Abstract

The study aimed to gain new fundamental knowledge in the field of biological production of carbon monoxide (CO) during composting of biowaste, in particular in the field of: (i) determination of optimal aeration level and thermal conditions for CO production during biowaste composting; (ii) isolation and identification of microorganisms responsible for CO production while biowaste composting; (iii) determination of CO emission factors from compost piles on a technical scale. Due to the toxic nature of the CO additional research aim was to assess the potential occupational exposure of composting plant workers to CO during biowaste composting. The state-of-the-art in the field of biological CO production was reviewed, as well as research was designed and performed, including mathematical modeling, laboratory analyses, and experiments on a technical scale, enabling the preparation of the concept of the biowaste composting process focused on CO generation along with recommendations taking into account ensuring the safety of such a process in the context of employees' exposure to this gas.

Research on the CO production potential during biowaste composting under controlled laboratory conditions depending on different aeration rates (2.7, 3.4, 4.8, and 7.8 $L \cdot h^{-1}$) and temperatures (T=35, 45, 55, and 65°C) proved that thermal conditions and aeration level affect CO concentrations but only at the low temperatures and aeration rates (<45°C and <3.4 $L \cdot h^{-1}$).

Analyses of the isolation and identification of microorganisms potentially responsible for CO production from compost samples taken from the pile on a technical scale indicated that all isolates were thermophilic and anaerobic bacteria. Their incubation in laboratory-scale bioreactors allowed the identification of bacterial strains producing CO at concentrations exceeding 1,000 ppm (*Bacillus paralicheniformis*), >800 ppm (*Bacillus licheniformis*), and close to 600 ppm (*Geobacillus thermodenitrificans*).

During research conducted on a technical scale on CO emission from compost piles located in a hermetised composting hall and in an open yard, before and after material turning, using the flux chamber method, it was proved that CO emission is 14x to 39x higher in the closed hall. In addition, net CO emissions to the atmosphere are between 1.7x and 13.7x higher after material turning. The modeling of the CO concentration in the composting hall showed that after 1 h the level of this gas can reach ~50 mg $CO \cdot m^{-3}$ before material turning and >115 mg $CO \cdot m^{-3}$ after, exceeding the World Health Organization (WHO) thresholds for 1-hour and 15-minutes exposure to CO, respectively.

In turn, modeling of the accumulation of CO concentration in a static bioreactor during 14 days of biowaste composting showed that in each of the analyzed variants of the ratio of headspace-to-waste volumes (H:W) (4:1, 3:1, 2:1, 1:1, 1:2, 1:3, 1:4), the CO level exceeded the value of 100 ppmv safe for 15 minutes of work in the composting plant. The CO concentration reached the maximum of 36.1% for the variant without bioreactor ventilation and 3.2% with the daily release of accumulated gas (bioreactor ventilation). Modeling has shown that the airflow required to keep the CO concentration below 100 ppmv should be at least 7.15 $m^3 \cdot (h \cdot Mg \text{ of wet mass of waste})^{-1}$, and that the process with H:W ratio >4:1 and compost pile height <1 m is less susceptible to CO accumulation.