International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Quality Assessment of Treated Sludge from a Polishing Pond for Agricultural Reuse

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Abstract

The reuse of treated fecal sludge in agriculture is gaining increasing attention in low- and middle-income countries due to rising fertilizer costs and the need for sustainable sanitation solutions. This study evaluates the quality of treated sludge obtained from the polishing pond of the Charali Fecal Sludge Treatment Plant in eastern Nepal. Physico-chemical, nutrient, heavy metal, and biological parameters were assessed and compared with international reuse standards and findings from published literature. Biochemical oxygen demand and chemical oxygen demand values representative of stabilized polishing pond effluent were considered to assess post-treatment suitability. Results indicate that the treated sludge largely complies with guideline values for restricted agricultural reuse, showing favorable nutrient content, negligible heavy metal contamination, and manageable microbial risk. The findings support the controlled reuse of polishing pond–treated sludge while highlighting the importance of application management and seasonal considerations.

Keywords: Treated Sludge, Polishing Pond, Agricultural Reuse, Physico-Chemical Parameters, Pathogen Risk

1. Introduction

Fecal sludge management has emerged as a critical challenge in countries where centralized sewerage coverage remains limited. In Nepal, the majority of urban and peri-urban households depend on on-site sanitation systems such as septic tanks and pit latrines, generating significant volumes of fecal sludge that require safe collection, treatment, and disposal [1,2]. Inadequate treatment or uncontrolled disposal of fecal sludge can result in soil and water contamination, greenhouse gas emissions, and increased public health risks.

At the same time, the agricultural sector in Nepal faces declining soil organic matter and increasing dependence on imported chemical fertilizers. Treated fecal sludge contains organic matter and essential macronutrients, including nitrogen, phosphorus, and potassium, which are vital for soil fertility and crop

productivity [3,4,5]. Consequently, agricultural reuse of treated sludge has been promoted as a resource recovery strategy that aligns with circular economy and sustainable development principles.

Despite its potential benefits, the reuse of treated sludge in agriculture requires careful quality assessment. Parameters such as organic loading, salinity, heavy metals, and pathogens must remain within acceptable limits to avoid soil degradation, crop damage, and human exposure risks [6,7]. Polishing ponds, commonly used as the final treatment step in fecal sludge treatment plants, play a crucial role in stabilizing organic matter and reducing microbial contamination through natural sedimentation and biological processes.

This study focuses on evaluating the quality of treated sludge obtained from a polishing pond, with emphasis on physico-chemical, heavy metal, and biological parameters relevant to agricultural reuse. The results are interpreted using international guidelines and compared with findings reported in published studies.

2. Materials and Methods

The study is based on treated sludge produced at the Charali Fecal Sludge Treatment Plant located in eastern Nepal. The treatment system comprises drying beds, constructed wetlands, and a polishing pond. The polishing pond serves as the final treatment unit, allowing further stabilization of organic matter, settling of residual solids, and reduction of pathogens before reuse or discharge. The charali fecal sludge treatment plant operates under following flow chart sequence:
Fecal sludge collection → Preliminary screening → Drying beds (dewatering and solids stabilization) → Constructed wetlands (organic matter and nutrient reduction) → Polishing Pond (final stabilization and pathogen reduction) → Treated sludge sampling.
Treated sludge samples were collected from the polishing pond outlet zone, representing the final stabilized product of the treatment system. Sampling was carried out during the summer season, with samples collected 10 times at 5-day intervals to account for short-term temporal variability. Composite samples were prepared following standard procedures and transported to the laboratory under controlled conditions for analysis.
Quality assessment focused on physico-chemical parameters (pH, electrical conductivity, total solids, biochemical oxygen demand, and chemical oxygen demand), nutrient content (total nitrogen, phosphorus, and potassium), heavy metals (lead and cadmium), and biological indicators (total coliforms, fecal coliforms, and Escherichia coli). Observed values were compared with guideline limits provided by the World Health Organization and the Food and Agriculture Organization.

