Elements Testing in Dried Urine & Dried Blood Spot

We are all exposed to different amounts of essential and toxic element depending on where we live, our diet and supplementation routine, or our lifestyle choices. Levels of both essential and toxic elements that we consume or are exposed to from the environment are determined by where we live, the water we drink, the supplements we take, and the levels in soil/irrigation water used to grow the foods we eat. We are also exposed to toxic elements through environmental pollution of the air we breathe, as well as exposure through our skin.

How do different levels of essential and toxic elements affect health?

Essential elements are only conducive to optimal health when they are within optimal ranges. Levels that are too low or too high can have detrimental effects on health. Therefore, it is important to know if essential or toxic elements are outside their optimal ranges.

Both iodine and selenium are good examples of essential elements that can be both beneficial and toxic, depending on their levels. Severe iodine deficiency and extreme excesses cause thyroid deficiency and goiter. The same is true for selenium. A severe deficiency impairs the enzymes necessary for anti-oxidant actions and thyroid deiodinases that convert inert T4 to bioactive T3. In contrast, an excess of selenium can cause death.

Bromine is in the same chemical family as iodine and excessive amounts will compete with iodine in the thyroid. This becomes particularly problematic when iodine levels are borderline low, or lower, and bromine is high. Lithium is important for brain health in trace amounts but is toxic when used in excessive amounts pharmacologically.

Copper and zinc are essential micronutrients that are needed in very small quantities in the diet, but are toxic at concentrations greater than is necessary for their biological functions. Magnesium is an essential element with a

Available Tests

Elements Dried Urine Profile

Tests included: Iodine, Selenium, Bromine, Lithium, Arsenic, Cadmium, Mercury

Assesses whether an individual has adequate, deficient, or excessive levels of iodine and selenium or the trace elements bromine and lithium, or if they have been exposed to excessive levels of the toxic elements arsenic, mercury, and cadmium.

Elements Dried Blood Spot Profile

Tests included: Cadmium, Mercury, Lead, Selenium, Zinc, Magnesium, and Copper

Assesses whether an individual has adequate, deficient, or excessive levels of the essential nutrients zinc, copper, selenium, and magnesium, or if they have been exposed to excessive levels of the toxic heavy metals mercury, cadmium, and lead.

Comprehensive Elements Profile

Tests included: Cadmium, Mercury, Lead, Selenium, Zinc, Magnesium, and Copper in Dried Blood Spot; Iodine, Selenium, Bromine, Lithium, Arsenic, Cadmium, Mercury in Dried Urine

Combines both Dried Urine and Dried Blood Spot Elements (see above)

1998 - 2018 20 years

significant role in cellular metabolism and protein synthesis, and its deficiency causes problems from muscle weakness to cardiac arrhythmias.

Arsenic, mercury, cadmium, and lead are toxic heavy metals with no known nutritional benefits in the human body. High levels of them lead to an increase in Reactive Oxygen Species (ROS) that damage proteins, lipids, and DNA. They also form tight bonds with essential elements such as selenium, reducing its bioavailability for enzymes such as glutathione peroxidase and thyroid deiodinase, both essential for thyroid hormone synthesis and activation. Arsenic, mercury, lead, and cadmium are extremely hazardous to human health. They represent the top four most toxic heavy metals according to the CDC's priority list of hazardous substances[1]. Lead, mercury, and cadmium accumulate and are retained in the body, and so their toxic effects are cumulative and more pronounced with aging.

Very little lead is excreted in urine, but it is readily taken up by red blood cells where it forms a tight complex with hemoglobin. For this reason whole blood, and not serum or urine, is used to monitor exposure to lead. Arsenic is only measured in urine and is not included in the blood spot profile because it is rapidly cleared from the bloodstream after exposure, and would therefore only be detected in blood if testing was done immediately after exposure.

