead screening tests required per federal and state guidelines.

Lead is a highly persistent heavy metal that has been used for centuries and is therefore widely distributed throughout our environment in air, water, and soil. Some sources of lead exposure include cosmetics, hair dyes, cigarette smoke, electronic cigarettes (e-cigarettes), vaping devices, groundwater, drinking water, lead pipes, dinnerware, glassware, paint found in older homes, dietary supplements from India and China, imported candies, bone broth, and pesticides. Other sources of exposure include fishing weights, car batteries, gasoline, roofing materials, caulking, pigments, plastics, pottery glaze, ceramics, TV glass, brass, bronze, buckles, ammunition, shooting ranges, candle wicks, PVC-containing products, electrical power cords, artificial Christmas trees, vinyl mini-blinds, lunch boxes, toys, and costume jewelry. The greatest source of lead exposure for children appears to be living in a home built before 1951.

Chronic lead exposure can increase the risk of developing ADHD, oppositional defiant disorder, conduct disorder, developmental delay, cognitive decline, neuropathy, ECG abnormalities, Parkinson's disease, Alzheimer's disease, cataracts, hearing loss, anemia, depression, fatigue, anxiety, hypertension, heart disease, immune dysfunction, cancer, kidney disease, obstructive lung disease, infertility, and other health concerns. Acute lead toxicity is characterized by symptoms of abdominal pain and colic, vomiting, constipation, peripheral neuropathy, cerebral edema, and encephalopathy, which can lead to seizures, coma, and death. Children are more susceptible than adults to acute lead poisoning.

Mercury (Hg)

Mercury exists in various compounds and forms including elemental, inorganic, and organic mercury. However, the analytical methods we use to test for mercury do not determine the specific forms of mercury present. This test measures total mercury and does not distinguish between its elemental, inorganic, and organic forms. Mercury has no known biological function, and accumulation of mercury in tissues and organs is associated with dysfunction and disease.

Because mercury occurs naturally in the environment, everyone is exposed to very low levels of mercury in air, water, and food. Industrial activities such as mining and the burning of fossil fuels contribute to further release of mercury into the environment. Common sources of increased mercury exposure include amalgam (silver) dental fillings, thermometers, batteries, fluorescent lights, fish and other seafood, pigments, skin lightening creams, fireworks, pesticides, agricultural chemicals, photography, taxidermy, electric equipment, textiles, and interior paint manufactured before 1990.

Occupations that have a greater potential for mercury exposure include manufacturers of electrical equipment and automotive parts that contain mercury, chemical processing plants that use mercury, construction where building parts contain mercury, and the medical professions where equipment may contain mercury. Dentists and dental assistants may be exposed to mercury from skin contact with amalgam restorations and breathing in mercury vapor released from amalgam fillings. Family members of workers who have been exposed to mercury also can be exposed to mercury if the worker's clothes or shoes are contaminated with mercury.

Symptoms of mercury exposure include fatigue, headache, depression, irritability, altered libido, deafness, tinnitus, changes in vision, speech impairment, dizziness, loss of coordination, loss of sensation, neuropathy, tremors, memory loss, difficulty concentrating, excessive salivation, nausea, diarrhea, ulcers, rapid heart rate, increased blood pressure, muscle pain, muscle weakness, joint pain, menstrual disorders, hair loss, and a metallic taste in mouth. Exposure to mercury also increases the risk of developing ADHD, birth defects, kidney disease, liver disease, heart disease, atherosclerosis, hypothyroidism, metabolic syndrome, insulin resistance, diabetes, and autoimmune disease.

Palladium (Pd)

While palladium exists naturally in various compounds and forms, the analytical methods we use to test for palladium do not determine the specific forms of palladium present. This test measures total palladium and does not distinguish between forms. Exposure to palladium may be associated with allergic reactions and other health concerns.

Palladium is widely used in catalytic reactions in industry, such as in the production of hydrogenated oils, as well as in jewelry, and in dental fillings and crowns where it has replaced the use of mercury amalgams and gold. However, the main use of palladium, along with rhodium and platinum, is in the three-way catalytic converters in car exhaust systems. Palladium is also present as a carrier element in the dietary supplement 'Poly-MVA'.

Palladium exposure may irritate the skin, eyes, mucous membranes, or respiratory tract. Liquid compounds that contain palladium may cause burns to skin and eyes. Palladium exposure is known to cause allergies at a very low dose in miners, dental technicians, and chemical plant workers, and is associated with increased risk of developing thyroid disease and autoimmune diseases.

Platinum (Pt)

While platinum exists in various compounds and forms, the analytical methods we use to test for platinum do not determine the specific forms of platinum present. This test measures total platinum and does not distinguish between forms. Exposure to platinum may be associated with allergic reactions and other health concerns.

