NETAJI SUBHAS UNIVERSITY ,JAMSHEDPUR

ENVIRONMENTAL

XENOBIOTICS

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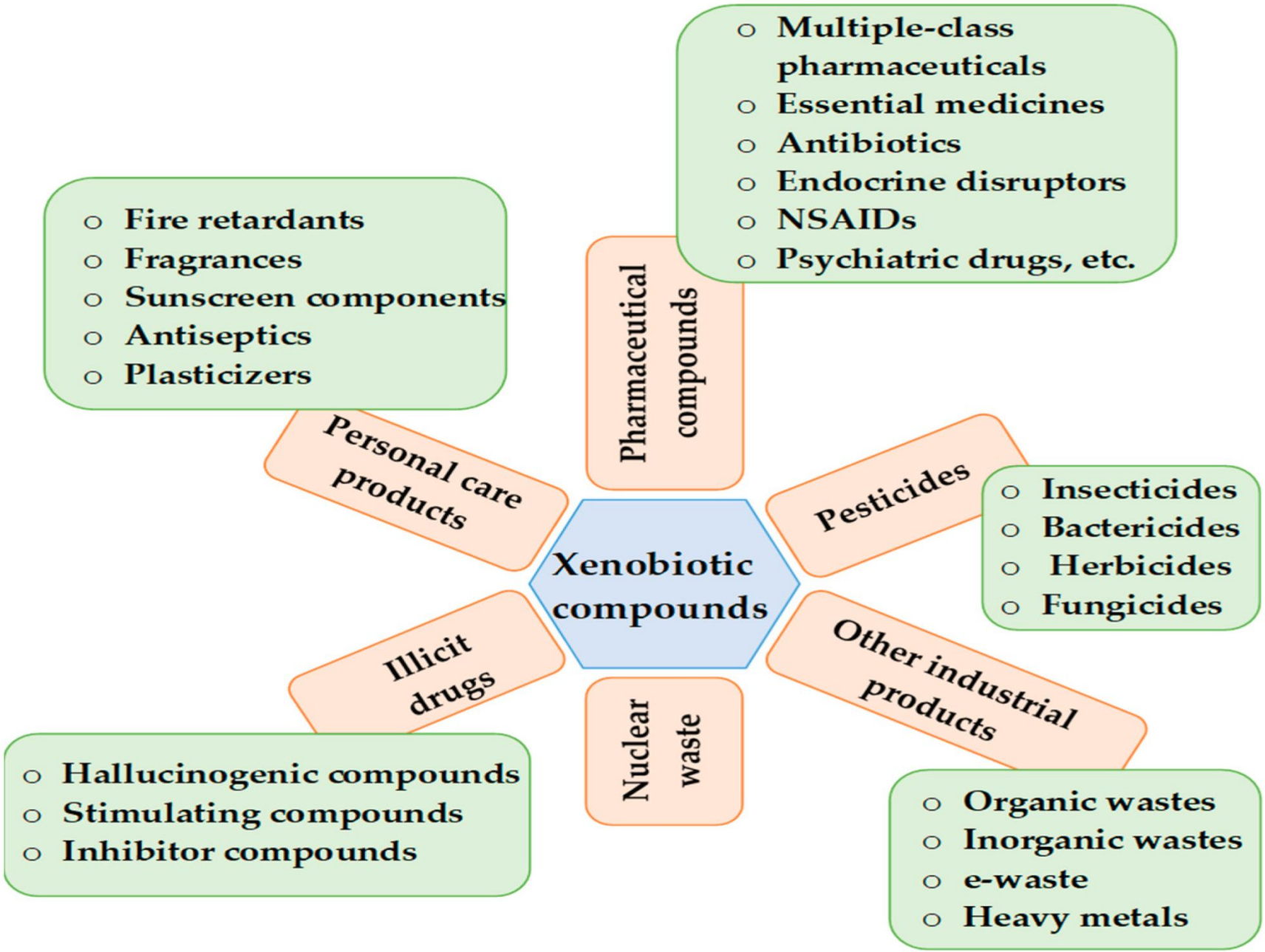
Meaning of Xenobiotic Compounds:

Xenobiotic compounds are man-made chemicals that are present in the environment at unnaturally high concentrations. The xenobiotic compounds are either not produced naturally, or are produced at much lower concentrations than man. Microorganism have the capability of degrading all naturally occurring compounds; this is known as the principle of microbial infallibility proposed by Alexander in 1965.

Microorganisms are also able to degrade many of the xenobiotic compounds, but they are unable to degrade many others. The compounds that resist biodegradation and thereby persists in the environment are called recalcitrant.


