EFFECT OF BIOCHAR ADDITION ON THE IMPROVEMENT OF THE QUALITY PARAMETERS OF COMPOST USED FOR LAND RECLAMATION

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INTRODUCTION

- The use of **biochar** with compost becomes highly attractive from a systemic perspective because of the expected lower environmental burden than mineral fertiliser use.

- The addition of **biochar** increases the composting temperature by 3-8 °C, extends the thermophilic phase and significantly reduces ammonia production or ammonium leaching into the ground and surface waters. It also improves the water-holding capacity of compost, promotes humification, reduces the mobility of organic pollutants, and contributes to the reduction of VOCs.

AIMS OF THIS ARTICLE

- This work aimed to verify the impact of the addition of biochar during pilot composting in real conditions concerning the release of VOCs and with a connection to other significant parameters determining the quality of the resulting compost.

- Furthermore, the possibility of using a special sampling device for collecting compost air has been verified to characterise the distribution of VOCs between the gaseous component, the solid phase, and the soil water better.

COMPOSTING TECHNOLOGY

- *The materials for fermentation*: horticultural waste, gastro-waste and undersize fraction from the sorting line of separated municipal waste in OZO Ostrava (< 100 mm), paper and cardboard packaging or wood packaging, soil, sewage sludge, and raw materials (ash and tailings).
- The primary phase of the conversion of biodegradable waste was prepared in automated fermenters at 65 °C for 5-10 days in the presence of thermophilic microorganisms.

- A mixture of the individual components was formed by 10 tonnes of fermentate, 2.5 tonnes of sludge from the waste - water treatment plant , 2.5 tonnes of soil, and 0.75 tonne of biochar.
- Biochar was added to this feedstock in the quantity of 5% (**Compost C1**).
- The second experiment represented composting with the same composition of raw materials without the addition of biochar (**Compost C2**).

SAMPLING AND ANALYTIC METHODS

- Solid compost samples were used for the determination of the *organic matter, moisture, the concentrations of major elements, Oxygen uptake rate (OUR), and after separation, the concentrations of humic acids*.
- Air samples (sorption tubes of Markes) were taken in a fermenter → sampling probe was loosely in space. The sampling probe for the compost air sample was embedded in the compost (depth about 22 cm).
- The sorption tubes were analysed using thermal desorption (*TD-GC/MS, Gerstel TD3,5+, Muelheim, Germany*) with subsequent separation of organic compounds on the gas chromatograph (7890A Agilent, USA) and identification of compounds by mass spectrometric detector (5977A, Agilent).

RESULTS

Basic information on raw material, compost characteristics, and composting process

