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Improving the cyanide toxicity tolerance of anaerobic reactor: Microbial interactions and toxin reduction

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HIGHLIGHTS

- Anaerobic batch study of 110 days.
- Acclimatization for cyanide biodegradation.
- Understanding inhibitory effects of cyanide on methane generation and VFA production.
- Identification of microorganisms tolerant to cyanide.
- Community analysis using DGGE and qPCR analyses.

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ABSTRACT

Anaerobic biological treatment of high organics containing wastewater is amongst the preferred treatment options but poor tolerance to toxins makes its use prohibitive. In this study, efforts have been made to understand the key parameters for developing anaerobic reactor, resilient to cyanide toxicity. A laboratory scale anaerobic batch reactor was set up to treat cyanide containing wastewater. The reactor was inoculated with anaerobic sludge obtained from a wastewater treatment plant and fresh cow dung in the ratio of 3:1. The focus was on acclimatization and development of cyanide-degrading biomass and to understand the toxic effects of cyanide on the dynamic equilibrium between various microbial groups. The sludge exposed to cyanide was found to have higher bacterial diversity than the control. It was observed that certain hydrogenotrophic methanogens and bacterial groups were able to grow and produce methane in the presence of cyanide. Also, it was found that hydrogen utilizing methanogens were more cyanide tolerant than acetate utilizing methanogens. So, effluents from various industries like electroplating, coke oven plant, petroleum refining, explosive manufacturing, and pesticides industries which are having high concentrations of cyanide can be treated by favoring the growth of the tolerant microbes in the reactors. It will provide much better treatment efficiency by overcoming the inhibitory effects of cyanide to certain extent.

1. Introduction

Cyanide is highly toxic in all forms, with hydrogen cyanide being the deadliest of all. It causes various health hazards like rapid breathing, tremors, weight loss, nerve damage and even risks to human and animal life. Many industrial wastewaters contain 0.01–10 ppm of total cyanide [1]. Wastewater from an electroplating industry may contain 10,000–30,000 ppm of cyanide. However, wastewaters from coke oven plants could contain up to 50 ppm of cyanide. It is also produced as waste from other industries like petroleum refining, explosives manufacturing, automobile manufacturing, printed circuit board manufacturing, chemicals industries, pesticide industries and synthetic fiber production units, and many other sources.

All such industrial effluents need to be treated to meet effluent disposal standards, before discharging these into the environment. The US Environmental Protection Agency (USEPA) has set a limit for cyanide contamination at 200 ppb for drinking water [2]. Similarly, in India The Central Pollution Control Board (CPCB) has set a limit for cyanide called as minimal national standard (MINAS) as 0.2 mg/L [3].

Cyanide treatment is mainly done by various chemical and physical methods, which are aerobic in nature. These methods of treatment are expensive and complicated [4]. The most com-

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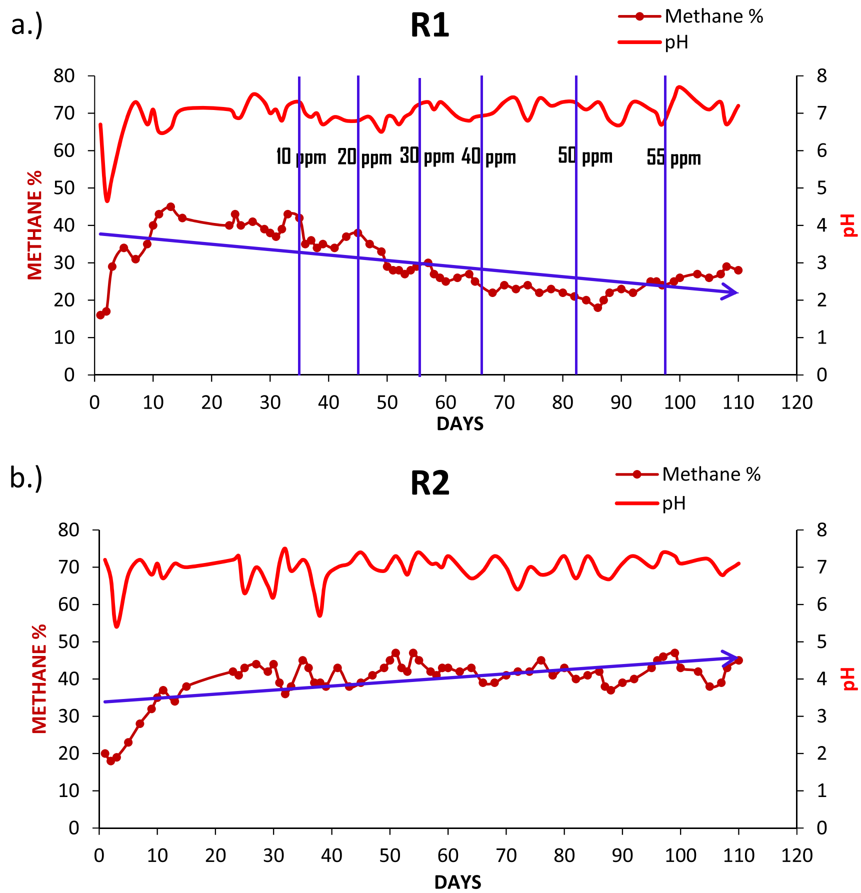

