CHARACTERIZATION AND TREATMENT OF MUNICIPL LANDFILL LEACHATE WITH FOCUS ON SIMULTANEOUS CARBON AND NITROGEN REMOVAL

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by

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CERTIFICATE

It is certified that thesis entitled "**Characterization and treatment of municipal landfill leachate with focus on simultaneous carbon and nitrogen removal**" submitted by Ms Vijaya Singh to the Indian Institute of Technology Delhi, for the award of degree of Doctor of Philosophy, is a record of the original bona fide research work carried out by her in conformity with the results and regulations of the institute. The thesis has reached the standard of fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted in part or full to any other university or institute for the award of any degree or diploma.

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(Vijaya Singh)

ABSTRACT

Landfilling is still the most commonly practiced form of municipal solid waste (MSW) disposal in developing countries like India. One of the problems encountered in the management of MSW landfills is related to the production and treatment of the leachate. Landfill leachate is a complex wastewater with considerable variation in both quality and quantity. The presence of significant amount of toxic organic and inorganic compounds in leachate makes its collection and treatment necessary. However, without knowing the nature of the chemical changes in leachate with time and space, it would be difficult to design a suitable system for leachate treatment. Till now there is no extensive database for the characterization of Delhi landfill leachates. Thus the purpose of this study was to compile a detailed database of leachate quality from the three Delhi landfill: Okhla, Gazhipur and Bhalsawa, analyse the temporal and spatial variations in leachate quality, and discuss the applicability of an aerobic biological process for Delhi leachates for simultaneous removal of C and N.

In order to determine the physicochemical and toxicological characteristics of Okhla, Gazhipur and Bhalsawa landfills, several leachate samples were collected over the entire study period. The degree of pollution and contamination varied substantially with space and time of sampling. Toxicological characterization using *Poecilia reticulata* fish bioassay demonstrated that all leachate samples were acutely toxic. A general relationship between physicochemical characteristics and toxicity could be observed and it was found that most (or least) contaminated leachates were generally most (or least) toxic. All parameters examined showed markedly higher values indicating significant risk to the surrounding environment and public health.

In a first attempt to identify organic molecules present in Delhi landfills, leachate samples were collected over a period of two years from Okhla, Gazhipur and Bhalsawa landfills. The extracts were analyzed using gas chromatography combined with mass spectrometry. Numerous compounds characterized by high toxicity were identified and attributed to the chemical classes of plasticizers, pesticides, pharmaceuticals, PAHs, and halogenated hydrocarbons. Total 117 compounds could be identified of which more than half having the potential to cause severe harm to human and environmental health. Detailed information on the toxicology of the identified compounds is also provided in order to give a comprehensive view on the pollution potential of Delhi landfill leachates.

In order to evaluate the simultaneous C and N removal from MSW landfill leachate, pure cultures of *Paracoccus pantotrophus* were studied in shaken flasks in batch mode. Performance of *P. pantotrophus* was studied under various levels of chemical oxygen demand/total nitrogen (COD/TN) ratios, aeration, cyclic addition of substrate and concentrations of leachate diluted with synthetic wastewater (SWW). With studies on SWW, the minimum required COD/TN ratio was detected as 9.09, to achieve the acceptable removal efficiency of 93.79, 64.25 and 51.59% for COD, NH_3-N and TN, respectively. Effect of aeration and cyclic substrate addition for N removal showed better efficiency for non-aerated reactor with removal of 100 and 92.16% for NH_3-N and TN respectively. To determine the effect of leachate concentration on C and N removal, varying concentrations of leachate were mixed with SWW on the basis of COD. Increased leachate concentration resulted in linear decrease in removal efficiencies which varied from 87.15, 58.20 and 47.43% in 10% leachate to 65.42, 21.02 and 9.07% in 80% leachate for COD, NH_3-N and TN, respectively. Although higher leachate concentration showed inhibitory effects on substrate utilization, *P. pantotrophus* could successfully perform aerobic denitrification resulting in simultaneous C

and N removal, rendering it as a useful candidate in the treatment of landfill leachate. The results of batch studies suggested that, the bacterium could perform better with fixed film systems which allow tapering of inhibitory effects of leachate such as rotating biological contactor (RBC).

For studies on a fixed film system, a four stage rotating biological contactor (RBC) was designed and operated to treat synthetic wastewater and leachate mixed with synthetic wastewater, containing 1000 mg/L COD and 112 mg/L NH_4^+-N. A mixed culture bacterial biofilm was developed consisting of the heterotrophic bacterium *Paracoccus pantotrophus*, nitrifiers and other heterotrophs. Attributing to the peculiar characteristics of *P. pantotrophus* of simultaneous heterotrophic nitrification and aerobic denitrification, high simultaneous removal efficiency of 91.88 ± 2.16 and 74.58 ± 12.65 % for COD and total nitrogen respectively, could be achieved in the fully aerobic RBC while treating synthetic wastewater. Whereas, inhibitory effects of leachate toxicants could be observed with increasing leachate concentration in leachate mixed synthetic wastewater, with removal efficiency being 85.22 ± 3.08 and 43.10 ± 7.25 in 10% leachate to 61.67 ± 3.22 and 14.18 ± 7.90 in 80% leachate for COD and total kjeldahl nitrogen (TKN) respectively.

The microbial community structure of the RBC biofilm was categorized based on the nitrate reduction, biochemical reactions, gram staining and morphology. The presence of *P. pantotrophus* within the RBC biofilm was confirmed with an array of biochemical tests. Isolates from the four stages of RBC were grouped into complete denitrifiers, incomplete denitrifiers and non-denitrifiers. This categorization showed dominant presence of *P. pantotrophus* in the first stage as compared to subsequent stages, where other nitrifiers and heterotrophs were significantly present. High total nitrogen removal of upto 68% was in

conformity with observations made using microbial categorization and biochemical tests. The dominance of *P. pantotrophus* over other heterotrophs and autotrophic nitrifiers in the biofilm revealed that it could successfully out-compete them in mixed bacterial biomass.

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