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Recent Advances in Bio - chemical Reactors for Treatment of Wastewater

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The importance of the treatment of wastewater in view of its potential health hazard has been highlighted. Typical compositions of wastewater from municipality as well as a few industries have been presented. The principle of working of the traditional free - cultured bioreactors and their performance constraints have been outlined. The relative advantages of various modern bio reactors working on immobilization technique have been projected. A comparative picture with respect to various modern bioreactors has been presented and the uniqueness of the fluidized and semifluidized bed bioreactors in the treatment of wastewater has been emphasized.

INTRODUCTION

The worldwide rise in population and the industrialization during the last few decades have resulted in ecological unbalance and degradation of the natural resources. One of the most essential natural resources which has been the worst victim of population explosion and growing industrialization **is** water. Huge quantity of wastewater generated from human settlement and industrial sectors accompany the disposal system either as municipal wastewater or as industrial wastewater. This wastewater enriched with varied polutants and harmful both for human being and the aquatic flora and fauna, finds it way out into the nearly flowing or stationary water bodies and thus make the natural sources of water seriously contaminated. The presence of some harmful pollutants in wastewater deteriorates the water quality considerably and has damaging effect on both aquatic life and human health.

It has been estimated that over 5 million chemical substances produced by industries have been identified and about 12000 of these are marketed which amount to around half of the total production. Due to discharge of toxic effluents long term consequence of exposure can cause cancer, delayed nervous damage, malformations in unborn children, mutagenic changes, neuro - logical disorders, etc. Various acid manufacturing industries discharge acidic effluent which not only make the land infertile but make the water of the river acidic also. The high acidity causes stomach diseases and skin ailments in human beings.

Alkaline effluents cause infertility of the soil and destroy the flora and fauna of the vicinity. Contaminated water by pesticides, such as DDT, aldrin, dieldrin, heptachlor, etc., are harmful for aquatic life and human beings as well. Discharge of cyanide contained wastewater to water mass may lead to death of fish and other aquatic life therein. Use of water containing fluoride can causes mental disorders and stomach ailments and can also reduces agricultural production.

So far as public health is concerned, wastewater from chemical process industries (CPI) are almost totally responsible due to the presence of toxic and harmful chemicals, like phenol, heavy metals (Pb, As, Cd, Cr, Zn, etc.), and pesticides therein. The characteristics of industrial effluents in wastewater vary with type of CPI. Wastewater characteristics from a few typical CPI are presented in tables 1, 2, 3, and that of municipal wastewater in tables 4 and 5 depicts the harmful effects of a few pollutants on human health. The pollutants present in wastewater are of organic and inorganic types. The organic matters which may be fast biodegradable, slowly biodegradable or bio - refractory can be controlled easily as compared to inorganic pollutants, like cyanides, heavy metals, fluorides, etc. However, similar wastewater streams can be tackeled by most common treatment methods. Recently EPA has come up with an approach in which all the chemicals are grouped together according to similar physical or chemical characteristics.

