Pollution Indicators and Pollution Control Strategies

Pollution

- Pollution has become one of the most frequently talked about of all environmental problems by the world at large and yet, in many respects, it can often remain one of the least understood.
- The word itself has a familiar ring to it and inevitably the concept of pollution has entered the wider consciousness as a significant part of the burgeoning 'greening' of society in general.
- However, the diverse nature of potentially polluting substances can lead to some confusion. It is important to realize that not all pollutants are manufactured or synthetic, that under certain circumstances, many substances may contribute to pollution and that, perhaps most importantly for our purposes, any biologically active substance has the potential to give rise to a pollution effect.
- This inevitably leads to some difficulty in any attempt at classifying pollutants, since clearly, they do not represent a single unified class, but rather a broad spectrum.
- While it is possible, to produce a means of systematic characterization of pollutant substances, though useful for a consideration of wider contamination effects, this is an inherently artificial exercise.

- The UK Environmental Protection Act (EPA) 1990 statutorily offers the following:
- ‘Pollution of the environment’ means pollution of the environment due to the release (into any environmental medium) from any process of substances which are capable of causing harm to man or any other living organisms supported by the environment.
- “The escape of any substance capable of causing harm to man or any other living organism supported by the environment”

  EPA, Section 29, Part II

- In essence, then, pollution is the introduction of substances into the environment which, by virtue of their characteristics, persistence or the quantities involved, are likely to be damaging to the health of humans, other animals and plants, or otherwise compromise that environment's ability to sustain life.
- It should be obvious that this is an expressly inclusive definition, encompassing not simply the obviously toxic or noxious substances, but also other materials which can have a polluting effect under certain circumstances.

Classifying Pollution

- It is possible to produce functional classifications on the basis of various characteristics.
- However, it must be clearly borne in mind that all such classification is essentially artificial and subjective, and that the system to be adopted will typically depend on the purpose for which it is ultimately intended.
- Despite these limitations, there is considerable value in having some method, if only as a predictive environmental management tool, for considerations of likely pollutant effect.

- Classification may, for example, be made on the basis of the chemical or physical nature of the substance, its source, the environmental pathway used, the target organism affected or simply its gross effect.
- The consideration of a pollutant's properties is a particularly valuable approach when examining real-life pollution effects, since such an assessment requires both the evaluation of its general properties and the local environment.
- This may include factors such as:
- toxicity;
- persistence;
- mobility;
- ease of control;
- bioaccumulation;
- chemistry.

Toxicity

- Toxicity represents the potential damage to life and can be both short and long term.
- It is related to the concentration of pollutant and the time of exposure to it, though this relationship is not an easy one.
- Intrinsically highly toxic substances can kill in a short time, while less toxic ones require a longer period of exposure to do damage. This much is fairly straightforward. However, some pollutants which may kill swiftly in high concentrations, may also have an effect on an organism's behaviour or its susceptibility to environmental stress over its lifetime, in the case of low concentration exposure.

- Availability also features as an important influence, both in a gross, physical sense and also in terms of its biological availability to the individual organism, together with issues of its age and general state of health.
- Other considerations also play a significant part in the overall picture of toxicity

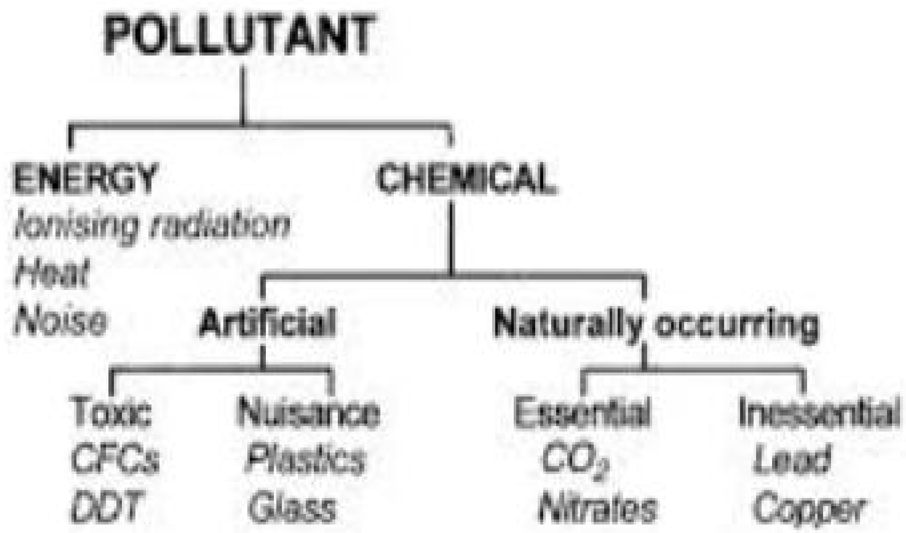


Figure 4.1 *Pollution classification*

Persistence

- This is the duration of effect.
- Environmental persistence is a particularly important factor in pollution and is often linked to mobility and bioaccumulation.
- Highly toxic chemicals which are environmentally unstable and break down rapidly are less harmful than persistent substances, even though these may be intrinsically less toxic.

Mobility

- The tendency of a pollutant to disperse or dilute is a very important factor in its overall effect, since this affects concentration.
- Some pollutants are not readily mobile and tend to remain in 'hot-spots' near to their point of origin.
- Others spread readily and can cause widespread contamination, though often the distribution is not uniform.
- Whether the pollution is continuous or a single event, and if it arose from a single point or multiple sources, form important considerations.

