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JOHN'S CORNER:

MINERALS - The Elements and What They Do (Part 1)

by John Ferguson

Over the years, the minerals have fascinated me. How they affect everything from soil and microbes to plants, animal and human health. Every gardener knows that if the soil is missing something, plants to not grow as well and have more insect and disease problems. Similarly, this applies to animal and human health.

My first exposure to the importance of trace minerals occurred about 20 years ago. I was planting some early spring vegetables in the garden behind my house. This extremely rich organic soil had been amended with compost and organic fertilizers for years. There was a new trace mineral package had just been introduced to the market and I decided to test it. I planted many of the cool season vegetables from transplants (cabbage, broccoli, Brussels sprouts, cauliflower, etc.) and for every other plant; I placed a tablespoon of the mineral package in the bottom of the hole. Nothing showed a response except the Brussels sprouts, but did they respond as shown in the picture below! Obviously, there was some trace mineral in the package that the plant needed that was limiting growth.

This experience reminded me of **Liebig's Law of the Minimum** , often simply called **Liebig's Law** or the **Law of the Minimum.** It is a principle developed in agricultural science by Carl Sprengel in 1828 and later popularized by Justus von Liebig. It states that plant growth is controlled; not by the total amount of nutrient resources available, but by the scarcest resource (the limiting factor). From Wikipedia "The availability of the most abundant nutrient in the soil is only as good as the availability of the least abundant nutrient in the soil." On the other hand, to use an old analogy, "A chain is only as strong as its weakest link."

Most agricultural and horticultural departments in our universities teach that we only need 16 elements to grow a plant. As the photo above shows, we really do not know what a plant needs, much less what an animal or humans need. If the trace elements are not in the soil, plants cannot take them up; hence, they do not get to the animals or to the humans that eat the animals.

To compile this information I have collected hundreds of articles from various journals and other publications as well as the books listed below to list a few.

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For those that do not have a technical background I am going to cover each element as they are listed in what is known as the periodic table. It is a method commonly used to organize the elements. Each element is shown using a one or two-letter abbreviation that reflects its name (most are straightforward but a few use Latin or the names in other languages). Most gardeners will recognize many of the common elements, such as nitrogen (N), calcium (Ca), phosphorous (P), iron (Fe), etc.

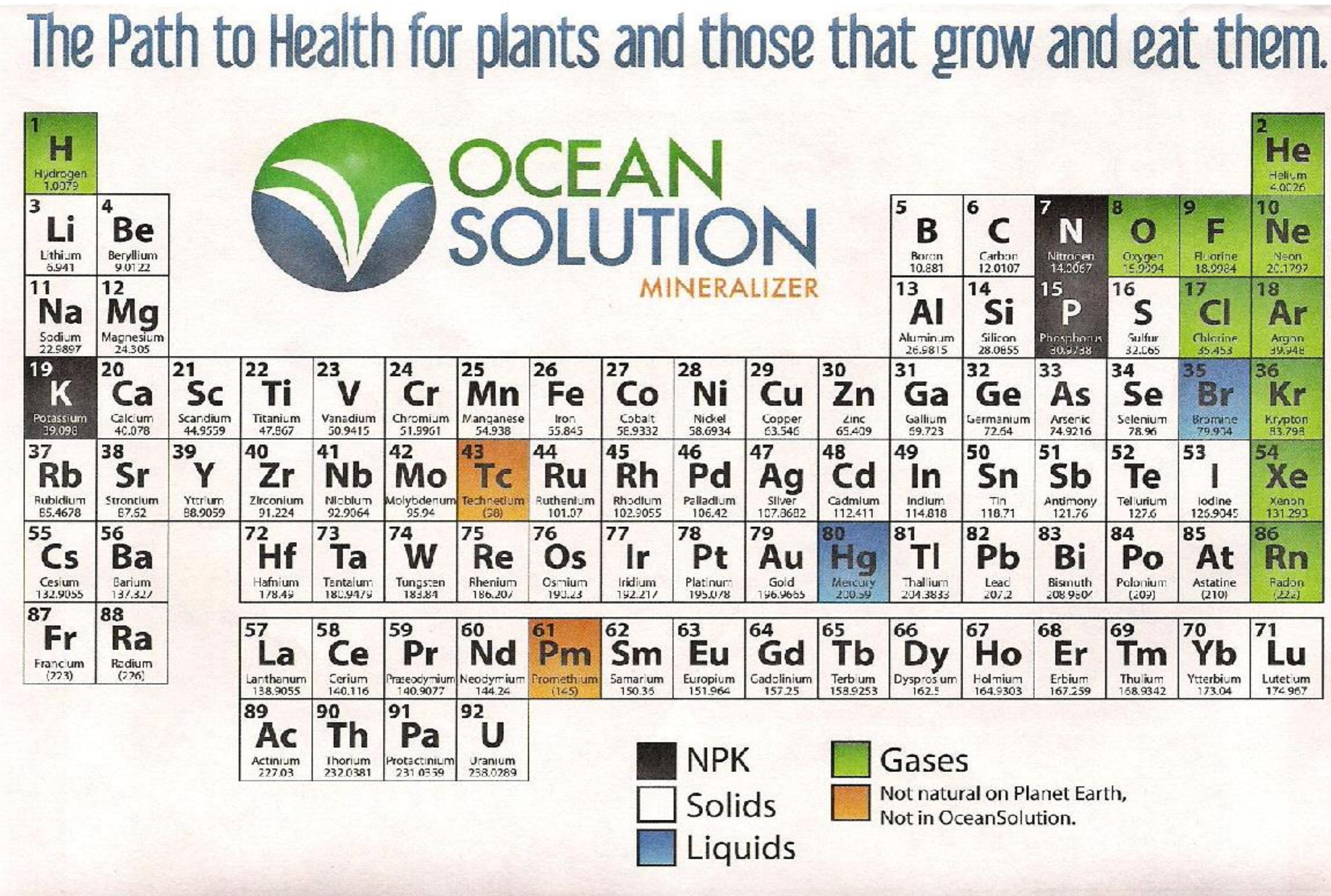
To help understand how an atom is organized, think of our solar system. We have the sun at the center and the planets revolve around it at different distances (orbits). For atoms, the protons and neutrons are in the center and the electrons revolve around them similar to the planets around our sun. The distance the planets are from the sun determines if they are hot or cold and icy. Similarly, the distance the electrons are from the center of the atom helps determines many of an element's chemical properties. This is why is one form of Chromium (Cr) may be good for you and another form of chromium very bad.

