Numerical Modeling of the Biodrying Process of the Organic Fraction of Municipal Solid Waste

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AGENDA

Introduction

Materials and methods

Conclusion

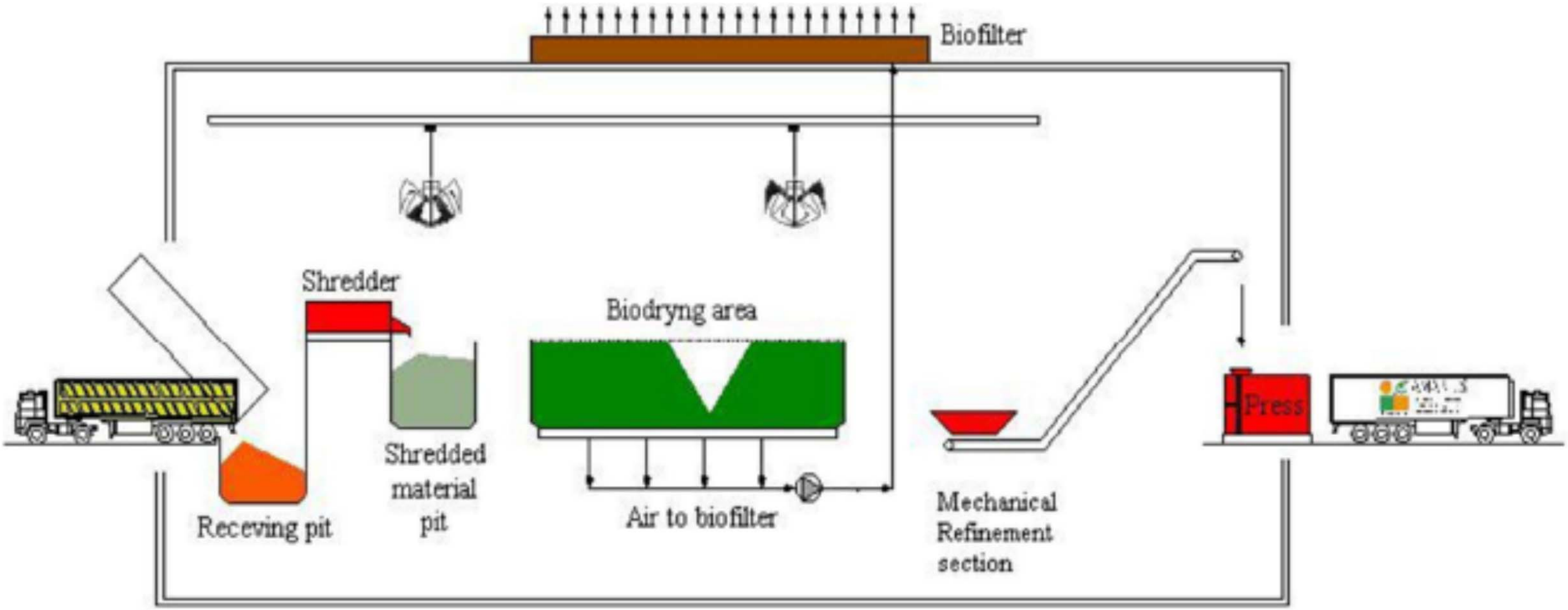
Introduction

Biodrying is an aerobic process during which the moisture content of waste is reduced while the degradation of organic waste is kept to a minimum.

The present research is an attempt to numerically model an aerobic bio-oxidation (biodrying) process based on relevant experimental data published in the literature.

Moisture content removal and generation of carbon dioxide and ammonia during the biodrying process were examined.

Furthermore, the potential of the biodrying process to produce a high quality refuse-derived fuel (RDF) product is discussed.


Biofilter
Shredder
Biodryng area
Shredded
material
pit
Receving pit
Air to biofilter
Mechanical
Refinement
section
Press