In summary, testing for these elements provides an excellent assessment of overall body burden of toxic elements, and is an indicator of excessive or inadequate supplementation with nutritionally essential elements.

Hormone Testing

Minimally-invasive home test kits

Dried Urine Testing

Urine dried on filter paper strips is a convenient and practical way to test essential and toxic elements that are excreted into urine. ZRT Laboratory is a pioneer in commercial testing for elements using a simple, two-point (morning and night) urine collection, into which filter paper strips are dipped and then allowed to dry. Filter strips containing the dried urine are then shipped to ZRT Laboratory where the elements are extracted from the filter strips and tested for elements by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Published research from ZRT Laboratory[2,3] has shown the dried urine test to be accurate and comparable to full 24-hour liquid samples.

Dried Blood Spot Testing

Whole blood dried on filter paper is a convenient alternative to liquid whole blood testing for elements, and is preferable to serum testing for certain elements that are found predominantly in red blood cells (lead and zinc). Whole blood is also advantageous for testing magnesium because it represents intracellular magnesium, whereas serum magnesium is not a useful test because it is kept within a tight range by homeostatic mechanisms and the test is therefore normal in most people, masking deficiency at the intracellular level. For the nutritional elements copper and zinc, dried blood spot testing reflects intracellular as well as blood (serum) levels and can reveal deficiencies earlier than a typical blood (serum/plasma) test.

Arsenic is not tested in dried blood spot because it is rapidly cleared from the bloodstream and therefore urine testing is the only clinically useful determinant of arsenic exposure.

Dried blood spot reference ranges are used for elements since published serum reference ranges are not comparable to whole blood/dried blood spot reference ranges.

Elements Tested in the Profiles

Essential Elements

Iodine

An essential component of the thyroid hormones T4 and T3. Iodine is an essential nutrient, commonly found in dairy products, seafood, iodized salt, and grains. Severe iodine deficiency compromises thyroid hormone production and leads to serious diseases including irreversible cretinism, pregnancy complications, goiter, and decreased cognitive function[4]. Mild to moderate iodine insufficiency can lead to thyroid deficiency. Excessive iodine intake, paradoxically, can also lead to thyroid deficiency. Iodine deficiency has also been associated with breast cancer. Since over 90% of dietary iodine is eliminated in urine, adequacy of recent iodine intake can be accurately assessed with dried urine testing[5]. For a fuller discussion of iodine's role in overall health and the value of testing, please see the Provider Data Sheet "Iodine Testing in Dried Urine."

Selenium

An essential dietary element that is incorporated into the selenoproteins in the body, which include glutathione peroxidases, thioredoxin reductases, iodothyronine deiodinases, and the extracellular glycoprotein, selenoprotein P[6]. These selenoproteins play vital roles in thyroid hormone synthesis, free radical scavenging, DNA synthesis, and cancer prevention[7]. Foods such as brazil nuts, seafood, eggs, and grains are significant selenium sources. The optimal therapeutic range for selenium is narrow. Excess selenium intake can result in toxicity, while inadequate selenium affects thyroid function because of impaired synthesis and conversion of T4 into the active T3[8]. Urine is the major route of selenium elimination; therefore urinary selenium is an indicator of dietary selenium intake. For individuals using dried blood spot for elements testing, the selenium test assesses nutritional adequacy of selenium. This is particularly helpful when determining if selenium is present in sufficient quantities to counteract heavy metal toxicity that impacts selenium's essential functions in the body, since heavy metals form tight complexes with selenium and reduce its bioavailability. Dried blood spot selenium levels reflect both free selenium in the blood and selenium as a component of selenoproteins.