Ease of control

- Many factors contribute to the overall ease with which any given example of pollution can be controlled, including the mobility of the pollutant, the nature, extent or duration of the pollution event and local site-specific considerations.
- Clearly, control at source is the most effective method, since it removes the problem at its origin.
- However, this is not always possible and in such cases, containment may be the solution, though this can itself lead to the formation of highly concentrated hot-spots.

Bioaccumulation

- As is widely appreciated, some pollutants, even when present in very small amounts within the environment, can be taken up by living organisms and become concentrated in their tissues over time.
- This tendency of some chemicals to be taken up and then concentrated by living organisms is a major consideration, since even relatively low background levels of contamination may accumulate up the food chain.

Chemistry

- Pollution effects are not always entirely defined by the initial nature of the contamination, since the reaction or breakdown products of a given pollutant can sometimes be more dangerous than the original substance.
- This is of particular relevance to the present discussion, since the principle underlying much of practical bioremediation in general involves the break down of pollutants to form less harmful products.

- This is further complicated in that while the chemistry of the pollutant itself is clearly important, other substances present and the geology of the site may also influence the outcome.
- Accordingly, both synergism and antagonism are possible. In the former, two or more substances occurring together produce a combined pollution outcome which is greater than simply the sum of their individual effects; in the latter, the combined pollution outcome is smaller than the sum of each acting alone.

The Pollution Environment

- It is important to remember that pollution cannot properly be assessed without a linked examination of the environment in which it occurs.
- The nature of the soil or water which harbors the pollution can have a major effect on the actual expressed end-result.
- In the case of soil particularly, many properties may form factors in the modification of the contamination effect.
- Hence, the depth of soil, its texture, type, porosity, humus content, moisture, microbial complement and biological activity can all have a bearing on the eventual pollution outcome.
- Inevitably, this can make accurate prediction difficult, though a consideration of system stability can often give a good indication of the most likely pollution state of a given environment.

- The more stable and robust the environmental system affected, the less damage a given pollution event will inflict and clearly, fragile ecosystems or sensitive habitats are most at risk.
- It should be obvious that, in general terms, the post pollution survival of a given environment depends on the maintenance of its natural cycles.
- Equally obviously, artificial substances which mimic biological molecules can often be major pollutants since they can modify or interrupt these processes and pollution conversion can spread or alter the effect.

Pollution Control Strategies

Dilution and dispersal:

- In principle, it involves the attenuation of pollutants by permitting them to become physically spread out, thereby reducing their effective point concentration.
- The dispersal and the consequent dilution of a given substance depends on its nature and the characteristics of the specific pathway used to achieve this.
- It may take place, with varying degrees of effectiveness, in air, water or soil

Air

- In general terms, air movement gives good dispersal and dilution of gaseous emissions. However, heavier particulates tend to fall out near the source and the mapping of pollution effects on the basis of substance weight/distance travelled is widely appreciated.

WATER

- Typically, there is good dispersal and dilution potential in large bodies of water or rivers, but smaller watercourses clearly have a correspondingly lower capacity. It is also obvious that moving bodies of water disperse pollutants more rapidly than still ones

Soil

- Movement through the soil represents another opportunity for the dilute and disperse approach, often with soil water playing a significant part, and typically aided by the activities of resident flora and fauna. The latter generally exerts an influence in this context which is independent of any bioaccumulation potential.

Concentration and containment

- Instead of relying on the pollutant becoming attenuated and spread over a wide area, it is an attempt to gather together the offending substance and prevent its escape into the surrounding environment.
- The inherent contradiction between these two general methods is an enduring feature of environmental biotechnology and, though the fashion changes from time to time, favoring first one and then the other, it is fair to say that there is a place for both, dependent on individual circumstances.
- As with so much relating to the practical applications of biotechnologies to environmental problems, the idea of a 'best' method, at least in absolute terms, is of little value.
- The whole issue is far more contextually sensitive and hence the specific modalities of the particular, are often more important concerns than the more theoretically applicable general considerations.

Practical Toxicity Issues

- There are two main mechanisms, often labelled ‘direct’ and ‘indirect’.
- In the former, the effect arises by the contaminant combining with cellular constituents or enzymes and thus preventing their proper function.
- In the latter, the damage is done by secondary action resulting from their presence, typified by histamine reactions in allergic responses.

- The significance of natural cycles to the practical applications of environmental biotechnology is a point that has already been made.
- In many respects the functional toxicity of a pollution event is often no more than the obverse aspect of this same coin, in that it is frequently an overburdening of existing innate systems which constitutes the problem.
- Thus the difficulty lies in an inability to deal with the contaminant by normal routes, rather than the simple presence of the substance itself.
- The case of metals is a good example. Under normal circumstances, processes of weathering, erosion and volcanic activity lead to their continuous release into the environment and corresponding natural mechanisms exist to remove them from circulation, at a broadly equivalent rate.
- However, human activities, particularly after the advent of industrialisation, have seriously disrupted these cycles in respect of certain metals, perhaps most notably cadmium, lead, mercury and silver.

