Research Article
ISSN:2249-1236
CODEN: IJRRBI (USA)
Sharma Radha *et al., Int.* J. Res. Rev. Pharm. Appl. Sci.,*(2018) 8(1) 088-106*
International Journal of Research and Reviews in Pharmacy and Applied sciences

TREATMENT OF WASTES: A BIOLOGIC WAY

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Abstract:

Toxicity can be defined as the degree to which a substance can harm an organism. It can also refer as the effect on whole organism, such as an animal, bacterium, or plant, as well as the effect on a cell (cytotoxicity) or an organ such as the liver (hepatotoxicity).

In pharmacology language the toxicity will be the degree to which a substance (a toxin or poison) can harm humans or animals. Acute toxicity involves harmful effects in an organism through a single or short-term exposure. Sub chronic toxicity is the ability of a toxic substance to cause effects for more than one year but less than the lifetime of the exposed organism. Chronic toxicity is the ability of a substance or mixture of substances to cause harmful effects over an extended period, usually upon repeated or continuous exposure, sometimes lasting for the entire life of the exposed organism.

Hazardous-waste management is the collection, treatment, and disposal of waste material. When improperly handled, it can cause substantial harm to human health and safety and to the environment. Hazardous wastes can be in the form of solids, liquids, sludges, or contained gases, and they are generated primarily by chemical production, manufacturing, and other industrial activities and heat (50ºC).

1. Introduction:

Toxicity can be defined as the degree to which a substance can harm an organism. It can also refer as the effect on whole organism, such as an animal, bacterium, or plant, as well as the effect on a cell (cytotoxicity) or an organ such as the liver (hepatotoxicity).

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Toxic wastes are the waste materials that can affect the life of living creatures by cause death, injury or by birth defects. The spreading process of contamination toxic wastes is quite easy. Toxic wastes can contaminate the environment like lakes, rivers, and the atmosphere. Toxic wastes are also termed as “hazardous waste”. The toxic effects of these wastes material can pose a long-term risk to health or environment.

Hazardous wastes are poisonous byproducts of manufacturing, farming, city septic systems, construction, automotive garages, laboratories, hospitals and other industries. The waste may be liquid, solid, or sludge and contain chemicals, heavy metals, radiation, dangerous pathogens, or other toxins. Even households generate hazardous waste from items such as batteries, used computer equipment, and leftover paints or pesticides. Some materials that may not be accepted at regular landfills are ammunition, commercially generated waste, explosives/shock sensitive items, hypodermic needles/syringes, medical waste, radioactive materials, and smoke detectors.

Toxic wastes often contain carcinogens, and exposure to these by some route, such as leakage or evaporation from the storage, causes cancer to appear at increased frequency in exposed individuals. People encounter these toxins buried in the ground, in stream runoff, in groundwater that supplies drinking water, or in floodwaters, as happened after Hurricane Katrina. Some toxins, such as mercury, persist in the environment and accumulate. As a result of the bioaccumulation of mercury in both freshwater and marine ecosystems, predatory fish are a significant source of mercury in human and animal diets.

The following lists in toxic products commonly found in the home.

Place	**Example**
In the yard	Insecticides, Pesticides,Pool chemicals,Propane cylinders (5 gallons and smaller),Weed killers, Fungicides.
In the house	Aerosol sprays,Asbestos,Batteries,Cleaners,Fire extinguishers,Fluorescent lamps, Medications, Nail polish & remover, Syringes/needles, Toiletries.
In the garage	Antifreeze, Auto batteries, Automatic transmission fluid,Brake fluid, Engine cleaners,Flares, Fuel such as butane, diesel, gasoline, kerosene & lamp oil, Oil & filters,Power-steering fluid.
In the workshop	Flammable liquids & solids • Glues • Paint • Paint thinners • Photo chemicals • Solvents • Treated wood • Wood finishes

2. Hazardous-Waste Management:

Hazardous-waste management is the collection, treatment, and disposal of waste material. When improperly handled, it can cause substantial harm to human health and safety and to the environment. Hazardous wastes can be in the form of solids, liquids, sludges, or contained gases, and they are generated primarily by chemical production, manufacturing, and other industrial activities. They may cause damage during inadequate storage, transportation, treatment, or disposal operations. Improper hazardous-waste storage or disposal frequently contaminates surface and groundwater supplies. People living in homes built near old and abandoned waste disposal sites may be in a particularly vulnerable position. In an effort to remedy existing problems and to prevent future harm from hazardous wastes, governments closely regulate the practice of hazardous-waste management.

3. General Characteristics of Hazardous-Waste:

Hazardous wastes are classified on the basis of their biological, chemical, and physical properties. These properties generate materials that are toxic, reactive, ignitable, corrosive, infectious, or radioactive.Toxic wastes are poisons, even in very small or trace amounts. They may have acute effects, causing death or violent illness, or they may have chronic effects, slowly causing irreparable harm. Some are carcinogenic, causing cancer after many years of exposure. Others are mutagenic, causing major biological changes in the offspring of exposed humans and wildlife.

Reactive wastes are chemically unstable and react violently with air or water. They cause explosions or form toxic vapours. Ignitable wastes burn at relatively low temperatures and may cause an immediate fire hazard. Corrosive wastes include strong acidic or alkaline substances. They destroy solid material and living tissue upon contact, by chemical reaction.

Infectious wastes include used bandages, hypodermic needles, and other materials from hospitals or biological research facilities. Radioactive wastes emit ionizing energy that can harm living organisms. Because some radioactive materials can persist in the environment for many thousands of years before fully decaying, there is much concern over the control of these wastes. However, the handling and disposal of radioactive material is not a responsibility of local municipal government. Because of the scope and complexity of the problem, the management of radioactive waste—particularly nuclear fission waste—is usually considered an engineering task separate from other forms of hazardous-waste management.

4. Transport of Hazardous Waste:

Hazardous waste generated at a particular site often requires transport to an approved treatment, storage, or disposal facility (TSDF). Because of potential threats to public safety and the environment, transport is given special attention by governmental agencies. In addition to the occasional accidental spill, hazardous waste has, in the past, been intentionally spilled or abandoned at random locations in a practice known as “midnight dumping.” This practice has been greatly curtailed by the enactment of laws that require proper labeling, transport, and tracking of all hazardous wastes.