Fig. 1. Methane-pH profiles for 110 days. (a) R1 reactor profile (b) R2 reactor profile (Where Methane% means methane content in the biogas produced).

mon method for cyanide treatment is via chlorine oxidation, where cyanide is oxidized by chlorination [5]. Cyanide removal via microbial treatment is also employed both aerobically as well as anaerobically. The biological treatment breaks and transforms the hazardous toxin into simple non-toxic substances. This is comparatively safer, quicker and economical way to remove cyanide wastes.

Most of the studies are done on aerobically treating effluents rich in cyanide and there is little knowledge available on anaerobic biodegradation processes, as they are known to be less successful [6–12]. This is due to slower growth rate and higher sensitivity of anaerobes to toxic compounds. In spite, of all these limitations it is an attractive treatment technology due to various advantages it offers like production of biogas, reduction in BOD and sludge volume, lower energy requirement. In anaerobic biological treatment, bacteria convert free and metal-complexed cyanides via the hydrolytic pathway into bicarbonate and ammonia, while the free metal is either adsorbed or precipitated out from solution [7]. However, hydrolytic reactions are catalyzed by cyanide hydratase, forming formamide, or cyanidase, which in turn produces formate and ammonia [13]. One of the major advantages of using this system is that it can degrade metal cyanide complexes [13]. The nitrogen produced from the cyanide degradation can be converted into organic nitrogen by the anaerobic biomass. With increasing complexity of the wastewaters the process of treatment becomes more difficult and complicated as needs further attention [14]. Therefore, focus on methods to improve treatment via anaerobic ways are important and needed. Acclimatization of anaerobic microbes with cyanide can improve the degradation rate. This study is additionally focused on identification of microorganisms that can produce methane in the presence of cyanide along with its acclimatization. This will aid in making anaerobic treatment of cyanide a feasible option from all perspectives. The results obtained will aid in filling the gaps on information available for effects of cyanide on specific methanogenic population and poorly understood mechanisms of acclimatization [10]. Acclimatization has been done previously for many other pollutants [15] to increase the resilience of the system so that it can absorb disturbances and still adapt to fluctuations of operating conditions, especially loading rate of toxins. The acclimated mixed culture (sludge) can further be used in high rate continuous reactors, capable of removing cyanide at higher rates. Attached cell systems are known to be more tolerant to toxins over suspended cell systems due to higher sludge retention times (SRT) giving them appropriate time for acclimation to the toxins.

Amongst the attached cell systems, fluidized granules based system offer multiple advantages like better stability, short start-up time, higher SRTs, elimination of dead zones with better sludge – wastewater contact etc., thus, making treatment more efficient.

2. Materials and methods

2.1. Experimental set-up

The mother inocula for experimental studies was developed using defined mixture (3:1) of mesophilic anaerobic sludge obtained from a local wastewater treatment plant, Okhla, New Delhi, India and cow dung. Cow dung was used as it is a rich source of anaerobic microbes. This inocula mixture was enriched for about three months before starting up the study (VSS = 5.5 g/l and TSS = 12.3 g/l). A glucose based media was used for the enrichment process (Table 1).