Practical Applications to Pollution Control

- Bacteria normally live in an aqueous environment which clearly presents a problem for air remediation.
- Frequently the resolution is to dissolve the contaminant in water, which is then subjected to bioremediation by bacteria, as in the following descriptions.
- However, there is scope for future development of a complementary solution utilising the fact that many species of yeast produce aerial hyphae which may be able to metabolise material directly from the air.

- A variety of substances can be treated, including volatile organic carbon containing compounds (VOCs) like alcohols, ketones or aldehydes and odorous substances like ammonia and hydrogen sulphide (H2S).
- While biotechnology is often thought of as something of a new science, the history of its application to air-borne contamination is relatively long.
- The removal of H2S by biological means was first discussed as long ago as 1920 and the first patent for a truly biotech-based method of odour control was applied for in 1934.

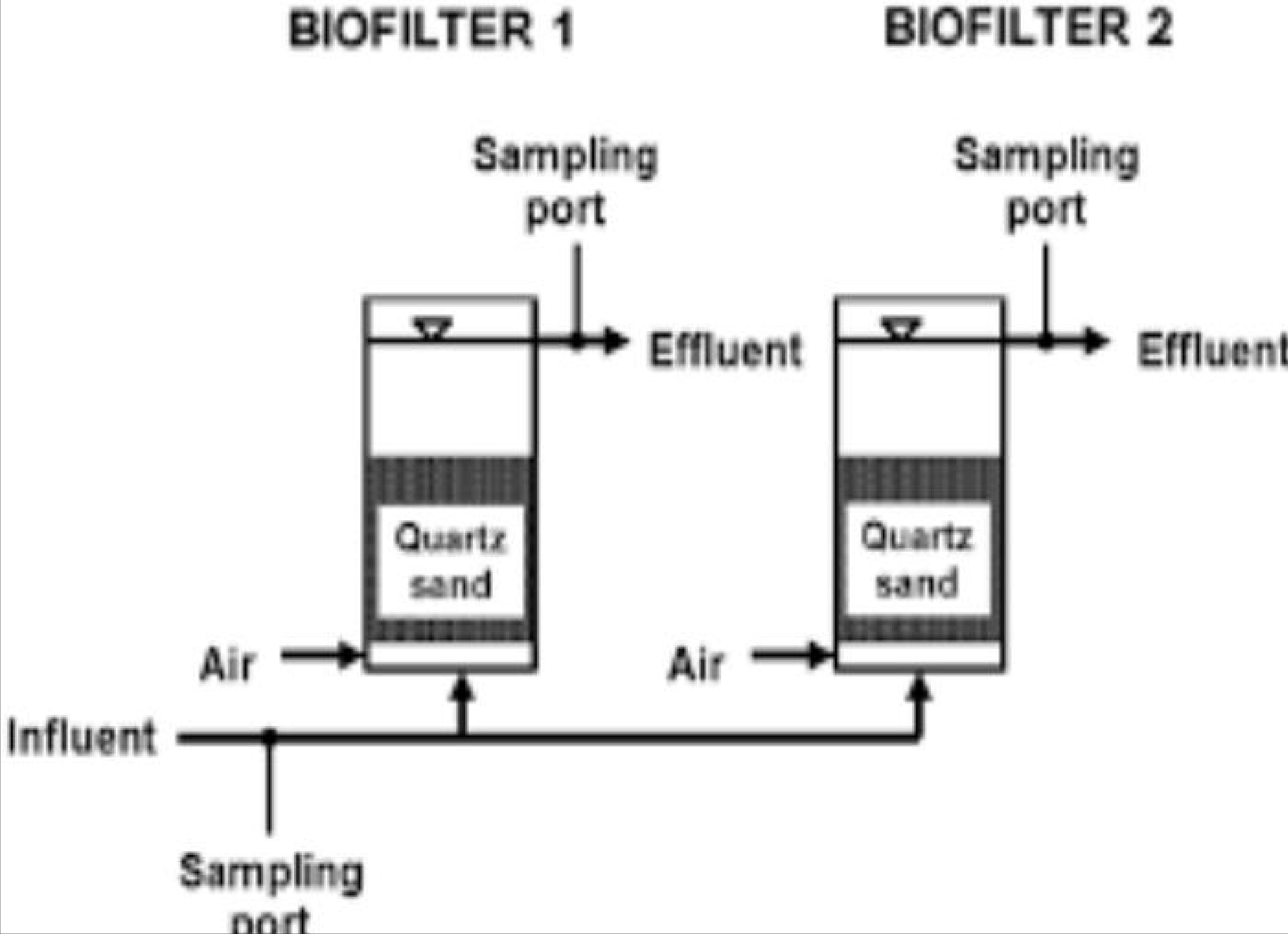
- It was not until the 1960s that the real modern upsurge began, with the use of mineral soil filter media and the first true biofilters were developed in the succeeding decade.
- This technology, though refined, remains in current use.
- The latest state-of-the-art developments have seen the advent of the utilisation of mixed microbial cultures to degrade xenobiotics, including chlorinated hydrocarbons like dichloromethane and chlorobenzene.
- A number of general features characterise the various approaches applied to air contamination.
- Typically systems run at an operational temperature within a range of 15–30◦C, in conditions of abundant moisture, at a pH between 6–9 and with high oxygen and nutrient availability.