2 T-2600

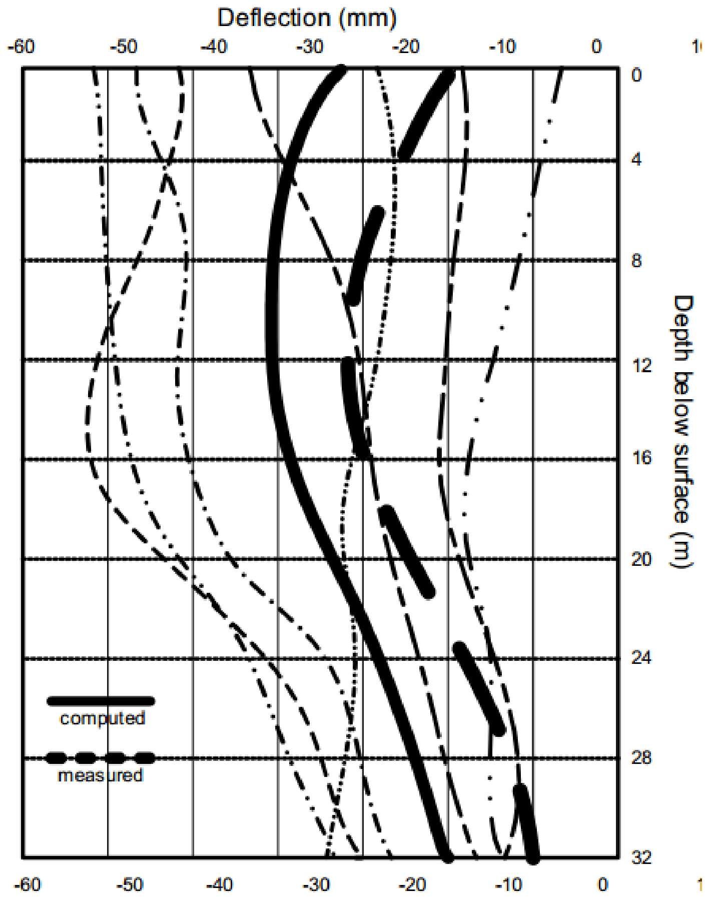


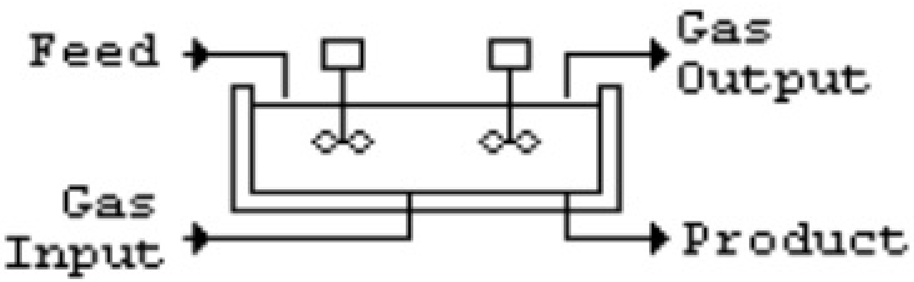
Figure 2-5 Comparison of predicted and measured lateral movements of a shoring wall (after Carter et al, 2000)

Carter et al. (2000) presented the results of a competition conducted by the German Society for Geotechnics. Packages of information were distributed to consulting engineers and university research groups. The participants were asked to predict the lateral deflection of a tie-back shoring wall for a deep excavation in Berlin. During construction, the actual deflection was measured with inclinometers. Later the predictions were compared with the actual measurements. Figure 2-5 shows the best eleven submitted predictions. Other predictions were submitted, but were considered unreasonable and consequently not included in the summary.

There are two heavy dark lines superimposed on Figure 2-5. The dashed line on the right represents the inclinometer measurements uncorrected for any possible base movement. It is likely the base of the inclinometer moved together with the base of the wall. Assuming the inclinometer base moved about 10 mm, the solid heavy line in Figure 2-5 has been shifted to reflect the inclinometer base movement.

Materials and methods

For the purposes of numerical modeling, the brand-name (e.g., SuperPro Designer) software package was chosen. Within the software, the well-mixed (WM) stoichiometric aerobic bio-oxidation procedure was selected (Figure 1).



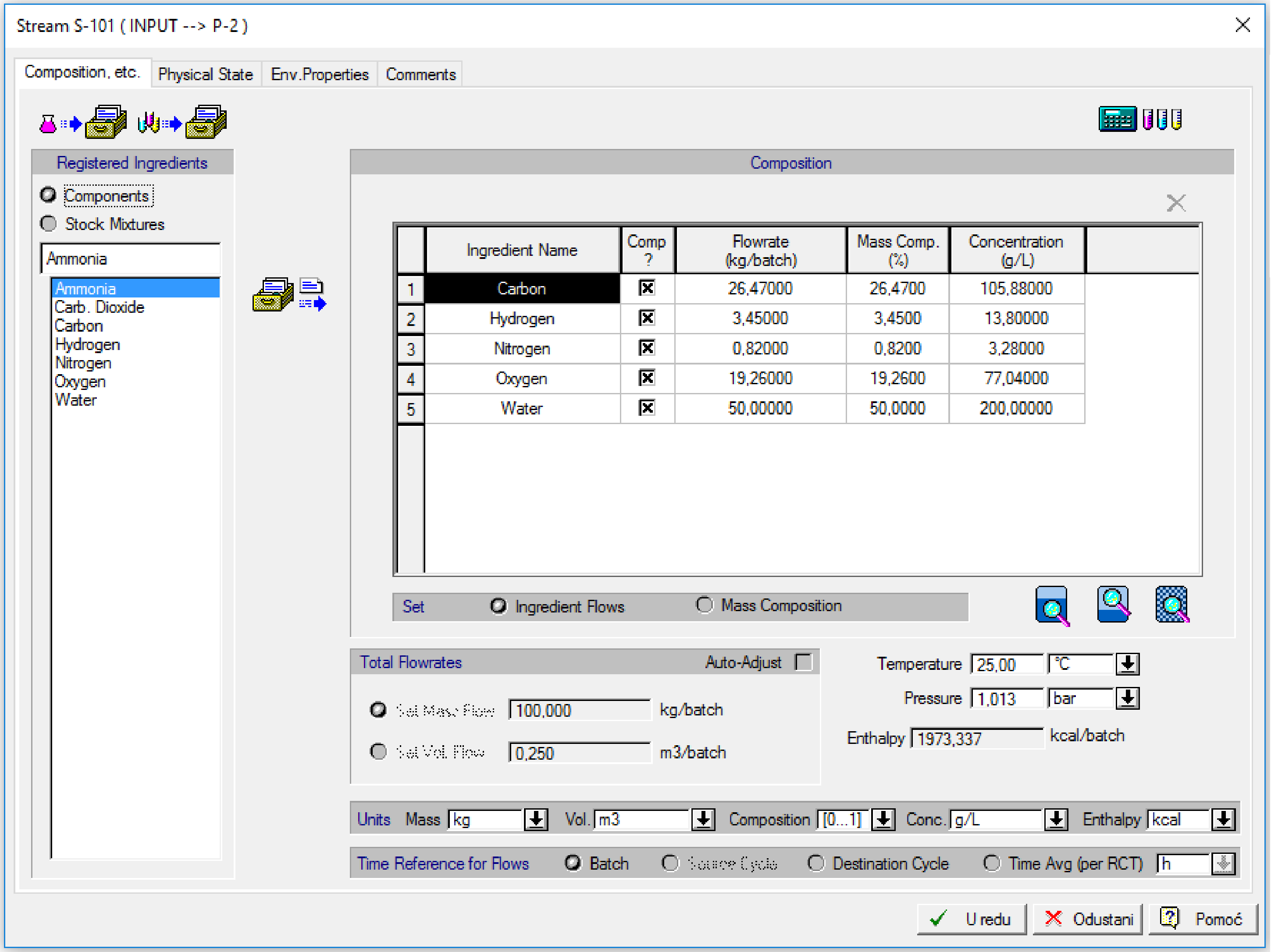
The biodrying process can be described with the following chemical equation:

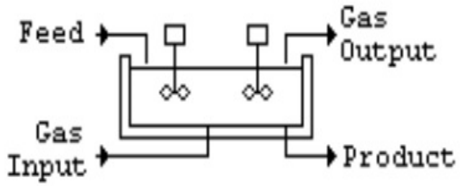
$$C_nH_aO_bN_c + \left(n + \frac{a}{4} - \frac{b}{2} - 3\frac{c}{4}\right) O_2 + H_2O(l) \rightarrow nCO_2 + \left(\frac{a}{2} - 3\frac{c}{2}\right) H_2O + cNH_3 + H_2O(g)$$

where $C_nH_aO_bN_c$ is the chemical formula of the organic waste

The representative chemical formula of the organic portion of municipal solid waste in Croatia is:

$C_{37,67}H_{58,51}O_{20,58}N$





Chemical element	Percentage by mass [%]
C	52.94
H	6.9
O	38.52
N	1.64
Total	100

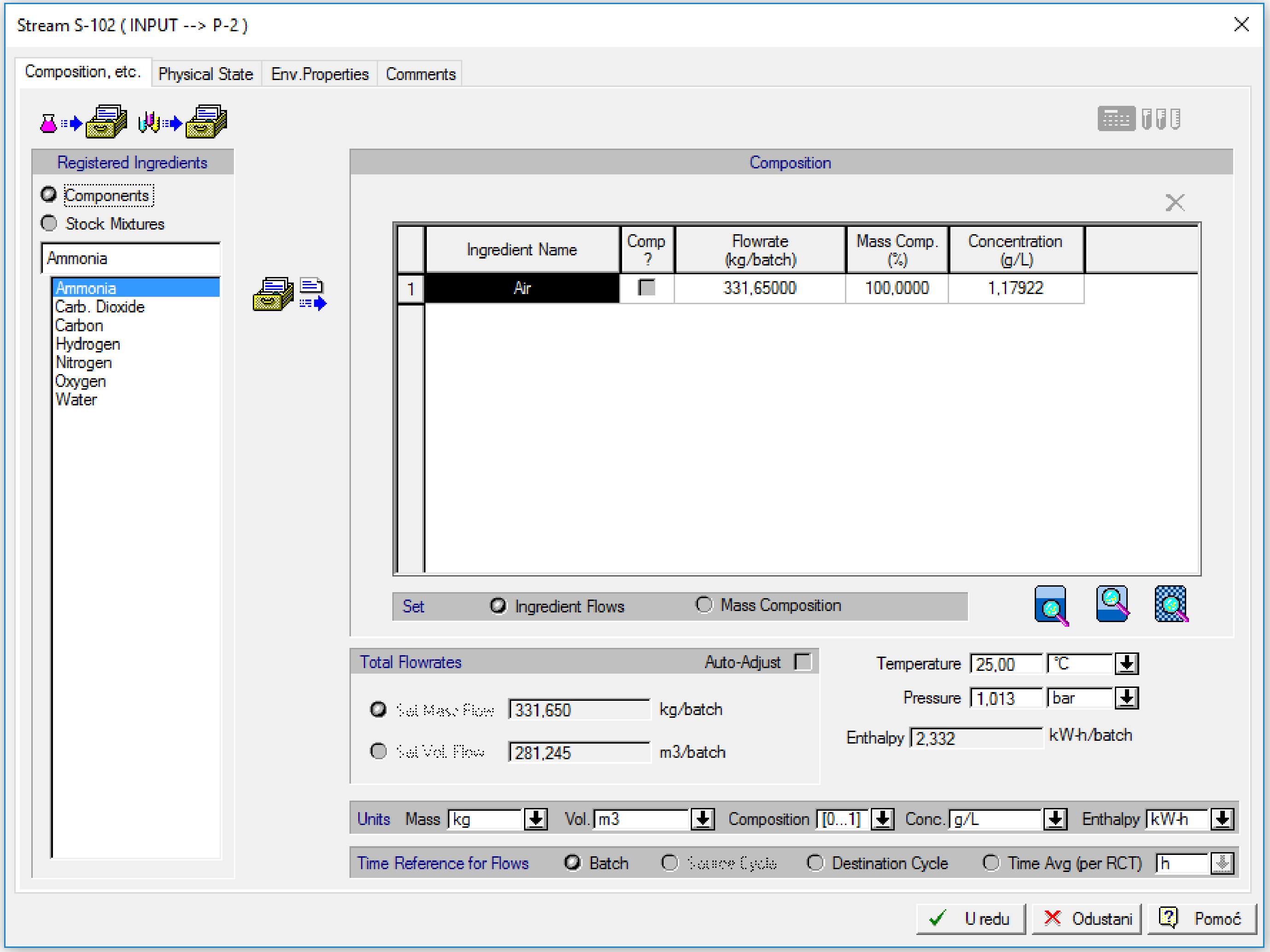
The total sample weight used in the model was 100 kg, and the initial moisture content was set to 50% (w/w).

