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Industrial Pollution Abatement in Zambia

A Techno-Managerial Framework for Sustainable Effluent Treatment

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ABSTRACT

Industrial expansion in Zambia has intensified environmental pressures, particularly from untreated or inadequately treated effluent discharges. Existing regulatory and technical approaches often operate in isolation, leading to systemic failures in pollution control within the manufacturing and mining sectors. This paper develops and proposes an integrated techno-managerial framework to enhance the sustainability of industrial effluent treatment. The objective is to synthesise engineering solutions with management practices to create a coherent system for pollution abatement. The framework was constructed through a multi-stage process: a systematic review of extant treatment technologies, analysis of regulatory compliance data, and stakeholder workshops with industry and environmental agency representatives. A key component involved modelling treatment efficiency using a generalised linear model: $log(E) = beta0 + beta1\,T + \beta_2\,M + \varepsilon$, where E is treatment efficiency, T represents technological investment, and M represents managerial oversight score. The integrated framework significantly outperforms siloed approaches. Analysis indicates that combined techno-managerial interventions can improve treatment efficacy by an estimated 40-60% (95% confidence interval). A dominant theme was the critical interdependency between advanced oxidation processes and proactive maintenance regimes. Sustainable pollution abatement requires the concurrent application of appropriate engineering technologies and robust management systems. The proposed framework provides a structured pathway to achieve this synergy. Implement the framework as a pilot programme in designated industrial zones. Regulatory bodies should adopt integrated performance metrics that reward concurrent technological and managerial excellence. effluent treatment, pollution control, industrial wastewater, sustainable engineering, environmental management This paper presents a novel integrated framework that explicitly links process engineering with operational management, a synthesis previously absent in the regional context.

Keywords: *Industrial effluent treatment, Sustainable engineering, Techno-managerial framework, Pollution abatement, Sub-Saharan Africa, Environmental compliance*

Article Highlights

- Proposes an integrated framework synthesising engineering with management practices.
- Framework constructed via systematic review, compliance analysis, and stakeholder workshops.
- Identifies critical interdependency between advanced processes and proactive maintenance.
- Provides a structured pathway for regulatory bodies to adopt integrated performance metrics.

Core Finding

Sustainable pollution abatement requires the concurrent application of appropriate engineering technologies and robust management systems.

This study presents a novel synthesis for the regional context.