- In addition, most of the substances which are commonly treated by these systems are water soluble.
- The available technologies fall naturally into three main types, namely biofilters, biotrickling filters and bioscrubbers.
- To understand these approaches, it is probably most convenient to adopt a view of them as biological systems for the purification of waste or exhaust gases.
- All three can treat a wide range of flow rates, ranging from 1000–100000m3/h, hence the selection of the most appropriate technology for a given situation is based on other criteria.

Biofilters

- These were the first methods to be developed.
- It consists of a relatively large vessel or container, typically made of cast concrete, metal or durable plastic, which holds a filter medium of organic material such as peat, heather, bark chips and the like.
- The gas to be treated is forced, or drawn, through the filter,
- The medium offers good water-holding capacity and soluble chemicals within the waste gas, or smelt, dissolve into the film of moisture around the matrix. Bacteria, and other micro-organisms present, degrade components of the resultant solution, thereby bringing about the desired effect.

- The medium itself provides physical support for microbial growth, with a large surface area to volume ratio, high in internal void spaces and rich in nutrients to stimulate and sustain bacterial activity.
- Biofilters need to be watered sufficiently to maintain optimum internal conditions, but waterlogging is to be avoided as this leads to compaction, and hence, reduced efficiency. Properly maintained, biofilters can reduce odour release by 95% or more.



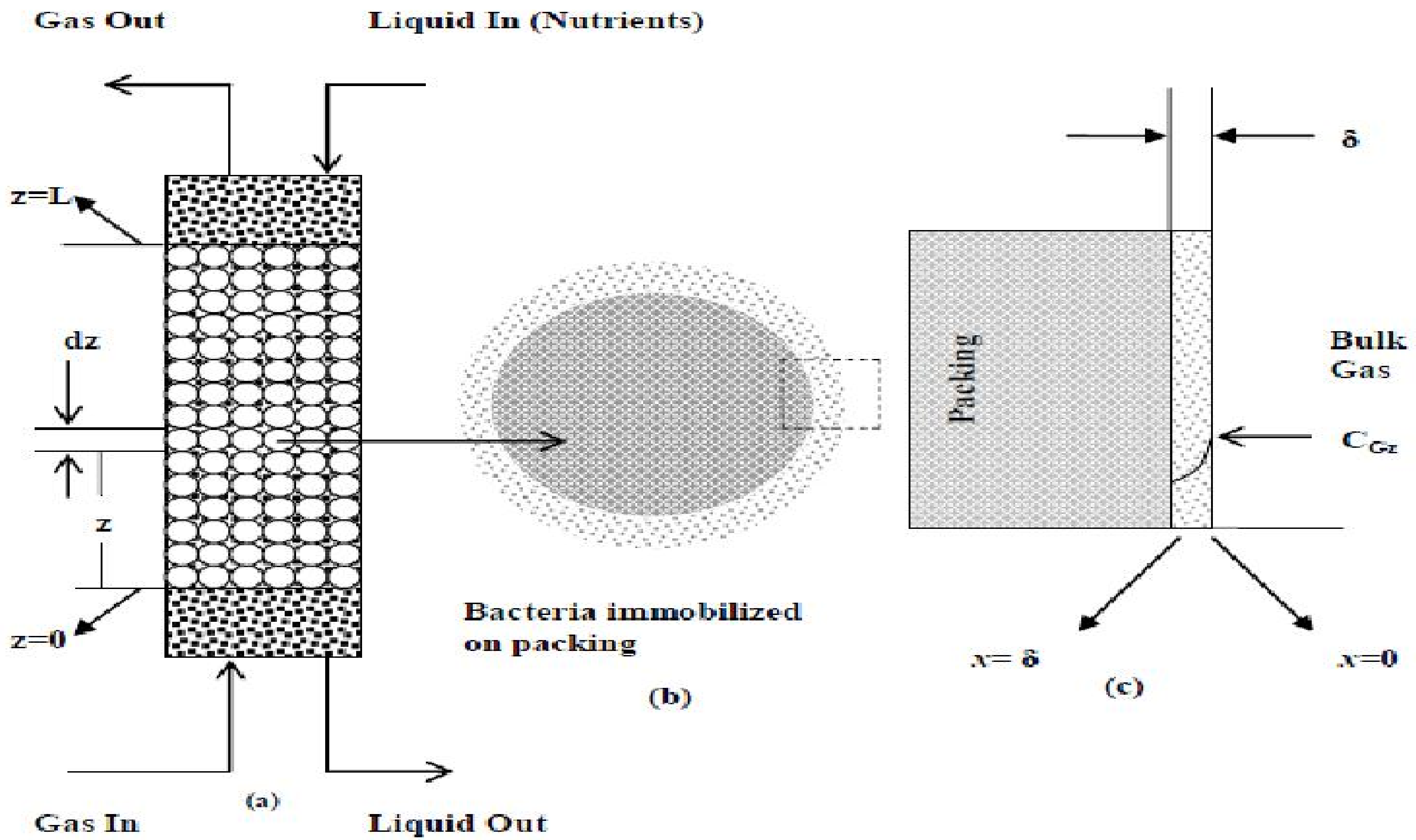
BIOFILTER 1
BIOFILTER 2
Sampling port
Sampling port
Effluent
Effluent
Quartz sand
Quartz sand
Air
Air
Influent
Sampling port

Biotrickling filters

- In many respects these represent an intermediate technology between biofilters and bioscrubbers, sharing certain features of each.
- Once again, an engineered vessel holds a quantity of filter medium, but in this case, it is an inert material, often clinker or slag.
- Being highly resistant to compaction, this also provides a large number of void spaces between particles and a high surface area relative to the overall volume of the filter.
- The microbes form an attached growth biofilm on the surfaces of the medium.
- The odourous air is again forced through the filter, while water simultaneously recirculates through it, trickling down from the top, hence the name.

