Microbiological and operational monitoring for the removal of H_2S and NH_3 under transient conditions by a biofiltration system using compost as packing material

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Introduction

Biofiltration is a low investment biotechnology with high-efficiency removal of hydrogen sulfide (H_2S), ammonia (NH_3) and volatile organic compounds (VOCs), produced in wastewater treatment plants (WWTP) [1].
However, the elimination efficiency decrease in gas mixtures and industrial conditions, due to inhibition of microbial activity caused by[2]:

- Transient conditions:
  - Changes in the gas load by gas concentration and residence time (EBRT)
  - Changes in bed moisture content
- Oxidation products accumulation (sulfate, ammonium).

In this work, the microbial community present in two biofilters, packed with composted chicken manure-sugarcane bagasse, was monitored during the simultaneous removal of H_2S and NH_3 under transitory conditions of gas load and bed moisture to establish optimal operative conditions.

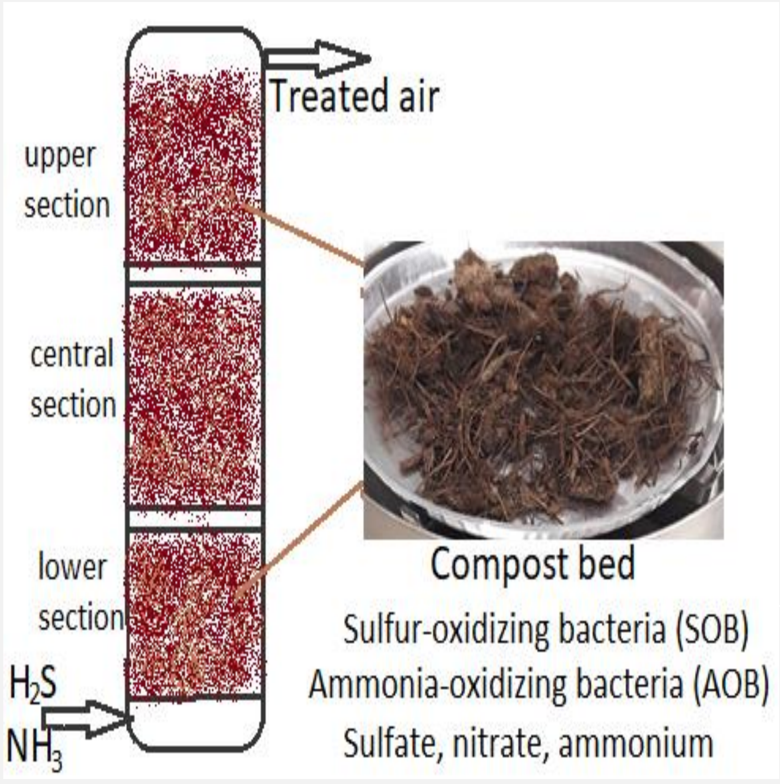


Figure 1: Compost based biofilter.
Height: 0.81 m, Volume: 0.007 m^3 (6.6 L)

Methodology

Evaluation of gas concentration and EBRT

- EBRT: 60,45,33,25 and 18 s
- 2 levels of gas concentration
  - Low: 52 mg H_2S/m^3 and 2.1 mg NH_3/m^3
  - High: 260 mg H_2S/m^3 and 9.9 mg NH_3/m^3

Evaluation of bed moisture content

- Decrease in moisture by dry air stream: 40%, 30%, 25% and 20%.
- EBRT: time with the highest elimination capacity
- Constant gas concentration: 75 mg H_2S/m^3 and 3.6 mg NH_3/m^3

Biofiltration performance

- Removal efficiency: $\%RE = \frac{(C_{inlet} - C_{out})_{*100}}{C_{inlet}}$
- Elimination capacity: $EC = \frac{Q_{gas} * (C_{inlet} - C_{out})}{Volume_{biofilter}}$

Bed analysis after change in conditions

- Oxidation metabolites: Ammonium, sulfate, nitrate, nitrite
- Bacterial abundance by of ammonium (AOB), and sulfur (SOB) oxidizing bacteria by colony count (CFU/g)

