

WASTEWATER TREATMENT IN RUBBER INDUSTRY WITH SPECIAL EMPHASIS ON ANAEROBIC SYSTEMS

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ABSTRACT

Natural rubber (NR) collected as latex by tapping the bark of rubber tree (*Hevea brasiliensis*) is one of the excellent raw materials suitable for many industrial products. The dry rubber content (DRC) of latex is about 30% and non-rubber part is about 70%. This 70% of non-rubber part together with water used for processing is discharged as the wastewater from rubber factories. Raw rubber industry has been identified as one of the largest sources of organic pollution of water in rubber growing countries including Sri Lanka. Presently, anaerobic wastewater treatment is gaining popularity as simple technology for the treatment of a variety of wastewaters. Many researches have shown that anaerobic digestion is the most important digestion method for wastewater treatment in developing countries due to its simplicity, low cost, effective treatment and recovery methods. This paper gives a short account on anaerobic wastewater treatment methods that have been reported recently and the Sri Lankan experience of the same.

INTRODUCTION

Hevea latex is traditionally processed in to different types of raw rubber such as latex crepe, ribbed smoked sheets and technically specified rubber. During production, rubber part is separated by acid coagulation. NR is also converted to concentrated form by centrifugation. The non-rubber part of latex, together with water and traces of chemicals used during processing of latex is discharged as the rubber factory effluent, causing environmental problems in rubber growing areas. According to Central Bank statistics from 1989 to 2004, the mean total production of natural rubber in Sri Lanka is about 100 million kg per year. Production of one kg of dry rubber, results in approximately 0.18 kg of dissolved chemical oxygen demand (COD) due to non-rubber constituents (Anon, 1992). This means that the natural rubber industry in Sri Lanka discharges approximately 18 million kg of COD annually to the environment.

Until 1990, regulatory standards for pollutants were not available for rubber factory effluent discharged in Sri Lanka. National Environmental (protection and quality) Regulations No. 1, enacted in 1990, specifies the standards for a number of specific industries for wastewater discharge including the latex crepe industry and concentrated latex industry. With this new legislation, almost all the rubber

processing factories are required to treat their effluents prior to discharge and finding a suitable cost effective treatment system for their factory effluent, has become a problem of serious concern.

From an economical point of view biological treatment is the most suitable for biodegradable liquid waste treatment when compared to extensive physical and chemical treatment methods. The soluble and colloidal organic substances in the rubber factory effluent are the major pollutants. These can be removed either by aerobic or anaerobic treatment or by a combination of both treatment methods. The high organic load and variable flows of rubber factory effluent and the limited land availability in many factory sites, means that the process chosen must be compact and have a low response time and also be capable of effective in operating over a wide range of loading rates.

Aerobic treatment methods are popular around the world for wastewater treatment because of less hassle and lesser problems encountered in operation of the system. Aerobic systems inherently use extensive energy for providing oxygen to the system and hence cost more. Anaerobic systems are not energy extensive as such, but in operation, more hassles and problems are encountered. Proper designing of the anaerobic treatment systems cut down the inherent problems encountered with them. Anaerobic treatment mainly converts biodegradable organic matter into methane, carbon dioxide, water, reduced salt and biomass. No added chemical (like oxygen in aerobic treatment) is required, the sludge yield is less, less nutrients and minerals are required and the sludge has a higher solids content (Barnes *et al.*, 1981). In addition, methane (biogas) produced can be used as a fuel. Recent developments in the digester design and recent advances in the understanding of the microbiology of the process have significantly improved the potential use of anaerobic method for industrial wastewater treatment.

Anaerobic treatment

Tchobanoglous & Burton (1991), have concluded that all of the biological processes are derived from the aerobic and anaerobic cycles occurring in the nature. Bacteria is the most important group of microorganism in biological wastewater treatment and maintained either by suspended form, fixed form or by both forms within the reactors. In biological treatment processes, the decomposition of waste is speeded up by controlling the environment of microorganisms.

Table 1. *Typical characteristics of a high-rate anaerobic system. (Weiland & Rozzi, 1991)*

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| • High organic loading rate | • Low energy demand |
| • Short hydraulic retention time | • High process reliability |
| • High COD removal efficiency | • Applicability to different wastewaters |
| • High tolerance to overloadings | • Easy operation and control |
| • Fast start-up and re-start after shutdowns | • Economic in material and design |

Conventional anaerobic treatment processes always face the problem of biomass retention (Lettinga *et al.*, 1980). All modern high-rate anaerobic treatment systems are based on some kind of sludge immobilization principle such as attachment to stationary packing material or to particulate carrier material or sludge aggregation through granulation or flock formation (Pol & Lettinga, 1986).

General acceptance of the impact of less tolerability of anaerobic treatment process to toxicity could be minimized by proper designing of the same (Speece *et al.*, 1986). Methane (bio-gas) production (Young, 1991; Lettinga & Pol, 1986; Tchobanoglous & Burton, 1991) is one of the beneficial points in anaerobic treatment. Anaerobic reactors generally have performed satisfactorily when operated at 25-38°C in the mesophilic range and 50-60°C at thermophilic range. Generally, operating in thermophilic range is not justified unless the waste temperature is already above 55°C because the energy needed to raise temperature is greater than the value of the additional methane obtained. Bio-gas collection is not significant from reactors treating low strength wastes (Young, 1991).

