Bioremediace a biodegradace

Smysl bioremediace = využít přirozené biodegradační pochody s cílem vyčistit kontaminované lokality.

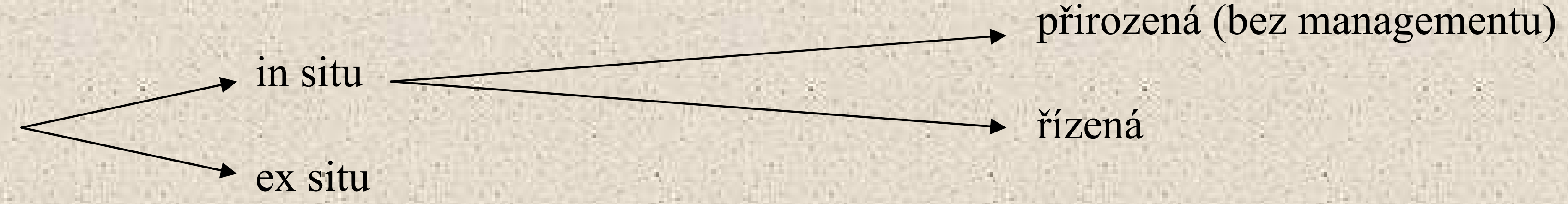
- systém, kdy se do půdy navrací ekologická funkce, kterou plní mikroorganismy

Pokud mikroorganismy selhaly:

- není žádná skupina, která by byla schopna mineralizovat či detoxifikovat daný kontaminant
- rychlost vstupu kontaminantu je větší než rychlost dekompozice
- chemické, fyzikální, či biologické limitace dekompozitorů
- polutant či koncentrace, které jsou toxické pro dekompozitory
- fyzikální či chemické faktory, které zabraňují kontaktu dekompozitorů a polutantu
- dekontaminace vede k podmínkám inhibující další procesy

bioremediace = mnohdy více technika než biologie či ekotoxikologie = management půdních fyzikálních, chemických, biologických a dalších faktorů tak, aby se výše uvedené body minimalizovaly a detoxifikační schopnost mikroorganismů byla co nejvyšší

- cílem tedy je detoxifikace, immobilizace, či mineralizace žádané látky (nejčastěji organických polutantů a sloučenin)



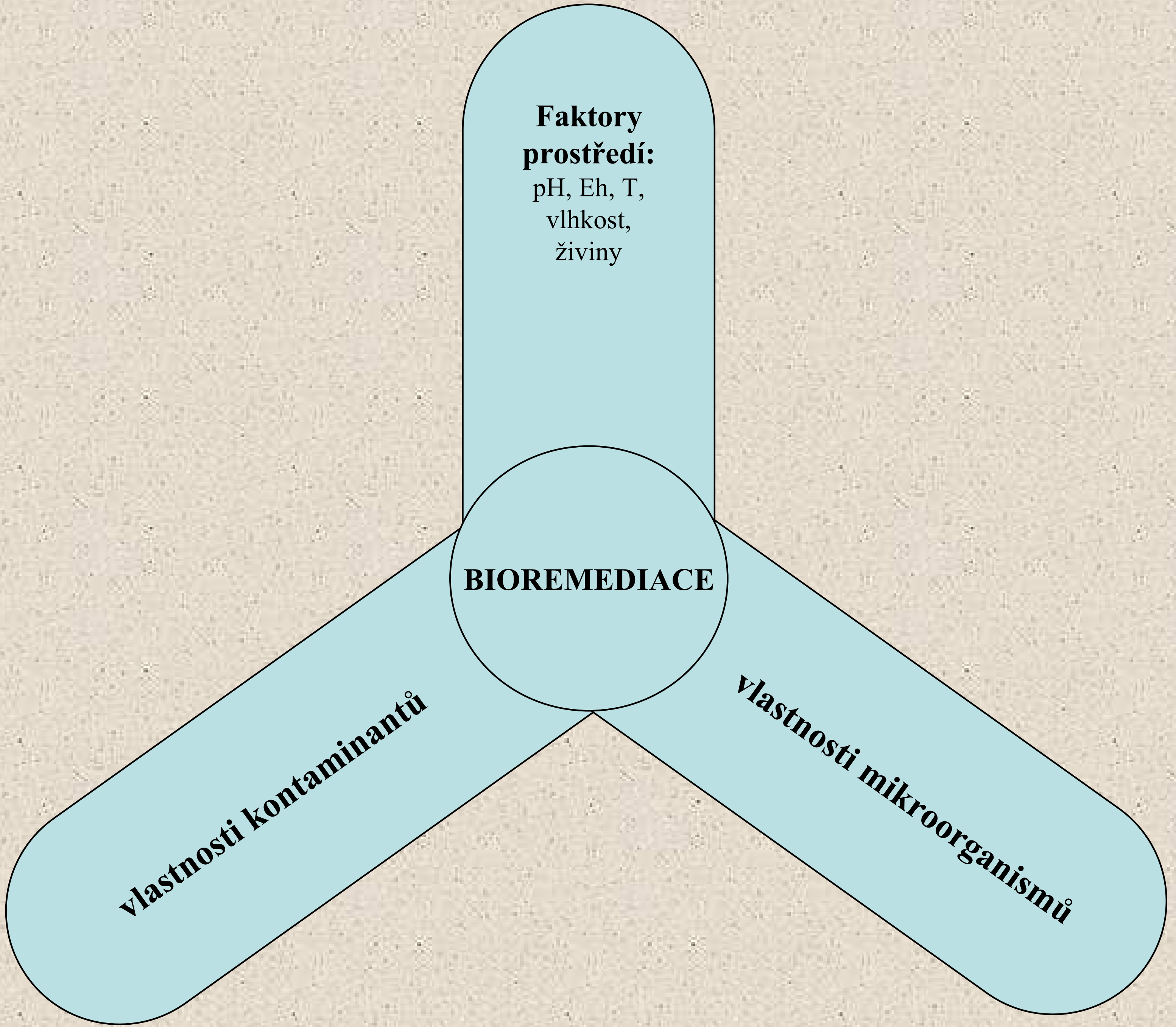
přirozená (bez managementu)