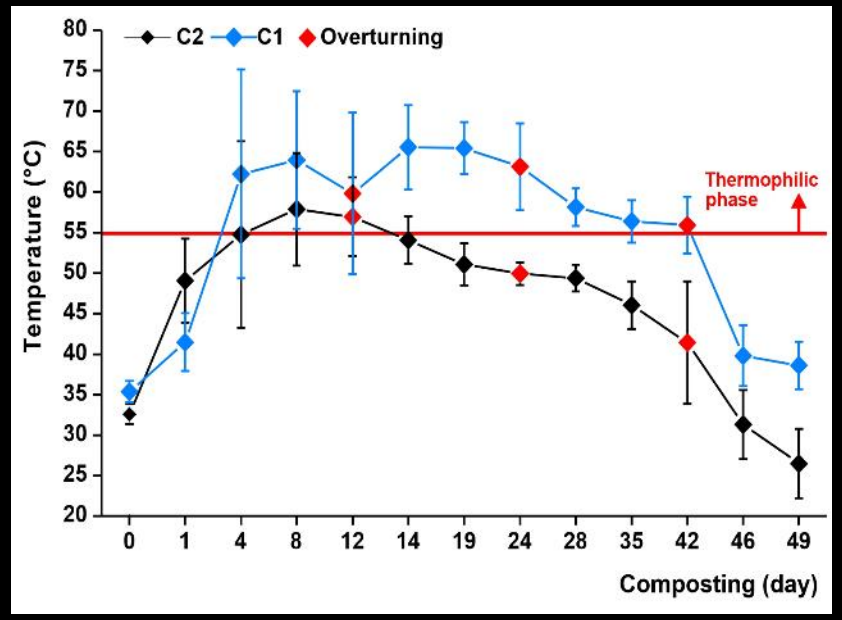
- Temperature
- Fermenter

Volatile Organic Compounds

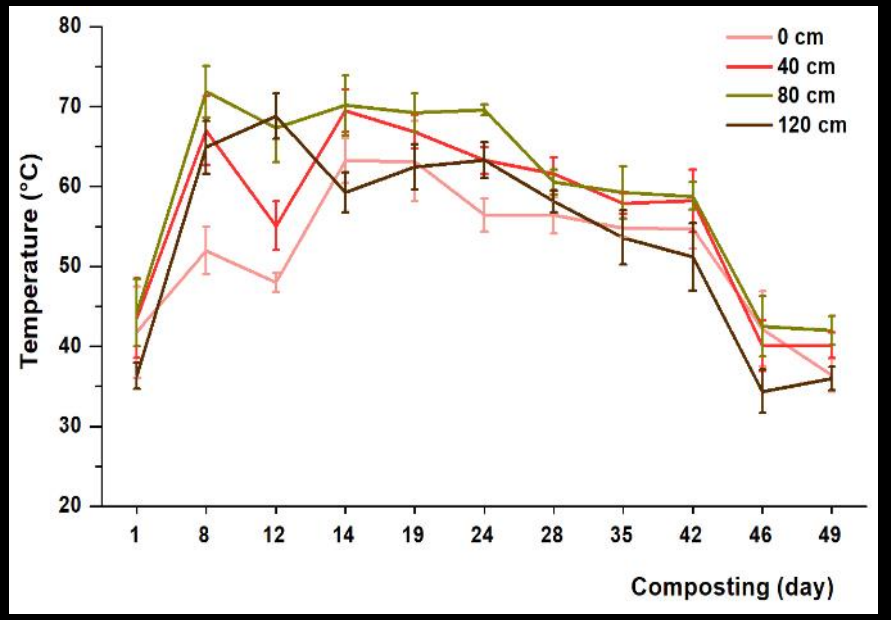
- Terpenes
- Alkanes
- Aromatic hydrocarbons
- Volatile sulfide compounds
- Heterocyclic organic compounds containing nitrogen
- Oxygenated compounds

TEMPERATURE

- Temperature is an essential factor in influencing the course of composting.