Platinum is used extensively for jewelry. Platinum is used also to make fertilizers, plastics, synthetic fibers, magnets, electrodes, wires, dental and orthopedic materials, medical instruments, pacemakers, silicone implants, and chemotherapeutic agents. Most catalytic converters contain platinum, and platinum is used in other automotive parts as well.

While pure platinum is non-toxic, platinum compounds can be harmful to human health. These compounds can cause hearing damage, bone marrow and kidney damage, immunosuppression, neurotoxicity, DNA damage, and cancer. Platinum compounds also may cause damage to the intestines and allergic reactions. Short-term exposure to platinum compounds may irritate the eyes, nose, throat, and skin.

Silver (Ag)

While silver exists naturally in various compounds and forms, the analytical methods we use to test for silver do not determine the specific forms of silver present. This test measures total silver and does not distinguish between forms. Exposure to silver may be associated with allergic reactions and other health concerns.

Silver is found as a by-product during the mining of copper, lead, zinc, and gold ores. Silver is used in jewelry, silverware, electronic equipment, dental fillings, photographs, brazing alloys and solders, and as a disinfectant for drinking water and swimming pools. Silver is used medicinally as a cauterizing agent for wounds and bleeding gums, as an antibacterial agent in eye drops and nose sprays, and as a dietary supplement (colloidal silver). Silver also has been used in lozenges and chewing gum to help people stop smoking.

Sources of silver exposure include food, drinking water, air, and medicines, as well as activities such as jewelry-making, soldering, and photography. Exposure from everyday use such as wearing jewelry or eating with silver-coated flatware does not result in much absorption. Most silver that is ingested or inhaled in small quantities is eliminated within about a week.

Chronic exposure to silver in large amounts may lead to argyria, a condition characterized by permanent blue-gray discoloration of the skin, eyes, nails, gums, and internal organs. Argyria is considered to be a benign, cosmetic change and generally is not associated with complications, however more extreme cases of systemic silver toxicity may result in thrombocytopenia, abnormal clotting, renal impairment, proteinuria, and neurological symptoms such as seizures and loss of coordination.

Exposure to dust containing relatively high levels of silver compounds such as silver nitrate or silver oxide may cause breathing problems, lung and throat irritation, and stomach pain. These effects have been seen in workers in chemical manufacturing facilities that make silver nitrate and silver oxide. Skin contact with silver compounds has been found to cause mild allergic reactions, such as rash, swelling, and inflammation.

Thallium (Tl)

While thallium exists in various compounds and forms, the analytical methods we use to test for thallium do not determine the specific forms of thallium present. This test measures total thallium and does not distinguish between forms. Thallium has no known biological function, and exposure to thallium is associated with dysfunction and disease.

Since thallium is found naturally in the environment, exposure can occur from air, water, and food sources, including fruits and green vegetables contaminated by thallium. Thallium is released into the air from coal-burning power plants, cement factories, and smelting operations and then may contaminate nearby gardens and crops. Exposure also can occur near chemical waste sites where thallium emissions have contaminated the water and soil. Cigarette smoke is another significant source of thallium exposure.

Those who work in coal-burning power plants, cement factories, and smelters that use or produce thallium can breathe in the chemical, or it may come in contact with their skin. Workers also can expose family members to thallium if they wear their work clothes and shoes home. Thallium is used to manufacture optical lenses, infrared instruments, scintillation counters, imitation jewelry, low-temperature thermometers, green-colored fireworks, semiconductors, and contrast agents for nuclear cardiography.

Thallium is highly toxic and exposure to thallium may adversely affect the nervous system, lungs, heart, liver, and kidneys, especially if large amounts are consumed in a short time. Acute symptoms of thallium poisoning can include difficulty walking due to loss of muscle control and balance, involuntary movements, numbness in toes and fingers, tremor, seizures, loss of consciousness, insomnia, leg pain, chest pain, lethargy, rash, difficulty swallowing, vomiting, abdominal pain, and constipation or diarrhea. Death may result after exposure to thallium since thallium can be fatal at a dose as low as 1 gram.

Symptoms in non-fatal exposures may include temporary hair loss, changes in vision, fatigue, gastroenteritis, painful neuropathy, and other symptoms, but research on these exposures is minimal. Chronic thallium exposure may increase the risk of cancer and lung disease. Thallium does cross the placenta during pregnancy, and exposure can cause low birth weight and congenital abnormalities.

Thorium (Th)

Thorium is naturally-occurring and exists in various compounds and forms. The analytical methods we use to test for thorium do not determine the specific forms of thorium present. This test measures total thorium and does not distinguish between forms. Thorium has no known biological function, and exposure to thorium is associated with dysfunction and disease.

Sources of thorium exposure include air, water, and food since thorium is found almost everywhere. Increased levels of thorium may occur near industrial sites that mine, mill, burn, or manufacture products containing thorium; uncontrolled hazardous waste sites; or research laboratories performing experiments with thorium.

