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# Physico- Chemical Characterization of Leachate of Passive Landfill Site at Bhanpura, Bhopal

#### Rajesh Kumar Misra, Dr. Bikram Prasad

Research Scholar, Department of Civil Engineering, LNCT University, Bhopal, India

Professor, Department of Civil Engineering, LNCT University, Bhopal, India

**ABSTRACT:** This study investigates the efficacy of low-cost, passive treatment methods aerobic biological treatment (aeration) and filtration using granular activated carbon (GAC), blast furnace slag (BFS), and sand for treating landfill leachate at the Bhanpura landfill in Bhopal, India. Laboratory experiments demonstrated that aeration achieved 100% ammonia-nitrogen removal and 96% turbidity reduction over a 16-day retention period, significantly improving leachate clarity and odor. Column filtration tests showed BFS as the most effective medium, removing 92% of soluble reactive phosphorus (SRP), followed by GAC (68%) and sand (40%). The combined approach of aeration and filtration offers a cost-effective, sustainable solution for leachate management in resource-constrained regions. Long-term leachate (2001–2024), with 35% of rainfall contributing to leachate production. These findings support the development of integrated leachate treatment systems and improved solid waste management (SWM) practices for Bhopal, addressing environmental and public health challenges posed by landfill leachate.

**KEYWORDS:** Landfill leachate, aerobic treatment, filtration, blast furnace slag, granular activated carbon, solid waste management, Bhopal.

#### I. INTRODUCTION

Landfilling remains the predominant method for municipal solid waste (MSW) disposal globally, particularly in developing nations like India, where approximately 75% of waste is dumped unscientifically. In Bhopal, the Bhanpura landfill, operational since the 1980s, receives 900–1100 metric tons of MSW daily, generating highly contaminated leachate that threatens groundwater and ecosystems. Leachate, formed by the interaction of waste with water, contains high levels of organic matter, ammonia, heavy metals, and other pollutants, necessitating effective treatment before environmental release.

Conventional leachate treatment methods, such as advanced oxidation and membrane filtration, are often resource-intensive, making them impractical for developing regions. This study evaluates two low-cost, passive treatment approaches aerobic biological treatment (aeration) and filtration using GAC, BFS, and sand to address these challenges. The objectives are to assess their effectiveness in reducing key pollutants, propose an integrated treatment system, and recommend sustainable SWM strategies for Bhopal. Municipal Solid Waste Management in Bhopal

In Bhopal, solid waste reduction and disposal follows two main steps, similar to other countries:

1. **Collection and Transportation**: Trucks called tippers are used to accumulate waste materials from homes on a consistent schedule. Concrete reuse bins and containers are positioned at key location-+ns in cities for the collection of trash, which is subsequently raised by trucks or tractors for transportation. Nevertheless, inadequate infrastructure, upkeep, and improvements affect the three primary facets covering key aspects of waste management such as: collection, transportation and disposal.

2. Waste Disposal through Landfilling: The second step involves disposing of waste through landfilling. When alternative waste management options unavailable, around 92% of municipal solid waste is dumped in landfills. Most municipal centers only have one landfill, or in some cases, none at all. In such



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cases, municipal solid waste is disposed of in rivers, valleys, streams, or low-lying areas. Approximately 60-70% of the solid waste in landfills is biodegradable, indicating that the waste in Bhopal contains minimal glass, electronics, or metals. The combined constituents of solid waste in Bhopal is depicted in Figure 1





#### **II. MATERIALS AND METHODS**

#### 2.1 Study Site

The Bhanpura landfill, located on the outskirts of Bhopal, spans 40 acres and lacks engineered containment systems, leading to significant leachate migration into nearby aquifers. Leachate samples were collected from the site for laboratory analysis.



Figure: 2 Solid Waste Disposal Area

#### 2.2 Sampling and Analysis Components for Leachate Quality Determination

For the characterization of leachate in the Bhanpura area of Bhopal, three distinct data sets were obtained from different sources:

•Extended leachate monitoring records from the Bhanpura landfill, including leachate volume and rainfall,

•Environmental records from the India Meteorological Department (IMD) for the Bhopal region,

•Secondary information on solid waste management systems in Bhopal, gathered from research journals, government



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publications, and reports from non-governmental organizations.

#### 2.3 Experimental Setup

#### 2.3.1 Aerobic Biological Treatment

Leachate was treated in two 25-liter aeration tanks over 20 days. Tank A (control) was unaerated, simulating anaerobic conditions, while Tank B was aerated to maintain aerobic conditions. Key parameters ammonianitrogen, turbidity, electrical conductivity (EC), phosphorus, pH, and alkalinity were monitored using standard methods.