in situ

řízená

ex situ

Schéma bioremediace



Faktory prostředí:
pH, Eh, T,
vlhkost,
živiny

BIOREMEDIACE

vlastnosti kontaminantů

vlastnosti mikroorganismů

Bioremediace a biodegradace

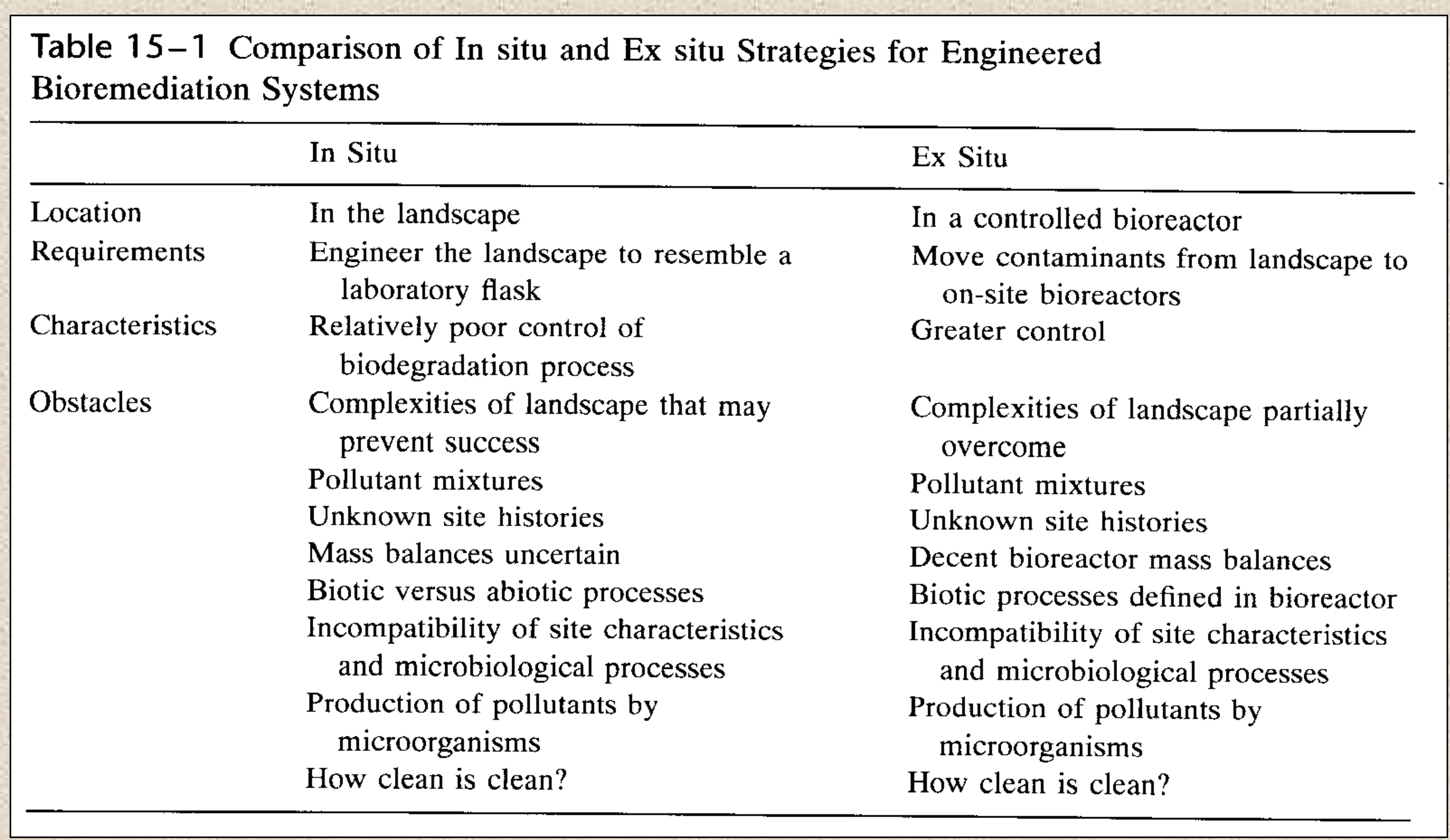


Table 15–1 Comparison of In situ and Ex situ Strategies for Engineered Bioremediation Systems

	In Situ	Ex Situ
Location	In the landscape	In a controlled bioreactor
Requirements	Engineer the landscape to resemble a laboratory flask	Move contaminants from landscape to on-site bioreactors
Characteristics	Relatively poor control of biodegradation process	Greater control
Obstacles	Complexities of landscape that may prevent success	Complexities of landscape partially overcome
	Pollutant mixtures	Pollutant mixtures
	Unknown site histories	Unknown site histories
	Mass balances uncertain	Decent bioreactor mass balances
	Biotic versus abiotic processes	Biotic processes defined in bioreactor
	Incompatibility of site characteristics and microbiological processes	Incompatibility of site characteristics and microbiological processes
	Production of pollutants by microorganisms	Production of pollutants by microorganisms
	How clean is clean?	How clean is clean?

Nezbytné je zabezpečit optimální podmínky biodegradace

Přidávání kyslíku a jiných plynů:
- bioventing je technika dodávky kyslíku přímo in situ do nesaturované zóny
- "air sparging" - tlakové vhánění kyslíku do saturační zóny
- kromě kyslíku se často dodává methan (zejména při degradacích chlorovaných látek)

Dodávka živin:
- hlavně přídavky dusíku a fosforu
- cíl: optimalizace poměru C:N:P na hodnotu cca 100:10:1

Stimulace anaerobních degradací:
- dodávka alternativních TEA (terminal electron acceptor) - dusičnany, sírany, Fe^{3+}, CO_2
- anaerobní degradace je sice pomalejší, ale dokáže "si poradit" s jinými polutanty než aerobní degradace (např. silně chlorované látky)

Dodávka surfaktantů:
- sníží povrchové napětí a zvýší biodostupnost kontaminantů

Dodávka mikroorganismů či DNA:
- introdukované organismy - bioaugmentace
- genetické inženýrství, uměle vytvořené mikroorganismy schopné vysoce efektivních biodegradací