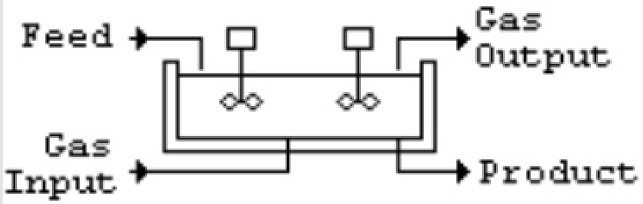
For the obtained chemical formula, the chemical equation of a 100% completed biodrying process with exact stoichiometric coefficients was established:

$$C_{37.67}H_{58.5}O_{20.58}N + 41.26O_2 + H_2O(l) \rightarrow 37.67CO_2 + 27.75H_2O + NH_3 + H_2O(g)$$

It can be easily calculated that 41.26 molecules of oxygen weighs 2.19234×10^{-27} kg and one molecule of organic waste material weighs 1.41926×10^{-27} kg.

Therefore, for complete aerobic biodegradation of 50 kg of organic waste material, it follows that 77.37 kg of oxygen or 331.65 kg of air is needed.


Stream S-102 (INPUT --> P-2)
Composition, etc.
Physical State
Env.Properties
Comments
Registered Ingredients
Components
Stock Mixtures
Ammonia
Ammonia
Carb. Dioxide
Carbon
Hydrogen
Nitrogen
Oxygen
Water
Composition
Ingredient Name
Comp ?
Flowrate (kg/batch)
Mass Comp. (%)
Concentration (g/L)
1
Air
331,65000
100,0000
1,17922
Set
Ingredient Flows
Mass Composition
Total Flowrates
Auto-Adjust
331,650
kg/batch
281,245
m3/batch
Temperature
25,00
°C
Pressure
1,013
bar
Enthalpy
2,332
kW-h/batch
Units
Mass
kg
Vol.
m3
Composition
[0...1]
Conc.
g/L
Enthalpy
kW-h
Time Reference for Flows
Batch
Destination Cycle
Time Avg (per RCT)
h
U redu
Odustani
Pomoć


Feed
Gas Output
Gas Input
Product

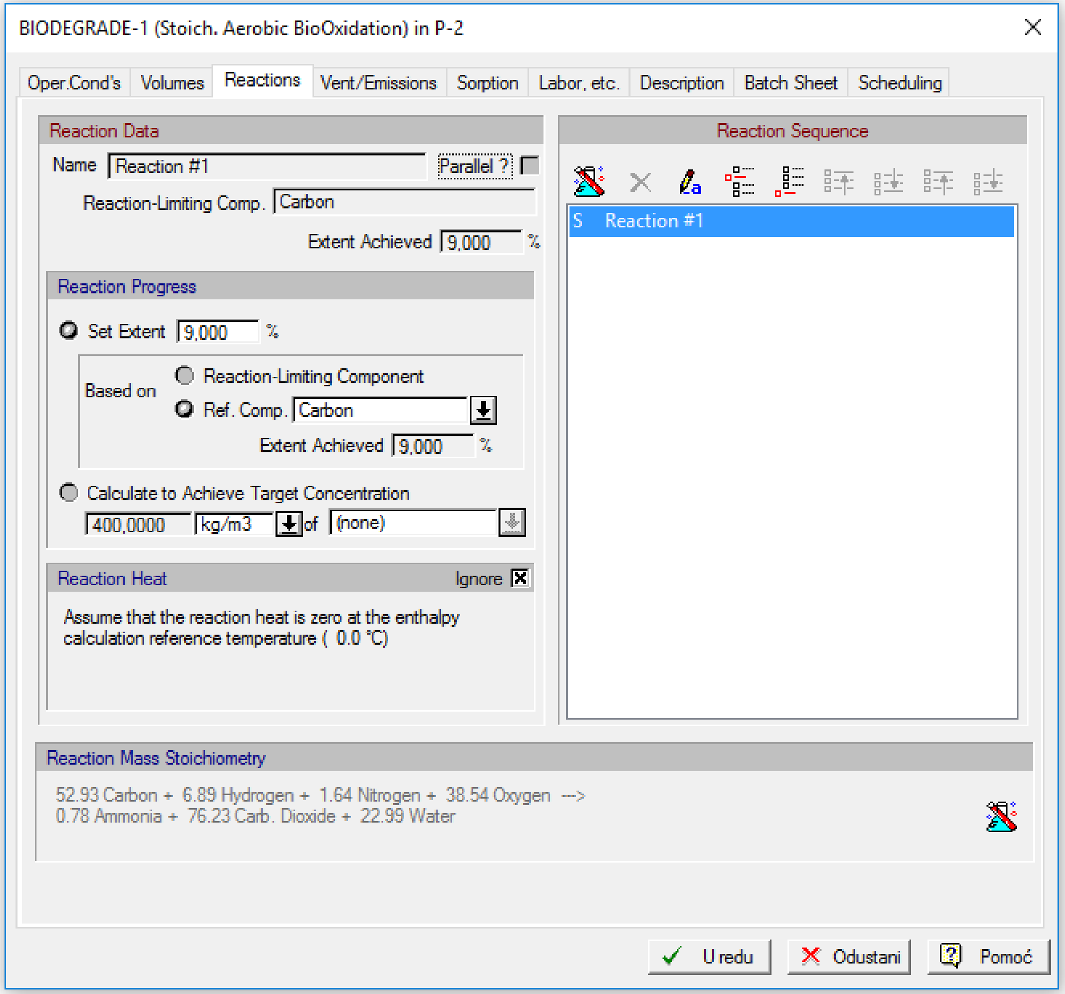
Only a minor portion of the initial organic waste mass is transformed into these chemical compounds, while a majority of the input organic waste materials remains unchanged.