4.1 Transport Vehicles:

Hazardous waste is generally transported by truck over public highways. Only a very small amount is transported by rail, and almost none is moved by air or inland waterway. Highway shipment is the most common because road vehicles can gain access to most industrial sites and approved TSDFs. Railroad trains require expensive siding facilities and are suitable only for very large waste shipments. Hazardous wastes can be shipped in tank trucks made of steel or aluminum alloy, with capacities up to about 34,000 litres (9,000 gallons). They also can be containerized and shipped in 200-litre (55-gallon) drums. Specifications and standards for cargo tank trucks and shipping containers are included in governmental regulations.

5. Treatment, Storage, and Disposal of Hazardous-Waste Management:

Several options are available for hazardous-waste management. The most desirable is to reduce the quantity of waste at its source or to recycle the materials for some other productive use. Nevertheless, while reduction and recycling are desirable options, they are not regarded as the final remedy to the problem of hazardous-waste disposal. There will always be a need for treatment and for storage or disposal of some amount of hazardous waste.

5.1 Treatment:

Hazardous waste can be treated by following ways:

- Chemical,
- Thermal,
- Biological, and
- Physical methods.

Chemical methods include ion exchange, precipitation, oxidation and reduction, and neutralization. Among thermal methods is high-temperature incineration, which not only can detoxify certain organic wastes but also can destroy them. Special types of thermal equipment are used for burning waste in either solid, liquid, or sludge form. These include the fluidized-bed incinerator, multiple-hearth furnace, rotary kiln, and liquid-injection incinerator. One problem posed by hazardous-waste incineration is the potential for air pollution.

Biological treatment of certain organic wastes, such as those from the petroleum industry, is also an option. One method used to treat hazardous waste biologically is called landfarming. In this technique the waste is carefully mixed with surface soil on a suitable tract of land. Microbes that can metabolize the waste may be added, along with nutrients. In some cases a genetically engineered species of bacteria is used. Food or forage crops are not grown on the same site. Microbes can also be used for stabilizing hazardous wastes on previously contaminated sites; in that case the process is called bioremediation.

The chemical, thermal, and biological treatment methods outlined above change the molecular form of the waste material. Physical treatment, on the other hand, concentrates, solidifies, or reduces the volume of the waste. Physical processes include evaporation, sedimentation, flotation, and filtration. Yet another process is solidification, which is achieved by encapsulating the waste in concrete, asphalt, or plastic. Encapsulation produces a solid mass of material that is resistant to leaching. Waste can also be mixed with lime, fly ash, and water to form solid, cement like product.

5.2 Surface storage and land disposal:

Hazardous wastes that are not destroyed by incineration or other chemical processes need to be disposed of properly. For most such wastes, land disposal is the ultimate destination, although it is not an attractive practice, because of the inherent environmental risks involved. Two basic methods of land disposal include landfilling and underground injection. Prior to land disposal, surface storage or containment systems are often employed as a temporary method.

Temporary on-site waste storage facilities include open waste piles and ponds or lagoons. New waste piles must be carefully constructed over an impervious base and must comply with regulatory requirements similar to those for landfills. The piles must be protected from wind dispersion or erosion. If leachate is generated, monitoring and control systems must be provided. Only non-containerized solid, non-flowing waste material can be stored in a new waste pile, and the material must be landfilled when the size of the pile becomes unmanageable.

A common type of temporary storage impoundment for hazardous liquid waste is an open pit or holding pond, called a lagoon. New lagoons must be lined with impervious clay soils and flexible membrane liners in order to protect groundwater. Leachate collection systems must be installed between the liners, and groundwater monitoring wells are required. Except for some sedimentation, evaporation of volatile organics, and possibly some surface aeration, open lagoons provide no treatment of the waste. Accumulated sludge must be removed periodically and subjected to further handling as a hazardous waste.

Many older, unlined waste piles and lagoons are located above aquifers used for public water supply, thus posing significant risks to public health and environmental quality. A large number of these old sites have been identified and scheduled for cleanup, or remediation.

5.3 Secure landfills:

Landfilling of hazardous solid or containerized waste is regulated more stringently than landfilling of municipal solid waste. Hazardous wastes must be deposited in so-called secure landfills, which provide at least 3 metres (10 feet) of separation between the bottom of the landfill and the underlying bedrock or groundwater table. A secure

hazardous-waste landfill must have two impermeable liners and leachate collection systems. The double leachate collection system consists of a network of perforated pipes placed above each liner. The upper system prevents the accumulation of leachate trapped in the fill, and the lower serves as a backup. Collected leachate is pumped to a treatment plant. In order to reduce the amount of leachate in the fill and minimize the potential for environmental damage, an impermeable cap or cover is placed over a finished landfill. A groundwater monitoring system that includes a series of deep wells drilled in and around the site is also required. The wells allow a routine program of sampling and testing to detect any leaks or groundwater contamination. If a leak does occur, the wells can be pumped to intercept the polluted water and bring it to the surface for treatment.
One option for the disposal of liquid hazardous waste is deep-well injection, a procedure that involves pumping liquid waste through a steel casing into a porous layer of limestone or sandstone. High pressures are applied to force the liquid into the pores and fissures of the rock, where it is to be permanently stored. The injection zone must lie below a layer of impervious rock or clay, and it may extend more than 0.8 km (0.5 mile) below the surface. Deep-well injection is relatively inexpensive and requires little or no pretreatment of the waste, but it poses a danger of leaking hazardous waste and eventually polluting subsurface water supplies.

6. Remedial Action:

Disposal of hazardous waste in unlined pits, ponds, or lagoons poses a threat to human health and environmental quality. Many such uncontrolled disposal sites were used in the past and have been abandoned. Depending on a determination of the level of risk, it may be necessary to remediate those sites. In some cases, the risk may require emergency action. In other instances, engineering studies may be required to assess the situation thoroughly before remedial action is undertaken. One option for remediation is to completely remove all the waste material from the site and transport it to another location for treatment and proper disposal. This so-called off-site solution is usually the most expensive option.