Results & Discussion

EFFECT OF GAS CONCENTRATION AND EBRT IN THE BIOFILTRATION

Biofiltration performance

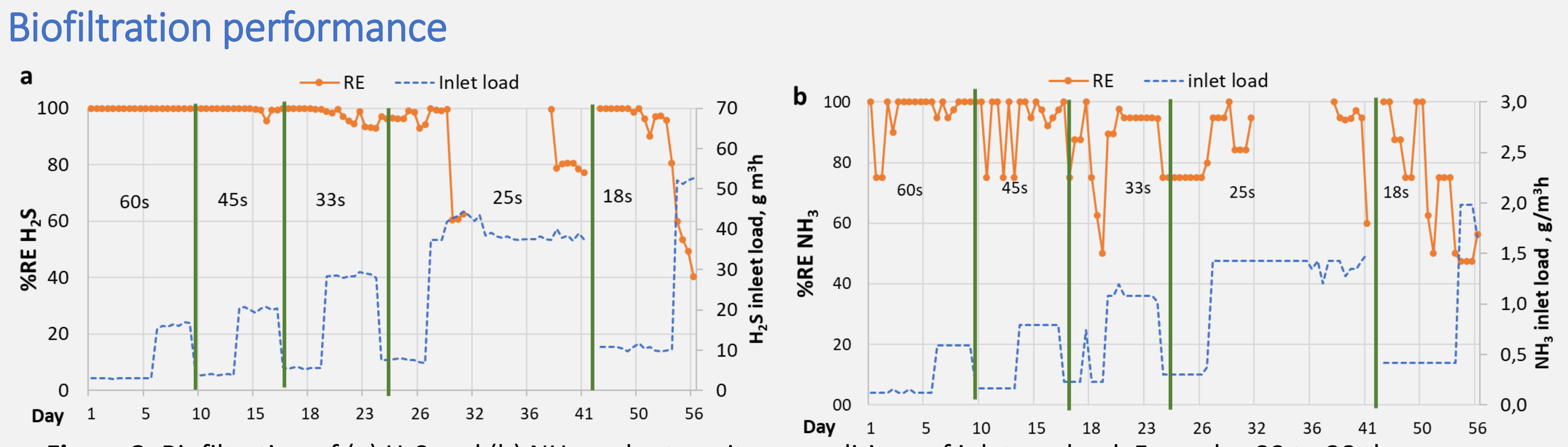


Figure 2. Biofiltration of (a) H_2S and (b) NH_3 under transitory conditions of inlet gas load. From day 32 to 38 there was a shutdown in operation (air compressor failed). %Removal efficiency (%RE) in orange line. Numbers inside correspond to EBRT. Green lines indicate change of EBRT

- At EBRT of 60 and 45 s, the removal efficiency of H_2S was near to 100%, even at the high level of gas concentration. The removal of ammonia was variable but remained between 80-100%.
- At EBRT of 25 s and high load, H_2S removal decreased significantly, however, the removal efficiency of H_2S increased to 80% under the same conditions, when the operation was restarted after the shutdown.
- The decrease in H_2S removal as EBRT at 18 s and high concentration could be caused by the limited solubility of H_2S that affects the mass transfer of gas to the biofilm, and consequently the biological process[3]. Ammonia removal showed a similar behavior, but it was more affected by the sudden increase in the gas load.
- Maximum elimination capacity was reached at 25 s: 32.19±4.72 g H_2S / m^{3}h and 1.26±0.13 g NH_3/ m^{3}h

Metabolic and Microbiological analysis

The biological activity during biofiltration of H_2S and NH_3 was followed by the measure of sulfate, ammonium, nitrite, and nitrate concentration in the compost bed, as well as abundance of SOB and AOB.