Thorium is used to make ceramics, lantern mantles, welding electrodes, flints for lighters, airport runway lighting, computer memory components, photoconductive film, target material for x-rays, and metals used in the aerospace industry. Thorium also can be used as a fuel for generating nuclear energy. More than 60 years ago, thorium oxides were used in hospitals as radiographic contrast agents. Liver disease, leukemia, myelofibrosis, aplastic anemia, and cirrhosis of the spleen were found to develop more frequently in people who received thorium injections.

Workers who have inhaled thorium dust may develop lung disease and cancer of the lung or pancreas many years after being exposed. Also, since thorium is weakly radioactive and may be stored in bone for a long time, bone cancer is a potential concern for those exposed to high levels of thorium. Minimal data exist on the health effects of exposure to thorium.

Tin (Sn)

While tin exists in both organic and inorganic forms in our environment, the analytical methods we use to test for tin do not determine the specific forms of tin present. This test measures total tin and does not distinguish between organic and inorganic forms. Tin has no known biological function, and exposure to tin is associated with dysfunction and disease.

Inorganic tin has many uses. It takes a high polish and is used to coat other metals to prevent corrosion, such as tin cans, which are made of tin-coated steel. Inorganic tin is found in decorative applications, containers, electronic cigarettes (e-cigarettes), vaping devices, polishing agents, catalysts, solders, bronze, and pewter. Inorganic tin compounds (i.e., stannous chloride, stannous sulfide, stannic oxide, stannous fluoride) are used in toothpaste, perfumes, cosmetics, soaps, food additives, and dyes.

Organic forms of tin ("organotins" such as dibutyltin, tributyltin, triphenyltin) are used to make plastics, food packages, silicon-coated parchment paper, plastic pipes, polyurethane foam, treated glass, pesticides, paints, and pest repellents. Organotins are used as wood preservatives; disinfectants; slimicides on masonry; and as biocides for cooling systems, power stations, pulp and paper mills, breweries, leather processing, and textile mills. Organotins may be released into the environment by smelting and refining processes, industrial uses of tin, waste incineration, as well as the burning of fossil fuels. To a lesser extent, organotin compounds may enter the environment by leaching into soil and groundwater from consumer products containing organotin compounds disposed of in landfills.

Antifouling paints containing organotin were once applied as a finish coat to the immersed sections of boats and floating structures. Although these paints were banned in 2008 due to their toxic effects on marine organisms, residual organotin compounds in coastal waters may lead to increased levels in seafood such as fish.

Organic and inorganic forms of tin have different toxicities. Exposure to high levels of inorganic tin can cause skin and eye irritation, respiratory irritation, gastrointestinal symptoms, liver and kidney problems, anemia, and neurological problems. Neurological dysfunction may persist for years after exposure. Lethal cases have been reported following ingestion of inorganic tin in very high amounts.

In contrast, organotins are known to be toxic at lower levels of exposure. Several organotin compounds, including dibutyltin, can cause nervous system damage, and the developing brain is particularly vulnerable. Certain forms of organotin are toxic to the immune system, and others may act as endocrine disrupters and obesogens. Organotins also can irritate the skin and eyes on contact.

Titanium (Ti)

While titanium exists in various compounds and forms, the analytical methods we use to test for titanium do not determine the specific forms of titanium present. This test measures total titanium and does not distinguish between forms. Titanium is present naturally in trace amounts in most plants and is considered to be non-toxic.

Titanium dioxide is added to food and other products to brighten white pigments. It is added to a wide variety of products including toothpaste, candies, chewing gum, vegan cheese, powdered doughnuts, white cake icing, mayonnaise, yogurt, dietary supplements, pharmaceuticals, cosmetics, and sunscreens. Titanium is used also to make drill bits, bicycles, fishing rods, golf clubs, backpacking equipment, watches, designer jewelry, laptop computers, paint, plastics, ink, ceramics, rubber, paper, coated fabrics and textiles, floor coverings, roofing granules, coatings, aircraft, spacecraft, missiles, crutches, wheelchairs, surgical and dental instruments, dental implants, orthopedic implants, prostheses, and pacemakers.

Titanium dioxide as a food additive in processed foods is Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration. Research on the safety and health effects of titanium metal implants and titanium dioxide nanoparticles in foods and cosmetics is ongoing.

Occupational exposure to titanium dust may cause tightness and pain in the chest, coughing, and difficulty breathing. Contact with skin or eyes may cause irritation.

Tungsten (W)

While tungsten exists in various compounds and forms, the analytical methods we use to test for tungsten do not determine the specific forms of tungsten present. This test measures total tungsten and does not distinguish between forms. Tungsten has no known biological function, and exposure to tungsten may be associated with dysfunction and disease.