Xenobiotic compounds
Pharmaceutical compounds
Multiple-class pharmaceuticals
Essential medicines
Antibiotics
Endocrine disruptors
NSAIDs
Psychiatric drugs, etc.
Personal care products
Fire retardants
Fragrances
Sunscreen components
Antiseptics
Plasticizers
Pesticides
Insecticides
Bactericides
Herbicides
Fungicides
Illicit drugs
Hallucinogenic compounds
Stimulating compounds
Inhibitor compounds
Nuclear waste
Other industrial products
Organic wastes
Inorganic wastes
e-waste
Heavy metals

The xenobiotic compounds may be recalcitrant due to one or more of the following reasons:

(i) They are not recognised as substrate by the existing degradative enzymes,
(ii) They are highly stable, i.e., chemically and biologically inert due to the presence of substitution groups like halogens, nitro-, sulphonate, amino-, methoxy- and carbamyl groups,
(iii) They are insoluble in water, or are adsorbed to external matrices like soil,
(iv) They are highly foxic or give rise to toxic products due to microbial activity,
(v) Their large molecular size prevents entry into microbial cells,
(vi) Inability of the compounds to induce the synthesis of degrading enzymes, and
(vii) Jack of the perm-ease needed for their transport into the microbial cells.

Types of Recalcitrant Xenobiotic Compounds:
The recalcitrant xenobiotic compounds can be grouped into the following 6 types:

(i) Halocarbons,

(ii) Polychlorinated biphenyls,

(iii) Synthetic polymers,

(iv) Alkylbenzyl sulphonates,

v) Oil mixture and

(vi) Others.

Halocarbons:

These compounds contain different numbers of halogen (e.g., CI, Br, F (fluorine), I) atoms in the place of H atoms. They are used as solvents (chloroform, $CHCI_3$), as propellants in spray cans of cosmetics, paints etc., in condenser units of cooling systems (Freons, CCI_3F, CCl_2F_2, $CClF_3$, CF_4), and as insecticides (DDT, BHC, lindane etc.) and herbicides (dalapon, 2, 4-D, 2, 4, 5-T etc.).

The C_1-C_2 halo alkanes like chloroform, freons etc. are volatile and escape into the atmosphere where they destroy the protective ozone (O_3) layer leading to increased UV radiation. Pesticides (herbicides, fungicides and insecticides) are applied to crops from where they leach into water bodies; many of them are subject to bio-magnification.

Poly chlorinated Biphenyls (PCB's):

These compounds have two covalently linked benzene rings having halogens substituting for H. PCB's are used as plasticisers, insulator coolants in transformers and as heat exchange fluids. They are both biologically and chemically inert to various degrees, which increases with the number of chlorine atoms present in the molecule.

The recalcitrant nature of the above two groups of compounds is due to their halogenation and as well their cyclic structure (PCB's).

Synthetic Polymers:

These compounds are produced as plastics, e.g., polyethylene, polystyrene, polyvinyl chloride etc., and nylons which are used as garments, wrapping materials etc. They are recalcitrant mainly due to their insolubility in water and molecular size.

Alkylbenzyl Sulfonates:

These are surface-active detergents superior to soaps. The sulphonate (—SO_3^-) group present at one end resists microbial degradation, while the other end (non-polar alkyl end) becomes recalcitrant if its is branched, (resistance increases with the degree of branching). At present, alkylbenzyl sulphonates having non-branched alkyl ends are used; these are biodegraded by β-oxidation from their alkyl ends.

Oil Mixtures:

Oil is a natural product, has many components and is biodegradable, the different components being degraded at different rates. Biodegradation is able to handle small oil seepages. But when large spills occur the problem of pollution becomes acute. Oil is recalcitrant mainly because of its insolubility in water and due to the toxicity of some of its components.

Xenobiotics in the environment

Xenobiotic substances are an issue for sewage treatment systems, since they are many in number, and each will present its own problems as to how to remove them.

Some xenobiotics substances are resistant to degradation. Xenobiotics such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and trichloroethylene (TCE) accumulate in the environment due to their recalcitrant properties and have become an environmental concern due to their toxicity and accumulation.

Some of the main sources of pollution and the introduction of xenobiotics into the environment come from large industries such as pharmaceuticals, fossil fuels, pulp and paper bleaching and agriculture

Bioconcentration of Xenobiotics

It refers to the accumulation of xenobiotic substances at quantities higher than those found in the immediate environment in particular tissues of organisms.

The bioconcentration factor (BCF) is defined as the concentration of a chemical in an organism divided by the concentration of the same chemical in the environment or a component of the environment (e.g., water).

The BCF is mostly used to predict the degree of accumulation of an organic contaminant in water by fish.

For terrestrial animals, food is usually the primary source of many xenobiotic compounds, and if the rate of intake is constant, a steady state is eventually formed.