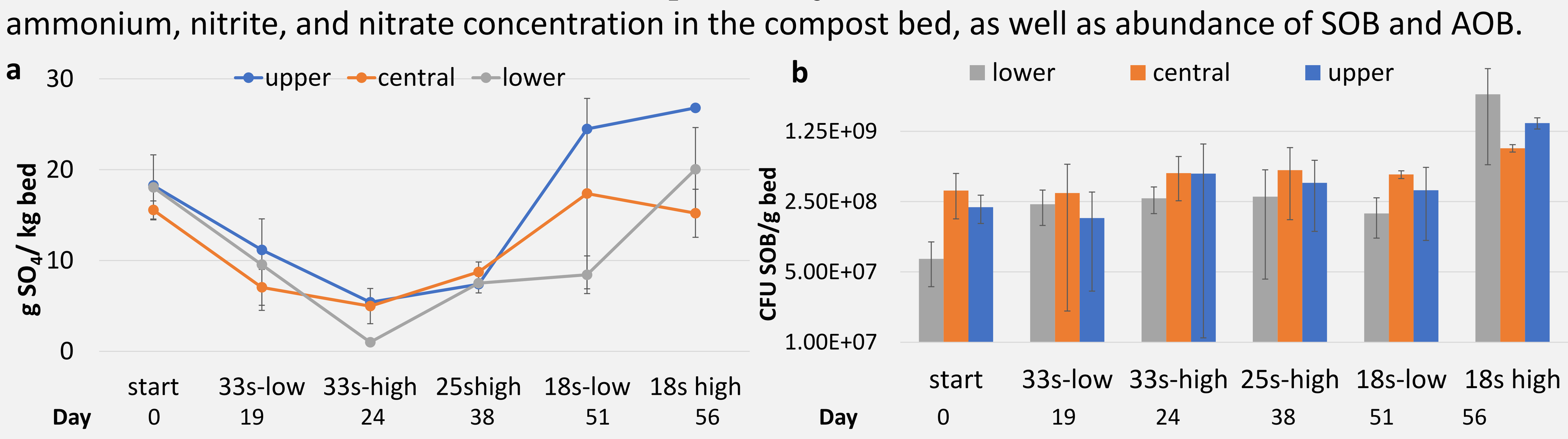
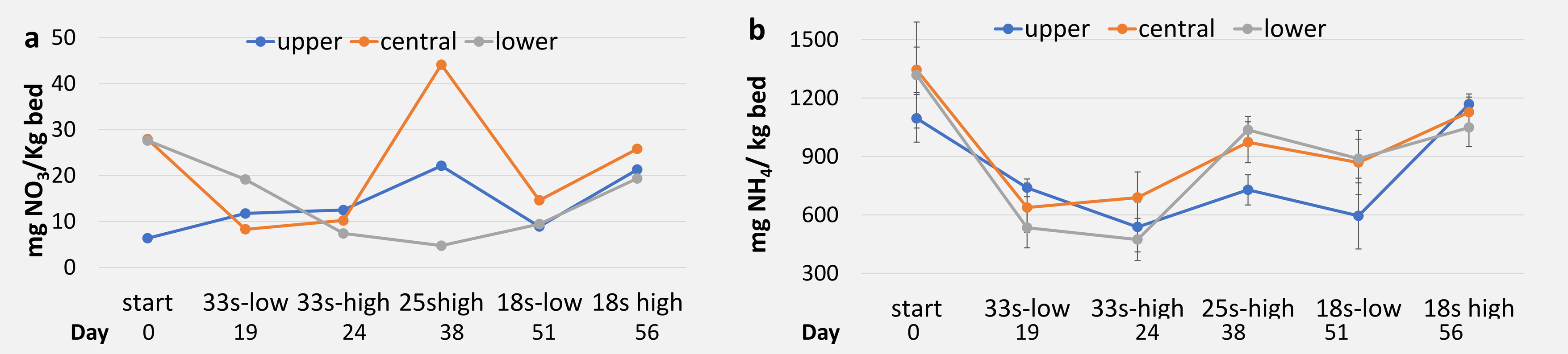


Figure 3. Sulfate production (a) and SOB abundance(b) in each biofilter section at different EBRT (33,25 and 18s) and level of gas concentration (high and low). "Day" indicates the biofiltration day of sampling