Table 2. *Benefits and limitations of anaerobic treatment of wastewater (Lettinga et al, 1980)*

Benefits	Limitations
<ol style="list-style-type: none"> 1. Low production of waste biological solids. 2. Waste biological sludge is a highly stabilized product that as a rule can be easily de-watered. 3. No energy requirements. 4. No energy requirement for aeration. 5. Production of methane, which is a useful end-product 6. Very high loading rates can be applied under favourable conditions 7. Active anaerobic sludge can be preserved unfed for many months 	<ol style="list-style-type: none"> 1. Anaerobic digestion is a rather sensitive process, e.g. The presence of specific compounds, such as CHCl₃, CCl₄ and CN⁻. 2. Relatively long periods of time are required to start-up process, as a result of the slow growth rate of anaerobic bacteria. 3. Anaerobic digestion is essentially a pretreatment method; an adequate post treatment is usually required before the effluent can be discharged into receiving waters. 4. Little practical experience has been gained with the application of the process to the direct treatment of wastewater.

Complete anaerobic treatment systems

Anaerobic filters

Anaerobic filter (AF) is a column filled with medium for biomass attachment used for the treatment of the carbonaceous organic matter in wastewater. There are many different types of media that are used in AFs. The feed mode of an anaerobic filter may be either down flow or up flow. This fixed film system has the ability of maintaining a high mean cell residence time. The gas production of AFs is very useful in mixing the contents within the reactor and this mixing behaviour increases with the height of the reactor (Tilche & Vieira, 1991; Samson & Kennedy, 1985).

Weiland & Rozzi, (1991) identified the bottle necks in industrial application of AF as:

- uniform distribution of the fed
- clogging and channelling of the bed
- periodic backwash of the bed
- accumulation of inert particles
- sludge separation from the effluent

When comparing with other anaerobic treatment systems, the biomass is more evenly distributed within the AF reactors as the medium is packed evenly throughout the reactor (Weiland & Rozzi, 1991) and this enhances the reactor performance. In biological filters, media act as a gas/solid separator (Young, 1991 and Tilche & Vieira, 1991). The packing media in AF helps in preventing biomass washout resulting from sludge flotation during high biogas production (Kennedy & Guiot, 1986).

Anaerobic pond/ lagoon process

Anaerobic pond commonly known as anaerobic lagoon is a deep earthen pond that have been constructed with depths up to 30ft. (9.1m) and consisted of an appropriate inlet and outlet piping. It is also effective in rapid stabilization of strong organic wastes (Tchobanoglous & Burton, 1991). This is a suspended growth process and odour problem is fairly common, especially during start-up and due to seasonally variable loading patterns (Barnes *et al.*, 1981). Under optimum operational conditions, COD (Chemical Oxygen Demand) removal efficiencies up to 85% could be achieved (Tchobanoglous & Burton, 1991).

Anaerobic contact process

Anaerobic contact process is a suspended growth treatment process in which untreated wastes are mixed with recycled sludge solids and then digested in an air sealed environment (Tchobanoglous & Burton, 1991). This is a completely mixed system. The suspended biomass is separated by methods such as external gravity, centrifugal separation *etc.* and returned to the reactor (Iza *et al.*, 1991). Basic requirement of the contact process (*i.e.* thoroughly mixing the digester content), is achieved by methods like gas recirculation; sludge recirculation or by mechanical agitation. (Lettinga *et al.*, 1980) This anaerobic process has been successfully used for high strength wastes (Tchobanoglous & Burton, 1991).

Up Flow Anaerobic Sludge Blanket (UASB) process

UASB concept was first investigated by Lettinga in 1971 (Lettinga *et al.*, 1980). The sludge blanket is composed of biologically formed granules or particles with superior settling characteristics (Lettinga *et al.*, 1980; Tchobanoglous & Burton, 1991). Wastewater to be treated is introduced from the bottom of the reactor and flows upwards through the sludge blanket. Gases produced cause internal circulation. Degassing baffles acts as the gas-solid separators. Biologically formed granules trapped with air bubbles move upwards and degassed when struck on degassing

baffles and dropped back to the surface of the sludge blanket. Gas released from the reactor is captured in the gas collection domes in the top of the reactor (Tchobanoglous & Burton 1991).

Fluidized bed/ expanded bed process

In fluidized bed reactors, fluidised carrier material is used to retain the active anaerobic biomass (Iza *et al.*, 1991). Sand and anthracite have been widely used as carriers. Wastewater is pumped upward with high velocities and this fluidizes the bed of medium with biomass attachments. The rate of liquid flow and the resultant degree of expansion of the bed determines whether the reactor is termed a fluidized bed or an expanded bed reactor (Iza *et al.*, 1991). These reactors maintain a very high concentration of active biomass content when compared to other anaerobic processes (Iza *et al.*, 1991; Tchobanoglous & Burton, 1991).

Sri Lankan experience

Covered Activated Ditch (CAD) system

This is a low cost reactor configuration, improved over the well known low cost pond /lagoon process. The acceleration is done by using Bio-brush media as the biomass retainer. This overcomes many inherent drawbacks of the pond process (Warnakula, 1996). The first CAD system was constructed to treat wastewater of Rayigam crepe rubber factory, Ingiriya where earthen ditches dug were lined with high density polyethylene (HDPE) sheet for waterproofing. Later, the ditches were constructed with cement blocks reinforced with concrete and lined with HDPE sheet for waterproofing. CAD systems run under anaerobic condition and are covered with an odour filter to control odour emissions. Finally, the pond is configured in to a set of ditches and the Bio-brush media is fixed in the ditches as the biomass retainer. These ditch type reactors are packed with stationary media; CAD system is related to anaerobic filter type reactor with cross flow. The practicability and the effectiveness of this new system have been proven at commercial scale treatment systems (Warnakula, 1996; 1997; 1998; 1999; 2000; 2001).

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