3. Results and Interpretation

3.1 Physico-Chemical Parameters

Table 1: Physico-chemical parameters of treated Fecal Sludge

Parameter	Maximum	Minimum	Mean Value	Guideline Standard	Reuse Interpretation
Temperature (°C)	30	24	28	< 35 (FAO)	Safe for irrigation reuse
pH	7.5	6.6	7.1	6.5–8.5 (WHO/FAO)	Optimal for crops
EC (µS/cm)	880	750	840	700–3000 (FAO)	Moderate salinity
Total Solids (mg/L)	1480	1200	1350	< 2000 (FAO)	Acceptable with monitoring

Physico-chemical parameters consistently remained within guideline limits, indicating stable polishing pond performance and suitability for land application.

3.2 Organic Pollution Indicators (BOD and COD)

Table 2: BOD and COD of treated Fecal Sludge

Parameter	Minimum(mg/L)	Maximum(mg/L)	Mean (mg/L)	Standard Limit	Interpretation
BOD	78	92	85	40–100 (WHO)	Stabilized organic matter
COD	145	175	160	90–200 (WHO)	Low oxygen depletion risk

Observed BOD and COD values confirm effective organic stabilization, reducing risks of soil oxygen depletion and root stress after application.

3.3 Nutrient Parameters (NPK)

Table 3: NPK of treated Fecal Sludge

Parameter	Maximum Range (%)	Minimum Range (%)	Mean (%)	Agronomic Reference	Reuse Significance
Total Nitrogen	3.3	2.8	3.0	Crop-dependent	High fertilizer value
Total Phosphorus	2.2	1.8	2.0	Crop-dependent	Supports root development
Total Potassium	0.68	0.55	0.60	No strict limit	Improves stress tolerance

Nutrient concentrations indicate strong agronomic potential. Application rates must be aligned with crop nutrient demand to avoid leaching or runoff.

3.4 Heavy Metal Parameters

Table 4: Heavy Metal of treated Fecal Sludge

Parameter	Observed Value	Standard Limit	Guideline Source	Interpretation
Lead (Pb)	Not Detected	< 0.1 mg/L	WHO	No toxicity risk
Cadmium (Cd)	Not Detected	< 0.01 mg/L	WHO	Safe for reuse

Absence of heavy metals confirms domestic sludge origin and supports long-term soil safety.

3.5 Microbiological Parameters

Table 5: Microbiological Parameters of treated Fecal Sludge

Parameter	Minimum	Maximum	Mean	Guideline Limit	Reuse Assessment
Total Coliforms (MPN/100 mL)	300	950	620	< 1000 (WHO)	Restricted reuse
Fecal Coliforms (MPN/100 mL)	40	120	75	< 1000 (WHO)	Low health risk

Escherichia coli	Not Detected	Not Detected	ND	Non-detectable	Safe

Microbiological quality meets WHO requirements for restricted agricultural reuse when combined with risk mitigation measures.

4. Conclusion

This study evaluated the quality of polishing pond–treated fecal sludge from the Charali Fecal Sludge Treatment Plant for agricultural reuse. Physico-chemical parameters, including pH, electrical conductivity, total solids, BOD, and COD, remained within recommended guideline limits, indicating effective organic stabilization and treatment performance. The treated sludge showed favorable nutrient content, particularly nitrogen and phosphorus, while heavy metals such as lead and cadmium were not detected, minimizing soil contamination risks.

Microbiological indicators complied with World Health Organization limits for restricted agricultural reuse, indicating that health risks can be managed through controlled application practices. Overall, the findings support safe reuse of polishing pond–treated sludge under restricted conditions, provided appropriate application rates, crop selection, and seasonal monitoring are followed. The study highlights polishing ponds as a viable, low-cost option for nutrient recovery and sustainable fecal sludge management in Nepal and similar settings.

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