Tungsten and its alloys are used in consumer products such as electronics, light bulb filaments, ceramic pigments, fire retardant coatings, fade-resistant dyes, cemented tungsten carbide grinding wheels, carbide-tipped tools, golf club components, fishing weights, darts, and “green” bullets. Tungsten also may be found in x-ray tubes, turbine blades, phonographic needles, welding electrodes, gyroscope wheels, and may be used as a catalyst to speed up chemical reactions and as a component of steel in high-speed tools.

Urban areas have higher levels of tungsten in the air because tungsten is released from industry, and tungsten also has been detected in municipal water supplies. Exposure to tungsten from air and water sources overall is generally insignificant, however individuals who are exposed to higher than normal levels of tungsten may have an increased risk of developing hypertension and stroke.

Occupational exposure to tungsten occurs primarily in workplaces where individuals work with hard metals containing tungsten. Pulmonary fibrosis, memory and sensory deficits, and increased mortality due to lung cancer have been attributed to occupational exposure to dust generated during the manufacture or use of tungsten, however these adverse health effects may be the result of exposure to cobalt or metals other than tungsten.

Uranium (U)

While uranium exists in various compounds and forms, the analytical methods we use to test for uranium do not determine the specific forms of uranium present. This test measures total uranium and does not distinguish between forms. Uranium has no known biological function, and exposure to uranium may be associated with dysfunction and disease.

Uranium is weakly radioactive and occurs naturally in nearly all rocks and soils. Uranium exposure occurs from food, air, soil, and groundwater, as it is naturally present in all these sources. Uranium in the soil is not taken up by plants, but rather, it is adsorbed onto the roots, therefore, the highest levels of uranium are found in root vegetables, primarily unwashed potatoes.

Populations living near uranium mills or mines or other areas with elevated uranium in soil may be exposed to higher levels of uranium from locally grown vegetables, especially root vegetables.

Uranium's primary health effects occur in the kidneys and the respiratory tract. Other potential targets of toxicity include the reproductive system and the developing fetus. Exposure to very high uranium levels can cause acute kidney failure, respiratory failure, and death. Exposure to lower levels of uranium can cause transient kidney damage. Chronic exposure to inhaled uranium may increase the risk of developing pulmonary fibrosis.

Zirconium (Zr)

While zirconium exists in various compounds and forms, the analytical methods we use to test for zirconium do not determine the specific forms of zirconium present. This test measures total zirconium and does not distinguish between forms. Zirconium has no known biological function, and exposure to zirconium may be associated with dysfunction and disease.

Zirconium is used in photographic flashbulbs and surgical instruments, to make the glass for television, in the removal of residual gases from electronic vacuum tubes, and as a hardening agent in alloys, especially steel. The paper and packaging industries use zirconium in surface coatings for water resistance and strength. The medical industry uses zirconium in prosthetics, dental restorations, and as a treatment to lower elevated potassium levels. Zirconium is used also to manufacture colored glazes, bricks, ceramics, abrasives, artificial gemstones, and some deodorants.

Individuals exposed to certain forms of zirconium may experience irritation to the respiratory tract, mucous membranes of the nose and throat, and skin and eye irritation. Chronic exposure may result in pulmonary edema and dermatitis.

ESSENTIAL AND TRACE ELEMENTS

Chromium (Cr)

While chromium exists in various compounds and forms, the analytical methods we use to test for chromium do not determine the specific forms of chromium present. This test measures total chromium and does not distinguish between forms.

Chromium is a naturally-occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases, and is an essential nutrient. Chromium is known to enhance the action of insulin, a hormone critical to the metabolism and storage of carbohydrate, fat, and protein in the body. Chromium is used also in industrial settings for making steel, chrome plating, dyes and pigments, leather tanning, and wood preserving. Releases of chromium into the air can occur from industries using or manufacturing chromium. Exposures to chromium also may be elevated for individuals living near hazardous waste facilities where chromium is present, or through cigarette smoke.

Chromium deficiency impairs the body's ability to use glucose to meet its energy needs and raises insulin requirements. The symptoms of chromium deficiency can include severely impaired glucose tolerance, weight loss, peripheral neuropathy, and confusion.

The most common health problems in workers exposed to chromium in the environment involve the respiratory tract. Workers also have developed allergies to chromium compounds, which can cause breathing difficulties and skin rashes. Elevated levels of ingested chromium in supplement form can cause abdominal pain, low blood sugar, and kidney or liver damage.

Cobalt (Co)

While cobalt exists in various compounds and forms, the analytical methods we use to test for cobalt do not determine the specific forms of cobalt present. This test measures total cobalt and does not distinguish between forms.

Cobalt is a naturally-occurring element found in rocks, soil, water, plants, and animals. Cobalt is used to produce alloys used in the manufacture of aircraft engines, magnets, grinding and cutting tools, and artificial hip and knee joints. Cobalt compounds also are used to color glass, ceramics, and paints, and as drying agents for porcelain enamel and paints.