CONVENTIONAL BIO - REACTOR FOR TREAT-

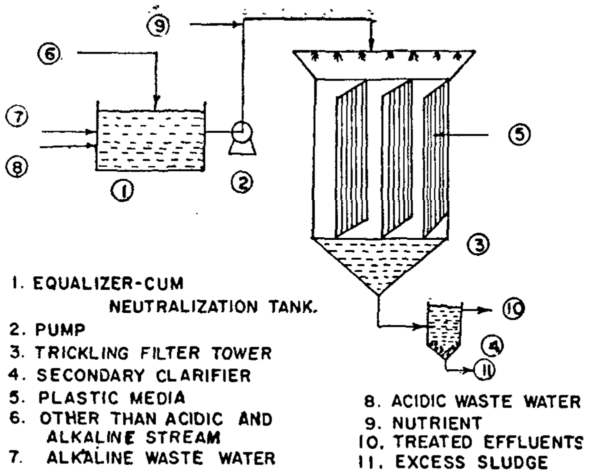

Figure 1. *Trickling filter*

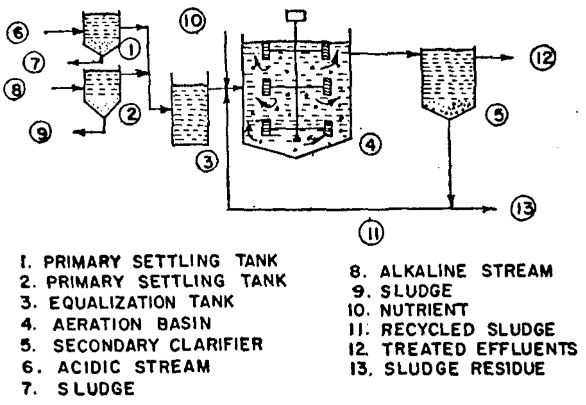

Figure 2. *Activated sludge process*

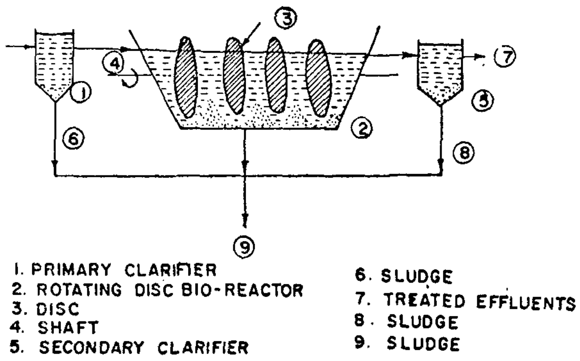

Figure 3. *Rotating disc bio - reactor*

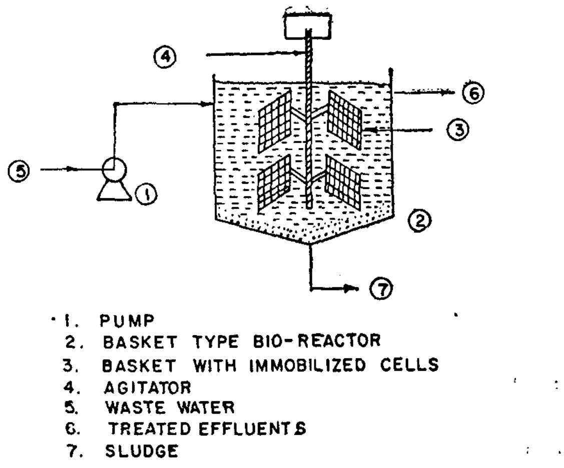

Figure 4. *Basket type bio - reactor*

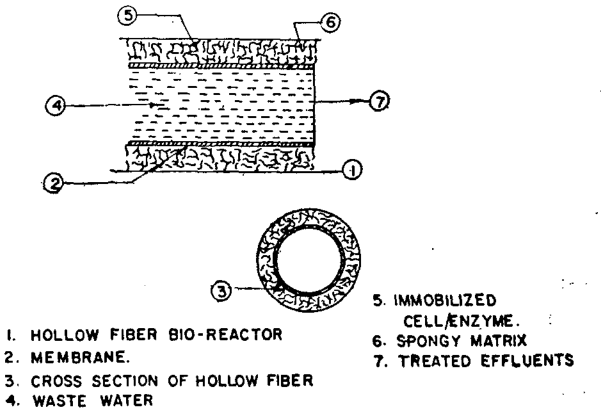

Figure 5. *Hollow fiber bio - reactor*

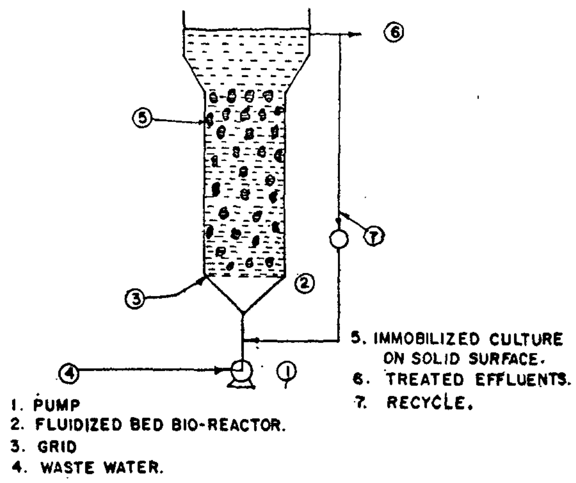

Figure 6. *Fluidized bed bio - reactor*

MENT OF WASTEWATER

Wastewater contains biodegradable organic matters in the form of settled, suspended and dissolved solids. To remove BOD different conventional bio - reactors are being used for the last few years. These commonly used conventional bio - reactors are : (1) Aerated lagoon, (2) Oxidation ditch, (3) Activated sludg tank, (4) Trickling filter, (5) Anaerobic digestion tank, and (6) Oxidation pond. Salient features of these reactors are outlined as under.

