COURES CODE: *SOS 516*

COURSE TITLE: *Soil Pollution Management*

NUMBER OF UNITS: 2 *Units*

COURSE DURATION: *Two hours per week*

COURSE DETAILS:

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COURSE CONTENT:

Major components of the environment; atmosphere, pedosphere, hydrosphere, and biosphere. Soil as an integral part of the environment. Soil quality and functions of soils. Impact of soil quality on ecosystem sustainability. Soil and pollution: chemical, physical and biological soil degradation; mechanisms of pollutant transport through soils. Types and sources of soil chemical pollutants; inorganic, organic and radionuclide contaminants. Major consequences of chemically degraded soils. Greenhouse gas emissions and mitigation. Environmental effects of organic and inorganic amendments including agrochemicals. Waste disposal; evaluation and management of contaminated sites. Soil remediation; physical, chemical and biological remediation including phyto-remediation.

Practical: Analyses of soils from industrial, agricultural and forest sites. Water analyses. Solute movement in soils. Analyses of soil gaseous phase.

COURSE REOUIREMENTS:

This is a compulsory course for all final year students in the Department of Soil Science, College of Plant Science and Crop Production (COLPLANT). In view of this, students are expected to participate in all course activities and have a minimum of 75 % attendance to be able to write the final examination.

READING LIST

1. Brady, N. C. and R. R. Weil. *The Nature and Properties of Soils*. 12^{th} ed. Prentice-Hall, New Jersey: Prentice-Hall Incorporated, 1999.
2. He, Z. L., X. E. Yang., P. J. Stoffella. 2005. Trace elements in agroecosystems and impacts on the environment. Journal of Trace Elements in Medicine and Biology 19:125–140.
3. Kabata-Pendias, A. 2004. Soil-plant transfer of trace elements-an environmental issue. Geoderma 122:143-149.

LECTURE NOTES:

1.0 The Environment

1.1 Definition: Is all of the external factors affecting an organism. These factors may be other living organisms (biotic factors) or non-living variables (abiotic factors such as temperature, rainfall, day length, wind and ocean currents. The interactions of organisms with biotic and abiotic factors form an ecosystem. Ecosystem refer to organisms living in a particular environment such as forest or a coral reef and the physical parts of the environment that affect them.

1.2 **Major Component**

The major components of the environment are:

1. The lithosphere i.e. the worlds of rock
2. The atmosphere i.e. the air
3. The hydrosphere, i.e. region occupied by water
4. Biosphere i.e. the living things
5. Pedosphere i.e. the soil

Note: Environment where all of those worlds interact are often the most complex and productive on earth, i.e. the soil.

2.0 Soil as Environmental Interface

The importance of soil as a natural body derives in large part from its role as an interface between the worlds of rock, air, water and biosphere.

The concept of the soil as interface means different things at different scales. **At the scale of kilometres**, soil channel waters from rain to rivers and transfer mineral elements from rocks to the oceans. They also run over and supply vast amount of atmospheric gases substantially influencing the global balance of methane and CO_2. **At a scale of few meters**, soil forms the transition zone between hard rock and air, holding both liquid water and O_2 gas often used by plant roots. It transfers mineral elements from the earths' crust to its vegetation. It processes or stores the organic remains of terrestrial plants animals and man. **At a scale of few millimetres,** soil provides diverse microhabitats for air-breathing and aquatic organism, channels water and nutrients to plant roots and provides surface and solution vessels for thousands of biochemical reactions. Finally, **at a scale of a few micrometers and less**, soil provides ordered and complex surfaces, both mineral and organic that acts as templates for chemical reactions and interacts with water and solutes. Also, at this scale its tiniest mineral particles form micro-zones of electromagnetic charge that attract everything from bacterial cell wall to proteins to conglomerates of water molecules

3.0 Factors Threatening the Environment

1. Population Growth
2. Global Warming

3. Depletion of the Ozone layer
4. Habitat destruction and species extinction
5. Air pollution
6. Water pollution
7. Ground water depletion and contamination
8. Chemical risks- Toxic substances that humans encounter regularly which poses health risks.
9. Environmental Racism- Studies have shown that not all individual are equally exposed to pollution
10. Energy production- Typical example i.e. environmental effects of the fossil fuel age.