Average temperature values during composting for C1 and C2

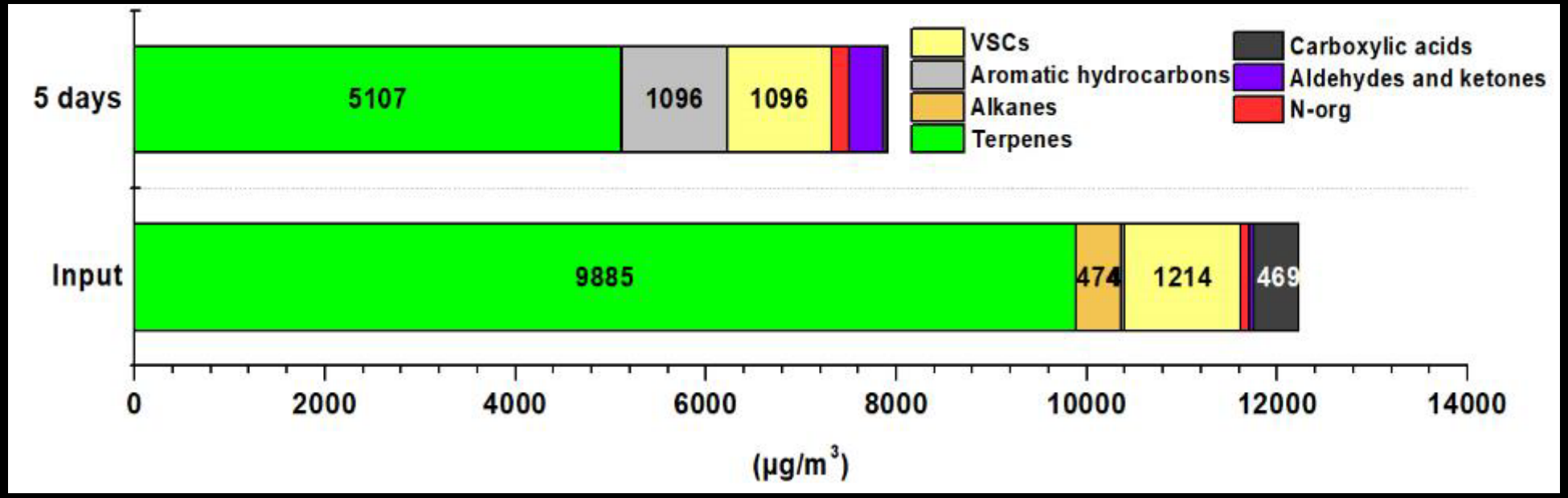


Temperature variability at observed depths for C1

- The C1 compost with biochar generated increased temperatures. The difference in temperature of **C1** and **C2** composts is between 3-30 °C (the average 13.4 ± 8.2 °C).
- The adding biochar causes extending the thermophilic phase by 14 days.

FERMENTER

- The most important groups of organic substances after the input of the raw material into the fermenter and on the fifth day of the composting process are represented in figure.



- Compared to the input material, the VOC concentration in the air decreased to **1/2** on the fifth day.
- The most significant decreases were found in *terpenes, carboxylic acids, alkanes and volatile sulfide compounds*.
- The concentrations in the compost air are increased for *aromatic hydrocarbons, aldehydes, ketones, and organic heterocyclic compounds with nitrogen*.

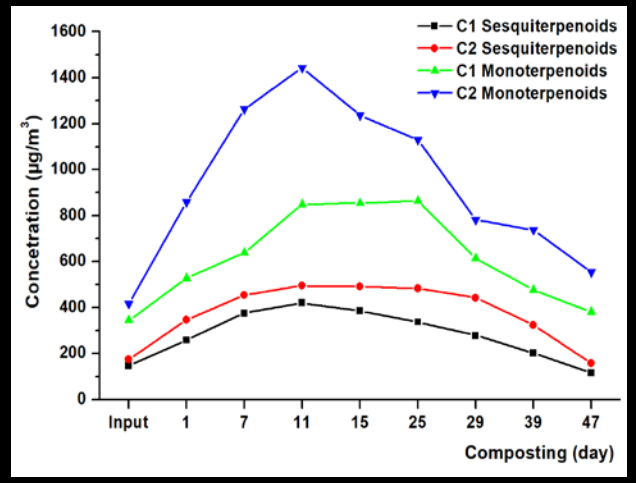
VOLATILE ORGANIC COMPOUNDS

- Compounds from groups of *terpenes, sterols, bicyclic hydrocarbons, alcohols, sulfur-containing compounds, compounds containing heterocyclic and aliphatic nitrogen, alkanes, alkenes, furans, ketones, aldehydes, carboxylic acids and aromatic hydrocarbons have been identified in the compost air*.

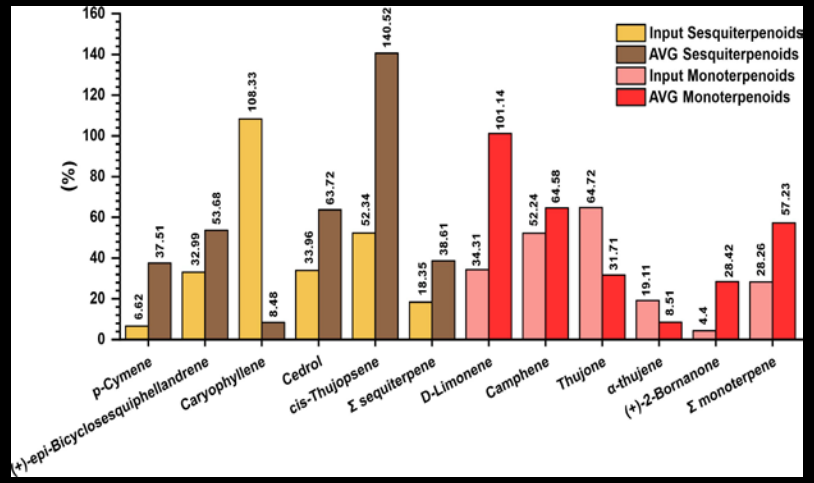
- A total of **268** compounds were identified in compost air without added biochar (**C2**), while **220** compounds were identified in compost air with added biochar (**C1**).

TERPENES

- Compost air from input raw material for compost C2 contains from the total amount of VOCs approximately 30.8% of terpenes, while for C1, it is 24.5% of terpenes.



