IJEP 15 ( 6 ) : 451 - 454 ( Received on April 29, 1995 )

# Biofluidization : A Novel Technique for the Treatment of Wastewater

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**Application of the principle of fluidization to various bio - conversion processes in general and the management of solid and liquid effluents in particular has been highlighted. Salient features of an aerobic fluidized bed reactor for the treatment of wastewater have been detailed and its priority over the operation of a conventional one (namely the activated sludge homogeneous reactor) has been established. Use of anaerobic technique for the effective and economic treatment of organic waste with high oxygen demand has been emphasized and the use of a fluidized bed for the purpose has been recommended. Some general design guidelines for aerobic and anaerobic biofluidizers have been presented. Bioconversion of liquid sludge through incineration and wet scrubbing has also been highlighted.**

## INTRODUCTION

During the last 15 year, principle of fluidization has found wide application in the fields of biotechnology and biomass conversion. Although these applications encompass a number of diverse fields, like biocatalysis, production of beer, wine and vinegar by fermentation, the main thrust of these fluidization studies has been in the areas of environmental technology and biomass conversion, that is the management of solid and liquid wastes and their treatment and/or disposal through fluidized - bed units. The present use of biofluidization can be broadly divided into the following areas : (i ) fermentation, ( ii ) aerobic and anaerobic wastewater treatment, (iii) immobilized cells and enzymes, ( iv ) metabolite production, ( v ) enzyme production, ( vi ) immobilized and pelletized microorganisms, and ( vii) biomass conversion.

Basically 3 types of particles can be used in a biological fluidized bed ( Atkinson and Mavituna, 1983 ) : ( 1 ) Flocculated microorganisms, ( 2 ) Solid supports with attached biomass, and ( 3 ) Biomass support particles, like stainless steel wirespheres, polypropylene toroids and even calcium carbonate pellets. Growth can initiate fluidization in a bed of inert particles when one flow is below the incipient fluidization velocity of the uninoculated bed. Also these beds can be operated both with steady and variable particle holdups.

## AEROBIC TREATMENT OF WASTEWATER

The oldest application of fluidization is in the area of nitrification and denitrification of wastewater ( Schiigerl, 1989). Nitrification is the biological oxidation of ammonia to nitrate according to the overall reaction :

$$NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 2H_2^+ + H_2O$$
$$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$$

Nitrification is carried out in immobilized biofilm reactors with mixed populations under aerobic conditions to prevent washout of bacteria as nitrification proceeds only after the complete consumption of the carbon substrate. Denitrification is the biological reduction of nitrate ions to nitrous oxide and nitrogen in the absence of oxygen, but in the presence of a suitable electron donor, like methanol. It can be accomplished by several facultative heterotrophic micro - organisms and the overall reaction may be given as :

$$6\ NO_3^- + 5\ CH_3OH \rightarrow 3N_2 + 5\ CO_2 + 7H_2O + 6\ OH^-$$

The possibility of treating wastewater by passing it through a fluidized bed of particles covered by a bacterial film was initially demonstrated by Freidman and co - workers in 1971 as reported by Andrews and Tien ( 1979 ). Sand and coal beds have been proposed for denitrification, secondary treatment of domestic sewage, and the removal of phenolics from coal processing waste. Their main advantage over conventional biofilm reactors like the trickling filter is their enormous surface area of film.