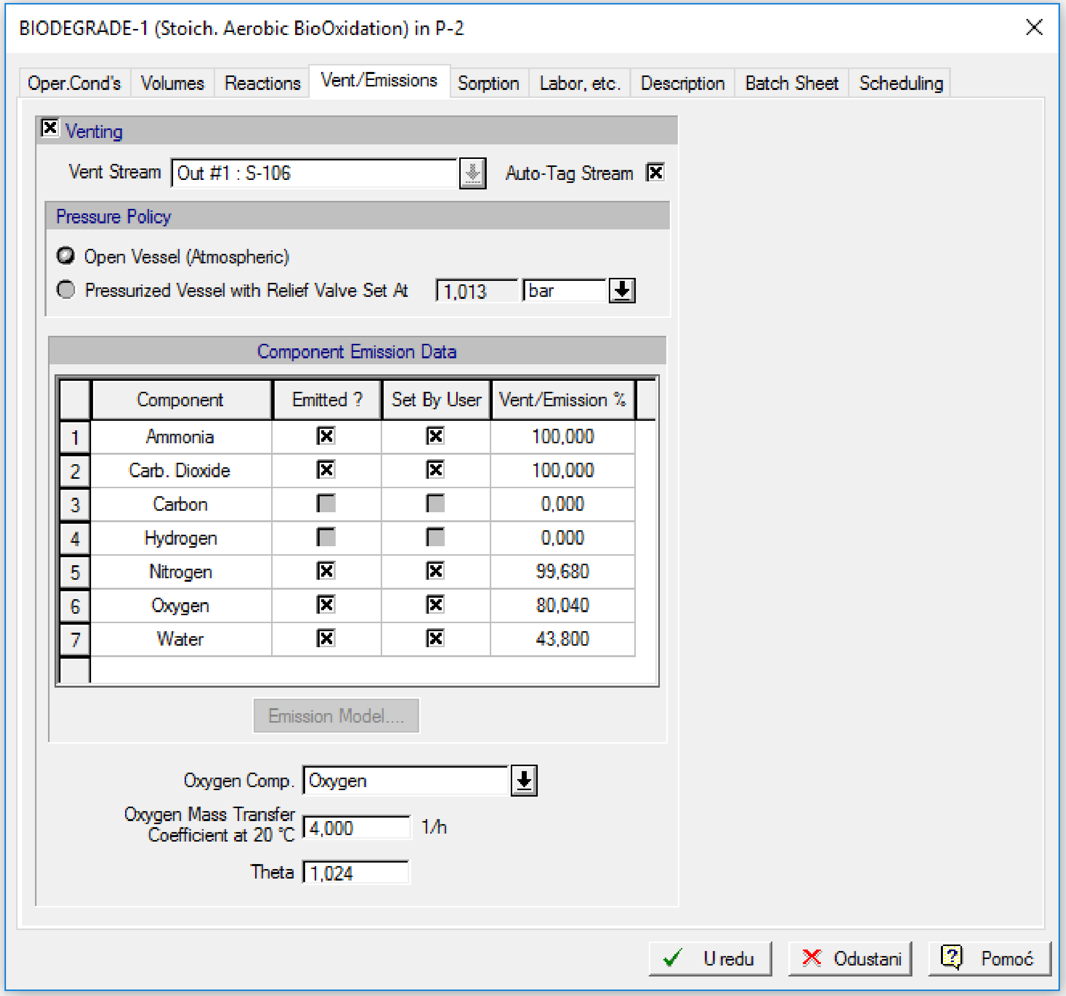
Thus, to simulate only partial degradation of organic components during the biodrying process, the reaction extent option, which is available within the WM procedure, has been used as a limiting factor.