- Thus a counter-current flow is established between the rising gas and the falling water, as shown in the diagram, which improves the efficiency of dissolution.
- The biofilm communities feed on substances in the solution passing over them, biodegrading the constituents of the smell.
- Process monitoring can be achieved relatively simply by directly sampling the water recirculating within the filter vessel. Process control is similarly straightforward, since appropriate additions to the circulating liquid can be made, as required, to ensure an optimum internal environment for bacterial action.
- Though the efficiency of the biotrickling filter is broadly similar to the previous method, it can deal with higher concentrations of contaminant and has a significantly smaller foot-print than a biofilter of the same throughput capacity.

- However, as with almost all aspects of environmental biotechnology, these advantages are obtained by means of additional engineering, the corollary of which is, inevitably, higher capital and running costs.

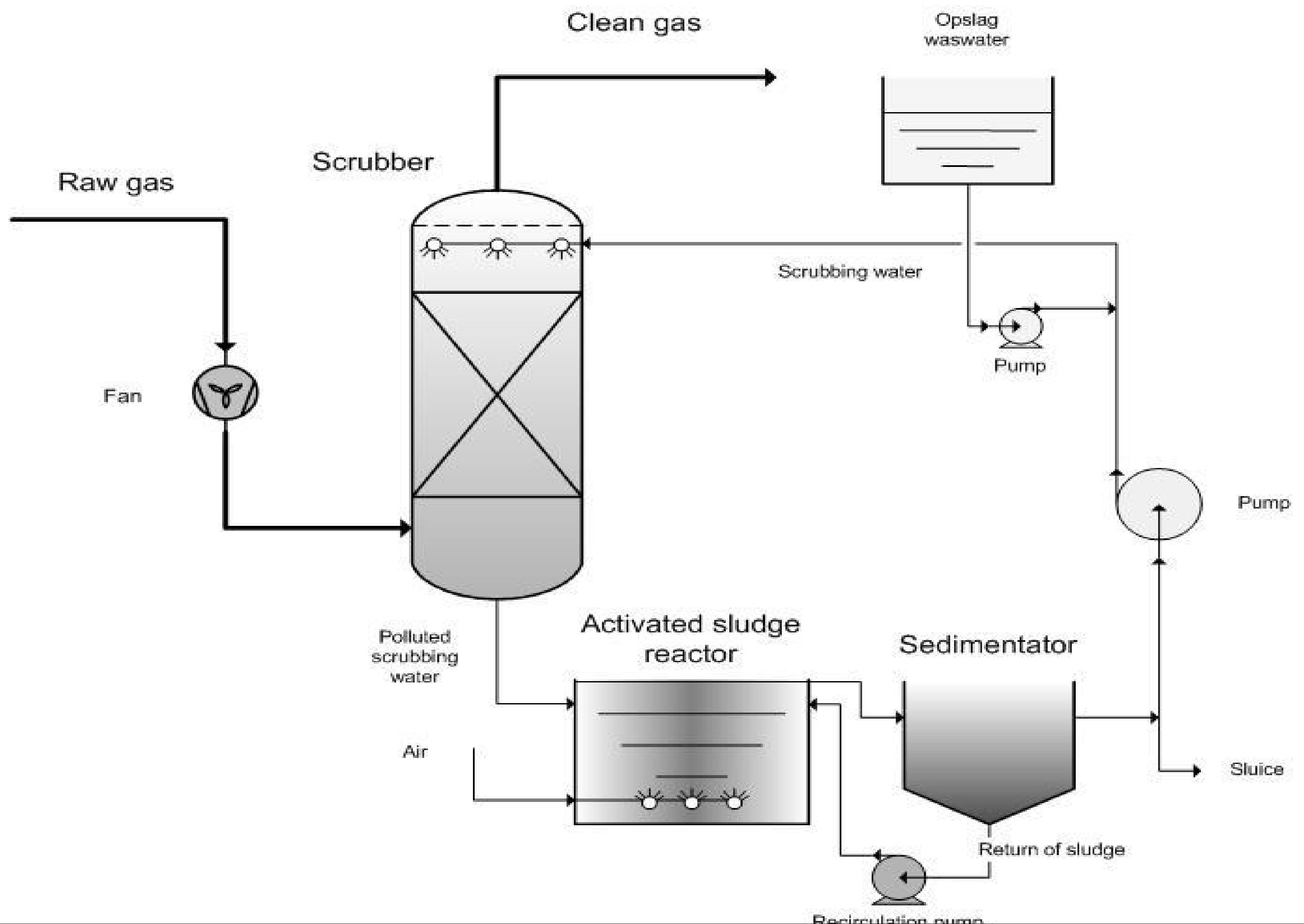


Bioscrubbers

- Although it is normally included in the same group, the bioscrubber is not itself truly a biological treatment system, but rather a highly efficient method of removing odour components by dissolving them. Unsurprisingly, then, it is most appropriate for hydrophilic compounds like acetone or methanol.
- The gas to be treated passes through a fine water spray generated as a mist or curtain within the body of the bioscrubber vessel.
- The contaminant is absorbed into the water, which subsequently pools to form a reservoir at the bottom. The contaminant solution is then removed to a secondary bioreactor where the actual process of biodegradation takes place.