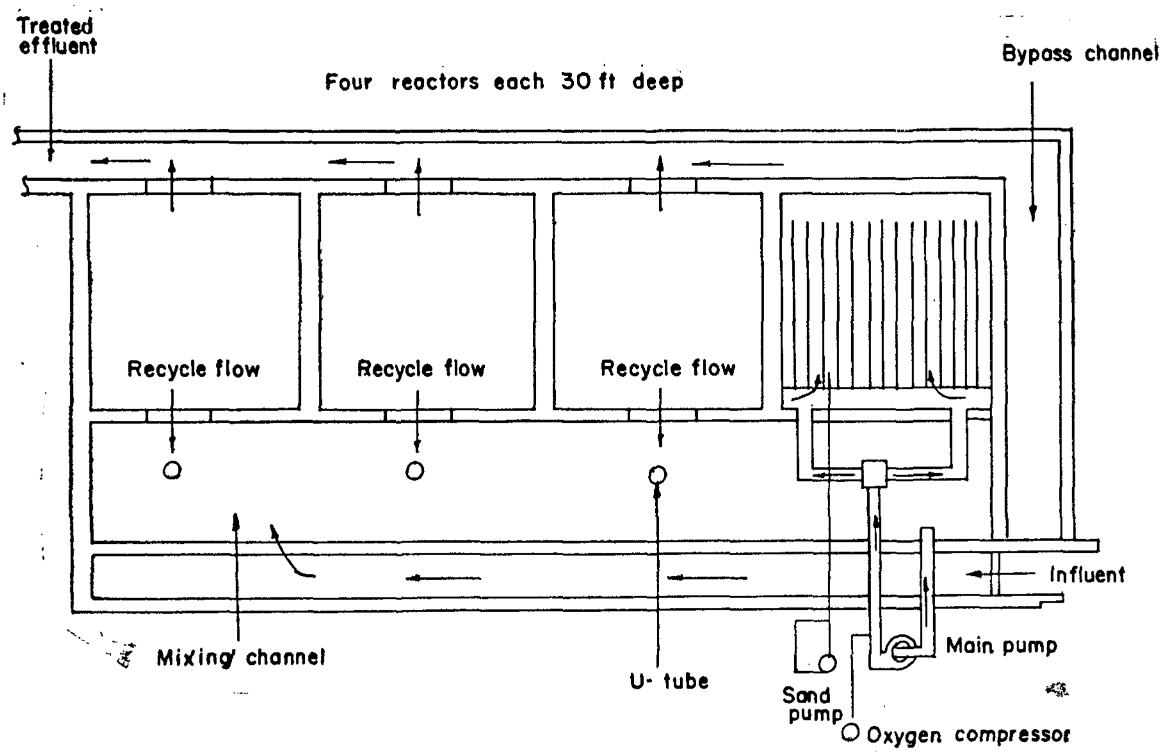


**Figure 1**. *Aerobic fluidised - bed reactor (plan view)*

which gives large removal rates in a relatively small reactor volume. Also they have a lower probability of clogging.

The biological treatment of soluble organic wastewaters of domestic and industrial origin, required Intimate contacting of the reactive components (substrate, biomass and oxygen). A method for increasing due rate of reaction is to increase the biomass concentration and thus reduce plant size, In conventional homogeneous reactors, such as activated sludge process, increase in biomass concentration is limited by oxygen transfer consideration and by the fact that at higher concentration above 6 gm/L, biomass separation from treated effluent by simple gravity settlement is not easy. Fluidized bed reactors offer a solution to these problems. Since the biomass is fixed as a film attached to the support medium, which due to its size, provides a high surface to volume ratio and results in high biomass concentration. Details of a typical aerobic fluidized bed reactor has been outlined in figure 1.

The operational aspects of an aerobic fluidized bed reactor for domestic sewage and simulated dairy waste treatment have been examined and described by Forster *et al.* (1986). Their use of a tapered *bed* design for a combined *oxygenator fluidized* bed system proved to be *an* efficient and stable method for treatment of soluble organic waste. The unit used both with settled sewage and a simulated dairy waste as a feed - stock gave from 70 - 95 % reduction in oxygen demand of the feed. The bed could be operated to control film thickness by media removal at a specified height to maintain film at a compact stage. They also showed that the film became porous and less dense as it grew in the unit.

## ANAEROBIC TREATMENT OF WASTEWATER

Aerobic treatment of organic wastes with a high oxygen demand can be costly as a consequence of the large volumes of air and the capital investment in aeration plant required for higher rate processes (for example activated sludge plants ) or the large areas of land needed for slower processos as practised in lagoons. Anaerobic treatment is an alternative but conventional anaerobic digestors have proved to be unsatisfactory for high rate treatment of liquid waste due to microbial washout at high volumetric loadings. Bull *et al.* (1982) examined the use of anaerobic fluidized bed process for treatment of high strength wastewater at ambient and elevated temperatures. This proved to be an effective method and was capable of attaining greater than 70 % COD reduction at COD leading of up to 6 kg/m$^3$/day. if operated at 37 $^0$C and 3 kg/m$^3$/day, if used at lower ambient temperature. The effluent suspended solids from re-

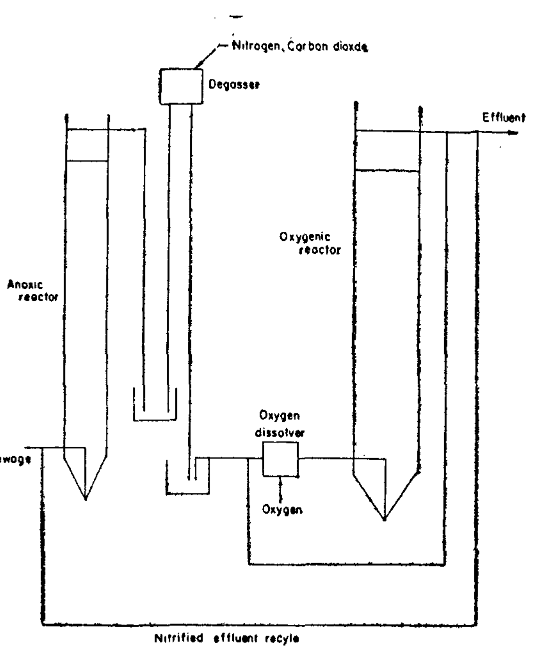


**Figure 2.** *TWO - reactor fluidised - bed system for complete sewage treatment including denitrification*

actors ware high in comparison to reactors treating dilute wastes and using light support particles due to higher upflow velocities required. The reactor was not adversely affected by temperature variation and was found to be capable of operating at high loading rates with minimal excess sludge production.

**The** overall anaerobic conversion of biodegradable organic solids to end products, like methane and carbon dioxide can be divided into 3 stages, which occur consecutively and simultaneously in a single stage digester : ( a ) hydrolysis of insoluble biodegradable polymers, ( b ) the production of acid from smaller soluble organic molecules, and (c ) methane formation. The hydrolysis of insoluble organic materials is the rate limiting step.