Problémy: - neschopné dlouho přežít v reálném ekosystému
- vážou se na půdní komplexy a tím jsou méně aktivní

Bioremediace a biodegradace

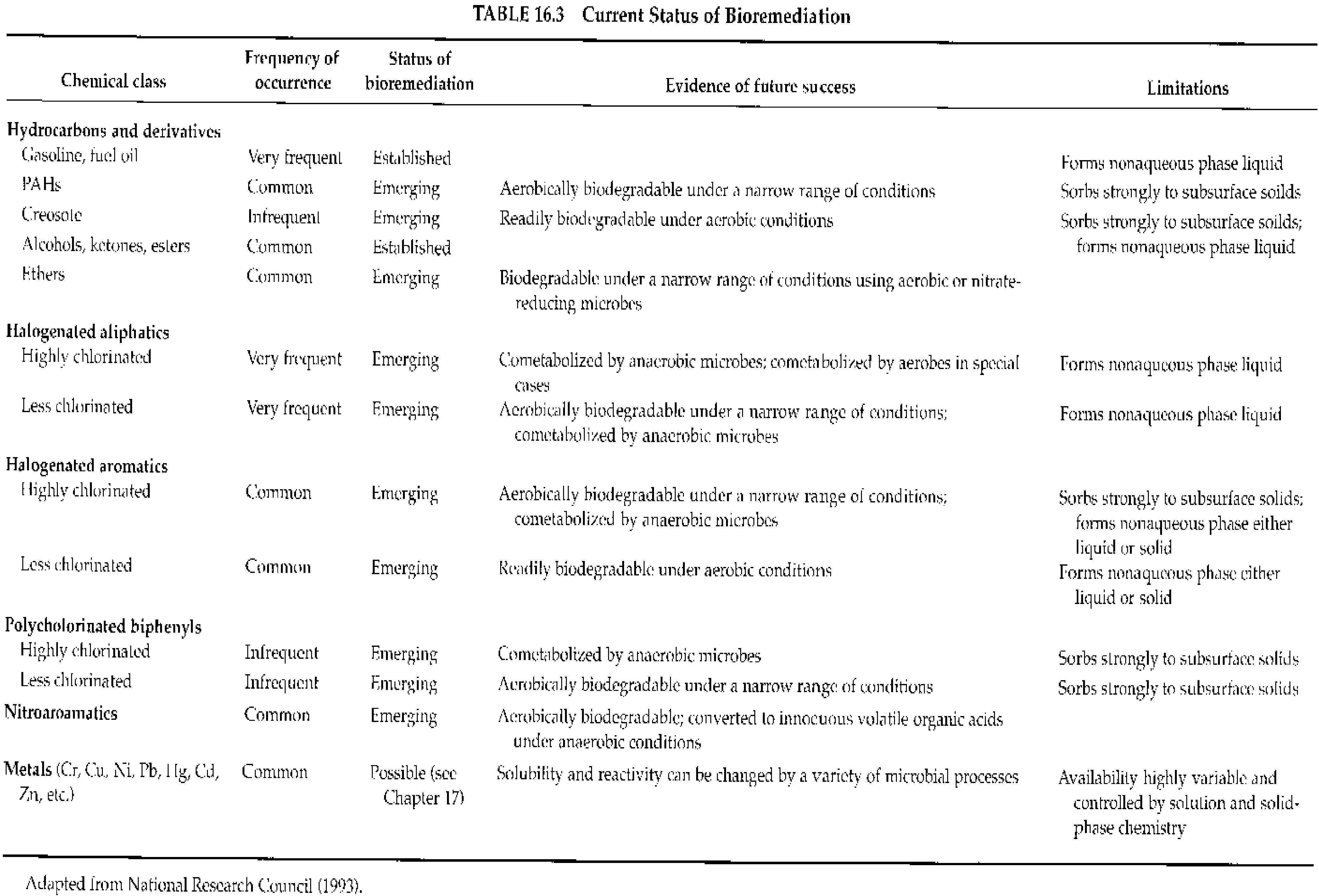


TABLE 16.3 Current Status of Bioremediation

Chemical class	Frequency of occurrence	Status of bioremediation	Evidence of future success	Limitations
Hydrocarbons and derivatives				
Gasoline, fuel oil	Very frequent	Established		Forms nonaqueous phase liquid
PAHs	Common	Emerging	Aerobically biodegradable under a narrow range of conditions	Sorbs strongly to subsurface soilds
Creosote	Infrequent	Emerging	Readily biodegradable under aerobic conditions	Sorbs strongly to subsurface soilds; forms nonaqueous phase liquid
Alcohols, ketones, esters	Common	Established		
Ethers	Common	Emerging	Biodegradable under a narrow range of conditions using aerobic or nitrate-reducing microbes	
Halogenated aliphatics				
Highly chlorinated	Very frequent	Emerging	Cometabolized by anaerobic microbes; cometabolized by aerobes in special cases	Forms nonaqueous phase liquid
Less chlorinated	Very frequent	Emerging	Aerobically biodegradable under a narrow range of conditions; cometabolized by anaerobic microbes	Forms nonaqueous phase liquid
Halogenated aromatics				
Highly chlorinated	Common	Emerging	Aerobically biodegradable under a narrow range of conditions; cometabolized by anaerobic microbes	Sorbs strongly to subsurface solids; forms nonaqueous phase either liquid or solid
Less chlorinated	Common	Emerging	Readily biodegradable under aerobic conditions	Forms nonaqueous phase either liquid or solid
Polycholorinated biphenyls				
Highly chlorinated	Infrequent	Emerging	Cometabolized by anaerobic microbes	Sorbs strongly to subsurface solids
Less chlorinated	Infrequent	Emerging	Aerobically biodegradable under a narrow range of conditions	Sorbs strongly to subsurface solids
Nitroaroamatics	Common	Emerging	Aerobically biodegradable; converted to innocuous volatile organic acids under anaerobic conditions	
Metals (Cr, Cu, Ni, Pb, Hg, Cd, Zn, etc.)	Common	Possible (see Chapter 17)	Solubility and reactivity can be changed by a variety of microbial processes	Availability highly variable and controlled by solution and solid-phase chemistry

Adapted from National Research Council (1993).