Changes in the concentrations of terpenes in the air from compost C1 and C2

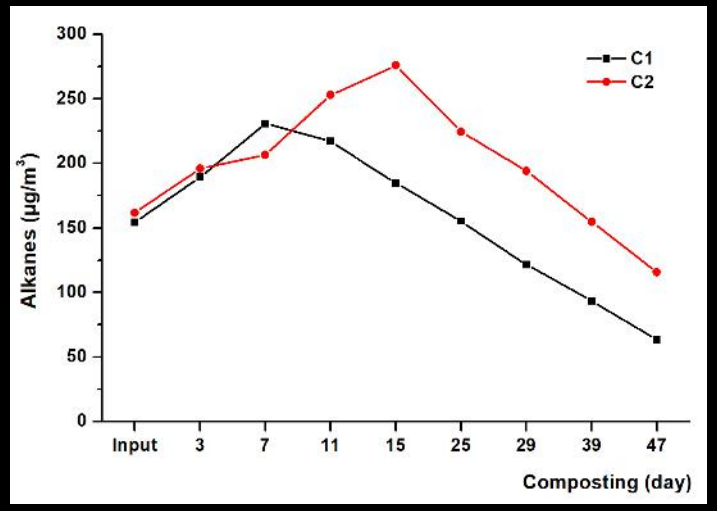


The difference between the concentration of compounds in C1 and C2 in the compost air in the feedstock and as an average value from each sampling

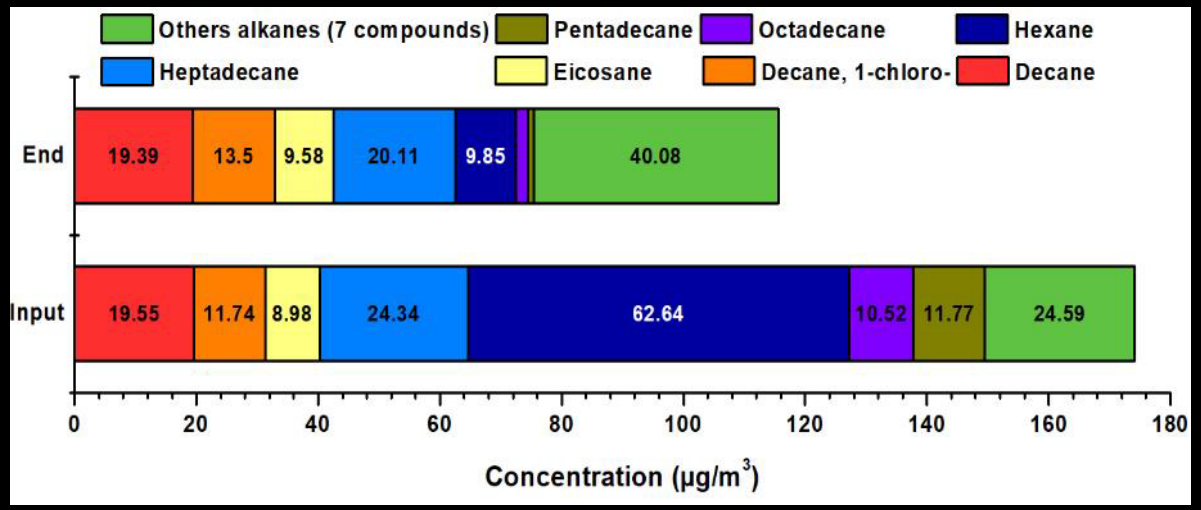
- In the **C2 compost** air, 30 compounds of the monoterpenoids group and 24 compounds of the sesquiterpenoids group were identified. Of monoterpenoids, D-limonene, camphene, thujone, α-thujene, 2-bornanone, and 3-carene were found at the highest concentrations.
- D-limonene accounts for up to 33% of the total terpene concentration in the **C2 compost** air. The most significant terpene in the sesquiterpenoids group is p-cymene, caryophyllene, (+)-epi-bicyclosesquiphellandrene and cis-thujopsene.

ALKANES

- The concentration of alkanes in the air after mixing feedstocks without the addition of biochar (C2) is 174 µg/m^3, and for compost **C1** with the addition of biochar is **154 µg/m^3**.
- The rapid increase of degradation processes for alkane formation was found for **C1** (less than seven days) while it was up to 15 days for **C2**.
- The concentrations of the individual alkane compounds at both the beginning and end of the **C2** composting process is shown in figure → the average increase in the concentration of alkanes in the air contained in compost without the addition of biochar. Immediately after mixing feedstock and biochar, the concentration in the air decreased by 5 to 120%.
- The addition of biochar reduced the concentration of Σ alkanes in the air of **C1** compost approximately by **1/2** compared to the concentrations in the feedstock.