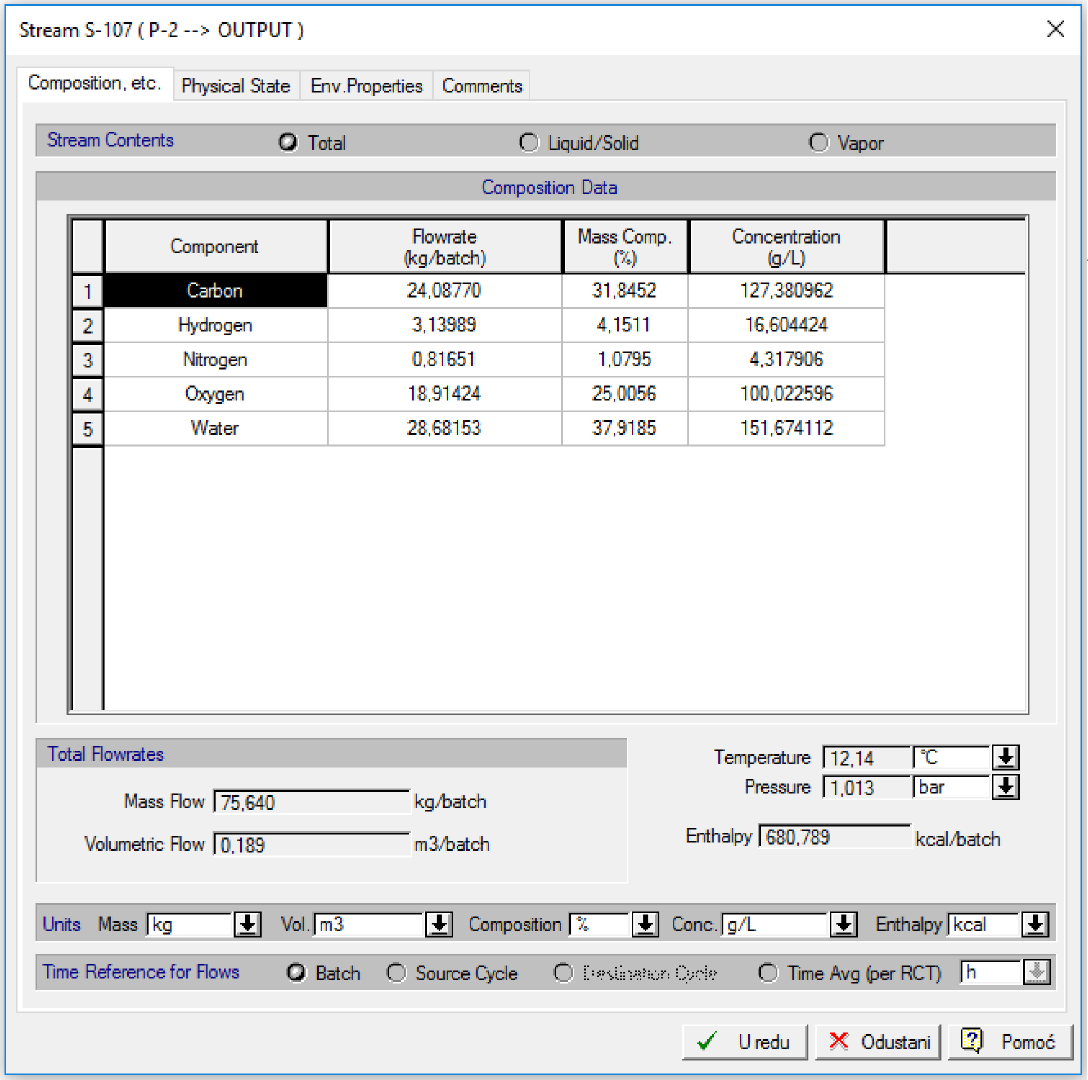
Within the WM stoichiometric aerobic bio-oxidation procedure, the reaction extent option can be used to stop the chemical process at a specific percentage and establish stoichiometric equilibrium at that point.

Thus the reaction extent, in conjunction with percentage of vent emissions of water vapor, were adjusted in order to simulate laboratory (1:7) and field (1:2.7) volatile solid consumption and water removal ratios.

The targeted mass reduction for both probes was set to 25% of the initial mass.


BIODEGRADE-1 (Stoich. Aerobic BioOxidation) in P-2
Oper.Cond's
Volumes
Reactions
Vent/Emissions
Sorption
Labor, etc.
Description
Batch Sheet
Scheduling
Reaction Data
Name
Reaction #1
Parallel ?
Reaction-Limiting Comp.
Carbon
Extent Achieved
9,000
%
Reaction Progress
Set Extent
9,000
%
Based on
Reaction-Limiting Component
Ref. Comp.
Carbon
Extent Achieved
9,000
%
Calculate to Achieve Target Concentration
400,0000
kg/m3
of
(none)
Reaction Heat
Ignore
Assume that the reaction heat is zero at the enthalpy calculation reference temperature (0.0 °C)
Reaction Sequence
S
Reaction #1
Reaction Mass Stoichiometry
52.93 Carbon + 6.89 Hydrogen + 1.64 Nitrogen + 38.54 Oxygen -->
0.78 Ammonia + 76.23 Carb. Dioxide + 22.99 Water
U redu
Odustani
Pomoć

