Peter Lechner (Ed.)

Humus - A quality criterion for composts

Infrared spectroscopy (FTIR)

A new evaluation tool and its application in practice

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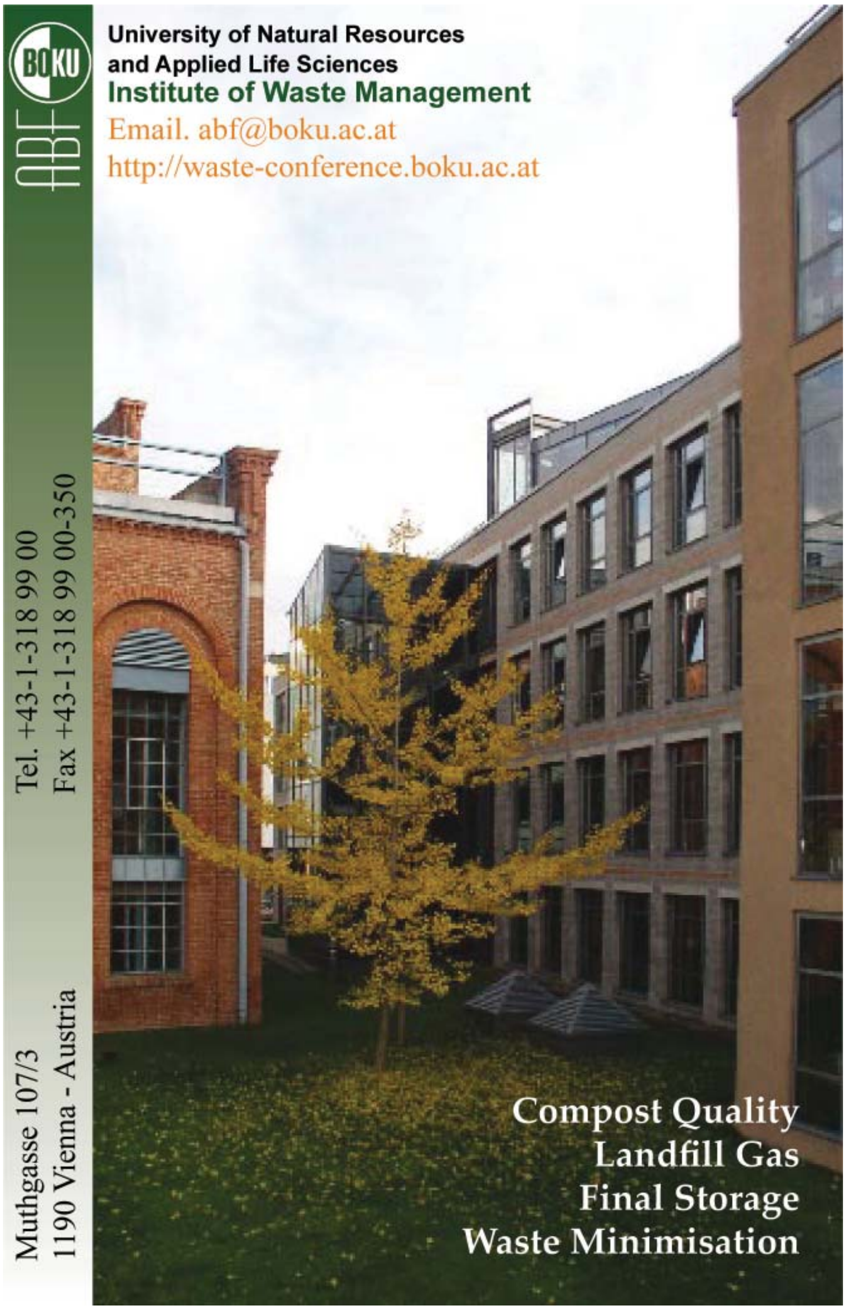
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FOREWORD

The **humus content in composts** has been established as quality criterion in several European countries. In the European Union the implementation of such quality parameter is under discussion.

The investigation of humic acids in 130 European composts showed that the majority of Austrian composts achieved a very good result being on the top with respect to this parameter.

