NEWS FROM THE WONDERFUL WORLD OF SOIL AND PLANTS

MINERALS - The Elements and What They Do

Today we continue with our study of all the minerals (elements) in the human body, what they do. See previous newsletters (9/17/21 and 9/24/21) for a list of references and introduction to the Periodic Table.

Today we look at elements 25-28 which are manganese, iron, cobalt, and nickel.

25) **Manganese (Mn)** - Manganese is a metal found in group 7 of the periodic table of elements. Manganese is a hard, brittle silvery metal that will burn in oxygen and react with water. The most common electrical state for manganese is +2 and it combines easily with other elements and is a component of hundreds of minerals.

Manganese can be found in igneous rocks at 950 ppm, shale at 850 ppm, limestone at 1,100 ppm and sandstone at 50 ppm. In most soils, it is around 850 ppm but is not often found in water, with fresh water having only 0.01 ppm and seawater even less.

One of the first uses for manganese was in its black oxide form, it was found in cave paintings from over 17,000 years ago where it was used to make a black paint. Manganese is very useful when mixed with iron (Fe) to form alloys that form high quality steel that can take a very sharp edge as in razors. Manganese is used in many items from baseball bats to golf clubs, from fuel additives to batteries. Potassium permanganate ($KMnO_4$) is a strong oxidizing agent used by water systems and creates an intense pink color when dissolved in water.

Manganese became famous by the efforts of the CIA to recover a sunken Russian submarine under the guise of mining manganese nodules from the ocean floor.

Manganese is essential for all living beings. It activates enzymes involved with glucose metabolism, energy production, and superoxide dismutase. It is a component of several metalloenzyme's, hormones and human proteins.

However, excess manganese in water systems and in some industrial processes can produce a Parkinsonian like syndrome and psychiatric disorders that resemble schizophrenia. Although an essential element manganese is neurotoxic at high levels.

"Children especially infants are vulnerable to its effects and are associated with neurodevelopment outcomes that include reduced IQ, inattention, hyperactivity, and impulsivity". Some water wells, water systems, and baby formulars have been found to have excessive levels. Environmental Health Perspectives (July 2021).

Manganese is also used by the body to convert superoxide a potentially harmful chemical into harmless water.

Manganese is used to strengthen nerves and is involved with their correct functioning. Manganese is involved with amino acid, lipid, and carbohydrate metabolism and is used as a co-factor in many enzymes. Excess manganese prevents the body from absorbing iron (Fe).

A very important enzyme for animals including humans is called glutamine synthetase which depends on manganese to function. As with many elements (+2 electrical charge), the chemical glyphosate found in herbicides like Round-Up prevents the absorption of these essential elements from our food.

It is estimated that over 75% of the USA population is deficient in manganese.

Deficiencies of manganese are linked to birth defects, asthma, convulsions, retarded growth, skeletal defects, osteoporosis, and disruption of fat and carbohydrate metabolism, to joint problems. The best-known deficiency disease is carpal tunnel syndrome where tens of thousands of surgeries and numerous devices are sold to correct a simple nutritional deficiency.

Manganese is used to make the molecule mucopolysaccharides which is used in collagen, bone and cartilage. Other deficiency related diseases include Alzheimer's, Parkinson's, depression, as well as effects on bone health and reproductive function.

Recent research has found that the essential gut bacteria Lactobacillus is dependent on manganese for antioxidant protection. Animals are more sensitive to manganese deficiencies than humans are.

Nuts, chocolate, cereal based products, sugar beets and some fruits are good sources of manganese along with snails (think French cuisine). Mussels, hazelnuts, pecans, brown rice, oysters and clams, and chickpeas are other sources.

Gardening and Landscaping Problems Associated with Manganese (Mn)

Manganese is mobile in most soils and in conditions of high humidity. Acid conditions leads to manganese being leached from soils.