Cobalt is an essential component of cobalamin (vitamin B12) and a necessary trace element in daily nutrition. Cobalt chloride was used from the mid-1940s until the 1980s to stimulate red blood cell production in cases of anemia, however this therapy

induced severe adverse effects, including organ damage primarily affecting the gastrointestinal tract, thyroid, heart, and sensory neurons.

Occupational exposure to high levels of cobalt also is known to lead to harmful health effects, including skin rashes and respiratory irritation. Workers exposed to air containing elevated levels of cobalt for six hours had difficulty breathing. Serious effects on the lungs, including asthma, pulmonary fibrosis, pneumonia, and lung cancer have been noted in individuals exposed to cobalt while working with hard metal, a cobalt-tungsten carbide alloy. Also, cobalt exposure is associated with an increased risk of developing hypertension.

Copper (Cu)

While copper exists in various compounds and forms, the analytical methods we use to test for copper do not determine the specific forms of copper present. This test measures total copper and does not distinguish between forms.

Copper occurs naturally throughout the environment, in rocks, soil, water, and air. Patients absorb some copper from eating, drinking, and breathing. Copper also is used in many products like wire, plumbing pipes, cookware, and sheet metal. Copper is combined with other metals to make brass and bronze pipes and faucets. Copper compounds are commonly used in agriculture to treat plant diseases like mildew, for water treatment, and as preservatives for wood, leather, and fabrics.

Copper is an essential nutrient. Together with iron, it enables the body to form red blood cells. It helps maintain healthy bones, blood vessels, nerves, and immune function, and it contributes to iron absorption. Copper deficiency is rare and can be remedied with appropriate copper supplementation.

Elevated exposure to copper dust can irritate the nose, mouth, and eyes, and cause headaches, dizziness, nausea, and diarrhea. Drinking water that contains higher than normal levels of copper can cause nausea, vomiting, stomach cramps, or diarrhea.

Iron (Fe)

While iron exists in various compounds and forms, the analytical methods we use to test for iron do not determine the specific forms of iron present. This test measures total iron and does not distinguish between forms.

Iron is the most used of all the metals, including 95% of all metal produced worldwide. Its applications go from food containers to family cars, from screwdrivers to washing machines, from cargo ships to staples. Steel is the best-known alloy of iron, and some of the forms that iron takes include pig iron, cast iron, carbon steel, wrought iron, alloy steels, and iron oxides.

Iron is naturally present in many foods and available as a dietary supplement. Iron is an essential component of hemoglobin, an erythrocyte protein that transfers oxygen from the lungs to the tissues, supports metabolism, and also is necessary for growth, development, normal cellular functioning, and synthesis of some hormones and connective tissue. Symptoms of iron deficiency include fatigue, hair loss, rapid heart rate, shortness of breath, and restless legs syndrome. Iron deficiency is the most common cause of anemia, the signs of which include impaired cognitive function, poor immune function, exercise intolerance, work performance issues, and body temperature regulation dysfunction.

Iron overload is an excess of iron in the body. Excess iron in vital organs, even in mild cases of iron overload, increases the risk for liver disease (cirrhosis, cancer), heart attack or heart failure, diabetes mellitus, osteoarthritis, osteoporosis, metabolic syndrome, hypothyroidism, and hypogonadism.

Lithium (Li)

While lithium exists in various compounds and forms, the analytical methods we use to test for lithium do not determine the specific forms of lithium present. This test measures total lithium and does not distinguish between forms.

Lithium is a naturally-occurring alkali metal, ingested from dietary sources, and present in trace amounts in the human body. The main sources of lithium in the diet are nuts, cereals, seafood, potatoes, tomatoes, cabbage, and some mineral waters. Many trace mineral formulas and other supplements also contain lithium.

Lithium is a component in rechargeable batteries for mobile phones, laptops, digital cameras, and electric vehicles, and is used in some non-rechargeable batteries for heart pacemakers, toys, and clocks. Aluminum-lithium alloys are used in aircraft, bicycle frames, and high-speed trains. Lithium carbonate is used in drugs to treat bipolar disorder.

Folate and vitamin B12 both require sufficient levels of lithium for their utilization. Folate and vitamin B12 are key nutrients required for optimum brain function, and low levels of either can result in depression, irritability, poor cognitive function, decreased mental and physical stamina, and a variety of neurological problems.

Excess lithium exposure can cause nausea, diarrhea, dizziness, muscle weakness, fatigue, and a dazed feeling. Tremor, frequent urination, thirst, and weight gain also can occur.

Manganese (Mn)

While manganese exists in various compounds and forms, the analytical methods we use to test for manganese do not determine the specific forms of manganese present. This test measures total manganese and does not distinguish between forms.

Manganese is an essential nutrient involved in the formation of bone and the metabolism of amino acids, cholesterol, and carbohydrates. Manganese is routinely found in groundwater, drinking water, and soil at low levels. For most individuals, manganese intake occurs primarily through food, with daily intake ranging from 2 to 9 mg.