An alternative is on-site remediation, which reduces the production of leachate and lessens the chance of groundwater contamination. On-site remediation may include temporary removal of the hazardous waste, construction of a secure landfill on the same site, and proper replacement of the waste. It may also include treatment of any contaminated soil or groundwater. Treated soil may be replaced on-site and treated groundwater returned to the aquifer by deep-well injection. A less costly alternative is full containment of the waste. This is done by placing an impermeable cover over the hazardous-waste site and by blocking the lateral flow of groundwater with subsurface cutoff walls. It is possible to use cutoff walls for this purpose when there is a natural layer of impervious soil or rock below the site. The walls are constructed around the perimeter of the site, deep enough to penetrate to the impervious layer. They can be excavated as trenches around the site without moving or disturbing the waste material. The trenches are filled with a bentonite clay slurry to prevent their collapse during construction, and they are backfilled with a mixture of soil and cement that solidifies to form an impermeable barrier. Cutoff walls thus serve as vertical barriers to the flow of water, and the impervious layer serves as a barrier at the bottom.

7. Environmental Biotechnology:

Various aerobic and anaerobic biological treatment methods are successfully being employed in the treatment of domestic and industrial wastes. Biological treatment methods have played significant role in improving human environment by converting complex- organic matter from the waste into simpler, that can be recycled. Single dwelling septic tanks, municipal (multiple-dwelling) trickling filters, activated sludge systems; lagoons etc. are employed in biological treatment of waste. Bioremediation, an emerging technology offers significant potential for cost-effective, environmentally acceptable treatment of contaminated waters and soils.

The two types of bioremediation are,

- **Ex-situ (or above ground) bioremediation**

  It involves design, construction and operation of an engineered reactor above the ground. Water is pumped from the ground or soil is dug-up, made into slurry and put into reactor located above ground.

- **In-situ (or in the ground) bioremediation**

i) **Natural (intrinsic) bioremediation**

  Which means no action is taken other than monitoring the site the rate of degradation by micro-organisms is faster than the rate at which the pollutants are leaving the site, the site will cleanse itself.

ii) **Engineered in-situ bioremediation**

  In which materials are added to stimulate growth of organisms. Nutrients like ‘N’, ‘P’ source and electron acceptor like oxygen are added.

Bioremediation is one of the few processes that actually destroy pollutants converting organic matter into CO2, water, chloride and other minerals. The process is less costly than physical and chemical methods and offers betters potential. The list of compounds successfully bioremediated includes, petroleum hydrocarbons (gasoline, diesel, jet fuel, oil), benzene, toluene, ethyl benzene and xylene (BTEX) compounds, alcohols, kerosene, esters, poly nuclear aromatic hydrocarbons, creosote, chlorinated aliphatic hydrocarbons, CFCs, chlorinated benzenes polychlorinated bio-phenyls. Phenols, chlorinated phenols, nitro aromatics, pesticides (EDB, alachor, atrazine, dinosels) etc.

8. Food Industry:

India is second largest food producer in the world. With the help of techniques of biotechnology it is possible to enhance the quality, nutritional value, variety of food availability for human consumption. It also helps in increasing efficiency of food production, food processing, food distribution and waste management.

- Wish the help of genetic engineering it is possible to increase amount of proteins/secondary metabolites or to decrease unwanted metabolites in an organism.
- By the application of biotechnology it is possible to modify fruit properties e.g. ripening the fruits on plants for better taste (increase in sugar content), large shelf life through delayed pectin degradation or by altered response to ethylene oxide, slow ripening of tomato helps its transportation made possible by removing the gene polygalactouronase responsible for softening and early ripening of tomatoes. High starch content potatoes are possibly produced by genetic engineering requires less oil for frying is important achievement. It is also possible to develop seeds with altered oil profile and production of wheat with no phenylalanine.
- Use of recombinant bovine ST (bST) a protein hormone for milk production shows 10 to 25% increase in the production of milk in dairy cows, without altering nutritive value of milk and effect on health of recipient cow. Porcine somatotropin (pST) acts as repartitioning agent helps in reduction of fattiness.
- It is possible to use micro-organisms to improve efficiency of fermentation, enzymatic processes, production of natural food ingredients (vanilla flavour), improve nutritional value, shelf stability, sensor characters, and efficient process techniques, in the production of food products.
- Biotechnological methods are also used to reduce time necessary to detect food borne pathogens, toxins, food contaminants with the help of microbial probes and biosensors. Based on the old skills, list of biotechnological processes were developed for the production of food products. Beverages and food products produced by conventional fermentation and fermentation and biotechnology includes.

A) Alcoholic beverages

a) Beer: The sugar solution produced by degradation of starch by barley Amylase is fermented by yeast to ethanol in presence of hop Extract.

b) Wine: The grape juice fermented by yeast

c) Champagne: Produced by second fermentation of wine by addition of sugar And yeast

d) Cider: Apple juice fermented by yeast

e) Sake: Rice starch, de-polymerized by amylase from Aspergillums oryzae fermented by yeast

f) Whisky: Extract of barley, yeast, rye or corn fermented by yeast and Distilled

g) Vodka: Extract of potatoes or wheat, fermented by yeast and distilled.

8.2 Fermented Food:

In which food value of vegetables can be prolonged by lowering the pH through formation of organic acids, as in sauerkraut and Pickles; digestibility can be improved by enzymatic hydrolysis prior to storage as in sausages; taste can be improved as in fermented milk products or improved flavour as in soy sauce.

a) Vinegar: It is used for acidification and preservation of vegetables, salads, rice and other food products.

b) Citric acid: It is used as an adjuvant and food preservative.

c) Lactic acid: It is used in food and beverages due to its pleasant acidic taste and Preservatives property.

d) Vitamin B2, B12 and C as animal feed.

e) Enzymes: These are additives in food technology.

E.g. Amylase: beer brewing

Cellulose/ hemicelluloses/ pectinases: fruit processing/ wine brewing

Proteases/chymosin/lipases: cheese manufacture and milk products.

A-amylase/proteases: flavour/bakery products.

f) Single cell protein (SCP) and single cell oil (SCO) etc.

9. Fuel Industry:

Burning of conventional, non-renewable fossil fuel is a major source of air pollution. Biotechnology provides solution to this environmental problem by producing ethanol, a clean burning fuel by fermentation of grains like wheat/corn, waste like sludge from paper and pulp mill, yard waste (grass/straw/leaves) and other solid landfills. Ethanol a biotechnological product is used as fuel and also as industrial solvent for preparation of toiletries, cosmetics and medicines for external use. Ethanol, manufactured from wheat grain by series of biochemistry reactions (fermentation), using naturally occurring special enzyme or by adding amyloglucosidase along with yeast Saccharomyces cervisiae. The enzyme slowly release glucose from wheat mash and is immediately used by yeast and process of fermentation occurs and completes in 56 hrs. Ethanol is recovered by distillation. Water in ethanol is removed by either filtration or treatment with chemicals. Sludge from pulp and paper industry considered as free 'feed stock', since it is waste product required to be disposed, generated from on-going process so no requirement of stock pile, which is advantages over straw. Pulp and paper sludge contains 45 to 70% of cellulose while straw contains only 30% of cellulose. Sludge pulp is best choice since it is preciously treated in paper recycling process, already in fragmented form of cellulose. Enzymes are added to convert cellulose into glucose, then yeast or some genetically modified bacteria are added for fermentation.