Biodegradation or biological degradation is the phenomenon of biological transformation of organic compounds by living organisms, particularly the microorganisms. Biodegradation basically involves the conversion of complex organic molecules to simpler (and mostly non-toxic) ones. The term biotransformation is used for incomplete biodegradation of organic compounds involving one or a few reactions. Biotransformation is employed for the synthesis of commercially important products by microorganisms.

Bioremediation refers to the process of using microorganisms to remove the environmental pollutants i.e. the toxic wastes found in soil, water, air etc. The microbes serve as scavengers in bioremediation. The removal of organic wastes by microbes for environmental clean-up is the essence of bioremediation. The other names used (by some authors) for bioremediation are bio-treatment, bio-reclamation and bio-restoration.

Metabolic Effects of Microorganisms on Xenobiotics

Although it is the intention of the biotechnologist to degrade the xenobiotics by microorganisms to the advantage of environment and ecosystem, it is not always possible.

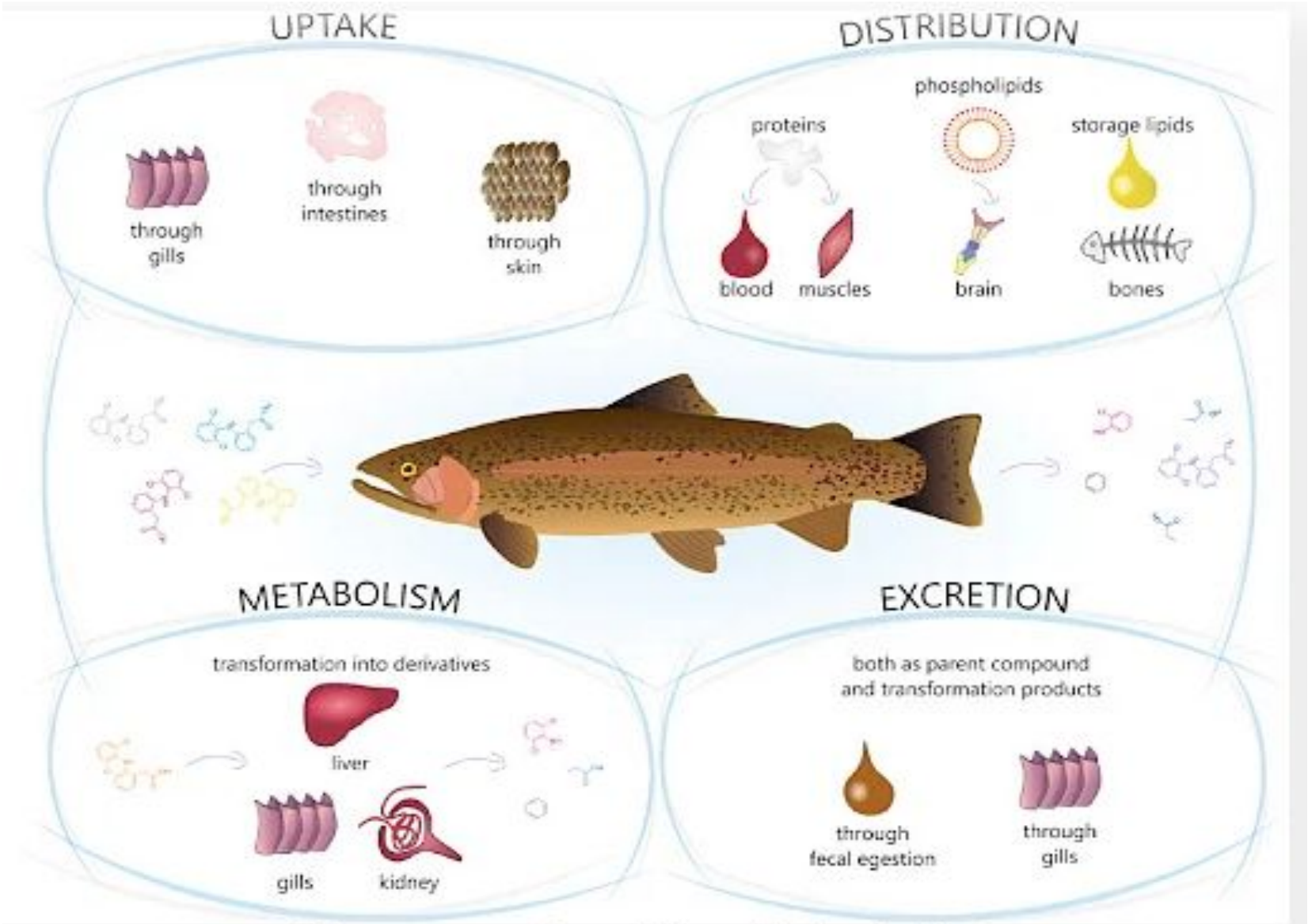
This is evident from the different types of metabolic effects as shown below.