Aerated lagoon

These are big cement tanks of 4 - 6 m in depth cal-

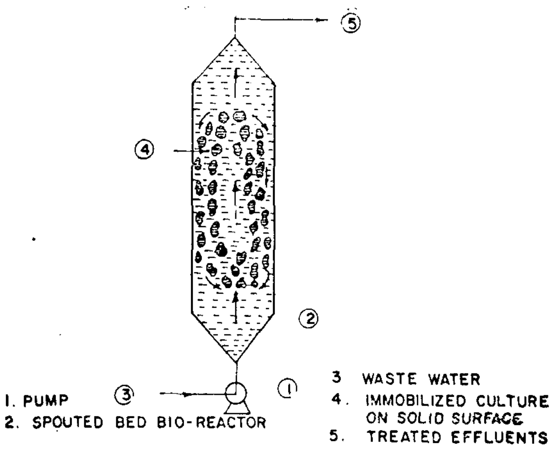

Figure 7. *Spouted bed bio - reactor*

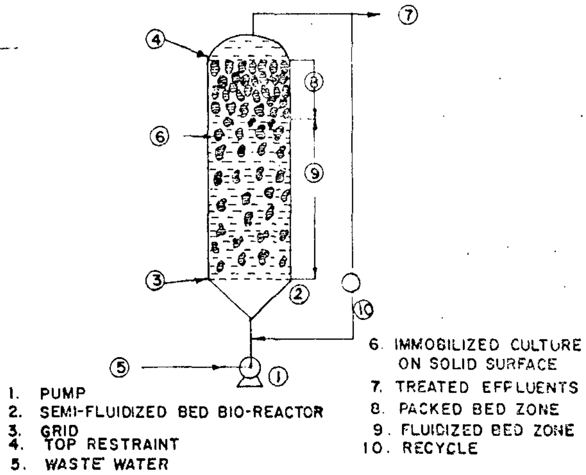

Figure 8. *Semi - fluidized bed - reactor*

led lagoons used for oxidation of dissolved organics. The wastewater passed through these lagoons are aerated mechanically. After 3 to 4 day sludge is formed, as a result of the oxidation of soluble organics present in the effluent. 85 - 90 % BOD can be removed by this process. The only drawback of this process is that it requires large space for lagoons.

Oxidation ditch

Oxidation ditch is a long continuous channel (lined with butyl rubber or plastic) about 1 - 2 m in depth. The wastewater after primary treatment is passed into oxidation ditch and is kept here for long time as it is a slow process. BOD of the process is 85-95 %. However, high retention time is its major drawbacks.

Trickling filter

Generally circular trickling filters are used. A bed of 2 - 3 m in depth consisting of broken stones, plastic media, PVC circular piece serves as a trickling filter (Figure 1). When effluent water after primary treatment is sprinckled over a bed of broken stones, the bacterial slimes (aerobic organisms) are generated on the stone or plastic and oxidise the effluent. This works with BOD removal of 75 - 83 %. However, cost of construction of trickling filter is high, and it has a low efficiency, in addition some operational troubles are encountered with such filters.

Anaerobic digestion

This treatment is in fact a slow oxidative digestion process carried out in absence of air in a closed container where ammonia, *methane,* etc., are released. In this process microbes actively digest the organic matters present. BOD removal of this process is 90 - 94 %. However, high retention time is the major drawback of the process.

Activated sludge process

In this process the effluent after primary treatment is mixed with 20 - 30 % of own volume of activated sludge, which contains a large concentration of highly active aerobic micro - organisms. The mixture enters an aeration tank, where the micro - organisms and the wastewater are intimately mixed together with a large quantity of air (Figure 2). Under these conditions, the moving organisms will oxidise the organic matter and the suspended and colloidal matters tend to coagulate and form precipitate which settles down readily. Settled mass is called activated sludge. BOD removal is generally 80 - 90 %. Some of the drawbacks are : (1) operating cost is high, (2) the quantity of sludge obtained is large and needs suitable thickening and disposal.