9. Waste Discharge and Effluent Treatment:

As world is moving towards greater and greater levels of urbanization and industrialization, public concern over state of environment is mounting day-by-day, and much more attention is now being given to improve environment for future generations. Waste is a side effect of production and consumption activity and arises from domestic (human, animal and vegetable bacteria), which works as a source of disease by residual pathogen city of enteric intestinal bacteria), industrial activity. The cost of proper dealing of waste thus arisen are escalating, includes cost of collection, storage, processing and removal. Various new branches of science are now working for efficient waste treatment.

- **Microbial ecology** is one which studies the inter-relationship between micro-organisms, their living (biotic) and non-living (abiotic) environment.
- **Environmental biotechnology,** which is the discipline that studies application biological processes in waste treatment and management.

Fermentation utilizes variety of raw materials to be converted into variety of product. Depending upon the micro-organisms, raw material and process employed every fermentation industry produces varying amount of wide range of waste materials. It includes, cell and cell debris, salts and organic matters from spent media, water accumulated in various steps of product recovery, filter aids, traces of solvents, acid alkalis, human sewage etc. Environmental pollution control Act do not permits dispose of the waste to a convenient area of land or into nearby watercourse and hence to be treated before its passage.

If the process employs plant or animal pathogen, the waste is required to be sterilized before its treatment. In fact it may be advantageous to sterilize fermentation wastes regardless of use of pathogens. The spent media or media residues are preliminary filtered to remove larger solids and biomass. Strong acids and alkalis are required to be neutralized before biological waste treatment. Depending on size and type of waste waters, it is to be either treated in municipal sewage treatment works (STW) or in its own effluent treatment plant. The goal of treatment is to oxidize completely all of the organic components into CO2 and water. Incompletely treated waste waters, on disposal into water course, are subject to further microbial oxidation of organic matter with consequent decrease in the level of dissolved oxygen in water. The lack of water favours less desirable fish, in extreme cases killing fish and other forms of higher water life and yields anaerobic conditions with consequent foul odours. Residual solids settle in the bottom to cause undesirable changes, favourable for certain micro-organisms.Oxidized inorganic salts also create some additional problems. Phosphate, nitrate and to some extent sulphate, ammonia and other salts are good fertilizers that promote growth of aquatic weeds and algae. At night when there is no photosynthesis, cellular tissues undergo decomposition, which makes further demands on the dissolved oxygen of the water.

Ideally, the oxygen concentration at the ambient temperature and salinity of water should be at least 90% of saturation concentration. Hence it is important to study effect of effluent on dissolved oxygen concentration i.e. level of decomposable organic matter in the waste water, is measured in terms of biological oxygen demand (BOD) or chemical oxygen demand (COD). BOD, which measures the quantity of oxygen demand required for the oxidation of organic matter in one litter of waste by micro-organisms, in a given time interval (usually 5 days) at a given temperature. As BOD takes 5 days COD can also are thus employed to ascertain the efficiency of treatment or load of decomposable organic matter still present. In practice complete survey of industrial operations become essential for any individual site before an economical waste treatment program can be planned. This is done to establish

1. Water sources, either to combine for the treatment or recycling
2. Concentrated streams which contains valuable waste to be recovered as

   Food, animal feed, fertilizer or fuel.
3. Toxic effluent needing special treatment.
4. Acid and alkalis needing neutralization.
5. Collection of effluent to be treated together in own treatment plant.
6. Collection of effluent, which do not require treatment to be discharged directly on to land or to a water course.
7. Collection of effluent to be discharged into STW

10. Treatment Methods:

Fermentation waste may be treated into own treatment plant or in STW. The various

factors affecting selection of methods are,

1. Nature and quantity of raw sewage.
2. Cost of the plant and its operation.
3. Sanitary requirements of the health department
4. Circumstances during the natural body of water for final disposal.

The treatment processes may also be described as,

1. Primary treatment: Includes physical methods e.g. sedimentation, chemical methods e.g. Coagulation.
2. Secondary treatment: Includes biological methods conducted after Primary treatment e.g. activated sludge treatment.
3. Tertiary treatment: Physical, chemical, biological treatments conducted after Secondary treatment to further improve quality of liquor.
4. Sludge conditioning and disposal: Includes physical, chemical and biological methods e.g. anaerobic digestion, de-watering followed by final disposal by incineration and land filling etc.

1. Physical treatment It is employed to remove suspended solids by screens to remove larger suspended or floating matter, comminatory to reduce particle size constant velocity channels (= 0.3 m/s) to remove grit, sedimentation tanks to remove finer suspended matter. Sedimentation tanks are circular or rectangular continuous flow tanks operating at retention time of 6 to 15 h with facility for continuous removal of settled sludge. It can remove up to 70% of suspended solids and 40% if BOD loads. Micro-strainers, slow sand filters, up-flow sand filters and rapid gravity sand filters are also employed in tertiary treatment of liquors.

2.Chemical treatment It is done by coagulation and or flocculation. Ferrous or ferric sulphate, aluminium sulphate (alum) calcium hydroxide (lime) and polyelectrolyte’s are often used coagulants, added into the effluent in vigorously mixed tank, precipitates suspended matter to be settled to form sludge. Drawn off, de-watered and subjected t further treatment.

3. Biological treatment Involves use of biological cell (s), micro-organisms. The decomposition of substances by microbial activities either by single organisms or more often by microbial consortia is defined as biodegradation. Microbes found in soil and water will attempt to utilize organic substances, which words as a source of energy and carbon, by enzymically breaking them into simple molecules that can be recycled in the ecosystem.