Magnesium

An essential element required for over 600 enzymatic reactions involved in cellular metabolism and protein synthesis[9]. Magnesium is important for strong bones and muscles, heart health, nerve function, and cellular energy production. Deficiency of magnesium results in muscle weakness or cramping, confusion, seizures, and even cardiac arrhythmias. Magnesium levels are affected by problems with kidney function and alcoholism, and some drugs such as diuretics and proton pump inhibitors can cause deficiency. It is estimated that up to 60% of people in the US do not get sufficient dietary magnesium and could be deficient; magnesium-rich foods include kelp, nuts, green vegetables, and whole grains. A serum magnesium test is not useful because the body raises serum levels at the expense of intracellular levels in order to keep serum levels within a tight physiological range, and therefore most people have normal serum magnesium even in a deficient state. Dried blood spot testing includes intracellular magnesium and is a better indicator of nutritional status.

Zinc

An essential dietary nutrient with an important role in the immune system, partly because of its bactericidal properties. Zinc is a cofactor in multiple enzyme systems and is present in the zinc fingers that are involved with stabilization of folds in protein structures, in particular those that interact with specific areas of DNA. Like copper, zinc is transported bound to ceruloplasmin, but it also binds to hemoglobin. Zinc deficiency compromises the immune system, wound healing, and the senses of taste and smell[10]. Excessive zinc intake above the RDA of 15 mg/day can cause copper deficiency, impaired immune function, and adverse effects on the LDL/HDL cholesterol ratio[11]. Disturbances in zinc and copper metabolism, including a low zinc/copper ratio, low zinc levels, or high copper levels, have been implicated in autism spectrum disorders[12]. Good sources of dietary zinc include red meat, poultry, beans, nuts, seafood (especially oysters), whole grains, and dairy products.

Copper

An essential element that is required as a cofactor in multiple enzyme systems, usually as a participant in redox reactions. Copper is transported in the bloodstream bound to the protein ceruloplasmin. Since copper is toxic at concentrations higher than required for its cellular functions, ceruloplasmin delivers copper safely to target tissues without causing damage. Copper is necessary for normal development of connective tissue, nerve sheaths, and bone, and is also a participant in energy metabolism. Deficiency can result in neurological dysfunction and connective tissue abnormalities, while excess copper can cause liver dysfunction[10]. The inherited genetic disorder Wilson's Disease is characterized by abnormal copper accumulation in the liver and other vital organs, resulting in copper toxicity. Too much dietary zinc can cause copper deficiency. Good sources of dietary copper include liver, oysters, nuts, seeds, dark chocolate, and whole grains.

Bromine

A common component of flame proofing agents, fumigants,

medications, food products, and pool/spa sanitizers. Although bromine was once thought to have no essential function in the body, recent studies suggest that it may also be an essential element at low levels and play a role in connective tissue formation[13]. High environmental exposure can lead to excess accumulation[14]. If iodine status is low, bromine competes with iodine uptake in the thyrocyte and for tyrosine binding sites within thyroglobulin, and theby impedes thyroid hormone synthesis. Bromine is mostly excreted in urine, so urine analysis can indicate excessive bromine exposure.

Lithium

Historically used as a mood-stabilizing agent, lithium is now known to play a positive role in overall health. By influencing the expression of more than 50 genes, this powerful mineral restores neural function and improves brain health[15]. One way in which lithium can help is by augmenting the activity of the enzyme responsible for metabolizing serotonin: aggression can result when serotonin levels build up with respect to its metabolite, 5-HIAA. Small amounts of ingested lithium appear to have other effects on well-being, including reduced susceptibility to cardiovascular and neurological disorders[16]. Multiple independent studies based on populations from different parts of the world report that when lithium exposure is too low, mood is affected and people are more easily agitated and reactive – manifested in increased rates of suicide, homicide and violent crimes in areas with low lithium in the water supply[17]. Sources of lithium include well water, meat, dairy, grains, and vegetables. There is no recommended daily allowance, but exposure to high levels of lithium is associated with renal damage, skin lesions, and thyroid disorders[18]. The majority of ingested lithium is excreted in urine within 24 hours, so urine testing is a good indicator of recent dietary exposure.

