Optimization of the Ventilation System through CFD and Advanced Biofiltration for Odour Control in a Wastewater Treatment Plant

Odour emissions from wastewater treatment plants (WWTPs) represent a significant environmental and social challenge, especially when diffuse emissions affect nearby urban areas. This study presents an integrated approach that combines Computational Fluid Dynamics (CFD) modelling and advanced biofiltration to mitigate odour emissions from the sludge dewatering building of a large WWTP.

Preliminary assessments identified substantial diffuse emissions and limited effectiveness of the existing odour control system, which was based on chemical scrubbing. To address this, a comprehensive CFD analysis was conducted to optimize the building's ventilation system, aiming to improve air capture efficiency, minimize internal pollutant dispersion, and improve extraction towards a newly designed biofilter.

The original ventilation design included a supply airflow of 74,000 m^3/h and an extraction airflow of 86,637 m^3/h. Based on the CFD results, a new geometric configuration was proposed, adding several air supply and extraction points to improve airflow distribution.

Three operational scenarios were simulated at 100%, 80%, and 70% of the nominal flow rate, analyzing airflow patterns and the dispersion of key odorous compounds, hydrogen sulfide (H_2S) and ammonia (NH_3).

The results showed that the 80% flow rate scenario achieved the best overall performance, optimizing pollutant capture and extraction while minimizing internal dispersion. In contrast, the 100% scenario led to increased dispersion within the building and, in the case of NH_3, incomplete extraction and reduced performance. The 70% scenario showed similar dispersion control compared to 80%, but the latter provided greater operational robustness and higher deodorization efficiency, balancing performance and energy consumption effectively.

For emissions treatment, an advanced biofiltration system using inorganic biomedia was implemented, designed to process a total airflow of 140,000 m^3/h across multiple process buildings. This resulted in deodorization efficiencies exceeding 95%.

This combined CFD and advanced biofiltration approach enabled identification of an optimal balance between odour abatement efficiency and energy consumption. The implementation of the redesigned ventilation system and high capacity biofilter significantly reduced diffuse emissions from the sludge dewatering facility. This work highlights the value of CFD as a decision-support tool in ventilation design and demonstrates the effectiveness of advanced biofiltration for treating high airflow rates in complex industrial environments, providing a scalable and sustainable methodology for odour control in WWTPs.