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Greenhouse Gas Emissions and Water Recovery in Solar Drying of Wastewater Sludge: Insights from LIFE-DRY4GAS

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Extended Abstract

Solar drying offers a promising solution to reduce both the costs and carbon footprint of conventional wastewater sludge management. In arid regions, where water scarcity is a critical challenge, understanding the impact of this process on greenhouse gas (GHG) emissions and the quality of recovered water is essential. This study was conducted in an industrial solar greenhouse dryer of wastewater sludge as part of the LIFE-DRY4GAS project [1], located in Murcia, Spain.

This study employed an optical absorption spectroscopy analyser (Picarro G2308/G2508) with continuous sampling to measure N_2O, NH_3, CH_4 and CO_2 emissions. Additionally, accumulated samples during light-hours and night-hours (10 h each) were taken using passive samplers (Radiello) [2]. Specific samplers included RAD168 (NH_3), RAD166 (NO_2, SO_2, HF, CH_3COOH, HCOOH), RAD170 (H_2S) and RAD 130 (VOCs). After sampling, RAD168 and RAD166 were analysed by ion chromatography, while H_2S was quantified by spectrophotometry [2] and VOCs were identified using GC-MS. Water vapour was recovered using a condensation system consisting of an air extraction pipe connected to an impinger and vacuum pump to direct airflow from the solar dryer into the impinger. The impinger was housed inside a stainless-steel thermostatic bath maintained at 4ºC to enable the condensation of water vapour for subsequent analysis. The water recovery device was operated during daylight hours (10 hours). The recovered water was analysed via ion chromatography for F^-, CH_3COO^-, $HCOO^-$, ClO_2^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}, and $C_2O_4^{2-}$.

GHG emissions decreased drastically from daytime to night-time for all compounds except for H_2S, which slightly increased during night hours. Peak emissions occurred at midday, with CO_2 reaching 3000 ppm/hour, followed by NH_3 at 900 ppm/hour. CO_2 emissions were highest during the initial hours of sludge drying, highlighting the influence of sludge moisture content on GHG release. Among the accumulated samples, the highest emissions were for H_2S (4710 $\mu g \cdot m^{-3}$), CH_3COOH (3420 $\mu g \cdot m^{-3}$) and NH_3 (22290 $\mu g \cdot m^{-3}$), and HCOO (95.7 $\mu g \cdot m^{-3}$) during daylight hours.

Water recovery during the 10-hour sampling period was limited to 600 mL by the pump's extraction capacity. Analysis revealed high concentrations of CH_3COO^- and $HCOO^-$ in the recovered water, with other compounds detected at lower levels, likely due to reduced gas-phase concentrations or limited water solubility. Further analysis of CO_2 and NH_3 in the recovered water is pending, but high concentrations of CO_2 and elevated BOD (Biochemical Oxygen Demand) are expected.

This findings highlight the need for further research to optimize GHG mitigation and water recovery during solar drying of wastewater sludge, particularly for compounds such as acetic acid, which are challenging to treat biologically. Innovations in air extraction systems could enhance eco-friendly water recovery while reducing atmospheric emissions, advancing sustainable sludge management practices.

References

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