Scientists have discovered 118 total elements of which 94 occur naturally in nature. Of these only 81 elements are considered stable.

In nature, the individual elements (atoms) are often found combined with other elements into what we call minerals. Today scientists have identified over 4,300 distinct minerals from the simple to the complex. We are all familiar with these simple minerals like common table salt that is sodium chloride (NaCl) or limestone, which is calcium carbonate ($CaCO_3$).
So, let us begin our journey through the elements.

The simplest atom is hydrogen, which has the chemical symbol (H). It has only one proton (a positive charged sub atomic particle) in its nucleus and one electron (negatively charged) outside the nucleus. It is assigned the number one (1). As we add additional protons and neutrons (electrically neutral sub atomic particles), the atoms become more complex and their chemical and physical properties change. When two protons are present, we now have the element helium (He) and it is number two (2). Every time we add a proton, the atom changes as they become larger and heavier.

For reference for those interested, I have included the periodic table. For the gardeners that do not have a technical background, elements in each column have similar chemical properties. This similarity affects how all life forms use them.



Now let us begin our journey and look at each of the elements, and discover what they do in soils, microbes, plants, and animals.

1) Hydrogen (H) - Hydrogen is one of the most common elements in the universe. As hydrogen is burned (fusion) in our sun, it gives off tremendous amounts of energy. It has one proton in its nucleus hence the number one on the periodic table. When two hydrogen atoms are combined with one

oxygen atom, we have the molecule that we all know as water (H_2O). Hydrogen is a building block in many common substances like hydrocarbons (gasoline and oil) or sugar.

The human body is more than 60% water and as all gardeners know, plants require water. Hydrogen is one of the three most used elements along with carbon (C) and oxygen (O). These three are the building blocks of organic compounds like carbohydrates, proteins, fats, DNA and RNA as well as cellulose and lignin found in plants. Plants combine hydrogen and oxygen from water, carbon dioxide (CO_2) from the atmosphere to form glucose (a simple sugar) or more complex molecules like cellulose and lignin. The energy to do this work comes from the sun via photosynthesis. When hydrogen is combined with nitrogen, we get ammonia and ammonium. Ammonia (NH_3), is a nitrogen atom connected to three hydrogen atoms and is often used as a common cleaning agent. If we add a 4th hydrogen atom, nitrogen atom we get Ammonium (NH_4^+) a plant nutrient.

