VIVEKANANDA COLLEGE THAKURPUKUR KOLKATA-700063

NAAC ACCREDITED ‘A’ GRADE

Topic: Plant Indicators: Metallophytes

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Plant Indicators: Metallophytes

The term 'indicator organism' refers to plant, animals and microbes, which, by their presence or absence, or by some specific charateristics, give clues to various ecological conditions. The occurrence, characters and behavior of plants indicate the combined effect of all factors prevailing in a habitat. Thus, a plant species or community indicating of a specific environmental condition is referred to as **phytoindicator** or plant indicator.

Characteristic features of plant indicators:

1. On the basis of distribution the indicators may be 'steno' species or 'eury' species. The 'steno' is used to indicate narrow limits of tolerance and 'eury' is used to indicate wide limits of tolerance. A plant may show wide limits of tolerance for certain conditions and narrow limits of tolerance for other conditions. For example, a plant may be indicator of wide limits of tolerance for heat but of narrow limits of tolerance for water. Plants with wide limits of tolerance of heat are called eurythermal and those with narrow limits of tolerance for water are called stenohydric.

2. Plants of large species are better indicator than the plants of small species.

3. Before relying on a single species or group of species as indicators, there should be abundant field evidence.

4. Numerical relationships between species, population and whole communities often provide more reliable indicators than single species.

Different types ofplant indicators have different roles in different aspects.

Metallophytes: The plant indicators that have evolved biological mechanisms to resist, tolerate, or thrive on the toxic metalliferous soils, and typically endemic to their native metalliferous soils are called Metallophytes. They can survive and reproduce on metal-rich soils without suffering toxicity. Metalliferous soils provide very restrictive habitats for plants due to phytotoxicity, resulting in severe selection pressures. Species comprising heavy-metal plant communities are genetically altered ecotypes with specific tolerances to, e.g., cadmium, copper, lead, nickel, zinc and arsenic, adapted through micro-evolutionary processes

Types of Metallophytes:
The following classification of metallophytes is adapted from Lambinon and Auquier (1963):

1. **Metallophytes:**

a. Obligate metallophytes; b. Facultative metallophytes

2. Associate species:

a. Metal-tolerant species; b. Non-metal-tolerant species

(1a) **obligate metallophytes:** species with an exceptional tolerance to heavy metals in soils as well as a dependence upon the occurrence of these metals in soil. Some are also hyper-metal-accumulators (‘hyperaccumulators’). They are not found outside this narrow ecological amplitude within the same phytogeographical area. These species are local endemics with sometimes a large geographical distribution. Examples are: *Alyssum pintodasilvae* , *Viola guestphalica* and *V. lutea* subsp. *Calaminaria*.

(1b) **Facultative metallophytes:** genotypes or ecotypes/subspecies of common species with a specific tolerance to metals. They also occur in distinct nonmetal-enriched phytogeographical areas. The highly specialised ecotype, subspecies or genotype is dependent on the occurrence of specific metals in the soil. Examples is: *Armeria maritima* s.l. (Baumbach & Hellwig 2007; Baumbach & Schubert 2008),

(2a) Associated metal-tolerant species: matrix species that are associated with the related plant association with a large ecological amplitude. They are either called ‘pseudo-metallophytes’ or ‘accompanying species’ of the true metallophyte vegetation. These species are moderately tolerant of heavy metals in soil, but not dependent on their presence. Examples of such species which are both common and have a wide geographic distribution are: *Achillea millefolium, Campanula rotundifolia, Euphrasia spp., Plantago lanceolata, Polygala vulgaris, Ranunculus acris, Rumex acetosella, Thymus pulegioides, Agrostis capillaris, Holcus lanatus and Phragmites australis.*

(2b) Associated non-metal-tolerant species from related associations, with little or no metal tolerance, the so-called ‘indifferent’ or ‘accidental’ species: these are usually weedy species, often annuals, showing neither vigour nor persistence on metalliferous soils.

Metallophytes are divided into the following types:

1. **Metal Hyperaccumulators:** Plants which can concentrate heavy metals in their above-ground tissues to levels far exceeding those present in the soils or non-accumulating plants are called metal hyperaccumulators. These plants are concentrated in the plant family Brassicaceae. They are used specially in mining regions, either alone or in combination with microorganisms, for phytoremediation of heavy metal-contaminated soils.
2. **Indicators:** Uptake and translocation by plants reflect soil metal concentration, plants exhibit toxic symptoms. They are used in geobotanical prospective.
3. **Accumulators:** Uptake and translocation by the plants reflect soil metal concentration without showing toxic symptoms.
4. **Excluders:** Ability of the plants of restricted uptake of toxic metals over a wide range of soil metal concentration. They may be essential for phytostabilisation purposes.

Some common Metallophytes:

i) Diamond: *Vallozia candida* grows in presence of diamond in Brazil.

(ii) Gold: *Equisetum arvense, Lonicera confuse, Papaver libonoticum, Alpinia speciosa, Thuja* species indicate the presence of gold minerals in the soil.