Some microbes (bacteria and fungi) help precipitate magnesium out of the soil solution by changing its common oxidative electrical state from +2 to +3 or +4 which then changes its chemical properties. Biological properties of the soil are critical for manganese utilization by plants. All manganese compounds are important as they are essential for plant nutrition and they control the behavior of many other trace elements. Microbes are essential for cycling manganese in terrestrial systems.

It is interesting that sterilizing soils in greenhouse applications has led to manganese toxicity in plants as the microbes prevented the plant from absorbing too much manganese.

Adequate manganese helps promote calcium (Ca) availability in the soil and is necessary for all plants. Uptake by plants is done passively and by microbial action. The interaction between roots and microorganisms can result in the oxidation of the available form of manganese (Mn^{+2}) into an unavailable form (Mn^{+3} or Mn^{+4}) as mentioned above. Manganese deficiency can occur on calcareous soils due to its alkalinity.

Research at Purdue University has found that the application of the glyphosate-based herbicide Round-Up, will tie up manganese within the soil and the plant, and alter the microbial populations in the rhizosphere. Note: It has been shown that this also happens in human digestive systems when we eat food grown and treated with glyphosate, preventing one from absorbing any manganese that might have been present in the food which then leads to numerous health problems like carpal tunnel.

Manganese is easily transported in plants, but tends to accumulate in older leaves and sheaths. Manganese is required for the plant enzymes arginase and phosphotranferase and may substitute for magnesium (Mg) in other enzymes. Manganese is involved with photosynthesis and the oxygen transport system. It is used in reducing nitrogen oxide ions (NO_2^-) during the reduction process hence; it is believed to affect the nitrogen assimilation process by plants.

For years, gardeners were told to use Mn EDTA (manganese ethylrnedaminetetraacetic acid) to correct manganese shortages. We now know this chemical actually made the deficiency worse as it induced more manganese deficiency.

Manganese is a micronutrient and plant tissue contain 5-500 ppm depending on the species. It is required for certain physiological processes such as enzyme and co-enzyme systems, and activates enzymes used in the growth process. It aids in the oxidase enzyme in carrying oxygen and enters into oxidation and reduction reactions needed in carbohydrate metabolism. Manganese is required for seed formation and involved in the production of chlorophyll. A deficiency sometimes causes a yellowing of plants leaves.

A deficiency results in poor uptake of other nutrients resulting in mineral imbalances in plant tissues. Symptoms frequently resemble iron deficiency and if there is excess sodium and potassium (10% or more of available nutrients) manganese will not reach the plant. Deficiency shows up on youngest leaves and stems, high pH soils, sandy soils, low organic matter soils, overly limed soils, and is seen as interveinal chlorosis.

Manganese deficient plants have retarded growth, lower resistance to disease and pests, and increased sensitivity to climate issues. This includes reduced cold hardiness. The most common symptom of manganese toxicity is iron (Fe) chlorosis and brown spots on leaves with browning of roots on some plant species. Excess manganese also prevents plants from absorbing cobalt (Co).

Excess phosphorous (P) from artificial fertilizers can cause or aggravate manganese deficiencies. Manganese toxicity occurs on soils with a pH of 5.5 or less (acid) on soils with lots of manganese and on poorly drained soils. Activities of some enzymes and hormones of plants are reduced with exposure to excess manganese. Many legumes will not fix nitrogen if there is too much manganese.

Deficiencies can be corrected by both soil and foliar applications of manganese. High levels of manganese can induce a calcium deficiency in plants. It also hinders grow of many pine species.

Note: Red meat and beef liver are often good sources of many elements including manganese, however, if the animals were fed Round Up ready feed (grains and corn) they become deficient in manganese and other elements, and are no longer a good source of these nutrients.

Note: Sewage sludge (Biosolids) and compost made from these wastes, is often a source of manganese toxicity.

Sources: compost, native mulches, manganese sulfates, chelates of manganese, basalt sand, re-mineralizer.