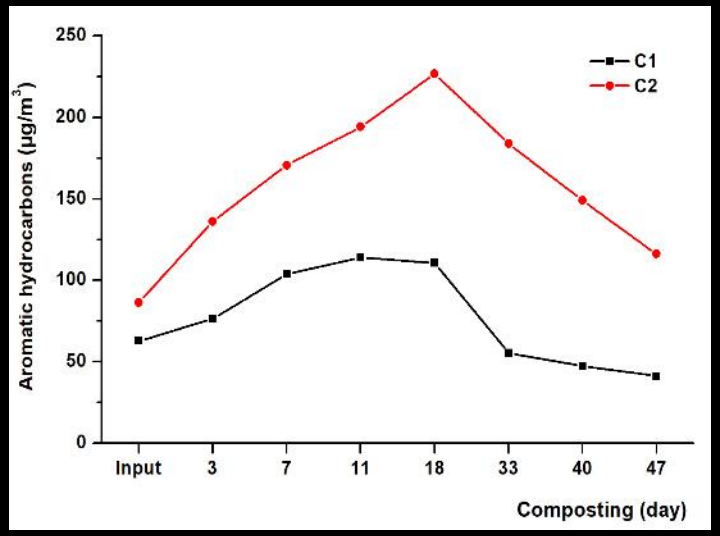
Changes in the concentrations of Σalkanes in the air from compost C1 and C2



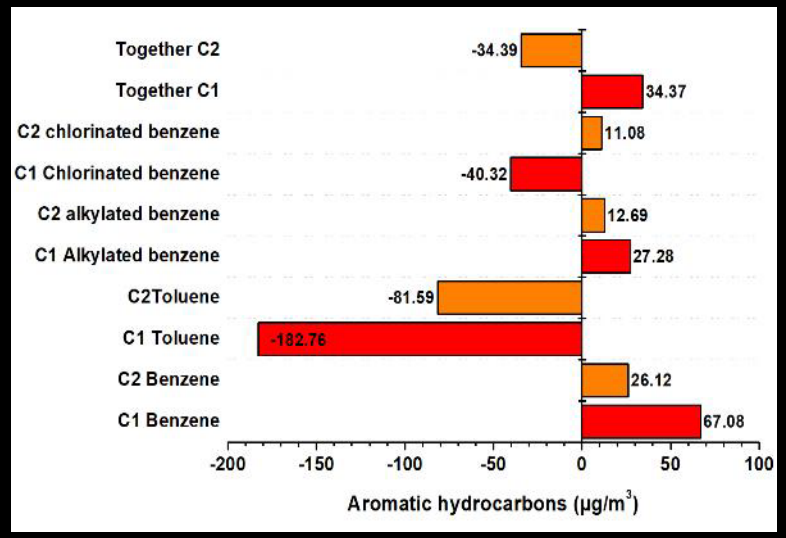
The concentrations of the individual compounds from the group of alkanes in the air of compost C2 at the beginning and after 47 days of composting

AROMATIC HYDROCARBONS

- The air from the feedstock to the fermenter contained 40 µg/m^3 of aromatic hydrocarbons, and after five days of fermentation, the concentration increased up to 125 µg/m^3.
- Air from the composting feedstock contains 30-35 µg/m^3 alkylated compound of benzene, 7.8-25 µg/m^3 toluene, about 16 µg/m^3 benzene, and 9-10 µg/m^3 benzene chlorinated.
- The amounts of aromatic hydrocarbons produced grow for both C1 and C2 up to 18 days (affected by overturning) and decrease.
- For toluene only, the concentration continuously increases from 7 to 22 µg/m^3 for compost **C1**, while for compost C2, it is from 25 to 50 µg/m^3.