**Figure:3 Oxidation Pond Mechanisms** 

#### 2.3.2 Column Filtration

Three filter media GAC, BFS, and sand were tested in column experiments to evaluate their sorption capacities. Columns were packed with each medium, and leachate was passed through at controlled flow rates. Effluent was analyzed for phosphorus, turbidity, EC, and other pollutants. Hydraulic conductivity and contact times were measured to assess performance.





Figure: 4. Schematic diagram column experimental setup [a] Various columns [b] Steady state head apparatus.

#### **III. ANALYTICAL METHODS**

Physicochemical parameters were analyzed per IS 2720 and APHA standards. Statistical analysis of 15-year leachate monitoring data was conducted to evaluate temporal variations and rainfall-leachate correlations.



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Table 3.1 Initial characterization of untreated leachate and DI water used as experiment (18th May 2024).

Variables	DeIonized Water	Leachate
Colour	Colourless	Dark
Turbidity (NTU)	0.32	62
pH	6.9	8.1
Total Alkalinity ( as mg/L as CaCO <sub>3</sub> )	33	4900
Electrical Conductivity (µS/cm)	16	11480
Temperature (°C)	NA	NA**
Dissolved oxygen	9	2.2
Ammonia-Nitrogen	UMR*	985
Nitrite-Nitrogen	UMR	0.22
Nitrate-Nitrogen	UMR	12
Soluble reactive phosphorus	0.02	26

#### IV. RESULTS AND DISCUSSION

#### 4.1 Aerobic Biological Treatment

Aerobic treatment in Tank B achieved complete ammonia-nitrogen removal (100%) and 96% turbidity reduction after 16 days, significantly outperforming the anaerobic control (Tank A), which showed 29% ammonia reduction and 46% turbidity decrease (Table 1). The process also improved leachate clarity (from dark brown to light orange) and eliminated foul odors, consistent with findings by.

Parameter	Tank A (Anaerobic)	Tank B (Aerobic)	
Ammonia-N Removal (%)	29	100	
Turbidity Reduction (%)	46	96	
EC Reduction (%)	Slight	Slight	
Phosphorus Removal (%)	Minimal	Slight	

Table 2: Performance of Aerobic vs. Anaerob	c Treatment
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The high ammonia removal in Tank B was attributed to nitrification, facilitated by aerobic bacteria (e.g., Nitrosomonas, Nitrobacter) at optimal pH (8.2–8.8) and dissolved oxygen levels (>1.0 mg/L). Phosphorus levels showed minimal change, as aeration is less effective for phosphorus removal without microbial assimilation.



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# Figure: 5 Tank A (left) and Tank B (right) are shown in the layout of the aeration study utilizing glass sided tanks and aerators

Filtration experiments demonstrated significant phosphorus removal, with BFS achieving 92% efficiency, followed by GAC (68%) and sand (40%) (Table 2). BFS's superior performance was linked to its low hydraulic conductivity (6 m/day) and chemical composition (Ca, Al, Si oxides), promoting precipitation and adsorption. GAC's high surface area facilitated pollutant removal but was limited by higher hydraulic conductivity (128 m/day).

Medium	P-removal (%)	Contact Time (min)	Hydraulic Conductivity (m/day)
BFS	92	40	29
GAC	68	3	192
Sand	40	12	33

#### Table 3: Phosphorus Removal Efficiency of Filter Media

All media reduced turbidity and EC, with BFS showing the highest overall pollutant removal due to its amorphous structure and reactive surfaces. Sand's lower efficiency was attributed to its inert composition and limited adsorption capacity.

#### 4.3 Leachate Characterization

Long-term monitoring (1980-2024) revealed two phases:

• Phase 1 (1980–2000): Neutral pH, low toxicity, high BOD/COD, low ammonia, and metals.

• Phase 2 (2001–2024): Alkaline pH, increased toxicity, elevated ammonia, and chloride levels.

Approximately 35% of annual rainfall (1165 mm) contributed to leachate production, aligning with global trends (15–50%).

#### 4.4 Integrated Treatment System

The complementary strengths of aeration (organic matter and ammonia removal) and filtration (phosphorus and inorganic pollutant removal) suggest an integrated treatment train: aerobic treatment as a primary clarifier, followed by filtration through BFS or GAC beds. This approach maximizes pollutant removal while minimizing costs, suitable for Bhopal's resource constraints.



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#### **V. CONCLUSION**

The study confirms that aerobic biological treatment and filtration using BFS, GAC, and sand are effective, low-cost methods for treating landfill leachate. Aeration achieved complete ammonia removal and significant turbidity reduction, while BFS filtration excelled in phosphorus removal. An integrated system combining these methods offers a sustainable solution for leachate management in Bhopal. The findings highlight the need for pilot-scale studies to validate field performance and recommend enhanced SWM practices, including source segregation, composting, and infrastructure upgrades, to mitigate environmental risks at the Bhanpura landfill.

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