Detoxification: This process involves the microbial conversion of toxic compound to a nontoxic one. Biodegradation involving detoxification is highly advantageous to the environment and population.

Activation: Certain xenobiotics which are not toxic or less toxic may be converted to toxic or more toxic products. This is dangerous.

Degradation: The complex compounds are degraded to simpler products which are generally harmless.

Conjugation: The process of conjugation may involve the conversion of xenobiotics to more complex compounds. This is however, not very common.



Bioconcentration of Xenobiotics in Fish

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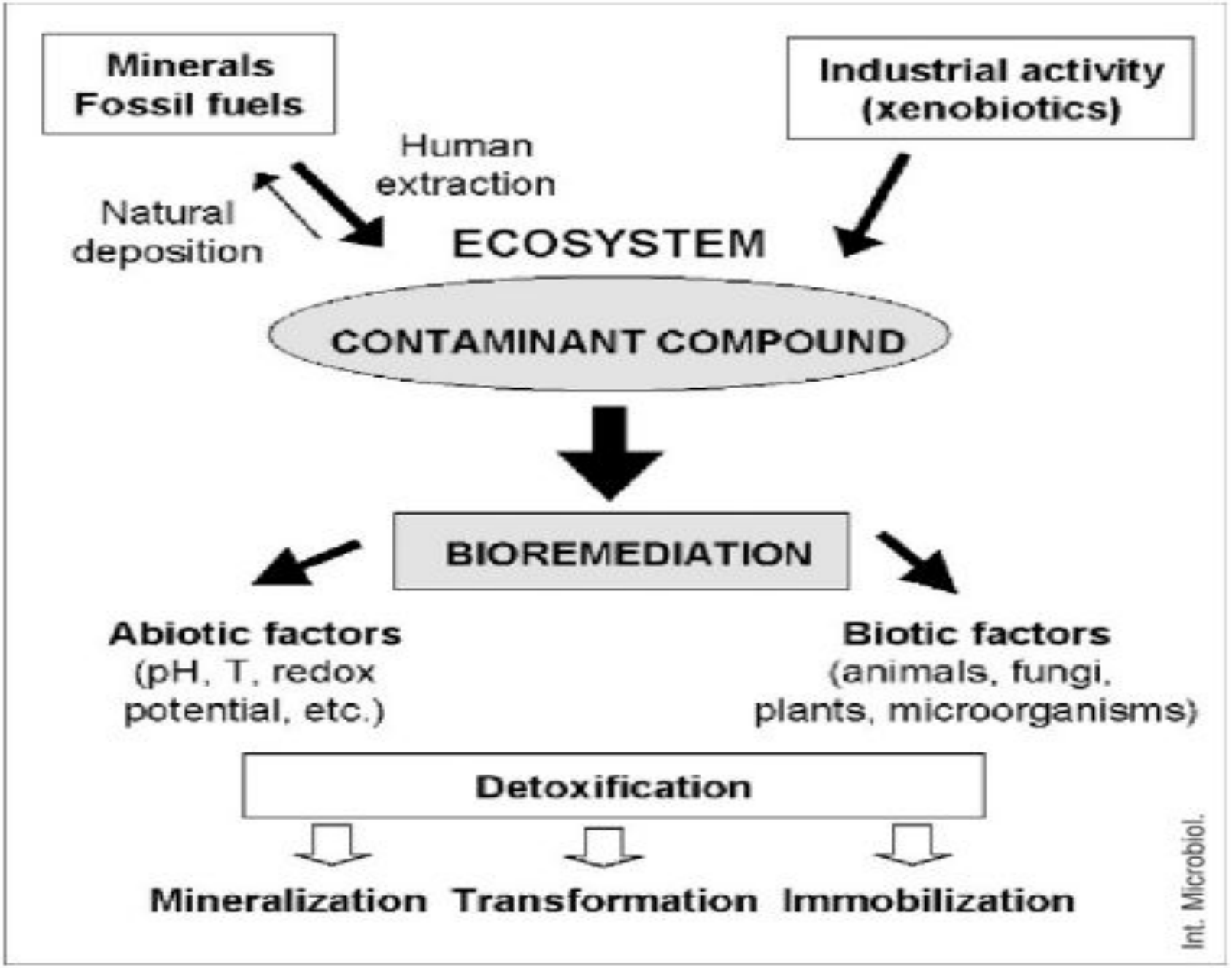
Minerals
Fossil fuels
Industrial activity
(xenobiotics)
Human
extraction
Natural
deposition
ECOSYSTEM
CONTAMINANT COMPOUND
BIOREMEDIATION
Abiotic factors
(pH, T, redox
potential, etc.)
Biotic factors
(animals, fungi,
plants, microorganisms)
Detoxification
Mineralization
Transformation
Immobilization
Int. Microbiol.