NOTE: There are a lot of international treaties to combat these global problems

4.0 The Concept of Environmentalism

Environmental quality seems to be a new topic when in fact; the current emphasis on environmental quality is a renewed interest in an old topic. We are becoming increasingly aware that exposure to various substances may cause human health problems ranging from death to subclinical effects such as attention deficit syndrome. The natural tendency is to eliminate or reduce our exposure to substances that we suspect may adversely affect human health.

An environmentalist is a person who works towards solving environmental problems and environmentalism is an attitude by a group of individuals, perhaps the whole society that the environment takes a high priority in the decision-making process. A more philosophical approach categorizes an individual's attitude about the environment into one of the three groups, namely:

1. Egocentric- In which an individual in an individual's action are guided solely by concern for him or herself

2. Homocentric- meaning concern for the human species

3. Ecocentric- meaning an overall concern for the environment.

Society as a whole and most individual have progressed slowly from egocentric attitudes towards more ecocentric attitudes.

5.0 SOIL QUALITY AND FUNCTIONS OF SOIL

Introduction

As compared to the environment of compartments air and water, soil is an extremely complex system. This is due to a huge variety of soil properties and chemical, physical and biological system conditions. The combination of these makes the development of general rules for quantitative evaluation of soil quality impossible. This is because soils have a much higher buffering capacity than air and water. This property (buffering capacity) is the capacity to allow contents of compounds, once present at optimum level, to increase without actual occurrence at negative effects.

5.1 Soil Quality in Relation to Soil Functions

The quality of soil is adversely influenced by contamination (pollution) of the system. The concepts of “contamination” and “pollution” of soil are used in a comparable way as they reflect only a difference in degree of drainage to the soil system. Any addition to soil, i.e contaminants- meaning the compounds that may exert adverse effect on soil functioning. It can be defined as soil contamination. Because most soils do have a certain buffering capacity, it usually takes some time before the negative effects become apparent. Once this situation occur, the soil can be considered as polluted, which for all practical purposes means that malfunctioning or dysfunctioning of the soil is apparent due to abundant pressure or availability of the compounds. Such malfunctioning may refer to one specific function in a particular but sometimes also in combination of different functions are:

1) The bearing function: For instance as playground for children and for building of houses/structures.

2) The Plant growth function: This may refer to natural vegetation and the production of crops for animal and human consumption

3) The filtering function of water: Ground water as well as surface water

4) The ecological function of soil: With its contribution to element cycling as an important aspect

Proper functioning of soil as stated above imposes a wide variety of quality criterion. This strongly hampers the introduction of a quality assessment methodology with general applicability and validity. At first sight, the bearing function would probably be the least demanding, at least once certain physical requirements are met. However, experience has shown that for building of houses, some minimal requirements of chemical conditions in the soil are needed; and a combination of use of the same site for waste disposal and later for urban expansion ie not always without problems.

Methods to assess health risks for people living in an area where there is unconscious combination of soil usages or in polluted areas, requires insight in the quantitative relationships between pollutant exposure of the organism under consideration on one side and the resulting effects to be expected from the exposure on the other side.

In the case of human, the exposure pathways are:

1) Soil ingestion, especially for children

2) Inhalation of air ,containing volatile polluting compounds

3) Drinking water

4) Food in the form of plant products and animal products

5) Radiation exposure

As a result of the adverse effects of heavy metals and other contaminants, environmental agencies proposed critical levels in soil above which toxicity is considered to be possible. For example the Table below shows the normal range and critical total concentrations of heavy metals for soil (Kabata-Pendias and Pendias, 1984).