Up to now the time consuming and expensive determination of humic acid contents has limited the general application of this parameter. Research on waste analytics over several years at the Institute of Waste Management (University of Natural Resources and Applied Life Sciences) has now led to the development of a method to determine humic acid contents very quickly by means of infrared spectroscopy and appropriate evaluation tools.

Such combination of infrared spectroscopy and evaluation tools does not only enable the quality assessment of the quality of composts on the basis of their humic acid contents, but also the discrimination of substrates or immature composts from being classified as good quality composts. Unusual compost mixtures are revealed by the proposed method.

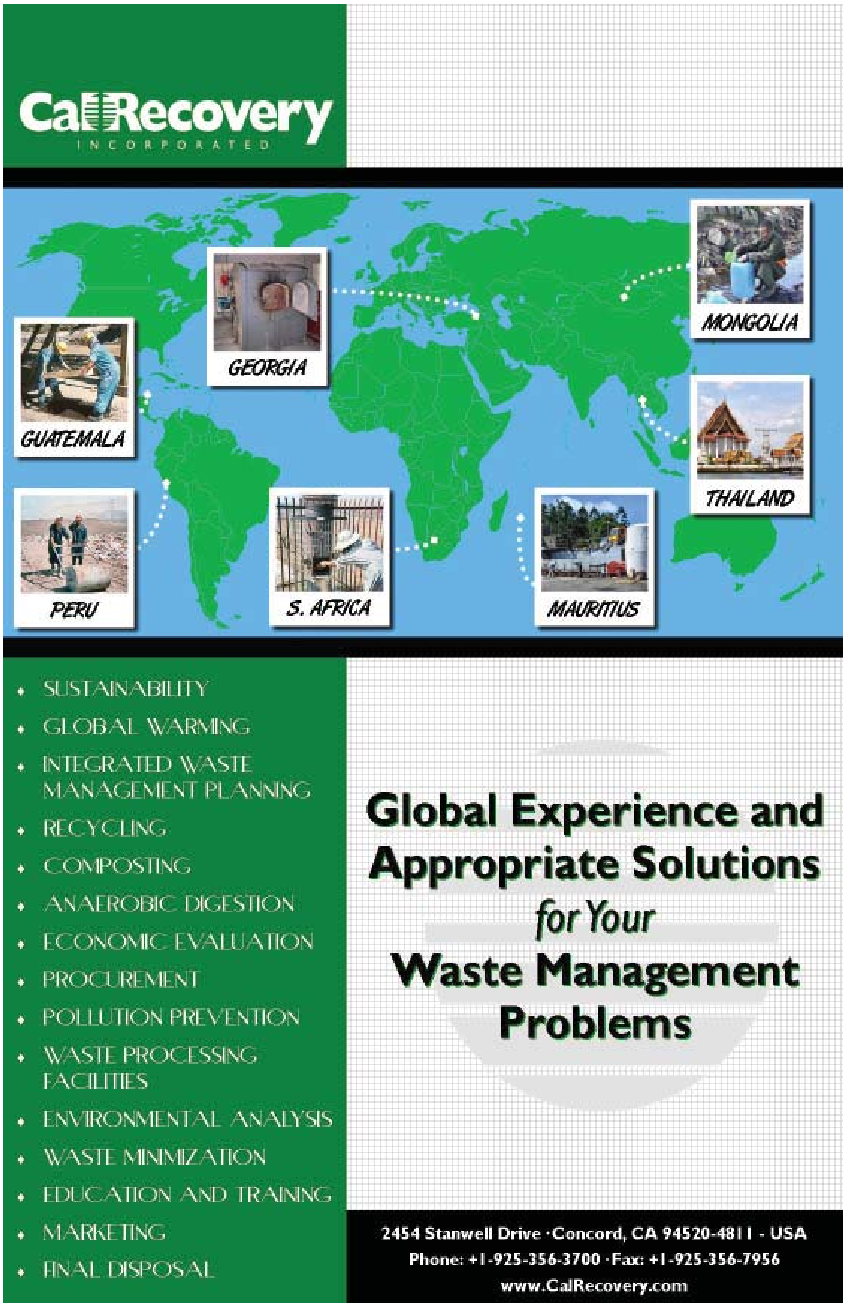
Due to the fast investigation, corrective actions can be taken during the composting process. Such intervention stands for a step towards quality management and cost savings. In addition, this research has shown which input materials and process conditions are favorable to promote the synthesis of humic acids.