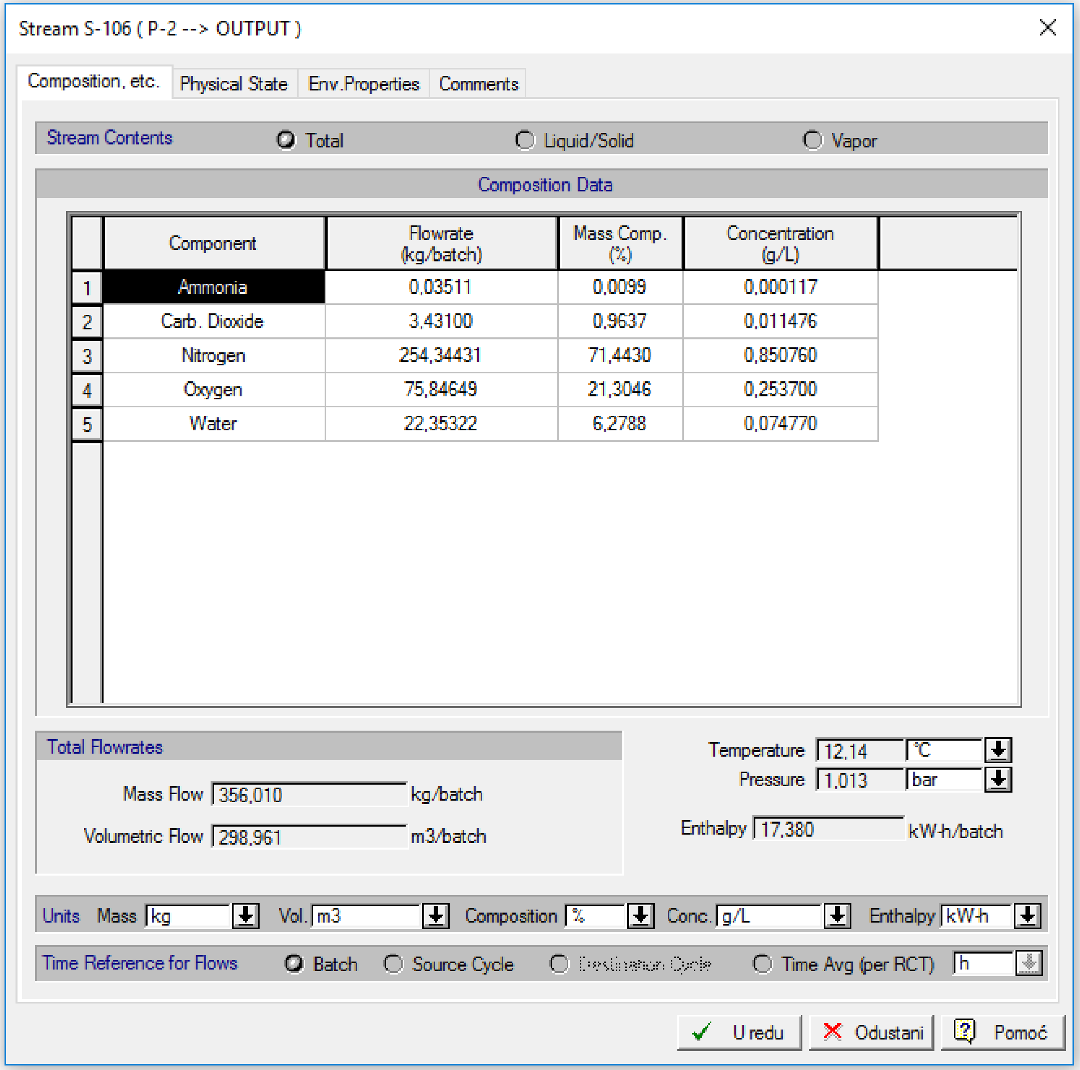

BIODEGRADE-1 (Stoich. Aerobic BioOxidation) in P-2
Oper.Cond's
Volumes
Reactions
Vent/Emissions
Sorption
Labor, etc.
Description
Batch Sheet
Scheduling
Venting
Vent Stream
Out #1 : S-106
Auto-Tag Stream
Pressure Policy
Open Vessel (Atmospheric)
Pressurized Vessel with Relief Valve Set At
1,013
bar
Component Emission Data
Component
Emitted ?
Set By User
Vent/Emission %
1
Ammonia
100,000
2
Carb. Dioxide
100,000
3
Carbon
0,000
4
Hydrogen
0,000
5
Nitrogen
99,680
6
Oxygen
80,040
7
Water
43,800
Emission Model....
Oxygen Comp.
Oxygen
Oxygen Mass Transfer Coefficient at 20 °C
4,000
1/h
Theta
1,024
U redu
Odustani
Pomoć



The total waste mass in Probe 1 has been decreased by 24.36%, and the achieved percentage of water removal was 42.63%.