26**) Iron (Fe)** - Iron is the fourth most abundant element in the earth's crust and is a component of many rock forming minerals. Iron is found in igneous rocks 56,300 ppm, shale at 47,200, sandstone at 9,800, and limestone at 3,800 ppm. In soils it is found at 38,000 ppm and when combined with oxygen it gives many soils the reddish color (ex. East Texas). However, in fresh water at only 0.67 ppm and seawater at 0.01 ppm. In marine plants, iron can be found at 700 ppm and land plants at 140 ppm. In some mafic rocks like basalt, iron can be up to 8% of the total minerals.

Iron is a silvery lustrous metal that rusts in air and dissolves in weak acids. The chemical symbol (Fe) comes from the word "Ferrum" which is Latin for iron.

Iron is one of the most important metals in human history allowing great advances in science and technology, hence the name the Iron Age. Even today iron, in the form of steel is used everywhere from cars, railroad tracks, bed frames, ovens and stoves, horse shoes, nails, bolts and screws, tools, drill bits, skillets, and many more items.

Iron has a unique geo-chemistry with electrical charges that range from +2 to +6 with +3 being the most common. This allows iron to combine with other elements in many ways. Iron (Fe) combines with oxygen (O) to form many minerals from common rust to even magnetic minerals like magnetite (Fe_2O_3). Another form of iron we find in nature when combined with sulfur (S) is "fool's gold" or iron pyrite (FeS_2).

Iron is essential for our health as it is required for hemoglobin, myoglobin, respiratory enzymes, a cofactor and activator of enzymes, and has many more functions. Iron (Fe) is to hemoglobin as magnesium (Mg) is to chlorophyll and to the process of electron transfer for utilization of oxygen that both plants and animals require.

Excess iron in the body can cause increased inflammation, fatigue, diabetes, joint and muscle pain, erectile dysfunction, arthritis and cirrhosis of the liver but it is rare compared to iron deficiencies (DNA Restart 2016). Excess iron also can cause a growth of pathogenic bacteria, fungi, and protozoa. It can also transform the relatively harmless hydrogen peroxide into the hydroxyl free radical (OH^-)

Iron from plants is only one percent absorbable while iron from meat is 10 percent absorbable. As a result, iron deficiency is often a cause of "pica" where children eat dirt. Iron deficiency is linked to many human diseases and health problems.

Studies have shown that iron deficiencies occur in over 34% of our population. A few iron deficiency symptoms in humans are anemia, brittle nails, fatigue, irritability, confusion, dizziness, fragile bones, anorexia, constipation, and weakened immune system.

The amount of iron in our food supply has decreased dramatically in recent years. For example, to get the same amount of iron one received from an apple in 1950 by 1998 we had to eat 36 apples! If we go back further and look at 1914 to 1992, we find calcium has declined by 48%, phosphorous by 85%, iron by 96% and magnesium by 83%. If we want to be healthy, we have to grow our own food and re-mineralize the soil that they are grown in!

The herbicide glyphosate (Round-Up) locks up iron and prevents it from being absorbed properly by plants. When we eat food sprayed with glyphosate (all grains including corn and other vegetables) we are eating glyphosate. The glyphosate then prevents us from absorbing what little iron that did make it into the food. This is another reason to purchase organic food and avoid GMO's.

A few food sources of iron are oysters, white beans, dark chocolate, liver, lentils, red meat, sardines, and spinach.

Microbes use iron and combine it with other elements to form over 18 different minerals in the soil. Since iron combines with other elements so easily, it is not very soluble or mobile in the soil and is why we do not find very much iron in water.

Iron is essential for phytoplankton and the limiting factor in their growth. The addition of iron can greatly increase their biomass. One of the ideas proposed to remove carbon dioxide (CO_2) from the atmosphere as a method to fight global warming, is to salt the oceans with iron dust, which would trigger a massive phytoplankton bloom. When the plankton dies, they would sink to the ocean bottom sequestering the carbon (C).