Until 1983, anaerobic fluidized bed systems had been operated only on laboratory and pilot - plant scales in contrast to other reactor types, like filter reactors, many of which have been In full scale operation. However, since 1984, several full scale anaerobic fluidized bed reactors have been functioning. These consist of 2 fluidized bed, in the first of which acidification is carried out while in the second the methanation is performed (schiigerl. 1989 ). The advantages of this 2 6tage system are : ( 1 ) much higher methane activity of the methanogenic sludge, as much as three times that of a single stage, ( 2 ) in acidification in a fluidized bed reactor, about 30 % of total methane

**Table 1.** *Operating data of full - scale anaerobic fluidized bed plant at Deflt*

| Parameter | Operating data |
|---|---|
| COD | 3.2 |
| Temperature, °C | 37.0 |
| pH | 6.8 |
| Residence time, hr | 2.4 |
| COD efficiency, % | 70.0 |
| Water flow, $m^3$/hr | 180.0 |
| COC conversion, kg/$m^3$. d | 22.0 |
| Biomass concentration, kg/$m^3$ | 20.0 |
| Fatty acids in effluent, mg/L | 100.0 |

is produced, ( 3 ) easier pH control and less alkali consumption, ( 4 ) better process stability with respect to loading shocks, ( 5 ) easier biolayer thickness control, and ( 6 ) higher purification capacity with higher purification efficiency.

Table 1 gives the operating data of 2 fullscale anaerobic fluidized bed plants built by Gist-Brocade. The Delft plant has 2 identical reactors (reactor diameter-4.6 m, fluidized bed height - 2 1 m ). At the top of the reactors in the 3 phase separator, the carrier particles are entrained by the high gas turbulence and are recovered. Sand of 0.1 to 0.3 mm diameter is used as carrier at liquid superficial velocity of 8 to 20 m/hr. An average COD conversion capacity of 20 kg COD/$m^3$/day and a purification efficiency of 60 to 70 % of COD was achieved at 37 °C at a liquid residence time of 1.2 hr per reactor and a biomass concentration of 20 kg/$m^3$ in the reactor. Figure 2 gives the flowsheet of a 2 reactor fluidized bed system for complex sewage treatment including denitrification using the carbon present in the settled sewage.

## GENERAL DESIGN GUIDELINES FOR AEROBIC AND ANAEROBIC BIO - FLUIDIZERS

The growth of a bacterial film in a fluidized bed will not clog it as the bed is able to expand and accomodate the extra volume. The resulting expansion being quite large, the bed height becomes an important operating parameter. The bed height has been related to the amount of biomass in the bed by Andrews and Tien ( 1979 ). Their relation can be used to predict bed height during the design stage, and to infer the quantity of biomass in the bed from its height during operation. The bed porosity for biofluidized bed can be calculated with the help of Rechardson and Zaki ( 1954 ) relationship. The biomass hold - up in a biofluidized bed depends upon the type of organism. Filamentous organisms give rise to loose biofilms and rather low biomass concentratron in comparision to the concentration obtained with rodshaped bacteria. Also the biomass thickness must be kept below 250 $\mu m$ in order to prevent nitrogen bubbles from adhering to the surface, which could result in sudden biomass carryover (Schiigerl, 1989 ).

Andrews and Tien ( 1982 ) have analyzed the bacterial growth in a fluidized bed adsorption column. This is specifically directed to bacterial films that develop on the surface of activated carbon particles in absorption columns treating biodegradable wastewater. The films have some beneficial effects, including direct uptake of organic matter from the waste stream and bioregeneration of the carbon. However, there are also deleterious effects, such as the extra mass transfer resistance that the film presents to absorption. These effects have been incorporated into a mathematical model, that is useful in the design of absorption columns and to evaluate various schemes for fluidized bed bacteria/carbon treatment units.

## BIO - CONVERSION OF LIQUID SLUDGES

Wastewater of high solid consistency ( sludge ) containing biomass can be disposed off by incineration, which is a very hygienic operation. Incineration has been used to reduce the volume of sludges after dewatering. The organic fracrion and/or biomass in sludges lend themselves to incineration if they do not have too much water. Fluid - bed incinerators have been used for sludge combustion ( Perry and Green. 1984). A fluid - bed incinerator uses hot sand as a heat reservoir for dewatering the sludge and combusting the organics. The turbulence created by the incoming air and the sand suspension requires the effluent gases to be treated in a wet scrubber prior to final discharge. The ash is removed from the scrubber water by a cyclone separator and is buried. The scrubber water is normally returned to the treatment process and diluted with total plant effluent. The process of incineration can be coupled with effective heat recovery depending upon organic/biomass content of the sludges.

## CONCLUSION

The technique of bio - fluidization has achieved commercial scale application in the fields of nitrification/denitrification of wastewater and anaerobic digestion of effluents. With the quality and quantity of research investigations going on in this field the world over, if is likely to achieve a greater significance in the waste management scenario of the near future.

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