Bioremediace a biodegradace

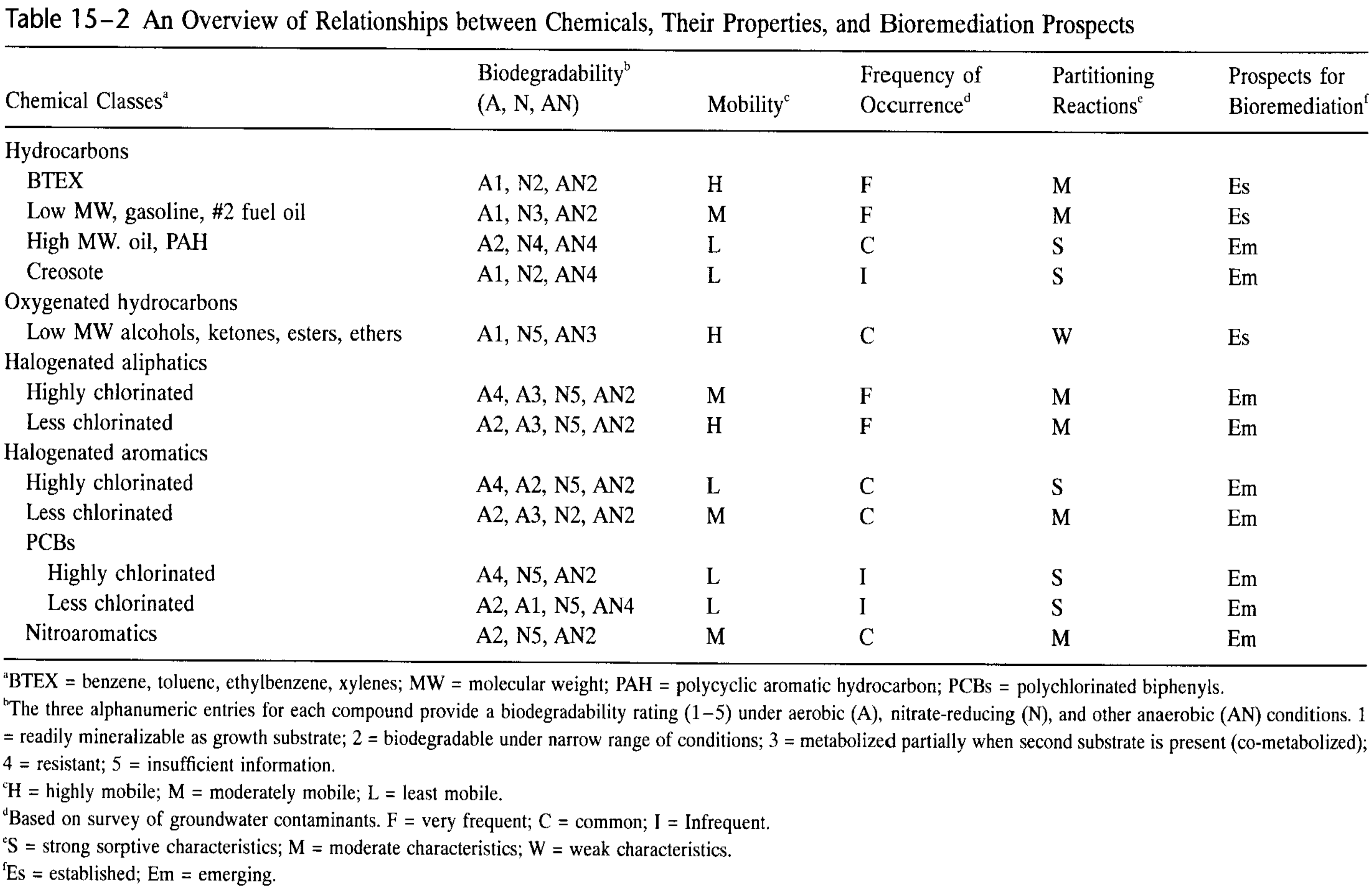


Table 15–2 An Overview of Relationships between Chemicals, Their Properties, and Bioremediation Prospects

Chemical Classes[a]	Biodegradability[b] (A, N, AN)	Mobility[c]	Frequency of Occurrence[d]	Partitioning Reactions[e]	Prospects for Bioremediation[f]
Hydrocarbons					
BTEX	A1, N2, AN2	H	F	M	Es
Low MW, gasoline, #2 fuel oil	A1, N3, AN2	M	F	M	Es
High MW. oil, PAH	A2, N4, AN4	L	C	S	Em
Creosote	A1, N2, AN4	L	I	S	Em
Oxygenated hydrocarbons					
Low MW alcohols, ketones, esters, ethers	A1, N5, AN3	H	C	W	Es
Halogenated aliphatics					
Highly chlorinated	A4, A3, N5, AN2	M	F	M	Em
Less chlorinated	A2, A3, N5, AN2	H	F	M	Em
Halogenated aromatics					
Highly chlorinated	A4, A2, N5, AN2	L	C	S	Em
Less chlorinated	A2, A3, N2, AN2	M	C	M	Em
PCBs					
Highly chlorinated	A4, N5, AN2	L	I	S	Em
Less chlorinated	A2, A1, N5, AN4	L	I	S	Em
Nitroaromatics	A2, N5, AN2	M	C	M	Em

[a] BTEX = benzene, toluene, ethylbenzene, xylenes; MW = molecular weight; PAH = polycyclic aromatic hydrocarbon; PCBs = polychlorinated biphenyls.

[b] The three alphanumeric entries for each compound provide a biodegradability rating (1–5) under aerobic (A), nitrate-reducing (N), and other anaerobic (AN) conditions. 1 = readily mineralizable as growth substrate; 2 = biodegradable under narrow range of conditions; 3 = metabolized partially when second substrate is present (co-metabolized); 4 = resistant; 5 = insufficient information.

[c] H = highly mobile; M = moderately mobile; L = least mobile.

[d] Based on survey of groundwater contaminants. F = very frequent; C = common; I = Infrequent.

[e] S = strong sorptive characteristics; M = moderate characteristics; W = weak characteristics.