Gardening and Landscaping Problems Associated with Iron (Fe)

Iron readily combines with oxygen to form rust. Think about a pair of pliers that was left outside in the dew and rain for a couple weeks. Rust is formed and the pliers are cemented together and will not move. The same thing happens in our soils; too much iron will cement soil particles together forming hardpan. This is very common when artificial fertilizers are used. A couple of the common iron minerals formed is ferricrete and ironstone. What do these names suggest to you?

Iron is a micronutrient and is required for the production of chlorophyll as it is involved with the building of chlorophyll molecules, although not contained in them. In addition to chlorophyll formation, iron is used as an oxygen carrier; it is used in cell division and growth, and used in nitrogen reduction and fixation.

Iron occurs in concentrations of 10-2,000 ppm in plant tissue and is involved with many plants physiological processes such as enzyme and co-enzyme systems. Iron is required as a carrier of oxygen in the process of biologic oxidation and aids in the prevention of chlorosis.

Iron deficiency results in poor uptake of other nutrients resulting in mineral imbalances in plant tissues. Plants best absorb iron when it is chelated in an amino acid form, however; iron is unavailable if there is excess calcium in the soil.

Mycorrhizal fungi have a great ability to bind iron at the root surface or in the root cells and make it available to plants. When one uses artificial fertilizers, plants do not form the mycorrhizal associations, hence they do not absorb critical elements needed for good health (see reduction in nutrients on apples mentioned above).

Too much iron prevents plants from absorbing several trace elements like manganese (Mn), nickel (Ni) and cobalt (Co) and can be toxic to plants. Too much phosphorous (P) in the soil interferes with iron absorption and utilization by plants. As mentioned, too much calcium in the soil will suppress iron availability and can lead to chlorosis. This is why applying gypsum, which is calcium sulfate ($CaSO_4$) when not needed, can create many other problems. Too much phosphate, copper, or manganese can cause iron deficiencies. The *balance* of nutrients (elements) is critical for good soil and plant health.

Plants use iron in its ferrous form (Fe^{+2}) rather than ferric form (Fe^{+3}) hence applying iron compounds in the wrong form can do more harm than good.

The solubility of iron decreases about 1,000 times for each whole number rise in pH hence iron is more available chemically in acidic soils. Cool temperatures or dry soils can reduce iron availability and cause temporary shortages of this nutrient.

Hence, it is critical to have plenty of fresh organic matter (compost and native mulches) in the soil to ensure the availability of iron via the soil-root-microbe system.

Iron is often in chemical forms that plants cannot use which then limits plant growth. Scientists at the Max Planck Institute for plant breeding research have found that plants will release substances from their roots (exudates called coumarins) to feed bacteria that have the ability to digest the iron bearing minerals and make the iron available to plants. For plants to use this mechanism it requires organically rich soil to support the bacteria and other microbes. Published in the journal Cell Host & Microbe (2020).

When we are low in iron (Fe) we tend to feel weak, dizzy and fatigued. Similarly, the microbes that make our soil healthy need iron also. When the soil is low in iron the microbes slow down the carbon absorbing process since they have to invest a lot of their energy into making mineral dissolving compounds to survive. Proceedings of the National Academy of Sciences (2020).

When iron is exposed to excess zinc (Zn) it forms the mineral franklinite ($ZnFe_2O_4$) which decreases the availability of both metals to plants. This has been proposed as one of the mechanisms as to why "rubber tire" mulch is so toxic to plants.

Iron deficiency is a major problem worldwide in cultivated fields, which are now low in *available content*. The most common deficiency symptom is interveinal chlorosis of young leaves that are yellow in areas between veins on older leaves, initiates first from top to bottom; veins margins and tips stay green. However, different species of plants respond differently to iron deficiencies.

Plants growing in compacted soils are more likely to develop iron deficiencies.