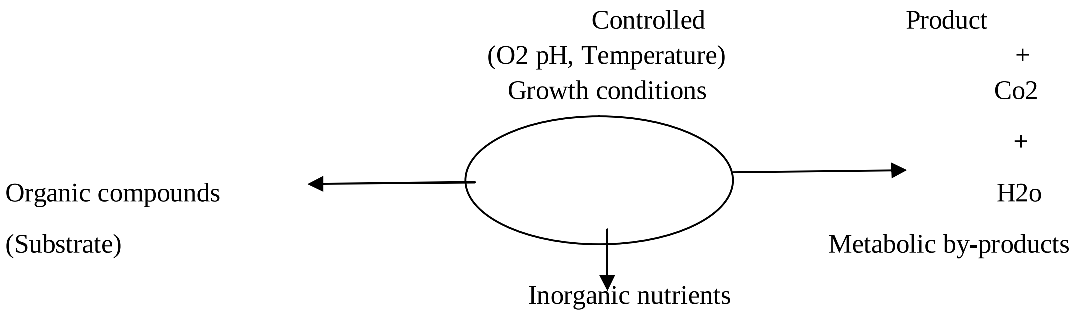

Fig. 1 Principal of biological treatment of wastes

4 Microbial biodegradation of compounds:

Various biological treatments, in the treatment of industrial and domestic wastes are employed. It can be single dwelling unit (e.g. septic tank) or municipal sewage treatment method, where waste is treated by use of aerobic processes and or anaerobic processes.

The methods are classified into,

Aerobic processes

a) Trickling filter
b) Towers
c) Biologically aerated filters (BAFs)
d) Rotating biological contactors (Rotating disc contactors)
e) Rotating drums
f) Fluidized-bed system
g) Activated sludge digesters
h) Lagoons

Anaerobic processes

Single-dwelling unit
septic tank
imholf tank

STWs
Anaerobic digesters

Anaerobic filters
up-flow anaerobic sludge blankets (UASB)

- **Aerobic processes**

Municipal sewage treatment works (STWs) employs combination of aerobic and anaerobic methods of treatments and different physical and chemical methods discussed earlier.

- **Trickling filters Through** the name is filter, it do not employ filtration but rather it is fixed bed bioreactor. It consists of cylindrical concrete tank (2to3 mts in depth and 8 to 16 mts in diameter), as rotary system allows more uniform hydraulic loading, packed with a bed of stone (usually granite) or special plastic packing. The packing material should of size 50 to 100 mm in diameter with specific surface area of 100 m2/m3 to give void space of 45 to 55 % to that of total bed volume.

The effluent is allowed to sediment in sedimentation or humus tank and then moves into trickling filters, to be spread by spray nozzle or mechanical distributor arms. The effluent trickles gradually through the bed to form slime layer (bio film) of bacteria, fungi, algae, protozoa and nematodes, on the surface of packing in the void age. The large surface area permits close contact between up flowing air, down flowing effluent and biologically active growth which converts complex the accumulation of biological film and prevent the filter from the clogging.

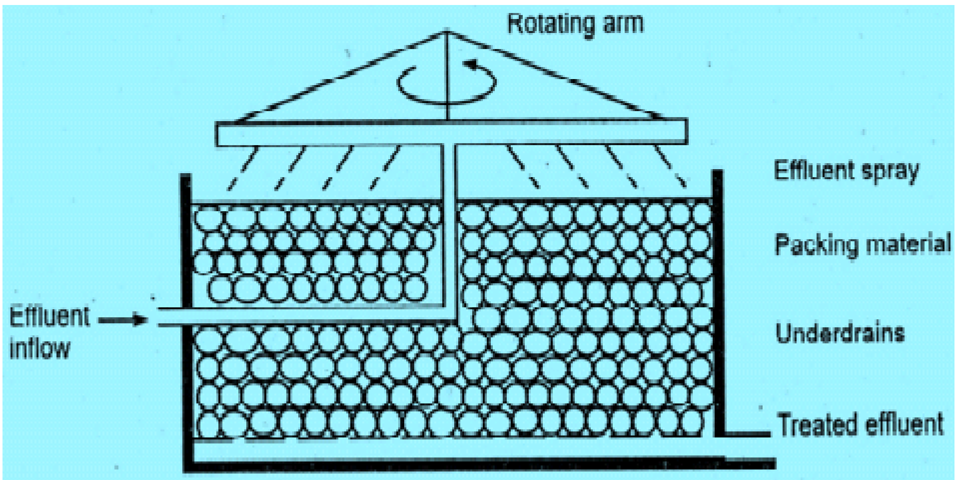

Fig 1. Trickling filter

It reduces BOD by 75 to 95 % and removes 90 to 95 % solids of organic loading rates of 0.06 to 0.012 kg BOD/m3/day. The limit of organic loading rate is modified by the use of two sets of filters and settling tanks in series, known as alternating double filtration (ADF).

- **Towers:** Because of comparatively low specific area and void age in conventional trickling filters and to overcome the large area requirement, towers are developed and are employed suitably in the treatment of industrial effluent. They are 6 to 9 m in heights, packed with light weight (40 to 80 kg/m3,) plastic multi-faced modules or small random packing. These packing are selectively open structures for better oxygen transfer with more specific area 100 to 300 m2 / m3 and void age (90 to 98 %). And are employed for 3.2 kg BOD/m3/day loading with 50% of BOD removal and at 1.5 kg BOD/m3/day loading with almost 70% of BOD removal.
- **Biologically aerated filters (BAFs):**These are recent developments of trickling filters. They also contains packed bed, which provides site for microbial growth, but unlike trickling filters, the reactor is flooded with the effluent to be treated, which pass upwards or downwards through the reactor by counter-current air supply. The packing material can be natural (e.g. pumice) or synthetic (polyethylene) and may be either of fixed structure or randomly packed. The combination of aeration and filtration allows high rate of BOD and ammonia removal together with solids capture, hence requires no prior sedimentation tank. However, regular back washing is employed to remove filtered solids and excess biomass. The organic BOD rate is improved to 90 % BOD removal, in the range of 0.7 to 2.8 Kg BOD/m3/day.
- **Rotating biological contactors(Rotating disc contactors)** The unit is composed of closely spaced discs of 2 to 3m diameter and 1 to 2 cm inter-disc space, on a central drive shaft rotated slowly at 0.5 to 15 r.p.m., through effluent so that 40 to 50 % the disc surfaces are submerged.