- At EBRT of ≥ 33s (days 1 to 19), sulfate concentration did not increase (Fig. 3a), despite the removal efficiency of H_2S higher than 95% (Fig. 2a). These results indicate that sulfide elimination was not achieved by complete oxidation to sulfate and instead was only oxidized to elemental sulfur.
- The increase in sulfate concentration, after the shutdown period (day 32 to 38), could be caused by the biological oxidation of the sulfur accumulated in the bed to sulfate during the shutdown[4]. These results suggest that the shutdown allowed the recovery of microbial activity after stress conditions due to previous gas shock loads.
- At 18s and high load, sulfate concentration (Fig. 3a) and SOB abundance (Fig. 3b) reached the highest values, despite the removal efficiency was dropping (Fig. 2a). These results can be explained by the accumulation of by-products such as sulfur in the biofilter bed, which can be consumed by SOB to produce sulfate. However, this accumulation also could decrease the superficial area available for the adsorption of gases[5], reducing the removal of H_2S.



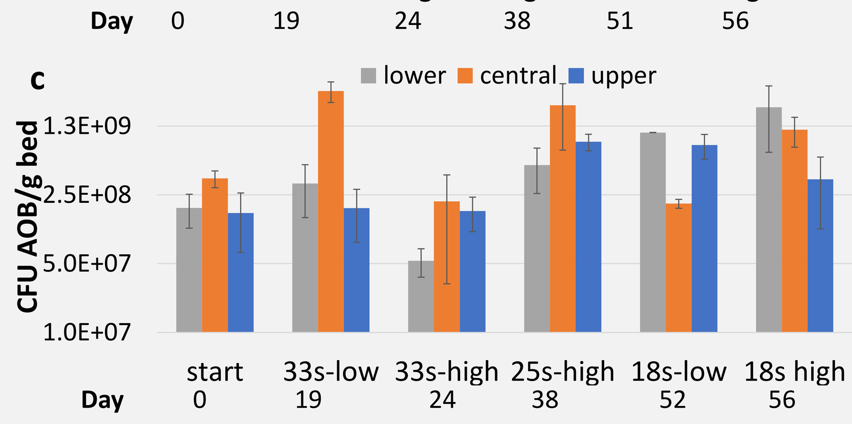
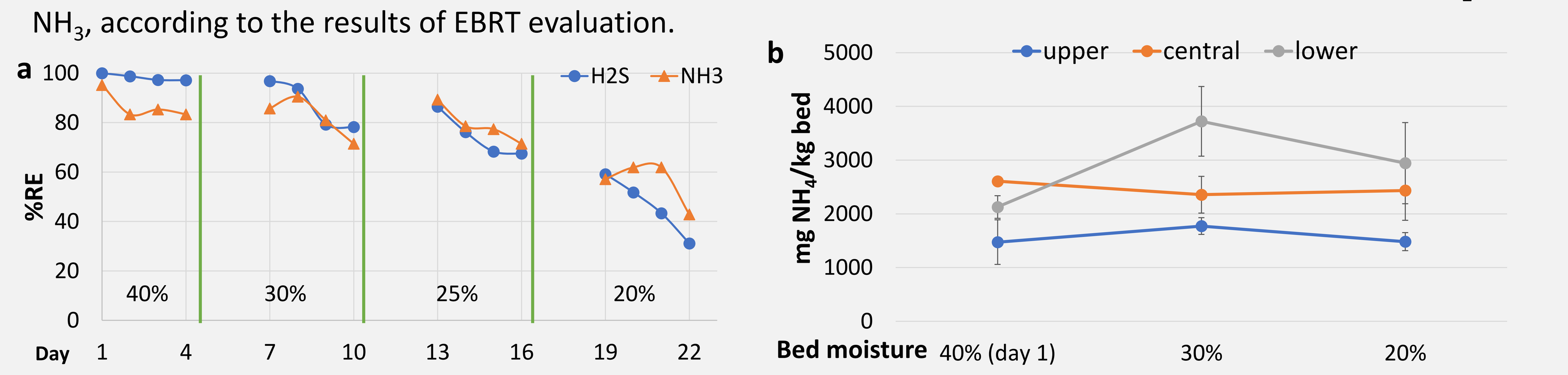


Figure 4. Nitrate production (a), ammonium accumulation (b) and AOB abundance (c) in each biofilter section at different EBRT (33,25 and 18s) and level of gas concentration (high and low). "Day" indicates the biofiltration day of sampling