A while back I reported that researchers found that basalt sand could speed up humus formation (carbon sequestering) in soils by 400%. Basalt is a good source of iron. Texas greensand is another natural source of iron. The red soil of East Texas is caused by iron that is oxidized (think rust). Re-mineralizer contains both greensand and basalt and a great way to get iron and other essential elements into one's soil.

Sources: basalt sand, greensand, compost, most organic fertilizers, native mulches, pyrite (iron sulfate), rust (iron oxide), chelated iron products, re-mineralizer.

27) **Cobalt (Co):** The name comes from the German word "kobald" which means goblin. Miners mined an ore called "smalite" which is cobalt arsenide ($CoAs_2$). When they tried to smelt the ore, arsenic gas was given off, and they cursed the ore saying it was bewitched by goblins, hence the name.

Cobalt is found in the earth's crust at 20 ppm on average and it is the 32nd most abundant element. In soils it averages only 8 ppm, (some soils are now less than 0.1 ppm). It is found in igneous rocks at 25 ppm, shales at 19 ppm, almost none in sandstones and limestones, almost none in fresh or salt water, in land animals at 0.3 ppm and marine animals at 0.5 ppm. Cobalt occurs in higher concentrations in mafic rocks like basalt where it can reach 200 ppm as compared to acidic rocks like granite. Soils derived from serpentine rocks or basalt rock can be much higher. Many soils around the world are absolutely devoid of cobalt. The geochemical cycling of cobalt in soils is similar to iron and manganese.

Cobalt is a lustrous silvery blue metal, which has the property of being ferro- magnetic and it is a member of group 9 on the periodic table. When cobalt is added to steel, it creates strong magnetic properties, which were used in WW-II to make mines to destroy shipping. Cobalt is used in alloys to make magnets, in ceramics, in catalysts, and in paints. It is found in stainless steel used to make razor blades and in body parts such as found in knee replacement, drill bits and milling machines where extreme hardness is required.

Cobalt was used for coloring glass to get a deep blue color as far back as 1361 BC. It is used as a starch for laundry purposes as it makes clothes appear whiter and it once was used to make invisible ink. Cobalt chloride was used to decorate flowers in the 1800's as people would dye white flowers pink and they would stay this color if the weather was moist and humid. As the flowers dried, however they would turn violet and then blue.

Cobalt is essential to all forms of life from algae, bacteria, fungi, insects, birds, reptiles, etc. It functions as a cofactor and activator for enzymes, and involved with fixing nitrogen during amino acid production.

Liming of soils and the use of artificial fertilizers is a major factor in preventing cobalt absorption (phytoavailability) by plants. This practice leads to a deficiency in plants and then creates a dangerous deficiency in ruminants. A few mammals like cows and sheep make enough B-12 for their needs **if** they graze on grass grown on soils with the element cobalt. As the microbes in their gut ferment and digest plant material, they also convert elemental cobalt into vitamin B-12 that the animals can absorb. Humans cannot make B-12 and it needs to come from our food. The vitamin B-12 has a ring structure similar to hemoglobin and chlorophyll.

Cobalt is a constituent of vitamin B-12 molecule, where it is one of the rare carbon to metal bonds found in nature and directly bonded to a methyl group. Vitamin B-12 is one of the most important vitamins in our bodies as it regulates our immune system. A lack of this vitamin causes pernicious anemia, where the body cannot produce enough red blood cells. Over 30% of B-12 originally in our food is destroyed by cooking.

If humans have a low salt content (NaCl), we cannot absorb B-12. This is why people on low salt diets have to have B-12 shots. Due to low cobalt in our soils and low salt diets, vegetarians frequently have B-12 deficiencies. Calcium (Ca) is also required for cobalt to cross from the intestine into the blood stream.

Cobalt is used in myelin formation as it helps convert cholesterol into myelin which protects our nerves; babies nursed by a mother deficient in B-12 can develop permanent nerve damage.

Cobalt has been found to be a necessary cofactor for the production of thyroid hormone. In mammals, it is essential for hemoglobin formation and for prevention of nerve degeneration.