Elements	Normal range in soil(mg/kg)	Critical soil total conc(mg/kg)
Cd	0.01-2.0	3-8
Co	0.5-6.5	25-50
Cr	5-1500	75-100
Hg	0.01-0.5	60-125
Pb	2-300	100-400
Ni	2-750	100

6.0 POLLUTION AND CONTAMINATION

6.1 *Preface:* The term contaminant is often used synonymously with pollutant, although difference in the definitions would indicate that these terms are not interchangeable.

Contaminant implies concentration of a substance is higher than would naturally occur but does not necessarily mean that the substance is causing any harm. However, pollution refers to a situation in which the concentration of a substance in which the concentration of a substance is higher than would naturally occur but also indicate that the substance is causing harm of some type. Therefore, a soil could be contaminated but not polluted. Pollution is often broadly categorized according to its source:

Point-source pollution: As the name implies, is pollution with a clearly identifiable point of discharge. E.g. waste water treatment plant etc

Nonpoint-source pollution: Is pollution without an obvious single point of discharge. E.g. Surface runoff of a commonly used lawn herbicide.

6.2 *Classification of Potential Pollutants*

Pollutant	Examples
Nutrients	N and P in commercial fertilizers, manures, biosolids
	Waste water treatment effluent
Agrochemicals	Insecticides ,herbicides, fungicides etc
Hazardous organic chemicals	Strong acids and bases
Acidification	Acid precipitation, acid mine drainage
Salinity or Sodicity	Saline irrigation water, salt water intrusion
Trace elements	Heavy metals, elements normally present at low
	Concentration in soil and plant
Sediments	Eroded soil in surface waters
Particulates	Dust (from wind erosion),volcanic dust ash

Greenhouse gases	$CO2$,$CH4$ and other relatively active gases
Smog form of compounds	Ozone, secondary products of fuel combustion

6.3 Mechanism of Pollution Transport through soil

6.3.1 Contaminant Fate and Transport

FATE: The environment plays a key role in the ultimate fate and transport of contaminants. The specific fate of contaminant following their release into the environment, depends on their chemical structure which is highly variable, abiotic factors within the receiving environment (e.g. organic carbon ,ph ,surface water) and interaction with the biotic environment which can result in degradation, transformation or bioconcentration of the contaminants. Once contaminants also reach the soil, they move in one of these directions:

1) Vapourized into the atmosphere without chemical change
2) Absorbed by soils, move downward through the soil in liquid or solution form and can be lost from the soil by leaching.
3) Undergo chemical reactions within or on the surface of the soil
4) Broken down by soil micro-organisms
5) Washed into streams and rivers in surface run-off
6) Taken up by plants or soil animal and move up the food chain

Transport Mechanisms

Channels or contaminants are transported through soil principally by 3 mechanisms:

1. Massflow of dissolved chemicals within moving solution

2. Liquid diffusion within soil solution

3. Gaseous diffusion within soil air voids.

1. Massflow: Refers to the passive transport of dissolved solution within moving soil water which is approximated as the product of the volume flux of water times the dissolved solute concentration.

2. Liquid diffusion: Refers to the transport of the dissolved solutes within solution by intermolecular collision which moves the solutes from regions of higher solute density to lower solute density(concentration)

$$q_c = Ddc/dx$$

3. Vapour diffusion- Chemical Vapour

Molecules in the soil air spaces also undergo molecular collision and spread out by vapour diffusion which is expressed as the product of the vapour density or concentration gradient and a proportionality coefficient called the soil vapour diffusion coefficient

6.4 LOSS PATHWAYS OF CONTAMINANTS IN SOIL

Contaminants added to a soil from the surface may leave the zone of incorporation by one of these three loss pathways.

1. Leaching takes place principally by mass flow and refers to the downward movement of the contaminants

2. Volatilization: Refers to the loss of contaminants in vapour form to the atmosphere through the soil surface

3. Degradation: Refers to the biological or chemical transformation of the contaminant to a different form with properties distinct from those of the contam inant prior to transformation.

