

Innovative High-Performance Bio-Digester for On-site Blackwater Treatment

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Abstract:

High-performance bio-digesters (HPBD-2 and HPBD-3) for efficient and sustainable blackwater treatment developed by the Defence Research and Development Establishment (DRDE). This innovative system addresses sanitation challenges in areas with limited infrastructure. IIT Roorkee optimises and evaluates the performance of the bio-digester. HPBD-2 has the provision of anaerobic as well as aerobic treatment followed by settling of the effluent while HPBD-3 has an additional provision of the roughing filter with HPBD-2. The installation was a pilot-scale HPBD-2 unit, catering to 5-7 users installed adjacent to the STP of IIT Roorkee. The aerobic treatment in HPBD-2 utilized Kaldnes MBBR media, while HPBD-2 incorporated high-performance bio-lace media for enhanced treatment efficiency.

Performance evaluations were focused on key parameters including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorus (TP), and Fecal coliforms (FC). Comparative studies revealed that HPBD-2 utilizing bio-lace media in its aerobic chamber exhibited superior degradation efficiency for BOD, COD, TSS, TN, and TP compared to HPBD-2 with Kaldnes media. The pilot-scale HPBD-2 operating under controlled conditions demonstrated significantly better pollutant removal than the overloaded field units.

HPBD-2 with bio-lace media achieved pollutant removal efficiencies more than 97% for COD, BOD, and TSS. The treated effluent yielded average concentrations of 68.5 ± 11 mg/L COD, 34.1 ± 5 mg/L BOD, and 34 ± 7 mg/L TSS, indicating high levels of pollutant reduction and stable performance. Ammonia removal rate was found more than 60% under steady-state conditions in HPBD-2. To enhance nitrogen removal, effluent recirculation from the settling chamber to the anaerobic chamber was introduced in HPBD-2, resulting in increased nitrification activity and improved TN removal.

HPBD-2 with recirculation, demonstrated outstanding TN removal efficiency, reaching over $89 \pm 6.3\%$ with average effluent TN values of 24.5 ± 3.2 mg/L at 300% recirculation (3QR). At 300% recirculation (3QR), the system delivered average effluent concentrations of 53.4 ± 9 mg/L COD, 20.4 ± 5.8 mg/L BOD, 30 ± 5.1 mg/L TSS, 24.56 ± 3.26 mg/L TN, and 10.48 ± 1.75 mg/L TP.

Further in HPBD-3, following tertiary treatment of effluent of HPBD-2A (3QR with bio-lace media) with roughing filter (RF), final effluent concentrations were reduced to 31.4 ± 6.15 mg/L COD, 9.98 ± 2.25 mg/L BOD, 12.93 ± 2.45 mg/L TSS, 18.23 ± 2.27 mg/L TN, and 8.97 ± 1.35 mg/L TP. The treated effluent consistently met the National Green Tribunal (NGT) discharge standards for COD, BOD, and TSS.

Additionally, post-disinfection of Roughing Filter effluent resulted in no detectable fecal coliform, with residual chlorine levels maintained below 0.6 mg/L.

HPBD-3 (3QR recirculation with bio-lace media) showed more than 99% removal efficiency for COD, BOD, and TSS, aligning with NGT standards for STP effluent discharge. The complete disinfection process ensured that the effluent was free of fecal coliforms.

The conclusive findings indicated that HPBD-3 (3QR recirculation with bio-lace media) provides robust and reliable blackwater treatment with BOD, COD, and TSS removal efficiencies exceeding 99%, offering a sustainable and compliant solution for decentralised blackwater treatment.