- At EBRT of ≥ 33s (days 1 to 19), the concentration of nitrate did not increase (Fig. 4a), despite the high removal efficiency of NH_3 (Fig.2b) and the reduction of ammonium concentration (Fig. 4b). This suggests that the ammonium was consumed in denitrification pathway to produce nitrous oxide or nitrogen, or in assimilative pathway.
- The increase in the AOB abundance at 25 ad 18s, after the shutdown (Fig 4c), could be related to the recovery of microbial activity after shutdown. This kind of recovery in the microbial community under transient conditions has been reported previously by Cabrol et al.[6]

EFFECT OF MOISTURE CONTENT IN THE BIOFILTRATION

A residence time of 25s was selected to carry out the evaluation of moisture content in the biofiltration of H_2S and NH_3, according to the results of EBRT evaluation.



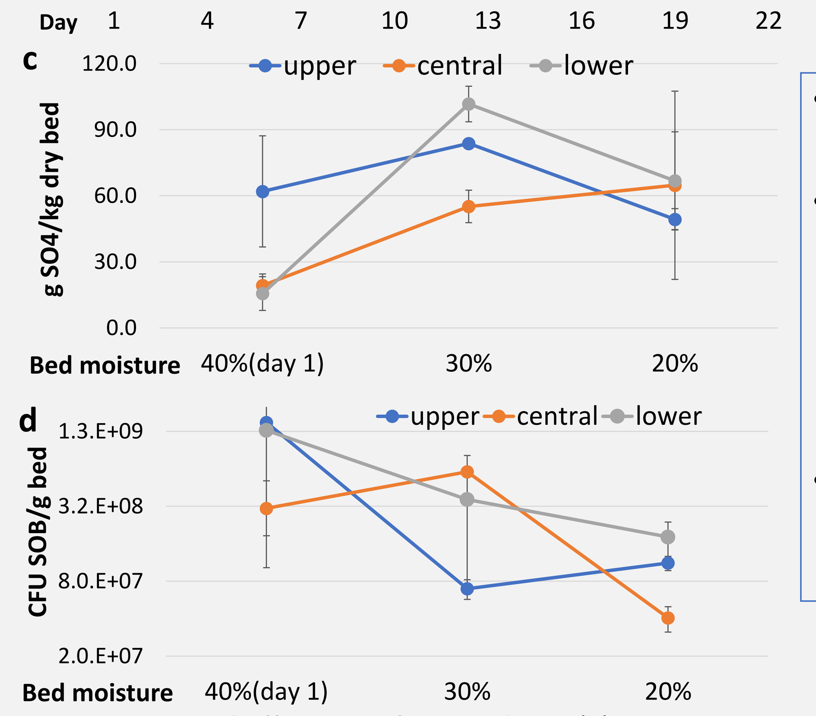


Figure 5. Removal efficiency of H_2S and NH_3 (a), ammonium accumulation (b), sulfate production (c) and SOB abundance (d) in each biofilter section at different moisture content of biofilter bed.

- The %RE for both gases gradually decreased when the moisture content was reduced (Fig 5a).
- The reduction in the removal is due to the decrease in the adsorption of gases in the biofilm that affects the subsequent oxidation, as it is shown by observing that the ammonium concentration remained constant, that is, the bed could not adsorb more ammonia from the air stream (Fig. 5b).
- The decrease in moisture affects the microbial activity, which was evidenced by a decrease in the abundance of SOB and low production of sulfate (Fig. 5c and d)

Conclusions

- The biofilter packed with compost of sugar cane bagasse and chicken manure reached 80% of removal efficiency of H_2S and higher than 90% for NH_3 at the highest concentration of the gases (260 mg H_2S/m^3 and 10 mg NH_3/m^3), when the residence time was 25s and moisture content of bed 40%.
- In these operative conditions, the biofilter could recover its activity after transient conditions such as shock load, and interruption of operation, that corresponded to those found in a wastewater treatment plant. These results showed the suitability of the evaluated compost biofilter for its use of the treatment of industrial emissions where these transient conditions are frequent.

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