(Subsurface) Transformation Processes

Transformation processes change the chemical structure of a compound which might result in one or more of the following

1. Detoxification: An irreversible change in a substance from a toxic to non-toxic form. This occurs most commonly when an organic substance breaks down into its inorganic constituents with water and CO2 being the main by-products

2. Transtoxification: Inverse the conversion of one toxic compound to another toxic compound. In the process, toxicity may remain the same, increase or reduce

3. Toxification: Is the conversion of non-toxic compound to a toxic substance

6.5 TOXIC ELEMENTS IN THE ENVIRONMENT

Included among the toxic elements are heavy metals such as Ag, Cd, Cr, Co, Cu, Fe, Hg, Mo, Ni, Pb, Sn, Zn as well as lighter elements such as Al, Ag and Sc.

Under certain environmental conditions, these elements may accumulate to a toxic concentration and cause ecological drainage.

6.5.1 MAJOR SOURCES

1. Naturally occurring contaminations, natural emissions of toxic elements to the atmosphere can take place by volcanic outputs or outgassing, and by vapour-phase of relative volatile elements such as As, Hg and Se. We can have contamination from metalliferous sites.

2. Anthropogenic sources of toxic elements

   Agricultural practice: From long-term use of pesticides sewage sludge (ie by-product of secondary treatments of municipal sewage)

   Pollution from (metal) mining and processing: Pollution from toxic elements is association with various aspects of minig and processing industries. Mining produces ore as a product along with a considerable amount of metal-contaminated wastes pollution around mines is caused by dumping of contaminated overburden, excavating wastes etc

   Oil pollution: The contaminations of soil and ground water with mineral oils, hydrocarbons or mineral oil-based products are among the most common negative effect of the industrial society.

7.0 MAJOR CONSEQUENCES OF CHEMICALLY DEGRADED SOILS

1. Environmental pollution / contamination
2. Bioaccumulation in plants and animals tissue
3. Accumulation of heavy metals

   a) Narrow Concentration Range – The margin between beneficial and harmful is narrow

   b) Food Chain – Plants, animals and humans

4. Eutrophication

Prevention of Inorganic Chemical Contamination

1. Reduce the application to soil
2. Immobilize the toxins – maintain pH$\geq$ 7.0
3. Removal of toxins – Remediation ("Clean up")

Physical Remediation

1. Incineration
2. Vacuum Extraction
3. Soil washing / Flushing
4. Leaching
5. Heating

Biological Remediation (Bioremediation)

1. Microbial Action
2. Phytoremediation

i) Phyto Extraction - *Hyperaccumulation*

ii) Enhanced Rhizosphere Phytoremediation

iii) Phytostabilization

iv) Phytodegradation

v) Phytovolatilization

Greenhouse Gas Emissions and Mitigation

What are greenhouse gases (GHGs)?

- Gases that create a greenhouse effect over the earth surface, thereby increasing the temperature of the earth.
- The principal GHGs are carbon dioxide (CO_2), Nitrous oxide (N_2O), and methane (CH_4). Other GHGs include chlorofluorocarbons.

Causes of GHG Emissions

1. Fossil fuel combustion
2. Land use change i.e. deforestation, biomass burning
3. Agricultural sources of carbon (CO_2):
    - Operation of farm machinery
    - Fertilizers and agricultural lime
    - Pesticides
    - Irrigation
    - Seed production

Impact on global climate change

Increased temperatures

2. Severe droughts

3. Floods

4. Sea level rise

Mitigation

One major way of reducing GHGs emission is *Soil Carbon Sequestration*.

Carbon Sequestration is the process of carbon storage in soils. Consequently soils could act as carbon "sinks".

"Sinks" - Forest soils, grassland soils, ocean, agricultural land

Effects of Global Warming

The resultant effect of greenhouse gases emissions is largely seen in global warming.