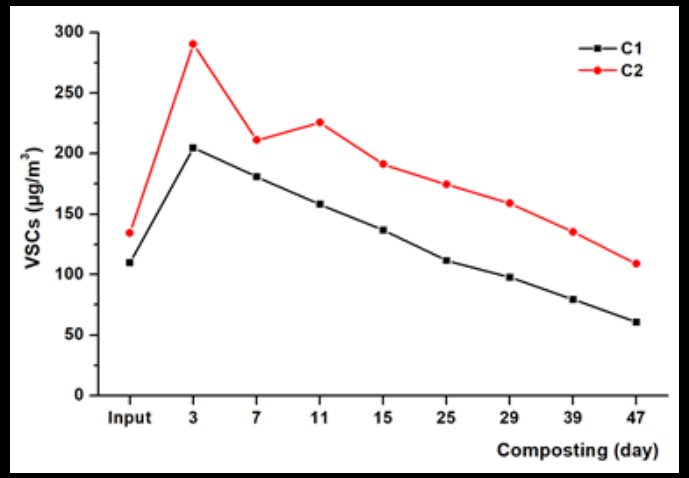
Changes in concentrations of Σ aromatic hydrocarbons



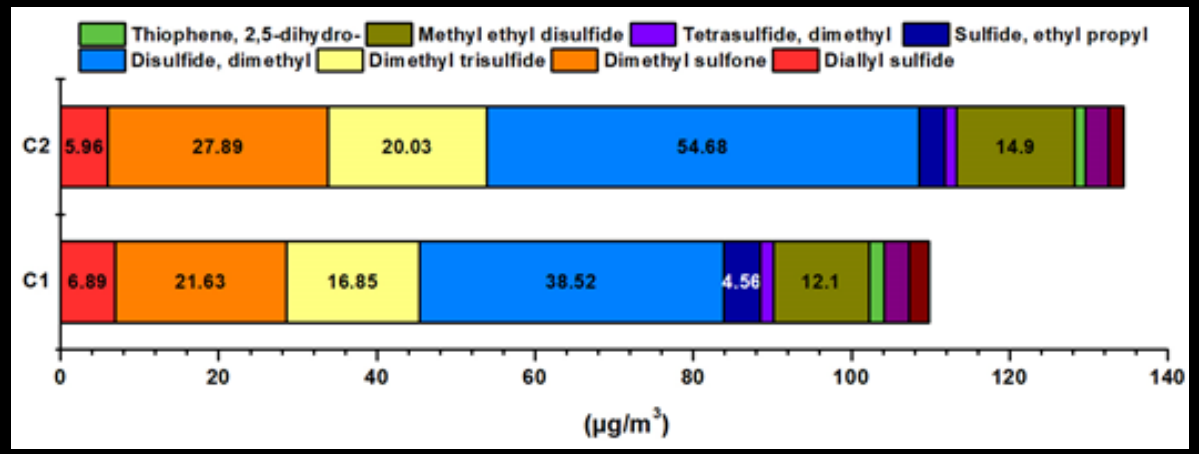
The degradation efficiency and aromatic hydrocarbon

VOLATILE SULFIDE COMPOUNDS (VSCs)

- By the third day from the addition of sewage sludge and earth, the concentrations of VSCs up to two-fold increases and then gradually decreases. After 47 days of composting, the VSC concentration in the **C2 compost** air decreased by approximately **20%**, while in the **C1** compost, it decreased by **45%**.
- Thus, the *addition of biochar* reduced total VSC production by approximately **1/3**.