- As in the preceding case, process control can be achieved by monitoring the water phase and adding nutrients, buffers or fresh water as appropriate.

Bioscrubber



Other options

- **Absorption:**

Absorbing the compound in a suitable liquid; this may oxidise or neutralise it in the process.

- **Adsorption :**

Activated carbon preferentially adsorbs organic molecules; this can be tailored to give contaminant-specific optimum performance.

- **Incineration:**

High temperature oxidation; effective against most contaminants, but costly.

- **Ozonation:**

Use of ozone to oxidise some contaminants, like hydrogen sulphide; effective but can be costly.

- The main advantages of biotechnological approaches to the issue of air contamination can be summarised as:
- competitive capital costs;
- low running costs;
- low maintenance costs;
- low noise;
- no carbon monoxide production;
- avoids high temperature requirement or explosion risk;
- safe processes with highly ‘green’ profile;
- robust and tolerant of fluctuation.

Clean’ Technology

- The mechanisms by which pollution or waste may be reduced at source are varied.
- They may involve changes in technology or processes, alteration in the raw materials used or a complete restructuring of procedures.
- Generally speaking, biotechnological interventions are principally limited to the former aspects, though they may also prove instrumental in permitting procedural change.
- The main areas in which biological means may be relevant fall into three broad categories:
- process changes;
- biological control;
- bio-substitutions.

Process Changes

- Placement of existing chemical methods of production with those based on microbial or enzyme action is an important potential area of primary pollution prevention and is one role in which the use of genetically modified organisms could give rise to significant environmental benefit.
- Biological synthesis, either by whole organisms or by isolated enzymes, tends to operate at lower temperatures and, as a result of high enzymatic specificity, gives a much purer yield with fewer byproducts, thus saving the additional cost of further purification.
- There are many examples of this kind of industrial usage of biotechnology. In the cosmetics sector, there is a high demand for isopropyl myristate which is used in moisturising creams.
- The conventional method for its manufacture has a large energy requirement, since the process runs at high temperature and pressure to give a product which needs further refinement before it is suitable for use.

- An alternative approach, using enzyme-based esterification offers a way to reduce the overall environmental impact by deriving a cleaner, odour-free product, and at higher yields, with lower energy requirements and less waste for disposal.

Biological Control

- The use of insecticides and herbicides, particularly in the context of agricultural usage, has been responsible for a number of instances of pollution and many of the chemicals implicated are highly persistent in the environment.
- Though there has been a generalised swing away from high dosage chemicals and a widespread reduction in the use of recalcitrant pesticides, worldwide there remains a huge market for this class of agrochemicals.
- As a result, this is one of the areas where biotechnological applications may have significant environmental impact, by providing appreciably less damaging methods of pest management.

- The whole concept of biological control took a severe blow after the widely reported, disastrous outcome of Australia's attempts to use the Cane Toad (Bufo marinus) to control the cane beetle.
- However, in principle, the idea remains sound and considerable research effort has gone into designing biological systems to counter the threat of pests and pathogens.
- The essence of the specifically environmental contribution of this type of biointervention lies in its ability to obviate the need for the use of polluting chemicals and, consequently, leads to a significant reduction in the resultant instances of contamination of groundwater or land.

- However, one of the major limitations on the effective use of biocontrols is that these measures tend to act more slowly than direct chemical attacks and this has often restricted their use on commercial crops.
- In fairness, it must be clearly stated that biotechnology per se is not a central, or even necessary, requirement for all of biological control, as many methods rely on whole organism predators, which, obviously, has far more bearing on an understanding of the ecological interactions within the local environment.
- However, the potential applications of biotechnology to aspects of pest/pathogen/organism dynamics, has a supportive role to play in the overall management regime and, thus, there exists an environmental dimension to its general use in this context.

- Biological control methods can provide an effective way to mitigate pesticide use and thus the risk represented to the environment and to public health.
- In addition, unlike most insecticides, biocontrols are often highly target-specific reducing the danger to other nonpest species.
- Against this, biological measures typically demand much more intensive management and careful planning than the simple application of chemical agents.
- Success is much more dependent on a thorough understanding of the life-cycles of the organisms involved and can often be much more of a long-term project.

- In addition, though high specificity is generally, a major advantage of biocontrol measures, under some circumstances,
- if exactly the right measure is not put in place, it may also permit certain pests to continue their harmful activities unabated.
- Considering the huge preponderance of insect species in the world, a large number of which pose a threat to crops or other commodities and thus represent an economic concern,
- it is small wonder that the global insecticide market has been estimated at over $8 billion (US) per year.
- Accordingly, much of the biological control currently in practice relates to this group of animals.

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Semiochemical agents

- However, perhaps one of the best examples of the use of such biological technologies in pest control is the development of isolated or synthesised semiochemical agents.
- Semiochemicals are natural messenger substances which influence growth,development or behaviour in numerous plant and animal species and include the group known as pheromones, a number of which are responsible for sexual attraction in many insects.
- This has been successfully applied to control various forms of insect pests, either directly to divert them from crops and trap them, or indirectly to trap their natural enemies in large numbers for introduction into the fields for defence.