Financial support was provided by the Austrian Research Promotion Agency (FFG), the Austrian Compost Quality Society (KGVÖ), The City of Vienna (MA 48) and several composting companies. We

gratefully acknowledge their financial support.

It is important to refer to the on-going elaboration of a standard procedure at the Austrian Institute of Standardization (Austrian prestandard: OE-NORM S 2125 – Anleitung zur FTIR-Messung von Abfällen).

Peter Lechner, August 2007
Vienna, Austria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CONTENT

A. Briefly…

PROPERTIES OF QUALITY COMPOST

The most essential properties of quality composts are

- High content of stable humified matter
- Steady release of plant nutrients
- Suppression of plant diseases and support of plant health
- Compliance with standards and limit values concerning inorganic and organic pollutants

Such quality features are the „business card“ of a quality product and provide multiple opportunities.

The content of stable organic matter in compost is strongly linked to the favorable properties mentioned above. The sum parameters that usually are applied to describe organic matter in composts according to standards and national rules (total organic carbon, TOC; loss on ignition, LOI) may not sufficiently reflect the favorable properties of compost.

FTIR-spectroscopy provides such information.

HUMIC ACIDS – A QUALITY CRITERION

Infrared spectroscopy is applied at the Institute of Waste Management to rapidly determine humic acid contents in composts. The commonly applied extraction method for the determination of humic acids is time consuming and expensive.

Infrared spectroscopy is the measurement of the interaction of infrared radiation with matter. Infrared light causes molecules to vibrate. The absorbed energy becomes visible as absorption bands in the spectrum. The majority of molecules absorb infrared light. The resulting infrared spectrum is like a „fingerprint“ of the sample. The infrared spectrum provides information on stability, maturity, and composition of the compost.

Changes of spectroscopic characteristics during the composting process also indicate changes of organic matter. Addition of mineral compounds, especially “dilution” of immature biogenic materials can be detected by means of the infrared spectrum. Biowaste composts from separate collection can be distinguished from compost containing sewage sludge (biosolids) or special ingredients as input materials.

Experience is necessary for spectra evaluation and interpretation, especially the knowledge of indicator bands that are assigned to specific stages of decomposition. For practical application, evaluation tools are necessary that enable the fast assessment of unknown samples and ensure an easy handling.

Such evaluation tools have been developed at the Institute of Waste Management. They are available for operators and users in internal laboratories and laboratories authorized to control and monitor compost quality for certification.

APPLICATION OF FTIR-SPECTROSCOPY IN PRACTICE

- Sampling according to the Compost Ordinance (BGBl. II 292/2001)
- Sample preparation according to OE-NORM EN 15002 and ONR 192123, to particle size < 0,2 mm (see preliminary instructions for standardization OE-NORM S 2125 – Instruction for FTIR spectroscopic measurements of waste materials)
- Equipment:
  — Pestle and mortar
  — Sample press
  — Instrument fitting for the mid-infrared area (wavenumber area 4000 - 400 cm^{-1}) and KBr pellets technique
- Application of the prediction model „InfraHUM“ to determine humic acid contents
- Accredited and internal laboratories are able to perform infrared spectroscopic investigations
- The expenditure of time for one infrared spectroscopic investigation including evaluation and prediction of humic acid contents is approximately 15 minutes.

EVALUATION TOOLS FOR OPERATORS AND USERS

Two evaluation tools are available for the determination of humic acids and the identification of biowaste compost (differentiation of other materials) :

- Prediction model „InfraHUM“ to determine humic acid contents in composts based on their infrared spectroscopic characteristic
- Classification model „InfraKLASS“ to distinguish quality (biowaste) compost from other materials.