Changes during VSC concentrations

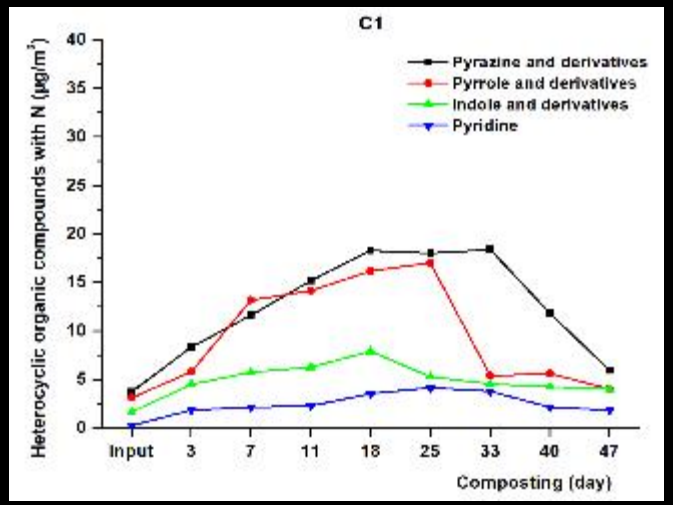


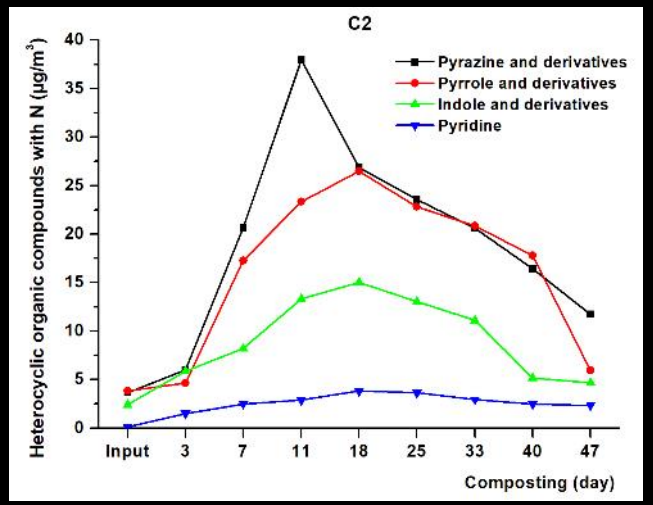
The concentrations of individual compounds in VSCs in C1 and C2 compost input

- Up to a 10-fold decrease in the VSC concentration in the compost air is observable in the preparation of the feedstock compost **C1** and **C2**, when the concentration dropped to between 1.1 and 1.3 mg/m^3.
- After adding sludge and soil to the fermentate, a decrease in VSCs of approximately **1/3** can be expected.

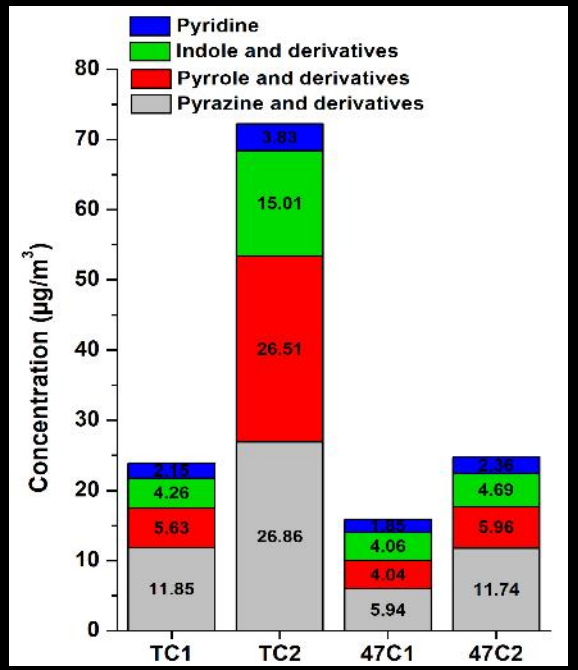
HETEROCYCLIC ORGANIC COMPOUNDS CONTAINING NITROGEN

- Biochar significantly reduces the nitrogen-containing organic compounds produced by the microbial transformation of N-compounds initially present in input materials for composting.
- In composting **C1** and **C2**, the most significant changes in compost air concentrations were found for pyrazine, pyrrole, and their derivatives.
- In **C1 compost**, pyrazine and its derivatives were generated for up to 33 days, and in the case of pyrrole up to 25 days. In **compost C2** the increase in pyrazine and its derivatives production ended after 11 days and pyrrole production ended after 18 days.
- The addition of biochar to the compost did most to reduce the concentration of indole in the air.





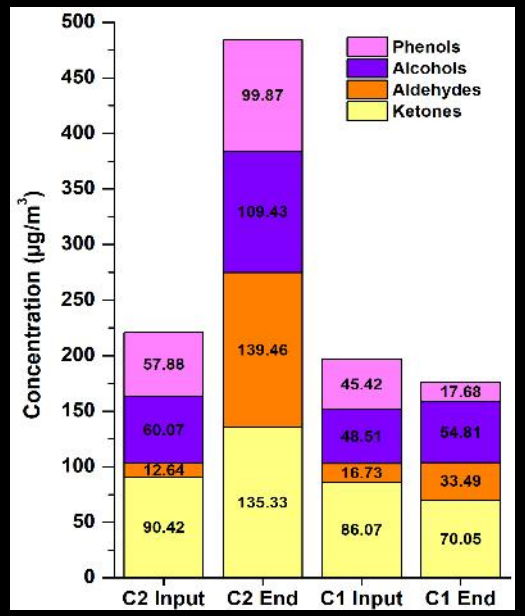
Changes in the concentrations of heterocyclic compounds containing nitrogen in compost C1 and compost C2