Oxidation pond

Oxidation ponds is infact nothing but a shallow-dug pond, surrounded on all 4 sides by high embankments. The wastewater after primary treatment is allowed to collect in this pond where along with sedimentation, the organic matter is oxidised through the combined action of algae and other micro - organisms. Some of the drawbacks are : (1) Adequate sunlight requirement, (2) high retention time,. (3) large area requirement, (4) nuisance due to mosquito breeding, and (5) bad odour.

RECENT BIO - CHEMICAL IMMOBILIZED REACTORS

Table 1. *Characteristics of wastewater from a petroleum refinery*

Parameter	Amount range, mg/L
Free oil	2000-3000
Emulsified oil	80-120
HS and mercaptans	10-220
Phenolic compounds	12-30
BOD	100-300
Suspended solids	200-400

Table 2. *Characteristics of wastewater from steel industry*

Parameter	Amount range, mg/L
pH	8.5-9.5
Phenol	500-1000
Total ammonia	800-1400
Cyanides	10-50
Sulphides	10-20
Thio - sulphate	110-220
Thio - cyanate	50-100
BOD	160
COD	790-2450
DS	125-800
SS	50-500
Fe and Mn	<0.4

Table 3. *Characteristics of wastewater from distillery industry*

Parameter	Amount range, mg/L
PH	4.5-5.5
BOD	1600-2100
COD	3026-52,000
Turbidity	350
Chlorides and sulphides	7000-10,000
Colour	Brownish yellow

The conventional free cultured bio - reactors have some drawbacks as outlined above. Also the mass transfer rate and performance of such bio - reactors are not so good, that is to bring down the pollution load in terms of BOD to a desireable standard is not satisfactory. In addition, their efficiency cannot cope - up with the future wastewater treatment demand, so far as economic and environmetal standards under Indian conditions are concerned. So wastewater treatment methods using modern immobilized bioreactors developed by various groups of research teams the world over, have become relevant in the present context.

Table 4. *Typical characteristics of domestic wastewater*

Parameter	Amount range, mg/L
TS	700
DS	500
SS	200
BOD	200
COD	500
Nitrogen	40
Chlorides	50
Phosphorous	10
Grease	100

Table 5. *Effects of specific water pollutants on human health*

Source	Effect
Wastewater from tanning and meet packaging industry containing pathogens and water borne bacteria	Typhoid, cholera, amoebic dysentery and gastoenteritis
Nitrate at high concentration	Methaemoglobin anemia, gastric cancer
Mercury and its compound	Gastrointestinal and pulmonary damage
Arsenic	Chronic intoxication
Cadmium	Pulmonary fibrosis
Cyanides	Mental confusion, weakness, vomiting and fatique

Immobilization

The technique of cell immobilization/enzyme immobilization is the process by which ceils are confined to a certain specified region of space in such a way that these exhibit totally different hydro dynamic characteristics than surrounding environment. Here cells can be continuously reused. The 4 methods of immobilization are entrapment, adsorption, covalent bonding and cross linking.

Advantages of immobilization over free - cultured bio reactors

There are various advantages of immobilization systems. Some of those are :

1. Continuous reactor operation at any desired liquid throughput without risk of cell or enzyme washout.

2. High population rate. This is a direct consequence of retaining a high concentration of cells or enzyme in the reactor.

3. Easy cell - treated water separation.

4. Repeated batch operation using same cell or enzymes.

5. Enhanced gas - liquid mass transfer due to elimination of viscosity problem often associated with high concentrations of dispersed cells.

6. Plugflow operation by maintaining the immobilized cells or enzymes as a stationary phase.

The salient features of immobilized reactors

The modern immobilized bio -reactors for wastewater treatment have the following features : (1) Small volume and site requirement; (2) Closed and emission proof reactor, (3) High - volume based purification efficiency, (4) Amenability to scale - up, (5) High operation flexibility, and (6) Prospect for industrial application.