Occupational exposure to manganese occurs in welding, industrial steel production, dry cell battery manufacturing, automotive mechanics, mining, and agricultural use of manganese-containing pesticides. Other sources of manganese exposure include fuel additives, automobile exhaust, and cigarette smoke. Manganese also is used as a contrast agent for magnetic resonance imaging.

Manganese deficiency is associated with chronic diseases such as diabetes, osteoporosis, and epilepsy. Because manganese is necessary for normal skeletal development, low levels may contribute to skeletal and postural abnormalities.

The inhalation of a large quantity of dust or fumes containing manganese can impair lung function. Chronic consumption or inhalation of excess manganese can lead to manganism, a condition caused by the neurotoxic effects of high levels of manganese. Symptoms of manganism mimic Parkinson's disease and include impaired motor function, impaired steadiness, tremor, behavioral changes, and cognitive dysfunction.

Molybdenum (Mo)

While molybdenum exists in various compounds and forms, the analytical methods we use to test for molybdenum do not determine the specific forms of molybdenum present. This test measures total molybdenum and does not distinguish between forms.

Molybdenum is an essential element common in the environment and serves mainly as an essential cofactor of enzymes and aids in the metabolism of fats and carbohydrates. The primary way patients are exposed to molybdenum is by eating food containing molybdenum, such as grains, legumes, nuts, and dairy. Molybdenum also is used in the production of stainless steel alloys and by the petroleum industry to catalyze the removal of organic sulfur compounds in coal and gas liquefaction processes.

Molybdenum deficiency is rare but may interfere with the metabolism of sulfur-containing amino acids, potentially leading to symptoms such as headaches, seizures, visual changes, and neurological disorders.

Molybdenum powder or dust in an industrial setting can adversely affect patients when inhaled. Contact can irritate the skin, eyes, nose, and throat, causing headache, fatigue, loss of appetite, and joint and muscle pain. Long-term exposure to molybdenum may damage the liver and kidneys and increase the risk of developing insulin resistance.

Nickel (Ni)

While nickel exists naturally in various compounds and forms, the analytical methods we use to test for nickel do not determine the specific forms of nickel present. This test measures total nickel and does not distinguish between forms.

Nickel occurs naturally in soil and as a trace element in many foods including chocolate, nuts, beans, peas, grains, fruits, vegetables, seafood, hydrogenated shortening, and baking powder. Drinking water and food are the main sources of nickel exposure. Nickel also may leach from nickel-plated utensils or stainless steel cookware, particularly during contact with acidic foods. Although nickel is an essential nutrient for certain bacteria, plants, and animals, it has no confirmed biochemical function in humans.

In addition to natural sources, nickel is released into the atmosphere by oil-burning power plants, coal-burning power plants, and trash incinerators; during nickel mining; by industries that make or use nickel, nickel alloys, or nickel compounds; and

from vehicle exhaust. Nickel compounds also can be found in tobacco smoke, electronic cigarettes (e-cigarettes), vaping devices, jewelry, wristwatches, surgical implants, dental appliances, coins, zippers, buckles, cell phones, rechargeable batteries, and eyeglass frames.

Those exposed to nickel may develop an allergy when jewelry or other items containing nickel are in direct contact with the skin or mucous membranes. The most common reaction to nickel is a skin rash at the site of contact. Less frequently, sensitive individuals may develop systemic dermatitis or asthma attacks following exposure. Individuals working in nickel refineries or nickel-processing plants have experienced chronic bronchitis, asthma, reduced lung function, and cancer of the lungs and nasal sinuses as a result of chronic nickel exposure. Implantation of nickel-containing devices also may cause systemic immunologic reactions and localized cancers.

Ingestion of excess nickel can cause nausea, vomiting, abdominal pain, and diarrhea. Consuming large quantities of nickel may damage the kidneys, liver, and cardiovascular system; may lead to insulin resistance and diabetes; may increase the risk of cancers of the lung, nasal sinuses, larynx, and prostate; and may increase the risk of preterm delivery.

Rubidium (Rb)

While rubidium exists naturally in various compounds and forms, the analytical methods we use to test for rubidium do not determine the specific forms of rubidium present. This test measures total rubidium and does not distinguish between forms.

Rubidium is a trace element found naturally in the environment. Rubidium is used in vacuum tubes as a getter, a material that combines with and removes trace gases from vacuum tubes. It is used also in the manufacture of photocells and special glasses. Rubidium salts are used in ceramics and in fireworks to give them a purple color. Rubidium-82 is used as a tracer in PET scans and is becoming one of the most widely used elements in heart imaging and procedures.

Rubidium is found in coffee, black tea, fruits, and vegetables, particularly asparagus; it also can be found in poultry and fish.

There are no harmful effects of rubidium exposure at levels typically found in the environment. If rubidium ignites, it will cause thermal burns. Rubidium readily reacts with skin moisture to form rubidium hydroxide, which causes chemical burns of eyes and skin.