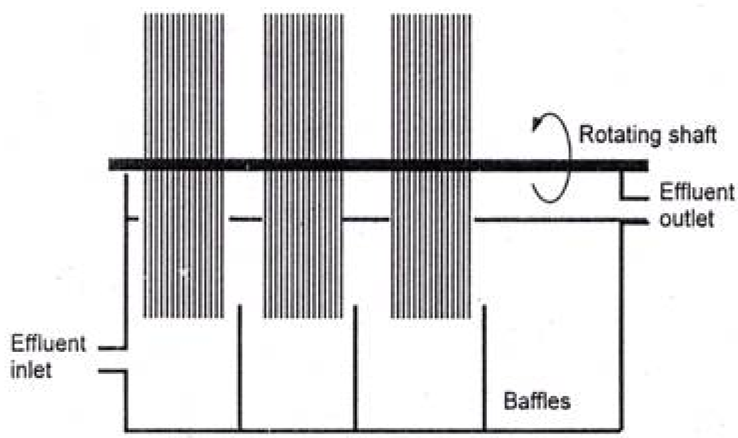

Fig 2. Rotating biological contractor

The discs are usually made up of synthetic material like polystyrene, PVC and arranged in stages or groups separated by baffles to minimize short circulating or surging. They may be flat or corrugated to increase surface area. The microbial film formed on these discs absorbs nutrient during submersion of the discs in effluent. Shear forces produced, removes excess bio film from the discs, hence a sedimentation tank is employed after biological contactor. Loding rate of 13 gm BOD/m2/day for domestic sewage and partial treatments of loads of 400g BOD/m2/day have been used.

- **Rotating drums:** In which large rotating drum, packed with random plastic packing material or spheres is employed. Loading rate for random packing were similar to rotating biological contactor, which plastic spheres used in partial treatment could cope with loads of 6 kgBOD/m2/day.
- **Fluidized bed system:** It is one of the recent methods of waste treatment in which support matrix, sand, anthracite or reticulated foam is fluidized by up flow of effluent through the reactor. On the support matrix, of high surface area, the bio film forms which can deal with high organic concentration and with high rates of treatment. The degree of bed expansion is controlled by the flow rate of waste water. It allows strong wastewaters to be treated in small reactor. The effluent after treatment can be decanted off without loss of support matrix. It can be operated either aerobically or aerobically. The matrix is regularly with drown to remove excess of biomass formed.
- **Activated sludge processes** The method is firstly reported by Arden and Lockett in 1914, and now it is most widely used biological treatment. The basic process consists of vigorous aeration and agitation of effluent in the presence of flocculated suspension of micro-organisms on particulate organic matter. Because of this finer particle clumps to form flocs. The formed flocs are allowed to be settled and then added into fresh vigorously aerated sewage. Thus induces rapid sedimentation. The process is repeated to bring quick and complete flocculation of sewage. This means sludge is recycled from sedimentation tank to aeration tank. Thus raw effluent initially enters a primary sedimentation tank, where coarse solids are removed, passing into second vessel, which can be of variety of designs based on mechanism of agitation and aeration. Paddles, stirrers are used for agitation and bubble diffusers, surface aerators for aeration. Vigorous aeration is used to ensure the contact of effluent and oxygen with activated sludge. After pre-determined time the flocculated solids are removed, the sludge is then dewatered, dried and used as fertilizer or incinerated or land filled. In conventional activated sludge digesters, organic loading rates are from 0.5 to 1.5 kg BOD/m3/day with hydraulic retention time of 1 to 2 h with BOD removal of 60 to 70%.

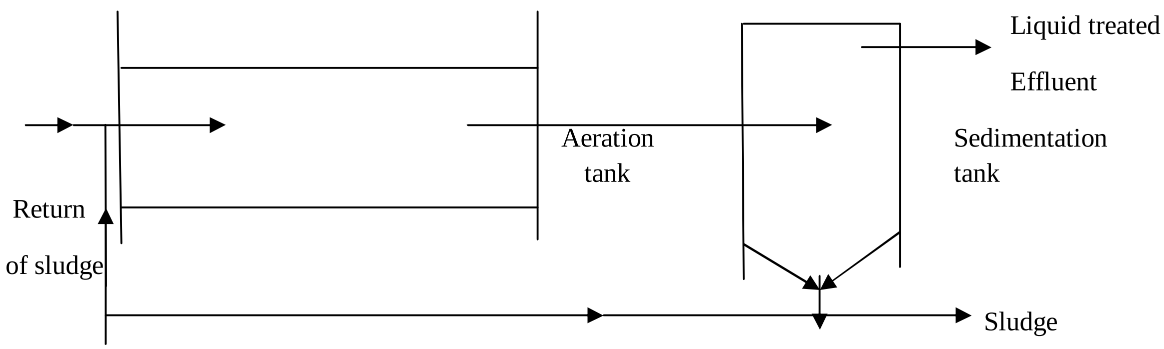

Fig. 3 Diagrammatic representation of activated sludge process

Advantages of activated sludge processes are,

1. Requirement of small area.

2. The process is efficient in reduction of BOD of effluent with great reduction of Suspended solids.

Disadvantages of activated sludge processes are,

1. Heavy foam formation in the process.

2. Presence of alky benzene sulfonate (detergent) creates problem in the process.

Various modifications in the basic process can be used to improve treatment efficiency, tapered aeration system and stepped feed aeration system. Used to balance oxygen demand of the biomass and contact stabilization, which exploits bio sorption. Denitrification (reduction of organic nitrate to nitrites) is also can be achieved by not employing aeration in the first tank. Once of the attempts to improve amount of the attempts to improve amount of oxygen availability led into the development of 'Deep-shaft'. It consists of 50 to 150 m deep shaft separated in to two regions, down comer and riser. Effluent is fed at the top of deep shaft and air is injected into down comer to make the liquid flow at the rate of 1 to 2m/s. The driving force for circulation is created by difference in density between down comer and riser. The BOD removal of almost 90% is achieved at organic loading of 3.7 to 6.6 kg BOD/m3/day at hydraulic retention time of 1 to2h.