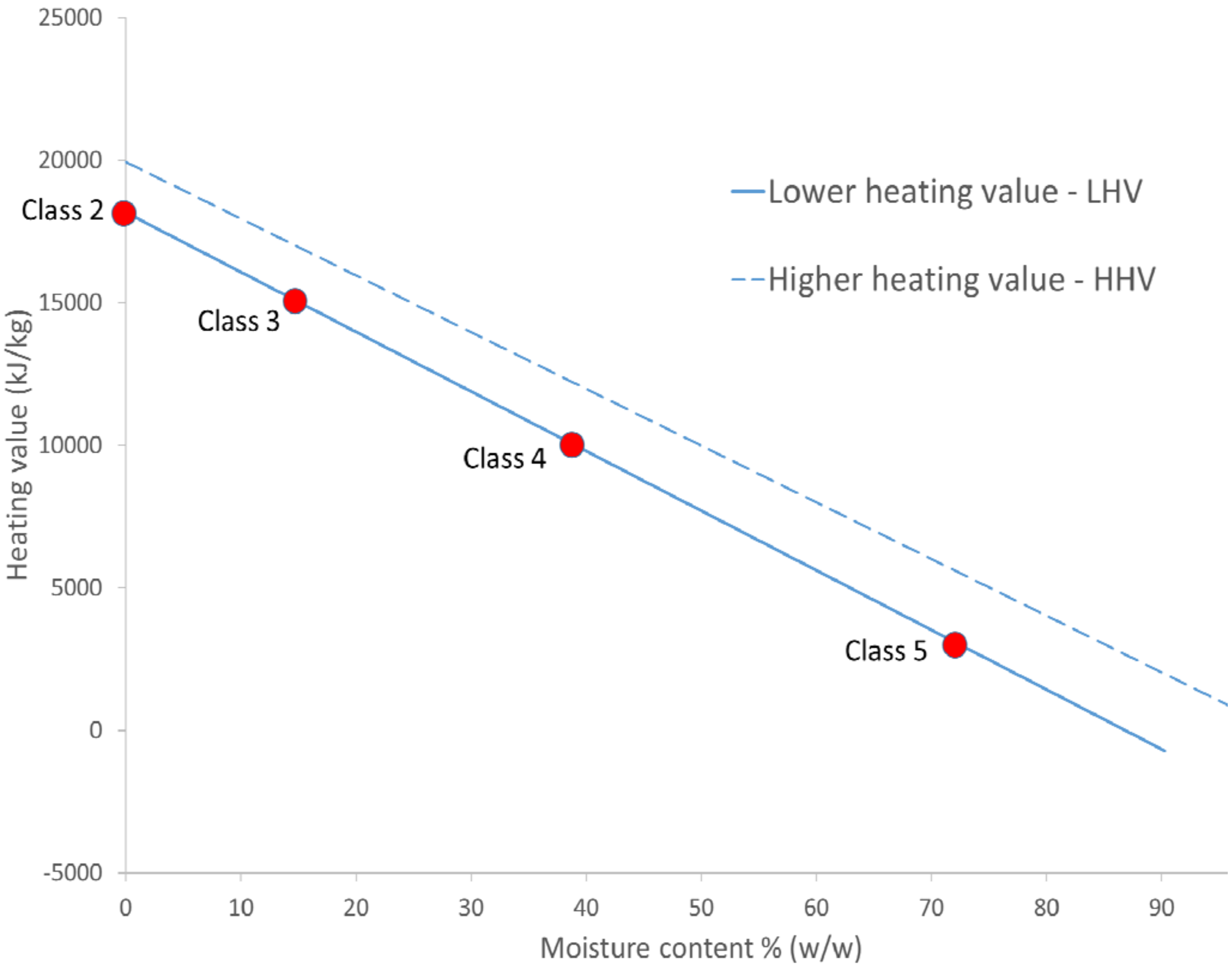
The total waste mass in Probe 2 has been decreased by 25.64%, and the achieved percentage of water removal was 37.10%.

However, even though the percentages of water removal were rather high, because of simultaneous reduction of total mass (w/w) during the biodrying process, the moisture content of Probe 1 decreased from an initial 50% to 37.9%, whereas the initial moisture content of Probe 2 decreased from an initial 50% to only 42.3%.



In addition, gas stream data revealed that 3.43 kg of CO_2 and 0.035 kg of NH_3 were generated in Probe 1, whereas 8.00 kg of CO_2 and 0.08 kg of NH_3 were generated in Probe 2.

Thus, it can be anticipated that under more realistic (large-scale field) conditions, the generation of carbon dioxide and ammonia will be approximately 2.5 times greater than that under optimal small-scale laboratory conditions.



Regarding RDF quality, Quaak et al. [13] presented the general relationship between calorific value of biomass and moisture content.

Lower heating value limits, as one of the main RDF classification properties, was also added.

Class 1 and Class 2 RDFs are almost completely dry fuels.

Class 3 RDFs can contain up to 15% moisture content (w/w).

Class 4 RDFs can contain up to 39% moisture content (w/w).

Class 5 RDFs can contain up to 73% moisture content (w/w).

Based on published data, along with the results obtained within the numerical model in the present study, it is anticipated that, after completion of the biodrying process, the RDF produced can be classified as Class 4, with a lower heating value close to 10,000 kJ/kg.

Conclusion

The removal ratio between volatile solids and water, with respect to the small differences in the final moisture contents obtained in Probes 1 and 2, does not seems to be a vital parameter. However, to obtain energetically reach product and to reduce the impact of the biodrying process on the environment as much as possible, it is crucial that the removal ratio between volatile solids and water during the biodrying process strongly favors water removal.

It is anticipated that under more realistic (large-scale field) conditions, the generation of carbon dioxide and ammonia will be approximately 2.5 times greater than that under optimal small-scale laboratory conditions.

Since biodegradation ceases at moisture contents less than 20%, it is highly unlikely that RDF material obtained via biodrying can be classified as Class 3 RDF or higher. To achieve RDF material of Class 1, 2, or 3, it is necessary to apply an additional (external) heat source.

With respect to the model used, the possible extensions are wide, including, for example, additions of an air conditioning system, a biofilter, an external heat source or any combination of such.