A lack of cobalt leads to the disease brucellosis in cattle and undulant fever in humans.

Cobalt is found in the bodies of microorganisms that live in the soil and bacteria in the soil make B-12, which is then absorbed by plants. In a marine environment blue - green algae and other nitrogen-fixing organisms require cobalt.

Food sources: sweet corn, lettuce, and cabbage are high in B-12, while fruits tend to be low, clams, sardines, salmon herring, liver, and eggs, nuts, chocolate are other sources of this element. Beef liver is another source if grass fed.

Foods exposed to light are quickly depleted of this vitamin and canning destroys this vitamin, while vitamin-C helps protect vitamin B-12

The RDA for B-12 is only 3-4 mcg, however new research is showing that people whom consume 250-400 mcg are much healthier, as unused B-12 is flushed out by our kidneys. As one doctor stated "I rather have expensive urine than cancer".

In our soils, cobalt can exist in its +2, +3 and +4 electrical (oxidation) states but mainly occurs in its +2 state. As in most other +2 elements, glyphosate (Round-Up) would prevent the microbes from absorbing cobalt and making B-12. Another reason to avoid purchasing GMO's foods and buy organic wherever possible.

Most of the soils that our agriculture is done on are depleted in cobalt. Over the years, microbes used cobalt to make B-12 and the plants (crops) absorbed it. Since cobalt is not one of the 16 elements that our agricultural universities deem important, farmers never replaced it. Now many of our agricultural soils are depleted of cobalt. Coupled with nutrient tie-up from artificial fertilizers, much of our food no longer supplies the essential vitamin B-12.

Gardening and Landscaping Problems Associated with Cobalt (Co)

For years, we thought that plants do not require cobalt. Now there is evidence that cobalt is used in chlorophyll formation and in mitochondrial respiration at the cellular level.

Plants can absorb cobalt through their leaves and cobalt is needed in legumes for nodule formation that enables nitrogen conversion and fixation. Seeds started without cobalt will not grow into a viable plant.

Cobalt is used in protein synthesis by plants, and it is required for nitrogen fixation by bacteria in the soil. Cobalt is also required by blue-green algae to fix nitrogen from the air.

Cobalt deficiency inhibits the growth of most plants especially legumes. In legumes cobalt deficient plants develop more lateral nodules but fewer crown nodules.

Excess cobalt will be transported to plant leaves where it will cause white leave margins and tips. However, some plant species like Nyssa sylvatica (Black Tupelo) grown in cobalt-contaminated soil may accumulate up to 800 ppm without *problems.* Some plants can accumulate cobalt such as legumes, borage, myrtle, and violets and levels of 2,500 ppm have been measured.

Sources: compost, seaweed, fish emulsion, basalt sand, re-mineralizer

28) **Nickel (Ni)** - Nickel is a metal that is in Group 10 of the periodic table which contains what is known as the platinum group metals (palladium, platinum, nickel). Nickel is a silvery white lustrous metal that is malleable, ductile and resists corrosion.

It is found in igneous rocks at 75 ppm, shale at 68 ppm, limestone at 5 ppm, sandstone at 2 ppm, very little in fresh or seawater, soils at 40 ppm, and some marine and land plants at 3 ppm. In mafic rocks like basalt nickel levels can reach 2,000 ppm but varies greatly around the world.

Nickel occurs in soils mainly at the +2 electrical oxidation state, and readily combines with iron. Organic matter and clay minerals exhibit a strong affinity to absorb nickel. As a result, in some oils and coals nickel can become concentrated.

Nickel is widely used in coins and in the United States; our nickel coins are only 25% nickel the rest being copper. Nickel is used over iron to prevent rust (e.g., automobile bumpers), and over brass to make it colorless rather than yellow, it is a component in stainless steel and nickel is a key ingredient for nickel-iron super alloys used in jet engines. Rechargeable batteries used to be made from nickel (nickel-cadmium) and even shiny decorative handcuffs are nickel-plated.