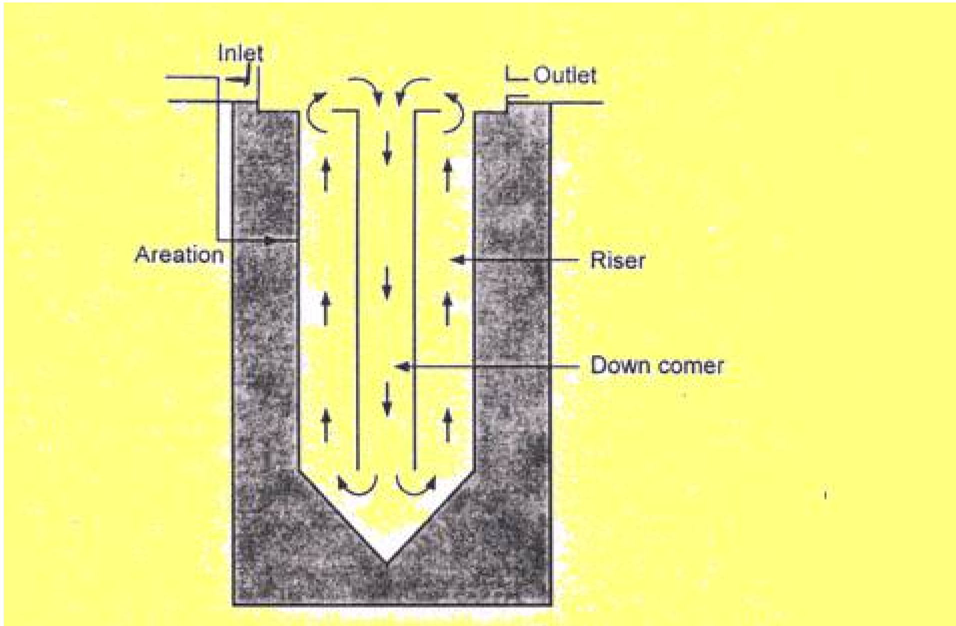

Fig 4. Deep shaft

- **Lagoons :**

Which are also called 'oxidation pond' or 'waste stabilization pond', is a large shallow body of water, 2 to 4 feet deep. It is one of the most important methods of sewage treatment in hot climates. Effluent either directly or after preliminary treatments for removal of large solids is added at a single point into the pond. Photosynthetic algae and aerobic bacteria are utilized to oxidize putrescible matter.

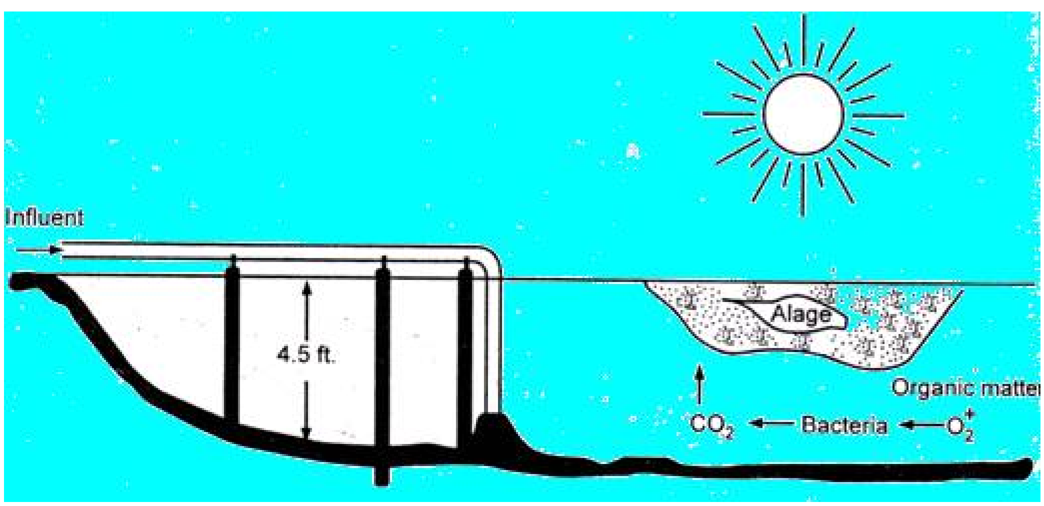

Fig 5. Lagoons

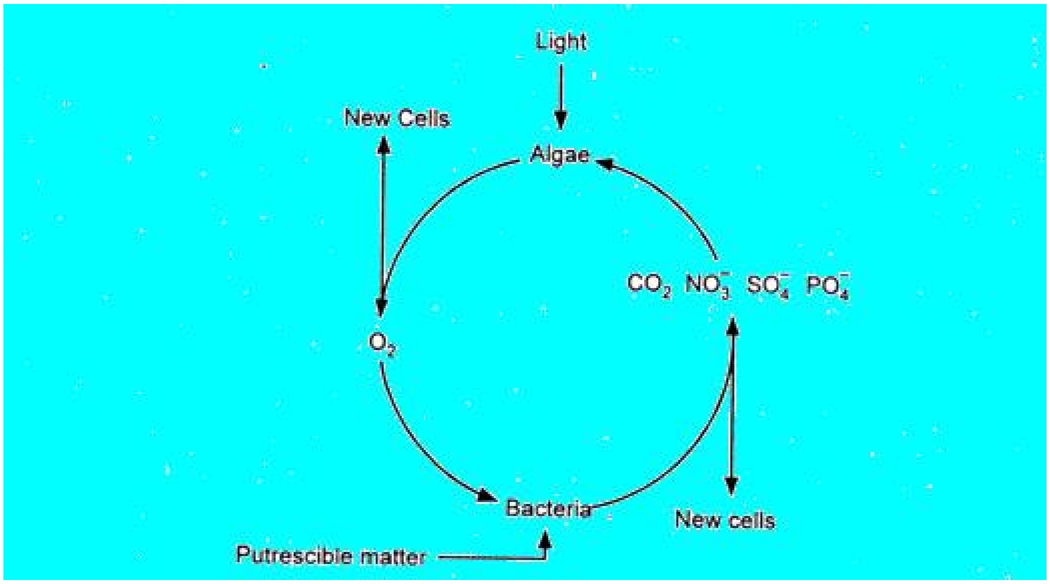

Fig 6 Symbiosis of algae and bacteria in lagoons

Symbiosis in the lagoons can be explained as, in the presence of sufficient light/ temperature/partial pressure of CO2 and oxygen, bacteria will utilize organic matter to convert into CO2 (along with phosphorus, nitrogen, other nutrients) to algae, which will be utilized as a source of energy by classical photosynthesis and as nutrients.

$$6CO_2 + 12H_2O \xrightarrow{\text{light/ algate}} C_6H_{12}O_6 + 6H_2O + 6O_2 \uparrow$$

The oxygen thus produced can be again helpful in multiplication of aerobic bacteria.

