What is "ecological engineering"?

The term, "ecological engineering," was first coined by Howard T. Odum in 1962. Howard Odum is now professor emeritus at the University of Florida, where his work in systems ecology has flourished.

Ecological engineering, he wrote, is "those cases where the energy supplied by man is small relative to the natural sources but sufficient to produce large effects in the resulting patterns and processes." (H.T. Odum, 1962, "Man and Ecosystem" Proceedings, Lockwood Conference on the Suburban Forest and Ecology. Bulletin Connecticut Agric. Station)

Another definition that follows from that relates to ecosystem management by human society (Center for Wetlands, University of Florida) :

"Ecological engineering is the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both. It involves the design, construction and management of ecosystems that have value to both humans and the environment. Ecological engineering combines basic and applied science from engineering, ecology, economics, and natural sciences for the restoration and construction of aquatic and terrestrial ecosystems. The field is increasing in breadth and depth as more opportunities to design and use ecosystems as interfaces between technology and environment are explored."

Another definition seeks to use the ecological paradigm to construct ecologies to solve vexing world-class problems, such as pollution:

It is predicated on the believe that the self-organizing order found in stable ecosystms is so universal that it can be applied as an engineering discipline to solve the pressing problems of global pollution, food production and efficient resource-utilization, while providing a high quality of life for all human society. (David Del Porto)

In this definition, the ecological paradigm reveals how to safely utilize the polluting components of unwanted residuals, or "wastes," to ultimately grow green plants that have value to human society, but not at the expense of aquatic and terrestrial ecosystems. Planning, design and construction with the ecological paradigm as a template is the work of ecological engineers.

Definitions

In 1995, Carol Steinfeld and David Del Porto wrote some definitions for Gale Publishing's Encyclopedia of the Environment. A Sustainable Strategies engineer posted them to the web page, simply to the boost the content. There they stayed, and over the years, many people have told us that they found these definitions valuable. So, to continue the tradition...

Phytoremediation, Sanitation, Sustainable Architecture, Permaculture

Phytoremediation

Phytoremediation combines the Greek word "phyton", (plant), with the Latin word "remediare", (to remedy) to describe a system whereby certain plants, working together with soil organisms, can transform contaminants into harmless and often, valuable forms. This practice is increasingly used to remediate sites contaminated with heavy metals and toxic organic compounds.

Planning, engineering and design with the ecological paradigm as our template is the work of Sustainable Strategies. For example, the ecological paradigm reveals how to safely utilize all of the polluting components and water of human and animal wastewater to ultimately grow plants that have economic value.

We use the term Wastewater Garden to describe our phytoremediation and evapo-transpiration approach to effluent management problems. The objective is to drain pretreated wastewater into an appropriately engineered gardens or forests of phreatophytes: plants known for fast growth and high water usage rates. These plants and their microbially-active rhizosphere will transform pollutants, including the nutrient nitrogen, into valuable biomass and use up the remaining water via evaporation and transpiration.

Phytoremediation takes advantage of plants' nutrient utilization processes to take in water and nutrients through roots, transpire water through leaves, and act as a transformation system to metabolize organic compounds, such as oil and pesticides. Or they may absorb and bioaccumulate toxic trace elements including the heavy metals, lead, cadmium, and selenium. In some cases, plants contain 1,000 times more metal than the soil in which they grow. Heavy metals are closely related to the elements plants use for growth. "In many cases, the plants cannot tell the difference" says Ilya Raskin, professor of plant sciences in the Center for Agricultural Molecular Biology at Rutgers University.

Phytoremediation is an affordable technology that is most useful when contaminants are within the root zone of the plants (top three to six feet). For sites with contamination spread over a large area, phytoremediation may be the only economically feasible technology. The process is relatively inexpensive because it uses the same equipment and supplies used in agriculture.

Soil microorganisms can degrade organic contaminants. This is called bioremediation and has been used for many years both as an in-situ process and in land farming operations with soil removed from sites.

Dr. Raskin also demonstrated the utility of certain varieties of mustard plants in removing such metals as chromium, lead, cadmium and zinc from contaminated soil and used hydroponic plant cultures to remove toxic metals from aqueous waste streams.

Plants can accelerate bioremediation in surface soils by their ability to stimulate soil microorganisms through the release of nutrients from and the transport of oxygen to their roots. The zone of soil closely associated with the plant root, the rhizosphere, has much higher numbers of metabolically active microorganisms than unplanted soil. The rhizosphere is a zone of increased microbial activity and biomass at the root-soil interface that is under the interface of the plant roots. It is this symbiotic relationship between soil microbes that is responsible for the accelerated degradation of soil contaminants.

The interaction between plants and microbial communities in the rhizosphere is complex and has evolved to the mutual benefit of both organisms. Plants sustain large microbial populations in the rhizosphere by secreting substances such as carbohydrates and amino acids through root cells and by sloughing root epidermal cells. Also, root cells secrete mucigel, a gelatinous substance that is a lubricant for root penetration through the soil during growth. Using this supply of nutrients, soil microorganisms proliferate to form the plant rhizosphere.