Note: Scientists like to use an abbreviation of an elements name; they also like to use a "short hand" that makes it *very easy* to describe the element or molecule formed by one or more elements. For ammonia above the short hand version (NH_3), tells us that there is one nitrogen atom connected to three hydrogen atoms. The subscript after the symbol tells us how many atoms of that element there is in that molecule. For ammonium (NH_4^+), the short hand tells us that this molecule has four hydrogen atoms connected to the nitrogen atom, the superscript (+) tells us the molecule has a positive electrical charge. When atoms have an electrical charge, we call them ions (short for ionized). If we have lots of hydrogen ions in the soil then the soil is acidic.
We find hydrogen in all living things and in minerals and rocks. Hydrogen is found in igneous rocks like granite and basalt at 1,000 ppm (parts per million) to maybe 5,600 ppm in shale's. In marine plants like Kelp it can reach 41,000 ppm to 55,000 ppm in land plants. Hydrogen is essential for all life.

2) Helium (He) - We are most familiar with this element in filling balloons to blimps as it is lighter than air (hydrogen is lighter and cheaper to use, however it is very reactive which led to many fires). Helium is one of the noble gases, which means that it is inert and reacts with nothing. Helium has two protons in its nucleus. There are traces of helium in the human body absorbed from the air. It serves no known biological role in plants or animals. It mainly comes from natural gas deposits from where it becomes trapped after being formed by radioactive decay of other elements deep inside the earth. Helium does

not become a liquid until it is very cold (4 ^{0} K which is -269 ^{0} C) or minus -452 ^{0} F. The major use of Helium today is in physics research on super conductors, which require very cold conditions. Helium is a very tiny atom, which is so small it can escape through the molecules that compose the walls of balloons (the reason they quickly go flat). As a result, we do not find much Helium, igneous rocks at 0.008 ppm and even less in seawater.

3) Lithium (Li) - Lithium is a very light and soft metal that will float in water. It is used in hundreds of consumer devices from batteries, plastics, and ceramics to pace makers.
Lithium is found in igneous rocks at 20-25 ppm (up to 40 ppm in acidic igneous rocks like some granite), shale's at 66 ppm, limestone at 5 ppm, and seawater at 0.18 ppm and in soils at 30 ppm. When Lithium is in the ion form (Li^+) it easily moves around in soils. Lithium is found at 5 ppm in marine plants, marine animals at 1 ppm, land plants at 0.1 ppm, and land animals at 0.02 ppm. In undisturbed natural soils, it is found from 13-28 ppm and is highest in heavy loamy soils and the least in sandy soils. In the coastal plains, it ranges from 4-6 ppm. As the primary rocks (minerals) break down, Lithium is incorporated into clay minerals or is easily absorbed by organic matter. As a result, it is readily available for plants. The ability to absorb or tolerate Lithium varies between plant families. Members of the *Rosaceae* family often have 0.6 ppm in their tissues. For the *Polygonacceae* they will only have 0.04 ppm. The *Solanaceae* have the most Lithium with levels reaching 1,000 ppm.
Historically, Lithium is not considered to be an essential plant nutrient. However, newer studies have shown that it can effect plant growth and development. Excess calcium (Ca) in the soil inhibits Lithium uptake by plants.

Since 1915 the risk of clinical depression has doubled with each generation and occurs at younger ages. Since Lithium is not considered an essential plant nutrient, thus it was not replaced as the various crops used it up. Most artificial fertilizers tend to make the soil very acidic, hence to counter act this, farmers apply large amount of lime (calcium oxide CaO) or limestone (calcium carbonate $CaCO_3$) to their fields. This practice creates excess calcium in our soils. Each generation of farmers have used more and more artificial fertilizers; as the toxic chemicals destroyed the fertility of their fields. I wonder how strong the link is to the mental problems we see in society today.

Lithium has been used for decades by psychiatrists to treat depression and other mental disorders. Animal studies have shown that a lithium deficiency results in reproductive failure, infertility, reduced growth rate, and multiple behavioral problems. Studies in Texas, California, and Oregon found that normal healthy people had 400 times the lithium in their hair than violent criminals. When Lithium is in the metallic form, it is not biologically available. A deficiency has been linked to several forms of cravings.

Several animal studies have shown that adequate levels of lithium increases their lifespan up to 18% as it has been found to activate a protein that protects cells against damage. Lithium has been found to be associated with the amino acid histidine and has been shown to help protect brain cells. Lithium is now considered an essential element for humans.

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