Advantages of lagoons:

1. Low cost treatment with minimum maintenance even by un-skilled person.
2. Greater efficiency in removal of pathogen.
3. Easy design with scope for alteration of treatment.
4. If required the land acquired can be reclaimed.
5. It works as a potential source of high protein food especially important in Fish farming.

Disadvantage:

1. Requires large land space.
2. In-efficiency in removal of fecal bacteria.
3. Dead algae, if not removed would become organic matter of sewage effluent itself.

- **Anaerobic processes**

The use of anaerobic process in the treatment of effluent has now been replaced by a variety of high rate digesters. The reasons for anaerobic treatment of wastewaters are,

1. Higher loading rates than aerobic processes.
2. Lower power requirement per unit BOD treated.
3. Production of digested sludge or combustible gas as by-product.
4. Rapid dewatering of sludge.
5. Easier handling of sludge due to reduced amount of biomass.
6. Lower need of supplementary nutrients due to the low level of microbial growth.

Treatment	Advantages	Disadvantages
Activated sludge	High BOD removal, Moderate ground requirement.	Consumption of high energy, Requires disposal of excess sludge, Sensitive to sudden high input.
Lagoons	High BOD removal, Operating cost is low, low skill requirement.	Fouling Considerable land requirement, requires hot weather.
Rotating biological	High BOD removal, removal, requires less space, Moderate energy requirement.	Possible fouling, Skill requirement, Excess sludge disposal.
Trickling filters	High BOD removal, cost is low, low Moderate space requirement, Employed with high input.	Moderate BOD removal, requires excess sludge removal.

Single-dwelling Unit:

1. Septic tanks: These are small rectangular, concrete chambers, sited below ground level.

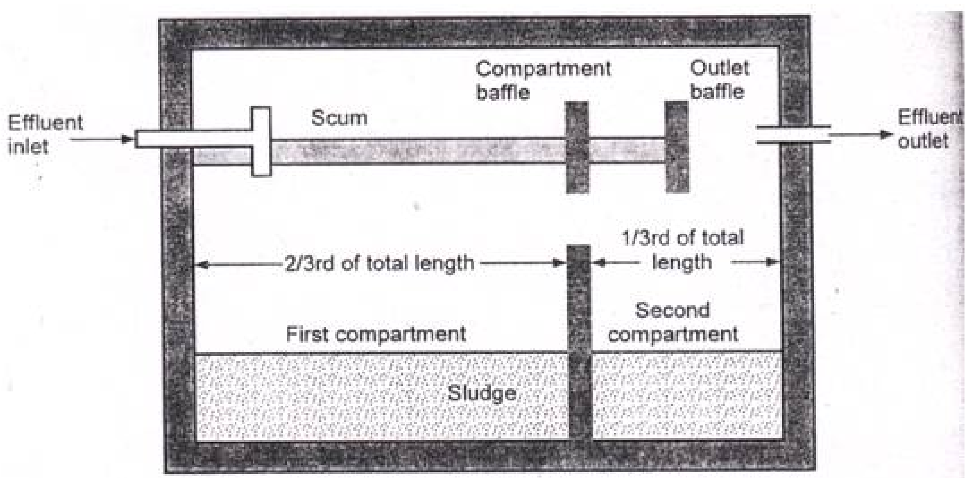

Fig 7. Septic Tank

The sewage enters into first tank, where particles settle at the bottom, with in retention time of 1 to 3 days, to form the sludge. Thick crust of scum is formed at the surface which makes the system anaerobic, allowing anaerobic digestion of sludge. Solids not settled in the first tank are settled in the second tank. The sludge accumulated is removed once in every 1 to 5 years, while effluent from the tank requires further treatment before its disposal into watercourse.

- **Imholf tank,** which functions in manner similar to septic tank, but differs in its physical design and larger size.
- **Anaerobic digesters:**The volume of the sludge can further reduced by anaerobic digestion. The solid of 80 % of degradable matter can be digested to reduce its solid contents by 50%. During the process fermenting bacteria degrade waste to free, volatile (- 60%) and CO2 (-40%). The gas produced called biogas is useful by-product and can be burned as fuel, fed to gas engines to generate electricity and used as vehicle fuel. Many high strength waste waters generally from food and agricultural industries are treated by the process. The digester tank of capacity up to 12,00 m3 with heating coils and mechanical agitations are employed either at mesophillic temperature (28 to 32) or at thermophillic temperature (55 to 63 c) for the retention time of 10 to 13 days.
    - **Anaerobic filters:** Anaerobic filters like, aerobic filters are employed in the treatment of waste by forming bio film on the inert packing. Packing can be natural or synthetic. It can even be operated in up flow and down flow made. Antibiotic fermentation waste, citric acid fermentation waste, brewery and winery wastewaters, distillery waste and waste from pharmaceutical are successfully treated with this process.
    - **Up-Flow anaerobic sludge blankets (USAB):**By which flocculated sludge developed in the reactor acts as a fluidized bed (the sludge blanket), above which particles flocculate and settle back in the blanket as sludge. Thus high level of active biomass are retained in the reactor by flocculation and is successfully employed in the treatment of domestic waste, sugar-beet wastes, slaughter house wastes, agricultural wastes, brewery wastes, winery wastes and distillery wastes etc.
    - **Final treatment** Solid sludge from the treatment can further Stabilized, dried and used as fertilizer or incinerated or buried. The liquor is chlorinated with 5 to 10 ppm chlorine and then passed into watercourse.

11. Dispose of Chemical Weapons:

There are two major ways to dispose of chemical weapons: incineration and neutralization. Incineration uses a tremendous amount of heat to turn the toxic chemical into mostly ash, water vapor, and carbon dioxide. Neutralization breaks the chemical agent down using water and a caustic compound, like sodium hyrdoxide. Both ways generate a waste product: incineration generates ash, and neutralization leaves a large amount of liquid waste that must be stored or further processed.

Leakage of chemical warfare agents may cause environmental pollution; as a result, there may be chances of serious health damage to the civilians. There are still many abandoned or dumped chemical warfare agents alover the world, therefore chemical agents containing arsenic are needed to be treated with alkaline for decomposition or to decompose with oxidizing agent. Presently, a huge amount of chemical warfare agents and the contaminated soil are processed by combustion, and industrial waste can be treated with sulfur compounds as the insoluble sulfur arsenic complex.

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