(iii) Silver: *Eriogonium ovalifolium* indicates the presence of silver minerals in soils in U.S.A.

(iv) Mercury: *Stellaria setacea* grows in Spain in mercury rich soils,

(v) Uranium: *Astragalus* species grows in USA in uranium rich soils,

(vi) Selenium: *Astragalus species, Neptunia amplexicaulis, Stanleya pinnata, Onopsis condensator*, etc. grow in selenium rich habitat.

(vii) Copper: *Viscaria alpina* in Norway, *Gymnolea acutiloba* in America, *Gypsophila patrini* in USSR grow on the soil rich in copper.

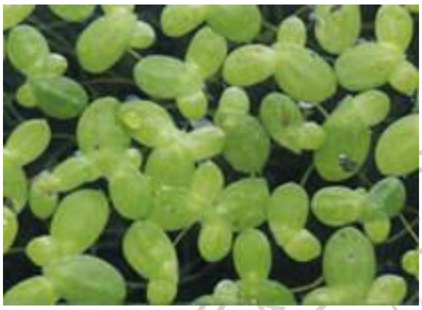
(viii) Zinc: *Viola calaminaria, V. lutea* in Europe grow on the soil rich in zinc minerals,

Hyper-accumulator Plants: The families dominating with hyperaccumulator plants are Asteraceae, Brassicaceae, Caryophyllaceae, Cyperaceae, Cunouniaceae, Fabaceae, Flacourtiaceae, Lamiaceae, Poaceae, Violaceae, and Euphobiaceae. Different genera of Brassicaceae are known to accumulate metals. Ni hyperaccumulation is reported in 7 genera and 72 species and Zn in 3 genera and 20 species. *Thlaspi* species are known to hyperaccumulate more than one metal i.e. *T. caerulescence* = Cd, Ni. Pb, and Zn; *T. goesingense* = Ni and Zn and *T. ochroleucum* = Ni and Zn and *T. rotundifolium* = Ni, Pb and Zn. These plants have tremendous potential for application in remediation of metals in the environment. Several aquatic species have the ability to remove heavy metals from water, viz., water hyacinth (*Eichhornia crassipes* (Mart.) Solms); pennywort *(Hydrocotyle umbellata* L.) and duckweed (*Lemna minor* L.). The roots of Indian mustard are effective in the removal of Cd, Cr, Cu, Ni, Pb, and Zn and sunflower removes Pb, U, 137Cs, and 90Sr from hydroponic solutions.

Table: List of Some Hyper-accumulator Plants

Metal	Plant	**Maximum accumulation (mg/kg of dry weight)**
Aluminium	*Miconia acenodendron*	66100
Arsenic	*Pteris vittata*	22630
Gold	*Brassica juncea*	57
Cadmium	*Thlapsi caerrulescens*	2130
Chromium	*Haumaniastrum robertii*	10231
Copper	*Aeollanthus subcaulis*	13700
Mercury	*Lemna minor*	25800

Brassica juncea ***Thlapsi caerrulescens***



Lemna minor ***Pteris vittata***

Figure.1 : Some Mtallophytes

Importance of Metallophytes as a Resource Base for Phytotechnologies

Metallophytes offer huge potential for the development of environmental phytotechnologies,for example, phytostabilization, phytoremediation, and phytomining. The majority of uses for metallophytes on metal-contaminated sites will, therefore, be reclamation or rehabilitation, where metallophytes' abilities to tolerate metals are exploited in the establishment of a vegetative cover.

- **Revegetation:** Metallophytes can be used for rehabilitation and revegetation of degraded metal-polluted areas. Establishing vegetative cover is one of the best ways to prevent metal migration from metal-contaminated sites via erosion, and metal-rich dusts or leachate. Phytostabilization has widespread application for capping sites contaminated with metals. Phytostabilization is used to vegetate metal-contaminated waste sites that tend to be recent.
- **Phytoremediation:** They can also be used to remediate contaminated land by exploitating their metal-accumulating properties(hyper accumulator) to scavenge metals from metalliferous soils (phytoextraction). Cleaning up metal-contaminated soils by phytoremediation is most feasible on low to moderately contaminated soils such as agricultural land impacted by the application of low-level metal sources, for example, sewage

sludge or atmospheric deposition. Here, the burden of metals might be extracted by phytoremediation in as few as 3–5 years .

- **Phytostabilization.** There are many thousands of species of metal-tolerant, nonaccumulating plants that might be considered for phytostabilization. These species are unified by the fact that Metal-tolerant plants that do not accumulate metals in their shoots, they restrict the transfer of metals to their shoots, which will reduce the entry of metals into the food chain.