In addition to this rhizosphere effect, plants themselves are able to passively take up a wide range of organic wastes from soil through their roots. One of the more important roles of soil microorganisms is the decomposition of organic residues with the release of plant nutrient elements such as carbon, nitrogen, potassium, phosphate and sulfur. A significant amount of the CO2 in the atmosphere is utilized for organic matter synthesis primarily through photosynthesis. This transformation of carbon dioxide and the subsequent sequestering of the carbon as root biomass contributes to balancing the effect of burning fossil fuels on global warming and cooling.

Compounds are frequently transformed in the plant tissue into less toxic forms or sequestered and concentrated so they can be removed (harvested) with the plant. For example, mustard greens were used to remove 45% of the excess lead from a yard in Boston to ensure the safety of children who play there. The sequestered lead was carefully removed and safely disposed of. Besides mustard greens, pumpkin vines were used to clean up an old Magic Marker factory site in Trenton, New Jersey. Hydroponically grown sunflowers were used to absorb radioactive metals near the Chernobyl nuclear site in the Ukraine as well as a uranium plant in Ohio. The mustard's hyper-accumulation results in much less material for disposal. The composting of plant material can be another highly efficient stage in the breakdown of contaminants removed from the soil.

When large plants such as willows, poplars and bamboo are used, the idea is to move as much water through them as possible so that they take up as much of the contaminants as possible. In 1991 the Miami Conservancy District Aquifer Update, No. 1.1 reported that a single willow tree can, on a hot summer day, transpire over 19 cubic meters of water (5,000 gallons)!, One hectare of a herbaceous plant like saltwater cord grass evapotranspires up to 80 cubic meters (21,000 gallons) of water per day. Once the heavy metals are absorbed, they are sequestered in the plants' leaves and/or roots. Any organic compounds that are absorbed are metabolized.

Absorption of large amounts of nutrients by plants (and only a small amount of plant toxins that might be harmful to them,) is the key factor. Plants generally absorb large amounts of elements they need for growth and only small amounts of toxic elements that could harm them. Therefore, phytoremediation is a cost-effective alternative to conventional remediation methods. Cleaning the top 15 centimeters (six inches) of contaminated soil with phytoremediation costs an estimated $2,500 to $15,000 per hectare (2.5 acres), compared to $7,500 to $20,000 per hectare for on-site microbial remediation. If the soil is moved, the costs escalate, but phytoremediation costs are still far below those of traditional remediation methods, such as stripping the contaminants from the soil using physical, chemical or thermal processes according to Dr. Scott Cunningham, a scientist at Dupont Central Research for Environmental Biotechnology.

Plants are effective at remediating soils contaminated with organic chemical wastes, such as solvents, petrochemicals, wood preservatives, explosives and pesticides. The conventional technology for soil cleanup is to remove the soil and isolate it in a hazardous waste landfill or incinerate it.

"Phytoremediation", says Dr. Ray Hinchman, botanist and plant physiologist at Argonne National Laboratory, is "an in-situ approach," not reliant on the transport of contaminated material to other sites. Organic contaminants are, in many cases, completely destroyed (converted to CO2 and H2O) rather than simply immobilized or stored.

Salt-tolerant plants, called halophytes, have reduced the salt levels in soils by 65% in only two years in one project involving brine-damaged land from run-off from oil and gas production in Oklahoma. After the salt was reduced, the halophytes died and native grasses, which failed to thrive when too much salt entered the soil, naturally returned, replacing the salt-converting plants.

The establishment of vegetation on a site also reduces soil erosion by wind and water, which helps to prevent the spread of contaminants and reduces exposure of humans and animals.

Classes of organic compounds that are more rapidly degraded in rhizosphere soil than in unplanted soil include:

- Total petroleum hydrocarbons; polycyclic aromatic hydrocarbons
- Chlorinated pesticides (PCP, 2,4-D)
- Other chlorinated compounds (PCBs, TCE)
- Explosives (TNT, DNT)
- Organophosphate insecticides (diazanon and parathion)
- Surfactants (detergents)
- Nutrients (N,P,K) and organic compounds

Some plants used for phytoremediation are:

- Alfalfa (symbiotic with hydrocarbon-degrading bacteria)
- Arabidopsis (carries a bacterial gene that transforms mercury into a gaseous state)

- Bamboo family (accumulates silica in it's stalk and nitrogen as crude protein in it's leaves)
- Bladder campion (accumulates zinc and copper)
- Brassica juncea (Indian mustard greens) (accumulates selenium, sulfur, lead, chromium, cadmium, nickel, zinc, and copper)
- Buxaceae (boxwood) and Euphorbiaceae (a succulent) (accumulates nickel)
- Compositae family (symbiotic with Arthrobacter bacteria, accumulates cesium and strontium)
- Ordinary tomato and alpine pennycress (accumulates lead, zinc and cadmium)
- Poplar (used in the absorption of the pesticide, atrazine)