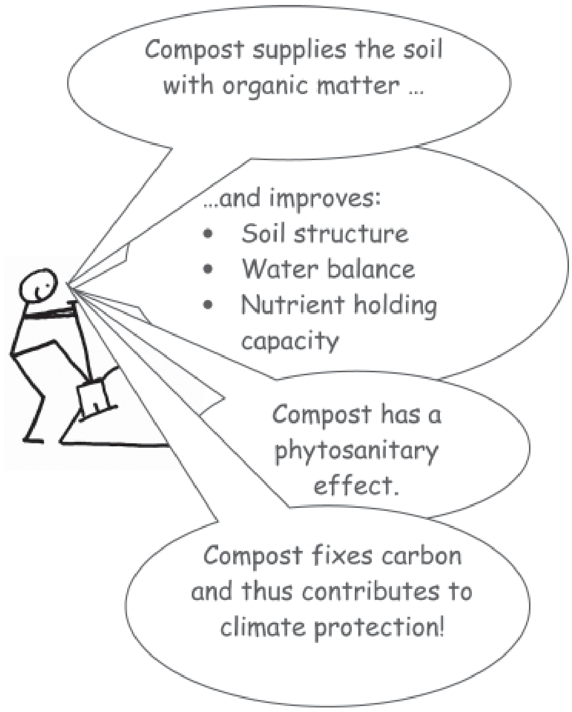
THE PREDICTION MODEL „INFRAHUM“

The basis of the prediction model „InfraHUM“ are data from 360 biowaste composts displaying different quality and maturity. Humic acid contents of these composts obtained by extraction and chemical analysis were correlated with infrared spectroscopic data. Humic acid contents are indicated in the spectrum. The evaluation of infrared spectroscopic data was performed by means of the multivariate statistical method. Humic acid contents were predicted from the spectrum. Therefore it is called „prediction“ model.

THE CLASSIFICATION MODEL „INFRAKLASS“

The classification model „InfraKLASS“ enables the identification of the biogenic material from separate collection having undergone an aerobic process (composting).

B. More details and examples

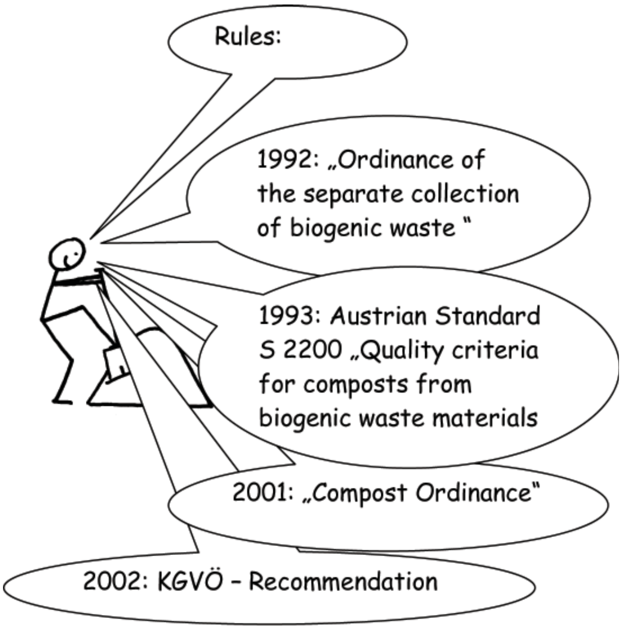

Compost supplies the soil with organic matter ...
...and improves:
• Soil structure
• Water balance
• Nutrient holding capacity
Compost has a phytosanitary effect.
Compost fixes carbon and thus contributes to climate protection!

THE PRODUCT „COMPOST“

Compost offers many positive effects. It improves soil properties and supports soil functions. Compost contains plant nutrients and suppresses plant diseases (phytosanitary effects). Sequestration of carbon in humic substances contributes to climate protection. These quality features are the reference of the compost and provide various market opportunities.

Such positive effects depend on the quality of organic matter. Therefore properties should be defined and established as a parameter. Analytical methods that are easy to handle in daily business are necessary to determine such parameters. Adherence to standards and limit values (e.g., heavy metals) is a prerequisite for the production of „quality composts“.

Approval of „Quality composts“ is aimed for in the European Union. The European Compost Network attempts the implementation of a standardized definition of compost quality. This purpose is a prerequisite for the development of marketing strategies and sales promotion at an international level.