Pollution indicators/Bioindicators

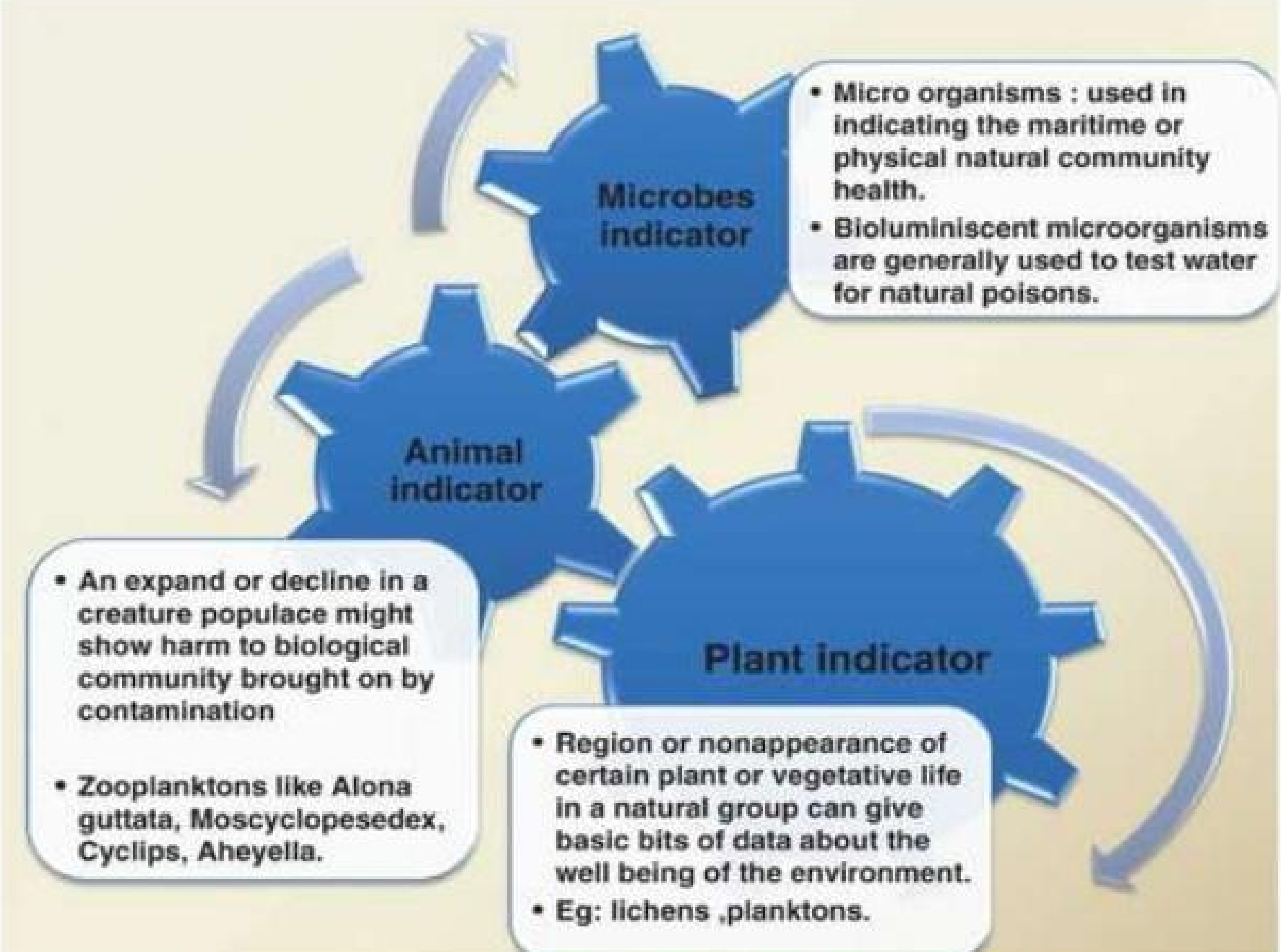
Introduction

- Bioindicators are the organism that indicate or monitor the health of the environment .
- A good bioindicator will indicate the presence of the pollutant and also attempt to provide additional information about the amount and intensity of the exposure.

- Naturally occurring Bioindicators are used to assess the health of the environment and are also an important tool for detecting changes in the environment, either positive or negative, and their subsequent effects on human society.
- There are a certain factors which govern the presence of Bioindicators in environment such as transmission of light, water, temperature, and suspended solids. Through the application of Bioindicators we can predict the natural state of a certain region or the level/degree of contamination.

HOW ARE THEY USED ?

- Different bioindicators are sensitive to different types of changes.
- Scientists observe changes in the populations of animal and plants bioindicators to see if an environment is healthy .
- Biological response of bioindicator reveals the presence of the pollutants by the occurrence of typical symptoms or measurable responses, and is therefore more qualitative .


Microbes indicator
• Micro organisms : used in indicating the maritime or physical natural community health.
• Bioluminiscent microorganisms are generally used to test water for natural poisons.
Animal indicator
• An expand or decline in a creature populace might show harm to biological community brought on by contamination
• Zooplanktons like Alona guttata, Moscyclopesedex, Cyclips, Aheyella.
Plant indicator
• Region or nonappearance of certain plant or vegetative life in a natural group can give basic bits of data about the well being of the environment.
• Eg: lichens ,planktons.