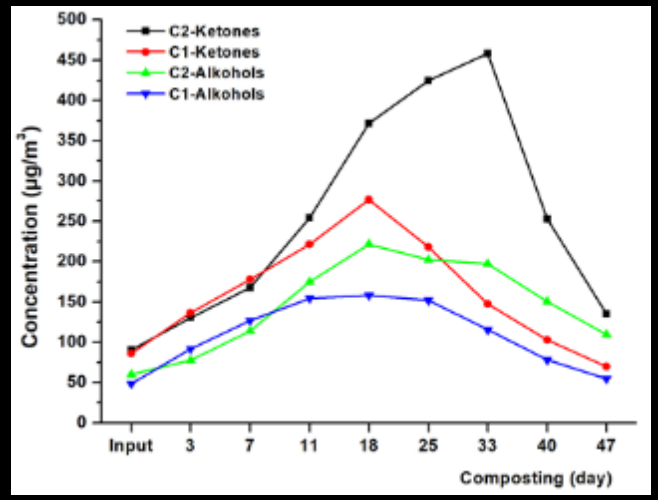
Differences in the concentrations of heterocyclic organic compounds containing nitrogen after the end of the thermophilic phase¨and at the end of the composting process

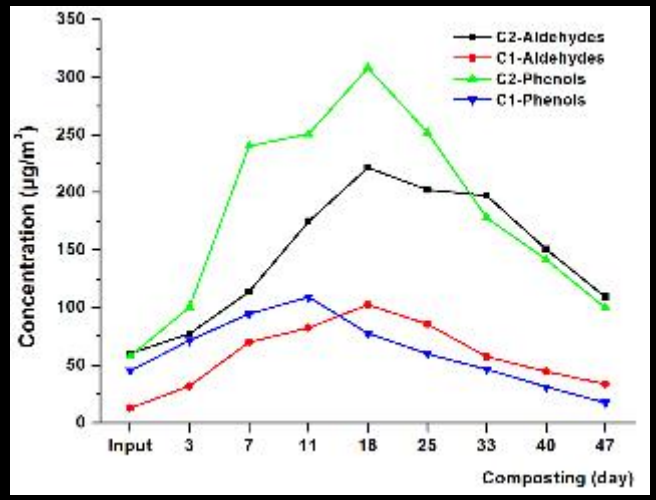
OXYGENATED COMPOUNDS

- Oxygenated compounds in the compost air of **C2** comprise ketones (41%), alcohols (27%), phenols (26%), and 6% of aldehydes. In the compost air of **C1** and **C2**, 18 compounds from the ketone group were identified.
- The concentrations of *aldehydes* in the **C2** compost air increase approximately three-fold compared to the feedstock at the end of the composting process. The concentration of aldehyde in the air compost **C1** is approximately three times higher at the end of the technological experiment, than at the start of the composting process.
- The concentration of *alcohols* in **C2** air was 24% higher than in **C1** at the beginning of the composting process. The average value of alcohol production in **C2** throughout the composting process was 90% higher than in **C1**.
- The concentrations of *Σ phenols* in the compost air from the **C1** compost has decreased to approximately 1/3 compared to the input material. The addition of biochar significantly reduces the release of phenols during the composting process.



Oxygenated compounds – the division of groups of organic compounds in the compost air at the beginning and end of the composting process





Time course of changes in concentrations of Σ ketones, alcohols, aldehydes and phenols in the compost air of C1 and C2 composts

CONCLUSIONS

- The addition of 5% biochar to the composting input affected the course of the physicochemical processes → *increase in the temperature, an extension of the thermophilic phase of approximately 14 days, and a reduction in the difference in the temperature profile of the row, an acceleration in achieving a degree of compost stability.*

- Immediately after the addition of biochar, all VOC-monitored groups showed a decrease in their concentrations in the compost air.

- Organic compounds with heterocyclic nitrogen showed a significant decrease in concentrations immediately after the addition of biochar to C1.

- After the addition of biochar the highest decrease occurred with compounds in VOCs: cis-thujopsene, D-limonene, and camphene.

- Thus, the addition of biochar to the compost has a positive effect on the compost properties.

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