- Weather - climate change
- Ice/glacier melt
- Sea level
- Agriculture
- Plants and Animals
- Human health

8.0 ENVIRONMENTAL EFFECTS OF ORGANIC, INORGANIC AMENDMENTS AND AGROCHEMICALS

8.1 INTRODUCTION

Over the past century humans have introduced a large number of chemical substances into the environment. Some are the waste from industrial and agricultural processes. Some have been designed as structural materials and others have been designed to perform various functions such as improving crop growth or killing pests and weeds. Obviously some chemicals are useful but many are toxic and their harm to the environment and our health far outweighs their benefit to society. We need to manage the risks better by only using chemicals, which are safe.

Agrochemical

—Any substance used in the management of an agricultural ecosystem, including fertilizers, pH-adjusting agents, soil conditioners, pesticides, and crop-growth regulators.

Fertilizer

—An agrochemical that is added to soil to reduce or eliminate nutrient-caused constraints to crop productivity. Fertilizers are substances that are added to farmlands to encourage plant growth and to increase crop yields.

Soil conditioners

—Substances added to soil to improve its aeration and water-holding capacity, with great benefits in terms of crop growth. Various organic compounds can be used as soil conditioners, but compost is the best. Materials used as soil conditioners include peat, livestock manure, sewage sludge, and even shredded newspapers

Pesticide

- Any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest. A pesticide may be a chemical substance, biological agent (such as a virus or bacterium), antimicrobial, disinfectant or device used against any pest.

Detrimental Effects of Agrochemicals on the Environment

The use of certain agrochemicals has also been associated with some important environmental ecological damages as outlined below:

1) Fertilizers:

i) Groundwater contamination: Excessive use of fertilizers can lead to the contamination of groundwater with nitrate, rendering it unfit for consumption by humans or livestock. Water containing large concentrations of nitrate can poison animals by immobilizing some of the hemoglobin in blood, reducing the ability to transport oxygen.

ii) Eutrophication: In addition, the run-off of agricultural fertilizer into streams, lakes, and other surface waters can cause an increased productivity of those aquatic ecosystems, a problem known as eutrophication. It starts by increasing the amount of phytoplankton in the water, this then blocks out the sunlight, which leads to plants being unable to photosynthesise, which in turn means that the fish and other creatures don't have anything to eat, which means they die and then in turn so do other animals that depend on them such as birds.

2) Pesticides: The use of pesticides raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil.

i) Air pollution by pesticides

Pesticides can contribute to air pollution. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. Pesticides that are applied to crops can volatilize and may be blown by winds into nearby areas, potentially posing a threat to wildlife.

ii) Water pollution by pesticides

There are four major routes through which pesticides reach the water:

a) it may drift outside of the intended area when it is sprayed,

b) it may percolate, or leach, through the soil,

c) it may be carried to the water as runoff or it may be spilled, for example accidentally or through neglect. d) it may also be carried to water by eroding soil.

There are some factors that also affect pesticide's ability to contaminate water and these include:

a) its water solubility,

b) the distance from an application site to a body of water,

c) weather,

d) soil type,

e) presence of a growing crop, and

f) the method used to apply the chemical.

iii) Soil pollution by pesticides

Many of the chemicals used in pesticides are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation. The use of pesticides decreases the general biodiversity in the soil. Not using the chemicals results in higher soil quality with the additional effect that more organic matter in the soil allows for higher water retention. This helps increase yields for farms in drought years, when organic farms have had yields 20-40% higher than their conventional counterparts. A smaller content of organic matter in the soil increases the amount of pesticide that will leave the area of application, because organic matter binds to and helps break down pesticides.

Effect of pesticides on plants

i) It hinders nitrogen fixation in legumes. The insecticides DDT, methyl parathion, and especially pentachlorophenol have been shown to interfere with legume-rhizobium chemical signaling. Reduction of this symbiotic chemical signaling results in reduced nitrogen fixation and thus reduced crop yields.

ii) Pesticides can kill bees and they are strongly implicated in pollinator decline and the loss of species that pollinate plants.

iii) On the other side, pesticides have some direct harmful effect on plant including poor root hair development, shoot yellowing and reduced plant growth.