[f] Es = established; Em = emerging.

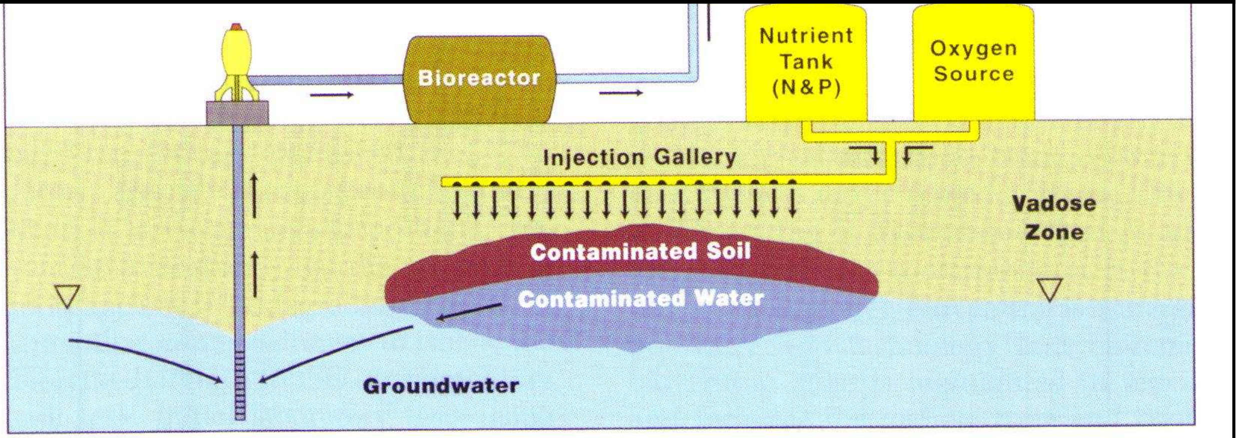
Bioremediace a biodegradace

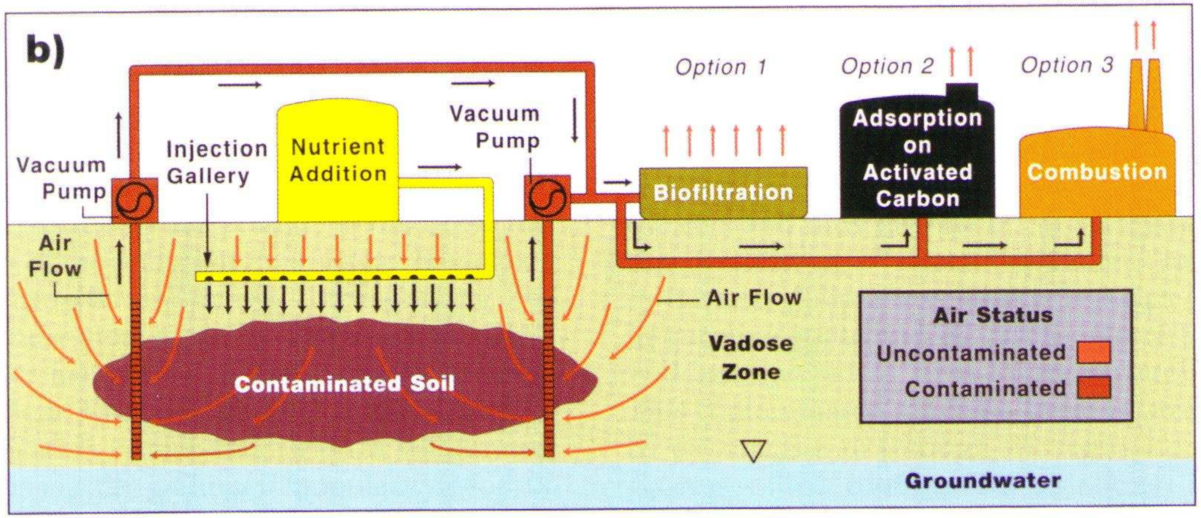
a) *In situ* bioremediation in the vadose zone and groundwater. Nutrients and oxygen are pumped into the contaminated area to promote *in sítu* processes. This figure also shows *ex situ* treatment. *Ex sítu* treatment is for water pumped to the surface and uses an aboveground bioreactor, as shown, or other methods, e.g. air stripping, activated carbon, off-water separation, or oxidation. An injection well returns treated water to the aquifer.

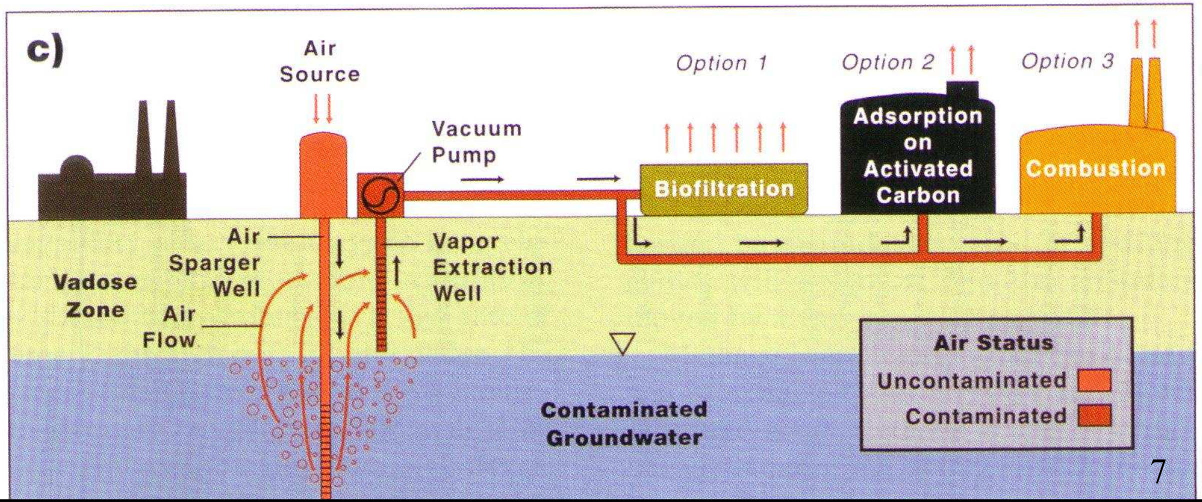
b) Bioventing and biofiltration in the vadose zone. Air drawn through the contaminated site (bioventing) stimulates *in situ* aerobic degradation. Volatile contaminants removed with the air are treated in a biofilter, by adsorption on activated carbon, or by combustion.

c) Bioremediation in the groundwater by air sparging. Air pumped into the contaminated site stimulates aerobic degradatlon in the saturated zone. Volatile contaminants brought to the surface are treated by biofiltration, activated carbon, or combustion.