Novel immobilized bio - reactors

Rotating disc biological reactors : The rotating disc biological reactor consists of large diameter plastic media mounted on a horizontal shaft and placed in a concrete tank (Figure 3). The contactor is slowly rotated at a rate of 1 - 2 rpm with about 40 % submergence in wastewater. After starting the operation organisms originally present in the wastewater adhere to the rotating surface and multiply in approximately one week covering the entire surface area with a coat of 1 to 4 mm thick bio - mass. The attached bio - mass contains approximately 50,000 to 100,00,0 mg/L of suspended solids. The biological population present on the surface area of the disc is mostly responsible for the treatment achieved. The rotating media serves the following functions :

1. Provides surface area for the development of a large volume of fixed biological culture.

2. Provides vigorous contact for the biological growth with the wastewater.

3. Efficiently aerates the wastewater.

Basket type bio - reactors : In a basket type bio - reactor immobilized cells are cultured in a basket, generally made up plastic or pvc materials (Figure 4). In the agitator baskets are mounted and rotates at low speed of 5 - 6 rpm. The wastewater is aerated by the agitator and immobilized bio - mass acts on the wastewater. This new technique is very much effective and cell retention time is also less.

Hollow fiber reactor : This type of reactor consists of a bundle of tubular hollow fibers inside a shell (Figure 5). the fiber is made of semipermiable membrane which keeps the flowing stream of wastewater segregated from the bio - catalyst. The substrate readily diffuses through the membrane and contacts the immobilized bed, which is packed in the shell side of fiber bundle. The product with concentration build - up in the immobilized bed diffuses out radially through the membrane and exits with depleted pollutant stream.

Fluidized bed bio-reactors : Fluidized bed bio - reactors (Figure 6) are becoming increasingly popular in the wastewater treatment. They are effective for aerobic treatments. Such reactors have a number of advantages over the conventional bio - reactors namely very high hold - up of bio - mass, prevention of washout of microbes, absence of cloging of bio - mass, increased resistance to variations in the substrate concentration, toxic chemicals, heavy metals, etc., ease of separation of cells from treated stream and large liquid - solid contacting area, and high mass transfer rate. For aerobic biological reactions, oxygen must be supplied to the micro - organisms by bubbling bed fluidized reactor to increase the dissolved oxygen level oi the incoming wastewater. Both 2 phase with pre - aeration and 3 phase fluidized bed reactors have been successfully applied to the aerobic biological treatment of wastewater. The gas - liquid immobilized cultured-cell (solid) fluidized bed has an inherent advantage over liquid - solid fluidized bed due to the improved supply of oxygen to the micro - organisms and the elimination of the need for pre - aeration of the wastewater.

Spouted bed bio - reactors : Spouting is a new technique developed for contacting wastewater with coarse grannular immobilized solids. In fact it is the combination of a dilute fluidized phase and co - ex--isting moving bed of solids (Figure 7). The velocity corresponding to the onset of spouting depends to a considerable extent on the orifice diameter, cone angle, the bed height and column diameter to orifice meter ratio. It has been established that smaller the cone angle, lesser is the amount of fluid need for spouting. The advantage of this technique is that the efficiency is very high.

Semifluidized bed bio - reactors : Semifluidization is a novel method of contacting solids with fluid which has been developed recently. The semifluidization phenomenon can be looked upon as simultaneous formation of a packed bed and a fluidized bed by prevention of free expansion of a fluidized bed with the introduction of an adjustable screen, which allows only the fluid to pass through (Figure 8). The bottom portion of the bed will be in a fluidized condition and the top portion of the bad in the packed bed state. Such technique will overcome the disadvantages of fluidized bed, namely back mixing, attrition and erosion of immobilized solids and will also overcome certain drawbacks of packed bed, such as particle segregation, non - uniformity in temperature and channeling. The characteristics of a semifluidized bed bio - reactors are greatly influenced by size, shape and density of immobilized cells, velocity and viscosity of wastewater and dimensions of the column and its configuration.

CONCLUSION

Although the conventional bio - reactors are simplest in construction and are largely in use in the bio- chemical treatment of wastewater , the modern immobilized bio - reactors are more efficient and also become cost effective in the long run. Specialy the fluidized and semifluidized bed bio - reactors in particular have offered better stability while working with the immobilized cells. Good flow characteristics permitting a high dilution rate of the medium keeps the cell growth under control. Also the solid particle entrapped in the Immobilized cell distribute uniformly throughput the reactor volume thereby ensuring uniform cell density and cultured environment. To meet significant environmental requirements in a cost - effective manner with respect to the continuous treatment of wastewater, immobilized fluidized and semifluidized bed bio - reactors will no doubt, become the ultimate choice of the future public health engineers.