Heavy Metals

Arsenic

An environmental toxin, found in well water as well as some foods such as fish, shellfish, seaweed, rice, and fruit. Arsenic is a heavy metal with multiple toxic effects in the body including carcinogenesis, goiter, diabetes, skin diseases, and damage to the liver, kidney, and the cardiovascular, nervous, and endocrine systems[19]. It also competes with selenium, preventing its incorporation into the selenoproteins. This reduces the levels of selenium-containing antioxidants and also the selenoenzymes that are essential for thyroid hormone production, thereby compromising thyroid function[20]. Urinary arsenic is a good indicator of recent arsenic exposure, since around 80% of dietary arsenic is excreted into urine with 3 days[21].

Cadmium

A toxic metal that is extremely hazardous to human health. Cadmium is classified by the World Health Organization's International Agency for Research on Cancer (IARC) as a group I carcinogen[22,23]. Occupational exposure arises mainly from smelting, battery manufacturing, and colored glass manufacturing[24]. Cadmium gets into the atmosphere as a result of industrial activity, as well as via fossil fuel combustion and waste incineration. It is deposited in the soil where it is taken up by food plants and enters the human food supply[25]. Tobacco leaves are particularly efficient at accumulating high levels of cadmium from soil, so smoking is a major source of human cadmium exposure. Smokers have about twice the body burden of cadmium compared to non-smokers. In non-smokers, the primary source of exposure is through the food supply. Particularly high cadmium levels are seen in green, leafy vegetables, potatoes and grains, peanuts, soybeans, and sunflower seeds that have been grown in soils containing high levels of cadmium. It also accumulates in shellfish. Apart from occupational exposure in cadmium-emitting manufacturing plants or waste incinerators, cadmium inhalation from the air is not a major source for most people. Once inside the body, cadmium binds to albumin and metallothionein in the circulation, and is filtered by the kidneys where it accumulates in the kidney cortex. In the kidneys, the half-life of cadmium is more than 10 years. Urinary cadmium correlates with tissue levels in the kidneys and is thus accepted as an accurate measure of long-term total body burden of cadmium[25]. Cadmium can also accumulate in the thyroid gland, resulting in damage to thyroid tissues with chronic exposure[26]. An overall positive association has been observed between urinary cadmium and levels of total T4, total T3, free T3, and thyroglobulin in the National Health and Nutrition Examination Survey (NHANES)[27]. Cadmium contributes to unexplained infertility in both men and women, having detrimental effects on both male and female reproductive organs through a variety of mechanisms, including endocrine signal disruption and testicular accumulation affecting spermatogenesis[28,29]. Cadmium also acts as an estrogen mimic or metalloestrogen by stimulating cell proliferation in estrogen-responsive tissues and therefore increasing risk of uterine fibroids and other reproductive tract diseases[30]. Cadmium was originally thought to act by binding directly to the estrogen receptor, but recent research suggests that it circumvents the estrogen receptor and activates the zinc-finger gene region that is ordinarily activated by estrogen receptor bound to estrogen[31]. Short-term cadmium exposure, reflected in elevated dried blood spot but not urine levels, has been associated with modest blood pressure elevations[32,33]. Urinary cadmium has been linked with peripheral arterial disease[34], indicating some cardiovascular toxicity with cadmium exposure.

Lead

A toxic heavy metal implicated in severe neurological defects in developing children. The presence of lead in the environment