From *Pollution Science* ©1996, Academic Press, San Diego, CA.)







Bioremediace a biodegradace

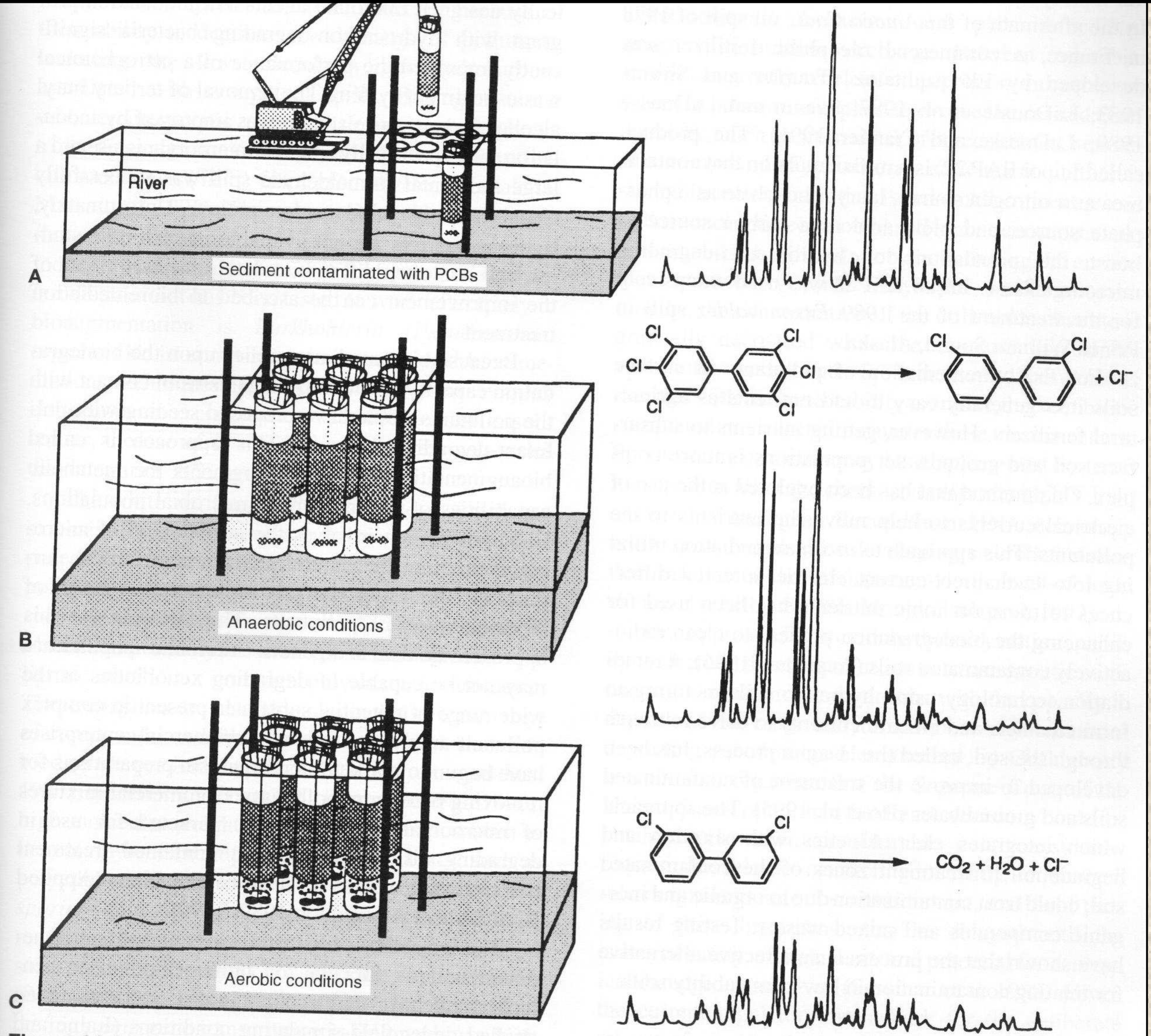
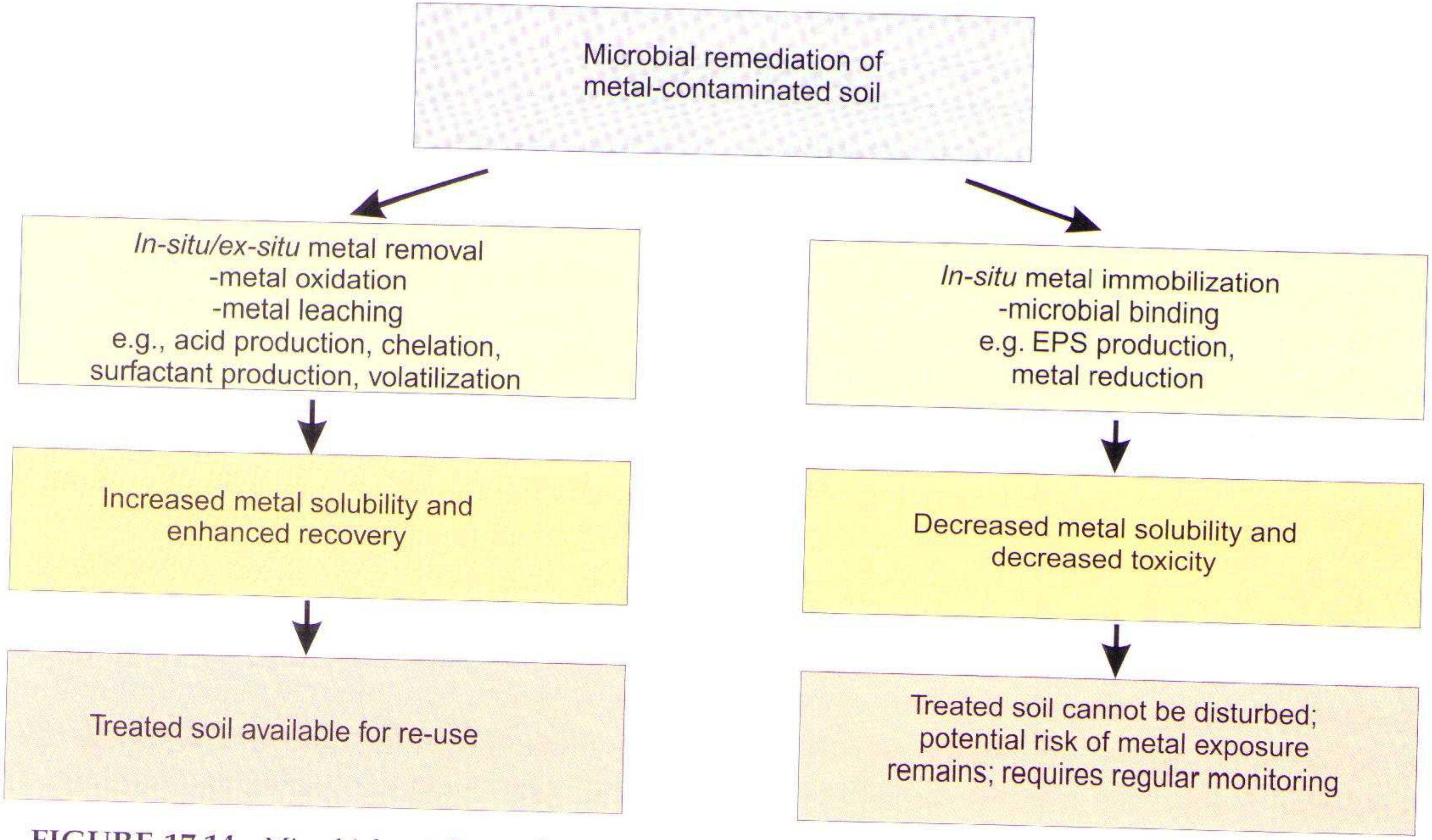