Selenium (Se)

While selenium exists naturally in various compounds and forms, the analytical methods we use to test for selenium do not determine the specific forms of selenium present. This test measures total selenium and does not distinguish between forms.

Selenium is a mineral found in soil, and it occurs naturally in certain foods, including whole grains, Brazil nuts, sunflower seeds, and seafood. Selenium is an essential nutrient needed for proper thyroid and immune system function. Selenium also is used as a catalyst in many chemical reactions, to decolorize glass and make red-colored glasses and enamels, and as a photographic toner in solar cells and photocells.

Selenium deficiency can cause Keshan disease (a type of heart disease) and male infertility. It also may contribute to Kashin-Beck disease, a type of arthritis that produces pain, swelling, and loss of range of motion.

Ingestion of excess selenium may cause nausea, vomiting, diarrhea, hair loss, nail discoloration or brittleness, skin discoloration, muscle or joint pains, headache, excessive tooth decay and discoloration, garlic odor, lack of alertness, and severe malaise. People working in or living near industries where selenium is produced, processed, or converted into commercial products may be exposed to selenium in the air. Exposure to high levels of selenium dioxide in the air can result in respiratory tract irritation, bronchitis, coughing, difficulty breathing, and abdominal pain.

Strontium (Sr)

While strontium exists naturally in various compounds and forms, the analytical methods we use to test for strontium do not determine the specific forms of strontium present. This test measures total strontium and does not distinguish between forms.

Strontium is a natural and commonly occurring element. Rocks, soil, dust, coal, oil, surface and underground water, plants, and air all contain varying amounts of strontium. Strontium compounds, such as strontium carbonate, are used in making ceramics and glass products, pyrotechnics, paint pigments, fluorescent lights, medicines, and other products. Strontium chloride hexahydrate is added to toothpaste to reduce pain in sensitive teeth, and strontium ranelate is a component of certain osteoporosis drugs.

In several double-blind trials, treatment with strontium in doses of 170-680 mg per day (as strontium ranelate) for two to five years significantly increased bone mineral density of the hip and spine and significantly reduced the incidence of fractures by 16-49%, compared with placebo, in postmenopausal women with osteoporosis. A subsequent review of seven trials and five publicly available regulatory documents concluded that the number of fractures prevented by strontium ranelate was similar to the number of extra cases of venous thromboembolism, pulmonary embolism, and myocardial infarction caused by this compound. Other forms of strontium supplementation such as strontium citrate may provide similar benefits to support bone mineralization with fewer adverse effects.

There are no harmful effects of stable strontium exposure at levels typically found in the environment. The only chemical form of strontium that is harmful by inhalation is strontium chromate, but this is due to toxic chromium and not strontium itself. Problems with bone growth may occur in children eating or drinking unusually high levels of strontium, especially if their diet is low in calcium and protein.

Vanadium (V)

While vanadium exists naturally in various compounds and forms, the analytical methods we use to test for vanadium do not determine the specific forms of vanadium present. This test measures total vanadium and does not distinguish between forms.

Vanadium is a naturally occurring element in soil, water, and air. Vanadium is used in producing rust-resistant, spring, and high-speed tool steels. Releases of vanadium into the environment are associated with industrial sources, especially oil refineries and power plants using vanadium-rich fuel oil and coal. Vanadyl sulfate and sodium metavanadate have been used in dietary supplements, however there is not enough scientific evidence to establish a recommended dose of vanadium.

Nausea, mild diarrhea, and stomach cramps have been reported in people taking sodium metavanadate or vanadyl sulfate for the experimental treatment of diabetes. Stomach cramps were reported in a study of people taking about 13 mg vanadium/day. Breathing air with vanadium pentoxide also can result in coughing which can last several days after exposure.

Zinc (Zn)

While zinc exists naturally in various compounds and forms, the analytical methods we use to test for zinc do not determine the specific forms of zinc present. This test measures total zinc and does not distinguish between forms.

Zinc is found in the air, soil, and water and is present in all foods. Zinc compounds are used as ingredients in vitamin supplements, sunblocks, diaper rash ointments, deodorants, athlete's foot preparations, acne and poison ivy preparations, and antidandruff shampoos. Zinc compounds also are widely used in industry. Zinc sulfide and zinc oxide are used to make white paints and ceramic and also are used in producing rubber. Zinc acetate, zinc chloride, and zinc sulfate are used in preserving wood and in manufacturing and dyeing fabrics. Zinc chloride is also the major ingredient in smoke from smoke bombs.

Without enough zinc in the diet, patients may experience loss of appetite, decreased sense of taste and smell, decreased immune function, slow wound healing, and skin sores. Zinc deficiency during pregnancy may cause birth defects. Conversely, if large doses of zinc (10-15 times higher than the RDA) are taken even for a short time, stomach cramps, nausea, and vomiting may occur. Ingesting high levels of zinc for several months may cause anemia, damage the pancreas, and decrease levels of high-density lipoprotein (HDL) cholesterol. Zinc supplementation at high levels may lead to copper deficiency.

