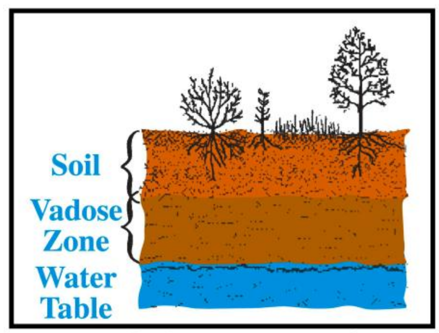
Plants and Soil Organisms Take Up Only Those Nutrients And Elements That Are Available in the Soil Solution

U.S. Patent 5,355,736
Canadian Patent 2,087,153

Bioavailability	***Bioavailability*** is much like the weather – everyone talks about it, but no one does anything about it! Bioavailability is defined as "those chemicals in the soil that are present in forms and amounts that plants (or other organisms) can take up during the time they are growing." This is obvious – but what does it really mean in practice? And how is it measured?
What is a Chemical?	The term chemical refers to any organic or inorganic substance. Various combinations of only a few elements (C, H, O, N, S, P, Cl, F, Br and I) make up practically all organic substances. Organic chemicals are, therefore, compounds with different arrangements of inorganic elements that give them specific properties. Examples of organic substances are fuels or their components such as BTEX (benzene, toluene, ethyl benzene, xylene), polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorinated solvents, many pesticides (such as DDT or atrazine), and PCP (pentachlorophenol). Many different organic and inorganic chemicals make up complex organic substances like sewage sludge and municipal waste compost. Plants and soil organisms cannot take up most organic molecules until they are broken down into either tiny units or into their individual inorganic elements.
Chemicals Entering the Food Chain	Plants and soil organisms are exposed to all the chemicals where they are growing. This may be in soil, groundwater, material between the root zone and groundwater (known as the vadose zone), or free water in wells, lakes, and streams (see Figure 1). Just the presence of some (particularly organic) chemicals may adversely affect organisms. Generally, however, it is more important to know if organisms will take up these chemicals, thus introducing them into the food chain where they may affect humans.  *Figure 1 – Organisms are exposed to chemicals in the "real" environment.*
Chemical Status	Organisms cannot absorb all forms of a chemical. Most chemicals are absorbed only when present as ions. Chemicals exist mostly in combined states – organic compounds for organic chemicals and mineral substances for inorganic chemicals. Nearly all soil nutrients (except N) are present in minerals that make up soil solid. Soil N is usually in organic compounds (soil organic matter) in the soil. For elements to become bioavailable, they must be converted from combined forms to the *ionic* state. For example, N in soil organic matter must be converted to the ions NH_4+ or NO_3- to be available for uptake. Nutrients present in soil minerals must also be converted to ionic forms (e.g., H_2PO_4- or K+). The same is true for other naturally present chemicals.
Time – Rate Availability	To illustrate the time factor, consider a plant that requires only a small amount of some nutrient. Early in the growth period that chemical may be present in the plant at a level too low to be detected by the analytical method used, so bioavailability will not register. When the plant continues to take up the chemical over time, eventually there will be enough of that chemical in the plant to detect, and its level of bioavailability revealed.

Diffusion Solution

Next, the location of chemicals relative to where organisms are growing, is very important. To be bioavailable, chemicals in the soil must be close to living organisms. This aspect of the system is called *positional availability*. If nearby, ions can diffuse toward roots or be swept along with the water being taken up, becoming available.

Soil Solution

Soil solution is the liquid water in a moist soil. Soil solution regulates bioavailability by: 1) letting ions form, and 2) providing a channel for ion movement to the plant root. To see how this works, consider a root absorbing ions from the soil solution that contacts the root (see Figure 2).

When a plant takes up nutrient ions from the solution surrounding its roots, that solution becomes deficient in those nutrients unless one of two processes occurs: (a) more solution moves from other portions of soil toward the plant root, or (b) more ions move through the soil solution toward the root. Process (a) is called “mass flow” caused by plant uptake of water, and (b) is “ion diffusion”, caused by the concentration gradient created when roots take up ions directly surrounding them. Active plant roots grow into new soil volumes to minimize distances for water or ions to move and help keep plants supplied.

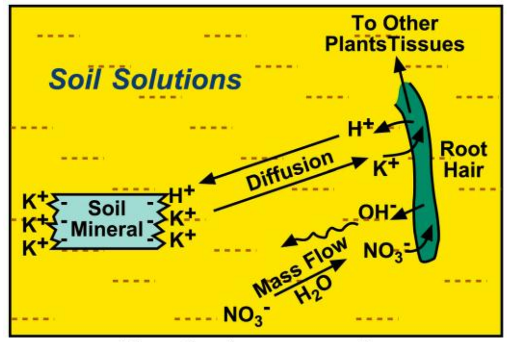


Figure 2 - plant roots receive a continuous supply of cations and anions.

Measuring Bioavailability

The best measure of bioavailability is to analyze an organism after it has grown for a period of time and see how much of each target chemical ended up in the organism. The next best measure are UNIBEST resin capsules that are designed to mimic the action of plant roots. Capsule values reflect active, dynamic components of each medium and its bioavailability system as it functions over some period of time. Methods that extract soil chemicals with other chemicals do not reflect how elements in a fresh soil respond to continuous removal by biological activity over time. Traditional analytical methods provide only a “snapshot” of chemical conditions when the soil was sampled.

Conclusion

- Bioavailability is the mechanism for chemical elements to enter the food chain.
- Nutrients and other chemicals are not available until they enter the bioavailability system — a dynamic solution-controlled system.
- The soil and other biological media are active through time. Bioavailability is *time-dependent.*
- A UNIBEST resin capsule is like the tape in a video recorder – a “picture” of chemical elements can be developed for any soil or other media as changes occur with time.

References

Skogley, E.O., A. Dobermann, G.E. Warrington, M.F. Pampolino and M.A. Adviento. 1996, Laboratory and field methodologies for use of resin capsules, Sciences of Soils Vol. 1, 1996 –http://www.hintze-online.com/sos/1996/ Toolbox/Tool1.

Skogley, E.O. and A. Dobermann. 1996. Synthetic ion-exchanges resins: Soil and environment studies. J. Environ. Qual. 25:13-24.

Doberman, A.,H. Langner, H. Mutscher, J.E. Yang, E.O. Skogley, M.A. Adviento and M.F. Pampolino.1994. Nutrient adsorption kinetics of ion exchanges resin capsules: A study with soils of international origin. Commun. Soil Sci. Plant Anal. 25:1329-1353.