BASED ON IUBS BIOINDICATORS ARE GROUPED INTO

A. Microbial system

B. Plants system

C. Animal system

D. Cell biology and genetics system

IUBS= International Union of Biological Sciences

A. MICROBIAL SYSTEM

- Microorganisms are diverse group of organisms found in large quantities and are easier to detect and sample.
- The presence of some microorganisms is well correlated with particular type of pollution and it serves as standard indicator of pollution.

- Some bio indicators indicating status of aquatic systems Micro organism/bacteria Status

Micro organism/bacteria	Status of aquatic system
Escherichia coli	Faecal origin
Streptococcus faecalis	-do-
kliebsella	-do-
Clostridium perfringens	-do-
C.perfringens	-do-
Spirillium volutants *pores*	Industrial chemicals and toxic chemical wastes

Bioluminescent bacteria as bioindicators:

- Bioluminescent bacteria:
  - These are used to test water for environmental toxins
  - If there are toxins present in the water, the cellular metabolism of bacteria is inhibited or disrupted
  - This affects quality or amount of light emitted by bacteria
  - It is very quick method and takes just 30 minutes to complete but could not identify the toxin *Vibrio fischeri*

B. PLANT SYSTEM

- The presence or absence of certain plant or other vegetative life in an ecosystem can provide important clues about the health of the environment. They can be from both higher and lower classes of Plantae

Lower Plants:

- Different plants indicate the nature of environment. The susceptibility of resistance towards a substance in the environment varies with species. For e.g. lichens

Higher Plants:

- Various groups of higher plants serve as bioindicators. Sensitive species are employed to detect and monitor specific air pollutants. Studies on higher plants are more specified on its ability to indicate the heavy metal pollution in water.

LOWER PLANTS

- Lichens are alga and fungi living symbiotically (they have to live together to survive).
- Lichens can live in extreme conditions, but they hate pollution
- The cleaner the air the bigger and more elaborate the lichen.
- So by looking at the lichens growing in a certain area you can tell how bad the air pollution is.
- Changes in Diatom community , decrease in plankton algae and aquatic hydrophyte indicated increased water acidity . Specific changes in aquatic flora can indicate the pH of the fresh water correctly.

HIGHER PLANTS

- The chlorite flakes of pine needle are good examples of ozone damages.
- The collapse, glazing and bronzing of leaf cells are products of damage by peroxyacetyl nitrate (PAN).
- *Caesalpinia pulcherrima* and grass (Cyndon dactylon) was evaluated as the bioindicators of heavy metals such as the Lead (Pb), Copper (Cu), Cadmium (Cd), Manganese (Mn), Zinc (Zn), Chromium (Cr) and Nickel (Ni)

C. ANIMAL SYSTEM

- An increase or decrease in an animal population may indicate damage to ecosystem caused by pollution.
- In addition to monitoring the size and number of certain species, other mechanisms of animal indication include monitoring the concentration of toxins in animal tissues, or monitoring the rate at which deformities arise in animal population.

- Earthworm density and biomass are strongly influenced by contamination. Therefore the earth worm is used as bioindicator to determine acute toxicity.
- Frogs are considered accurate indicators of environmental stress and the health of biosphere as a whole.
- Fish is a good indicator of water pollution .
- Macro invertebrates are often used as bioindicators because they are very sensitive to pollution, excess nutrients, increased turbidity, chlorine, etc.

D. CELL BIOLOGY, GENETICS SYSTEM

- Cellular and sub-cellular components, including chromosomes, adapted to specific environmental conditions, form an excellent parameter for bioindicator.
- Many animals show behavioral responses following the detection of environmental changes in the functioning of endocrine, nervous, muscular, cardiovascular and excretory systems.
- Such changes may be investigated at morphological, biochemical or physiological levels and can indicate the presence of toxic substances

Criteria for selecting bioindicator

- Sensitivity – dose responsiveness to specific stressors .
- Specificity – responds to specific stressors
- Broad Applicability – over temporal and spatial scale .
- Representativeness – role as surrogate for other responses .
- Cost – reasonable for available resources and scope of study .

Why are Bioindicators Better than Traditional Methods?

- Scientists have traditionally conducted chemical assays and directly measured physical parameters of the environment (e.g., ambient temperature, salinity, nutrients, pollutants and gas levels), whereas the use of bioindicators uses the biota to assess the cumulative impacts of both chemical pollutants and habitat alterations over time.
- Bioindicators have the ability to indicate indirect biotic effects of pollutants when many physical or chemical measurements cannot.

Bioindicator and biomonitoring

- Bioindicators qualitatively assesses biotic responses to environmental stress (e.g., absence of lichen indicates poor air quality) while biomonitors quantitatively determine a response (e.g., reductions in lichen chlorophyll content or diversity indicates the presence and severity of air pollution)
- Chemical measurement of pollutant area is like snapshot of that area while biological measurement is like taking video tape.
- Bioindicators actually indicate the general toxicity of the environment , without telling the exact quantity of the toxicity .

- Through bioindicators scientists need to observe only the single indicating species to check on the environment , they don't have to monitor whole community.