Exposure to zinc oxide in industrial settings, particularly from welding, can cause “metal fume fever.” This is a flu-like illness with symptoms of metallic taste in the mouth, headache, fever and chills, aches, chest tightness, and cough.

OTHER ESSENTIAL ELEMENTS

Calcium (Ca)

While calcium exists naturally in various compounds and forms, the analytical methods we use to test for calcium do not determine the specific forms of calcium present. This test measures total calcium and does not distinguish between forms.

Calcium is a mineral found in many foods. The body needs calcium to maintain strong bones and to carry out many important functions. Almost all calcium is stored in bones and teeth, where it supports their structure and hardness. The body also needs calcium for muscles to move and for nerves to carry messages between the brain and every body part. Also, calcium is

used to help blood vessels move blood throughout the body and to help release hormones and enzymes that affect almost every function in the human body.

Insufficient intake of calcium does not produce obvious symptoms in the short term because the body maintains calcium levels in the blood by taking it from bone. Over the long term, intakes of calcium below recommended levels have health consequences, such as osteopenia and increasing the risks of osteoporosis and bone fractures. Symptoms of serious calcium deficiency include numbness and tingling in the fingers, convulsions, and abnormal heart rhythms that can lead to death if not corrected.

Getting too much calcium can cause constipation. It also might interfere with the body's ability to absorb iron and zinc, but this effect is not well established. In adults, too much calcium (from dietary supplements but not food) might increase the risk of kidney stones. Some studies show that people who consume high amounts of calcium might have increased risks of prostate cancer and heart disease, but more research is needed to understand these possible links.

Magnesium (Mg)

While magnesium exists naturally in various compounds and forms, the analytical methods we use to test for magnesium do not determine the specific forms of magnesium present. This test measures total magnesium and does not distinguish between forms.

Magnesium is present naturally in many foods, added to other food products, available as a dietary supplement, and present in some medicines (such as antacids and laxatives). Magnesium is a cofactor in more than 300 enzyme systems that regulate diverse biochemical reactions in the body, including protein synthesis, muscle and nerve function, energy production, blood glucose control, and blood pressure regulation. Magnesium contributes to the structural development of bone and is required for the synthesis of DNA, RNA, and the antioxidant glutathione. Magnesium also plays a role in the active transport of calcium and potassium ions across cell membranes, a process that is important to nerve impulse conduction, muscle contraction and relaxation, and normal heart rhythm.

Common symptoms of mild-to-moderate magnesium deficiency include anxiety, depression, fatigue, insomnia, irritability, panic attacks, muscle cramps and twitches, chest tightness, hyperventilation, faintness, difficulty concentrating, memory loss, confusion, headaches, intestinal complaints, tremor, palpitations, and certain types of cardiac arrhythmias. Low intakes or excessive losses of magnesium due to certain health conditions, chronic alcoholism, and/or the use of certain medications can lead to magnesium deficiency. Other signs of magnesium deficiency may include loss of appetite, nausea, vomiting, and weakness. As magnesium deficiency worsens, numbness, tingling, muscle contractions and cramps, seizures, personality changes, abnormal heart rhythms, and coronary spasms can occur. Severe magnesium deficiency can result in low serum calcium or potassium levels.

Ingesting too much magnesium from food does not pose a health risk in healthy individuals because the kidneys eliminate excess amounts in the urine. High doses of magnesium from dietary supplements or medications often result in loose stool that can be accompanied by nausea and abdominal cramping. Forms of magnesium most commonly reported to cause loose stool include magnesium carbonate, chloride, gluconate, and oxide.

Phosphorus (P)

While phosphorus exists naturally in various compounds and forms, the analytical methods we use to test for phosphorus do not determine the specific forms of phosphorus present. This test measures total phosphorus and does not distinguish between forms.

Phosphorus is a nonmetallic element that is found in the blood, muscles, nerves, bones, and teeth and is a component of adenosine triphosphate (ATP: the primary energy source for the body's cells). Phosphorus helps keep patients' bones healthy. It also helps keep blood vessels and muscles working. Phosphorus is found naturally in foods rich in protein, such as meat, poultry, fish, nuts, beans, and dairy products. Phosphorus also is added to many processed foods.

Lower than sufficient levels of phosphorus can cause muscle weakness, fatigue, and a low tolerance for exercise. Insufficient phosphorus coinciding with low levels of calcium and vitamin D can lead to weaker, softer bones over time. This causes joint and muscle pain.

Elevated levels of phosphorus can cause kidney disease. Ingesting too much phosphorus and not enough calcium can lead to an excess of phosphorous. Phosphorus levels that are too high or too low can cause medical complications, such as heart disease, joint pain, or fatigue.