Combining nickel with aluminum and a dash of boron creates a metal alloy 6 times stronger than steel, which gets stronger as it is heated. Nickel is used in medicine, food, kitchen equipment, along with dyes in ceramic and glass manufacturing.

Nickel is considered a serious pollutant that is often released from metal processing plants or from the combustion of oil and coal (nickel pollution can now be measured in rainwater). Sewage sludge and some high phosphorous (P) artificial fertilizers are sources of nickel pollution on agricultural land. Sewage sludge (Bio-solids) can have 800 ppm and the organic matter makes the nickel more mobile.

Animal requirements of nickel have firmly been established, as it is used in RNA in land animals (0.8 ppm). In animals, a nickel deficiency has been linked to; poor growth, lower hematocrit (anemia), depressed oxidative ability of the liver, high newborn mortality, rough/dry coat, dermatitis, delayed puberty, and poor zinc absorption.

In humans, the role of nickel is not firmly established. However, nickel is found in almost every part of the human body. Some studies have shown that small doses of nickel are beneficial in some cases, while high levels of nickel can cause adverse health effects. However, only 10% of the nickel we ingest is absorbed, hence excess nickel is not common. We do know that nickel functions as a co-factor for metalloenzyme's and facilitates gastrointestinal absorption of iron and zinc. We require optimal levels of vitamin B-12 in our tissues for the biological use of nickel in our bodies (See article on cobalt and B-12). Researchers in Taiwan have found that eating lemon or orange peel helps the body remove excess nickel.

Food sources of nickel are black tea, nuts and seeds, cacao, chocolate, meat and fish.

Gardening and Landscaping Problems Associated with Nickel (Ni)

Nickel in soils is highly mobile as it reacts with humic and fulmic acids (some soluble and some not), and the microorganisms also affect the solubility of nickel.

Nickel is required by bacteria to fix nitrogen from the air. Nickel is also required by legumes (urease enzymes) to help transport nitrogen atoms from the bacteria into the plant and nickel is required for hydrogen usage. The bacterium *Bradyrhizobium japonicum* requires nickel to fix nitrogen from the atmosphere.

Too much nickel in the soil disrupts the activity of some enzymes such as dehydrogenases (used in oxidation reactions), urease (used by bacteria, fungi and algae to convert urea into carbon dioxide and ammonia), and phosphatases (used by microbes to make phosphate available to plants).

There is no direct evidence that plants use nickel, however there is lots of indirect evidence. It is now believed that nickel is essential for plants.

Plants grown on nickel deficient soils can reduce seed germination by 70%. The plant *Alyssum bertalonii* has 300 ppm, while the microbe *Rhizopus arrhizus* has 1,600 ppm. Over 200 species of plants have been identified as nickel hyper accumulators. The flower *Hybanthus floribundus* will accumulate as much as 6,000 ppm. In plants, nickel tends to be accumulated in seeds and leaves.

Native plants growing in serpentine derived soils have developed the ability to absorb very large amounts of nickel to over 7,000 ppm, which is a higher concentration than many naturally occurring rock ores. These plants may be useful in bio-geo-chemical prospecting where plants are used to mine or recover elements out of the soil and the plants are then smelted to recover the element, in this case nickel.

Too much nickel in the soil reduces plants absorption of other nutrients, disturbs some metabolic processes, and strongly retards root growth. Nitrogen fixation in soil by legume plants is retarded. The most common symptom of nickel toxicity is chlorosis (possibly caused by preventing iron absorption).

Some plants like beans and maize are very sensitive to nickel and even watering them with only a 40-ppm solution will kill them. Clover will not grow on soils with 80 ppm nickel or higher while oats will. Increasing pH reduces the absorption of nickel and colonization of plant roots by mycorrhizal fungi prevents plants from absorbing too much nickel.

SOURCES: basalt, sewage sludge, coal ash, re-mineralizer.