has been causing problems to human health since Roman times, but widespread occupational exposure to lead became a significant issue during the industrial revolution[35]. Exposure of the general population to high levels of environmental lead occurred largely as a result of its use as an additive in gasoline and paint. Since these products have been discontinued, overall lead exposure and levels have declined significantly. However, lead is still found in older plumbing systems and paint and soil contaminated with this industrial chemical before its use was banned. For this reason lead remains ubiquitous in the environment. Lead exposure is particularly dangerous in children, in whom it can negatively affect brain development and intelligence. Since children tend to crawl on the floor or put toys and other objects in their mouths, they are also more susceptible than adults to lead exposure by oral ingestion of lead dust or lead-based paint. Current guidelines recommend that there is no safe level of lead exposure in children[36]. Gastrointestinal lead absorption is also considerably more efficient in children than in adults. In addition to causing neurological defects, high lead exposure can reduce vitamin D and hemoglobin synthesis. Lead absorbed by the body is taken up by red blood cells and binds to hemoglobin. Therefore, measurement in whole blood provides a more accurate assessment of lead exposure than urinary lead measurements, which are not clinically useful. Measurement of lead in dried blood spots by ICP-MS is a reliable and convenient method to assess lead exposure[37].

Mercury

A highly toxic heavy metal that can accumulate in body tissues including the brain. Besides occupational exposure, most human exposure to mercury is through dental amalgams, seafoods, and vaccinations[38]. Mercury toxicity can cause nervous system damage, leading to symptoms such as paresthesia, mood changes, and sensory disturbances, while very excessive exposure can also lead to renal toxicity, respiratory failure and death[39]. Mercury and selenium have a very high affinity for each other and form a tight complex[40]. As a result, mercury reduces the biological availability of selenium and may inhibit the formation of selenium-dependent enzymes, affecting thyroid function in the same way as selenium deficiency or arsenic exposure. This is particularly problematic in people with inadequate selenium intake and consequent low selenium levels. Selenium can protect against mercury toxicity by sequestering mercury, reducing its bioavailability[41]. The low toxicity of mercury in fish is related to its interaction with selenium. There are three forms of mercury in the environment: elemental, inorganic, and organic. Elemental mercury (HgO) comes from batteries, thermometers, and dental amalgams. Elemental mercury is most commonly breathed in as a vapor (e.g., from amalgams) and absorbed through the lungs. It is volatile and nonpolar and quickly penetrates the blood brain barrier where it is oxidized to inorganic mercury and retained in the brain. Inorganic mercury (Hg^{2+}) is found primarily in mercuric chloride and skin-lightening creams. Organic mercury, mostly in the form of methylmercury, is found in sea foods. Inorganic and organic mercury compounds are ingested and absorbed through the intestine. The predominant form of mercury in urine is inorganic mercury, while in blood the organic species, mainly methylmercury, predominate. Urinary mercury level is an excellent biomarker for whole body exposure to both elemental and inorganic mercury[42]. Assessment of mercury in dried blood spot is a good indicator of recent exposure to organic mercury, mostly methylmercury, particularly from dietary sources such as fish.

Creatinine

A metabolic by-product that is excreted at a relatively constant rate as long as kidney function is not impaired. It is used to normalize the amount of elements extracted from the filter paper and to correct for hydration status; the greater the fluid intake, the lower the creatinine level. Iodine, bromine, selenium, arsenic, mercury, and cadmium results in urine are therefore expressed in μg/g creatinine to allow for urine dilution.

Advantages of Dried Urine and Dried Blood Spot for Testing Essential & Toxic Elements

- Urine and dried blood spot collections are simple and can be done conveniently at home and shipped directly to the testing laboratory, saving time for the patient and their health care practitioner.
- Simple collections of urine directly on a filter strip in the morning and before bed at night are much easier than a 24-hr urine collection, and provide equal accuracy.
- Essential and toxic elements in dried urine and dried blood are exceptionally stable for weeks at room temperature allowing more flexibility in collection, storage, and shipment in an envelope from anywhere in the world.
- Urine element results expressed in μg/g creatinine auto-corrects for differences in urine concentration on the filter strip and for urine dilution resulting from excessive liquid consumption.

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For more information, see also:

- Provider Data Sheet: Iodine Testing in Dried Urine
- Provider Data Sheet: About Dried Urine Testing
- Provider Data Sheet: About Dried Blood Spot Testing
- Informational Guide: Elements and the Thyroid