- **Phytomining** is the production of a `crop' of a metal by growing high-biomass plants that accumulate high metal concentrations. Some of these plants are natural hyperaccumulators, and in others the property can be induced. Pioneering experiments in this field might lead to a `green' alternative to existing, environmentally destructive, opencast mining practices. Phytomining for a range of metals is a real possibility, with the additional potential of the exploitation of ore bodies that it is uneconomic to mine by conventional methods. On some sites, phytomining to extract Ni, Co, Tl, and Au for their economic value may be possible, generating a metal-rich smelter feedstock **("bio-ore");** the driving factor here is the high dollar-value of these metals .

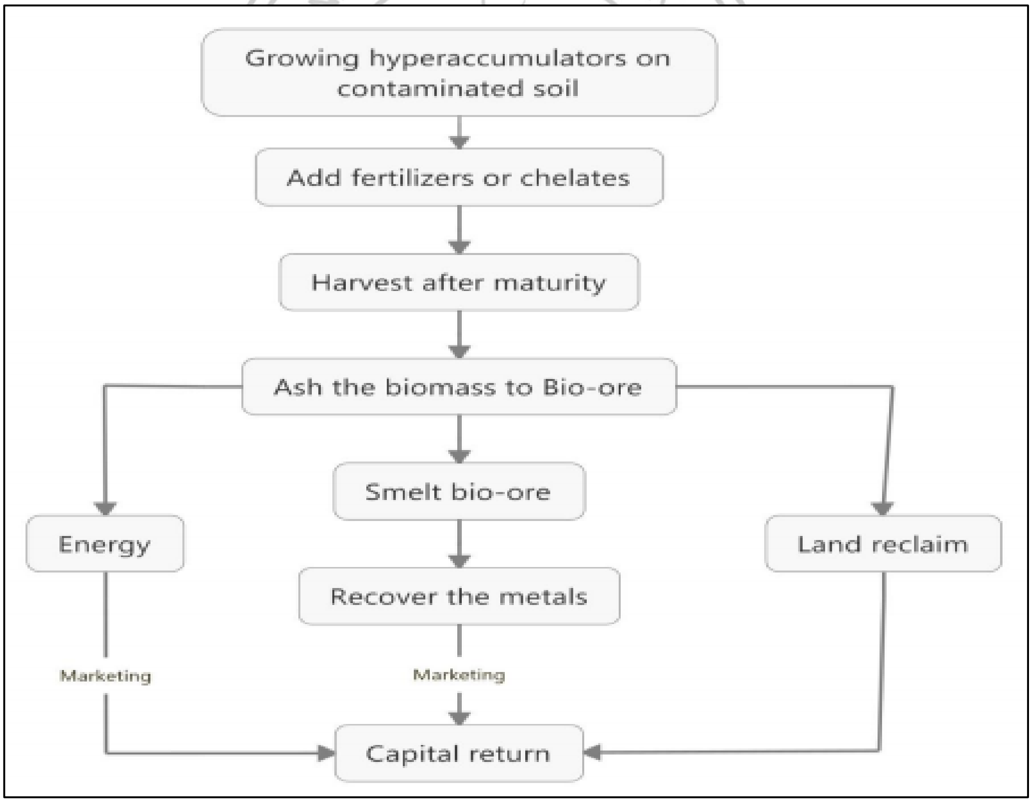


Figure.2 :An Illuatrative Model of Commercial Phytomining of Heavy Metals

Glossery

Ecological restoration: The Society for Ecological Restoration (SER) defines ecological restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (Society for Ecological Restoration Science and Policy Working Group 2002). The term (ecological) restoration can be applied to the use of metallophytes in revegetation only where the site (and/or reference site) originally had those metallophyte species.

Remediation is defined as the process of rendering metalliferous contaminants less toxic, or ideally removing them from the contaminated environment. In terms of using metallophytes for remediation, this will predominantly be the process of phytoremediation (see below).

Phytoextraction is the process of using metal- or hyperaccumulating plants to remove metals and metalloids from soils. The plants sequester the metals in their shoots, which can then be harvested. Two technologies are based on the principle of phytoextraction:

Phytoremediation is the use of metal-accumulating plants to remove pollutants from contaminated soils. This is a transient process because the vegetative cover of metallophytes is removed when the substrate is clean so that the site can be used for other purposes.

Phytomining exploits metal-accumulating plants to recover commercially valuable metals from metal-loaded substrates. Here, the metals are not necessarily considered as contaminants of the soils; the metals may be naturally present at high concentrations because the soils have developed over mineralized bedrock.

Suggested readings:

Metallophytes: the unique biological resource, its ecology and conservational status in Europe, Central Africa and Latin America, In book: Ecology of industrial pollution, Chapter: Metallophytes: the unique biological resource, its ecology and conservational status in Europe, central Africa and Latin America, January 2010, Publisher: Cambridge University Press, Cambridge, pp.7-40.

Sharma PD, Ecology and Environment, 12th Revised Edition (2014-2015), Rastogi Publications,Meerut-New Delhi.

Shukla RS, Chandel PS, A Textbook of Plant Ecology,12th Revisedand Enlarged Edition (2014), S. Chand Publication, New Delhi.