Figure 14.4
Bioremediation of PCB-contaminated river sediments. (A) Placement of steel caissons into sediments; chromatographic tracing showing full range of contaminating PCB congeners. (B) Nutrients added to sealed caissons lead to creation of anaerobic conditions: anaerobic dehalogenation converts higher-molecular-weight congeners to ones with fewer chlorines; chromatographic tracing shows disappearance of higher-molecular-weight congeners with 4–6 chlorines and increased concentrations of lower-molecular-weight PCBs with 2–3 chlorines. (C) Forced aeration and stirring create aerobic conditions; biodegradation of lower-molecular-weight congeners leads to cleaner sediments.

Bioremediace lokalit kontaminovaných těžkými kovy

Kovy - jednoprvkové polutanty - jiný princip:

- není biodegradace, proto 1) immobilizace kovu in situ (zabránění mobilitě a biodostupnosti) a 2) odstranění kovů



Microbial remediation of metal-contaminated soil

In-situ/ex-situ metal removal
-metal oxidation
-metal leaching
e.g., acid production, chelation, surfactant production, volatilization

Increased metal solubility and enhanced recovery

Treated soil available for re-use

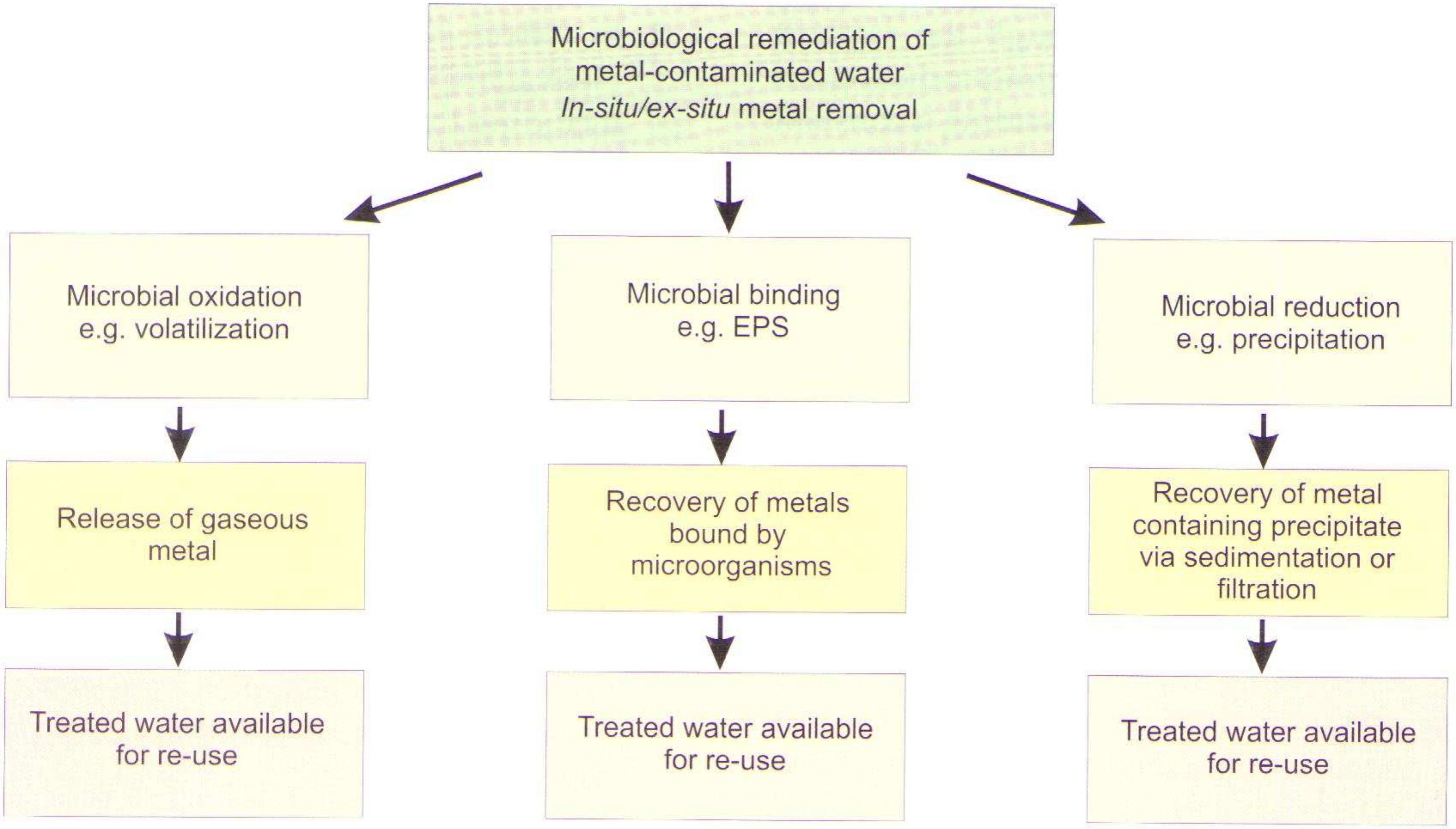
In-situ metal immobilization
-microbial binding
e.g. EPS production, metal reduction