Effect on animals

Pesticides inflict extremely widespread damage to biota, and many countries have acted to discourage pesticide usage through their Biodiversity Action Plans.

i) Animals may be poisoned by pesticide residues that remain on food after spraying, for example when wild animals enter sprayed fields or nearby areas shortly after spraying.

ii) Widespread application of pesticides can eliminate food sources that certain types of animals need, causing the animals to relocate, change their diet, or starve.

iii) Poisoning from pesticides can travel up the food chain; for example, birds can be harmed when they eat insects and worms that have consumed pesticides.

iv) Some pesticides can bioaccumulate, or build up to toxic levels in the bodies of organisms that consume them over time, a phenomenon that impacts species high on the food chain especially hard.

v) Some pesticides come in granular form, and birds and other wildlife may eat the granules, mistaking them for grains of food. A few granules of a pesticide is enough to kill a small bird.

vi) The herbicide paraquat, when sprayed onto bird eggs, causes growth abnormalities in embryos and reduces the number of chicks that hatch successfully, but most herbicides do not directly cause much harm to birds. Herbicides may endanger bird populations by reducing their habitat.

vii) Fish and other aquatic biota may be harmed by pesticide-contaminated water. Pesticide surface runoff into rivers and streams can be highly lethal to aquatic life, sometimes killing all the fish in a particular stream.

Effect on Humans

Pesticides are implicated in a range of impacts on human health due to pollution

i) Pesticides can enter the human body through inhalation of aerosols, dust and vapor that contain pesticides; through oral exposure by consuming food and water; and through dermal exposure by direct contact of pesticides with skin.

ii) Pesticides are sprayed onto food, especially fruits and vegetables, they secrete into soils and groundwater which can end up in drinking water, and pesticide spray can drift and pollute the air.

iii) Exposure to pesticides can range from mild skin irritation to birth defects, tumors, genetic changes, blood and nerve disorders, endocrine disruption, and even coma or death.

Pest resistance

Pests may evolve to become resistant to pesticides. Many pests will initially be very susceptible to pesticides, but some with slight variations in their genetic makeup are resistant and therefore survive to reproduce. Through natural selection, the pests may eventually become very resistant to the pesticide.

3) Persistent organic pollutants

Persistent organic pollutants (POPs) are compounds that resist degradation and thus remain in the environment for years. Some pesticides, including aldrin, chlordane, DDT,dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, and toxaphene, are considered POPs. POPs have the ability to volatilize and travel great distances through the atmosphere to become deposited in remote regions.

9.0 WASTE DISPOSAL; EVALUATION AND MANAGEMENT OF CONTAMINATED SITES

9.1 INTRODUCTION

What is waste?

Waste is any plastics, paper, glass, metal, foods, chemicals, wood, oil, soil, effluents, liquids that have been discarded. How the waste gets generated is from commercial, household and industrial sources. Sewage sludge is another source. Domestic and municipal waste is generated by the consumption of goods, manufacturing, sewage treatment, agriculture, the production & disposal of hazardous substances and construction. They are essential parts of the process of production as the emission of carbon dioxide by human is part of breathing process. From time immemorial, waste disposal has been a problem, and after industrialization the problem has only compounded. In the past, trash was carried to the outskirts of cities and discarded in the open, but now that can no longer be done. Over time, various waste disposal methods have been devised, like compost, burning, landfill, biological reprocessing, etc. However, before going to these details, we need to understand the different kinds of wastes.

Types of Wastes

There are basically three types of wastes generated and they are classified based on their chemical, biological and physical characteristics viz:

a) **Solid wastes** include materials like mining wastes and industrial wastes besides household garbage.

b) **Liquid wastes** are those in which the composition of solids is less than 1% and there is a high concentration of metals and salts.

c) **Sludge** contains a mixture of solid and water.

What is Waste Disposal?

Waste Disposal is the management of waste to prevent harm to the environment, injury or long term progressive damage to health. Disposal of wastes can be made to three locations namely surface water, atmosphere and land. The land represents not only the appropriate disposal medium for many wastes but also provides opportunity to manage wastes with a minimum of adverse environmental effects. Disposal of waste could be done through the following methods.