Decreased metal solubility and decreased toxicity

Treated soil cannot be disturbed; potential risk of metal exposure remains; requires regular monitoring

FIGURE 17.14 Microbial metal remediation in metal-contaminated soils relies on either metal removal or, more commonly, metal immobilization. Metal removal is ideal because following treatment the soil is available for reuse. In metal immobilization, soil reuse is limited because of the continued potential risk of exposure.

Bioremediace lokalit kontaminovaných těžkými kovy



Microbiological remediation of metal-contaminated water
In-situ/ex-situ metal removal

Microbial oxidation e.g. volatilization

Release of gaseous metal

Treated water available for re-use

Microbial binding e.g. EPS

Recovery of metals bound by microorganisms

Treated water available for re-use

Microbial reduction e.g. precipitation

Recovery of metal containing precipitate via sedimentation or filtration

Treated water available for re-use

FIGURE 17.15 Microbial metal remediation approaches for metal-contaminated waters. In each method, the treated water is safe to release into the environment. Both metals and microorganisms can easily be recovered during treatment for proper disposal.

Bioremediace lokalit kontaminovaných těžkými kovy

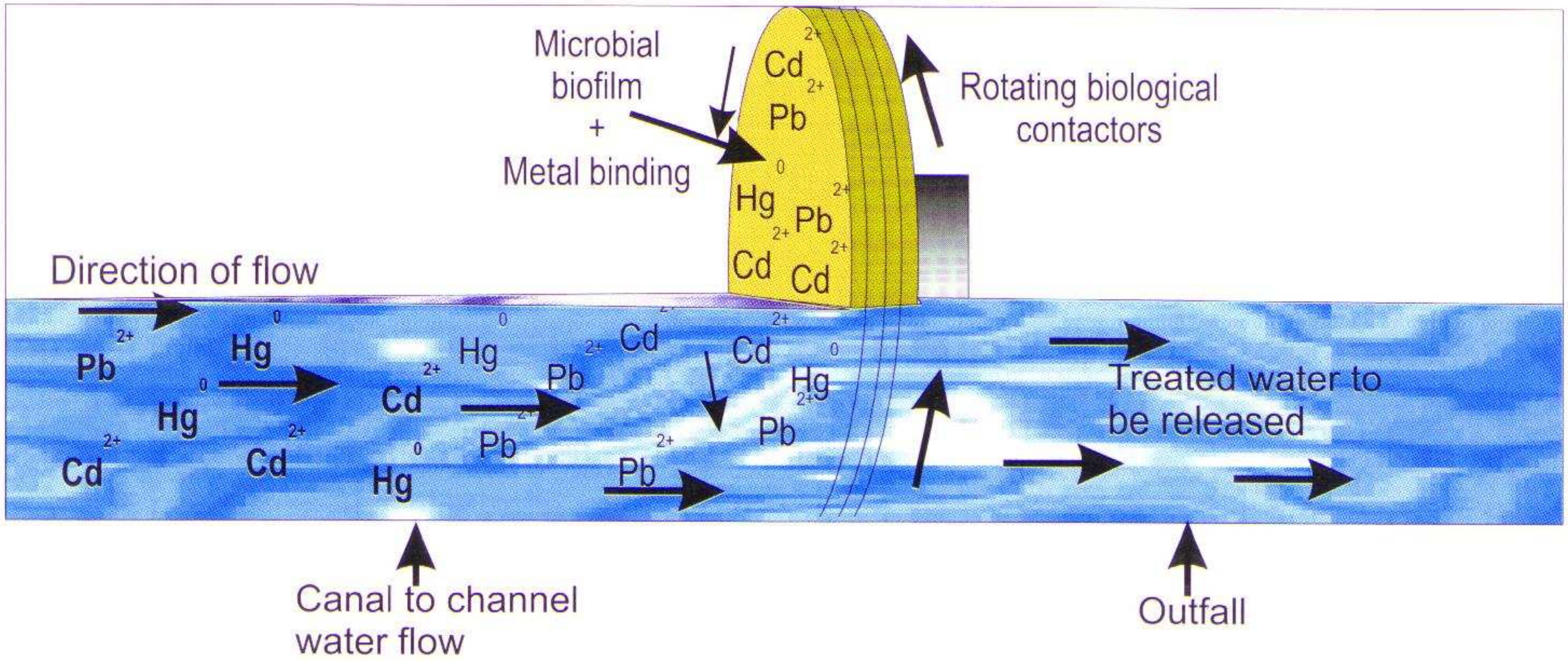


FIGURE 17.16 Schematic demonstrating how microbial biofilms are used in removing metals from contaminated wastestreams. The biofilm located on the rotating drum accumulates metals as the water passes through the drum. The treated water can be safely released. The biofilm may either be viable or nonviable. When viable, the biofilm rarely needs to be replaced; however, non-living biofilms need to be replaced periodically for their metal removal efficiency will decrease with time.