Methods of Waste disposal

1. Integrated waste management (IWM)

Integrated waste management using LCA (life cycle analysis) attempts to offer the best option for waste management. IWM entails using a combination of techniques and programmes to manage the municipal/urban waste stream.

2. Landfill

Disposing of waste in a landfill involves burying the waste, and this remains a common practice in most countries. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials.

Advantages:	**Disadvantages:**
• volume can increase with little addition of people/equipment • filled land can be reused for other community purposes	• completed landfill areas can settle and requires maintenance • requires proper planning, design, and operation

3. Incineration

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of residue of both solid waste management and solid residue from waste water management.

Advantages:	**Disadvantages:**

• requires minimum land • can be operated in any weather • produces stable odor-free residue • refuse volume is reduced by half	• expensive to build and operate • high energy requirement • requires skilled personnel and continuous maintenance • unsightly - smell, waste, vermin

4. Recycling

Recycling refers to the collection and reuse of waste materials such as empty beverage containers. The materials from which the items are made can be reprocessed into new products. Material for recycling may be collected separately from general waste using dedicated bins and collection vehicles, or sorted directly from mixed waste streams.

Advantages:	**Disadvantages:**
• key to providing a liviable environment for the future	• expensive • some wastes cannot be recycled • technological push needed • separation of useful material from waste may be difficult

5. Ocean Dumping

This is the deposition of waste into the water bodies, particularly the ocean. Controversy surrounds ocean dumping as a waste disposal method. Although the waste may provide nutrients for some sea life, it's widely believed that the harmful effects would outweigh any benefits.

Advantages:	**Disadvantages:**
• convenient • inexpensive • source of nutrients, shelter and breeding	• ocean overburdened • destruction of food sources • killing of plankton • desalination

6. Open Dumping

This method involves disposing waste on an open land. As simple as this is, it is not without its own shortcoming.

Advantages:	Disadvantages:
• inexpensive	• health - hazard - insects, rodents etc. • damage due to air pollution • ground water and run-off pollution

7. Biological reprocessing

Waste materials that are organic in nature, such as plant material, food scraps, and paper products, can be recycled using biological composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes

8. Energy recovery

The energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel. Recycling through thermal treatment ranges from using waste as a fuel source for cooking or heating, to anaerobic digestion and the use of the gas fuel (see above), to fuel for boilers to generate steam and electricity in a turbine.

9. Avoidance and reduction methods

An important method of waste management is the prevention of waste material being created, also known as waste reduction. Methods of avoidance include reuse of second-hand products, repairing broken items instead of buying new, designing products to be refillable or reusable (such as cotton instead of plastic shopping bags), encouraging consumers to avoid using disposable products (such as disposable cutlery), removing any food/liquid remains from cans, packaging, and designing products that use less material to achieve the same purpose (for example, light weighting of beverage cans).

Waste management

Waste management is the collection, transport, processing, recycling or disposal, and monitoring of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health, the environment or aesthetics. Waste management is also carried out to recover resources from it.

Waste management concepts

There are a number of concepts about waste management which vary in their usage between countries or regions. Some of the most general, widely used concepts include:

- **Waste hierarchy** - The waste hierarchy refers to the "3 Rs" reduce, reuse and recycle, which classify waste management strategies according to their desirability in terms of waste minimization. The waste hierarchy remains the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.
- **Extended producer responsibility** - Extended Producer Responsibility (EPR) is a strategy designed to promote the integration of all costs associated with products throughout their life cycle (including end-of-life disposal costs) into the market price of the product. Extended producer responsibility is meant to impose accountability over the entire lifecycle of products and packaging introduced to the market. This means that firms which manufacture, import and/or sell products are required to be responsible for the products after their useful life as well as during manufacture.
- Polluter pays principle – This is a principle where the polluting party pays for the impact caused to the environment. With respect to waste management, this generally refers to the requirement for a waste generator to pay for appropriate disposal of the waste.