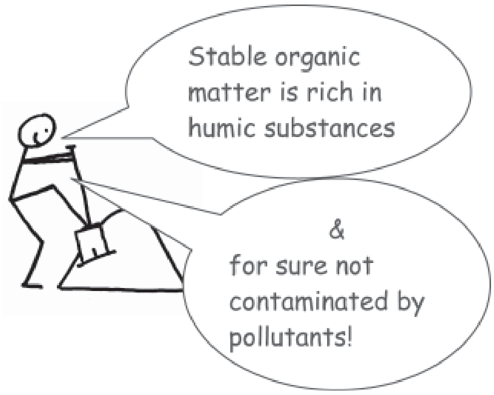

Rules:
1992: „Ordinance of
the separate collection
of biogenic waste "
1993: Austrian Standard
S 2200 „Quality criteria
for composts from
biogenic waste materials
2001: „Compost Ordinance"
2002: KGVÖ – Recommendation

LEGAL FRAME

Composting has been practiced in Austria for a long time. From the outset there has been an endeavor to define and to improve compost quality. In 1989 a quality standard for municipal solid waste compost (OE-NORM S 2022) was established. However, shortly afterwards, it became evident that a continuous application could not comply with the demand of prevention with respect to heavy metal contamination and accumulation in soils. As a consequence the „Ordinance for the separate collection of biogenic waste from households" (1992) was enacted. It includes the recycling and use of these materials. Austrian standards for composts from biogenic waste were elaborated (OE-NORM S 2200, OE-NORM S 2201 and OE-NORM S 2023). They were replaced by the requirements of the "Compost Ordinance" (2001).

These rules are limited to the compliance with limit values of pollutants (especially heavy metals), foreign matter (plastics, glass, metals) and plant compatibility (maturity, toxic components). The Compost Ordinance provides several compost classes that are defined by the input materials and by specific limit values of heavy metals. However, a rule for favorable properties does not exist. Contents of nutrients should be indicated, but minimum requirements are not specified. Positive effects on soils and plants have not been taken into consideration in currently valid rules.

The description of favorable compost features requires additional criteria. Sum parameters such as total organic carbon (TOC) or loss on ignition (LOI) can not reflect the positive properties of composts.


Stable organic matter is rich in humic substances
&
for sure not contaminated by pollutants!

DEFINITION OF COMPOST QUALITY

As mentioned before, compost has many favorable properties:

- Refeeding of soils with humus,
- nutrient supply and
- support of plant health.

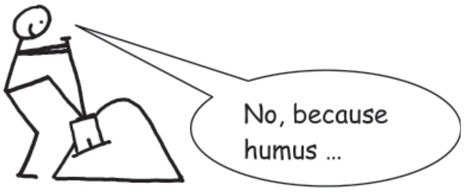
In order to take such positive properties into account compost quality should be defined from this point of view.

The content of stable organic matter in terms of humic acids is a positive criterion. The content of humic acids in composts can be determined. It is related to the favorable properties of compost organic matter mentioned above.

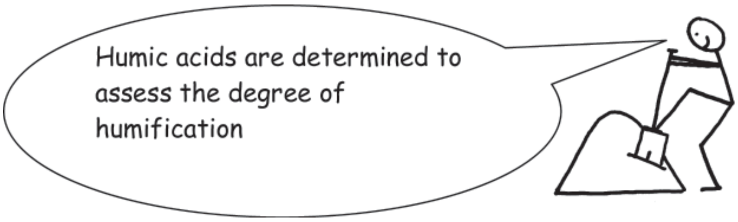
The slow release of nutrients and the beneficial impact on plant health are affected by the content of humic acids.

A good compost is characterized by

- a high content of stable organic matter rich in humic acids,
- standard quality that means undershooting of limit values of pollutants.



… consists of litter and humified matter. In litter the structure of the input material is still visible, whereas humified matter represents an extensively degraded stage of the original materials. Humic substances (HS) are subdivided into extractable and non extractable humic substances. Extractable humic substances comprise the fractions of humic acids and fulvic acids. Humic acids are a suitable parameter to assess the degree of humification in composts.



HUMIC SUBSTANCES

Humic substances do not have a particular formula. The heterogenous composition of humic substance molecules can be traced back to different input materials.
Molecule moieties have been widely investigated and identified. They originate from degraded organic biomolecules in the compost (e.g., lignin from woody plant compounds, lipids, carbohydrates, proteins, and others). They are involved in humic substances synthesis.

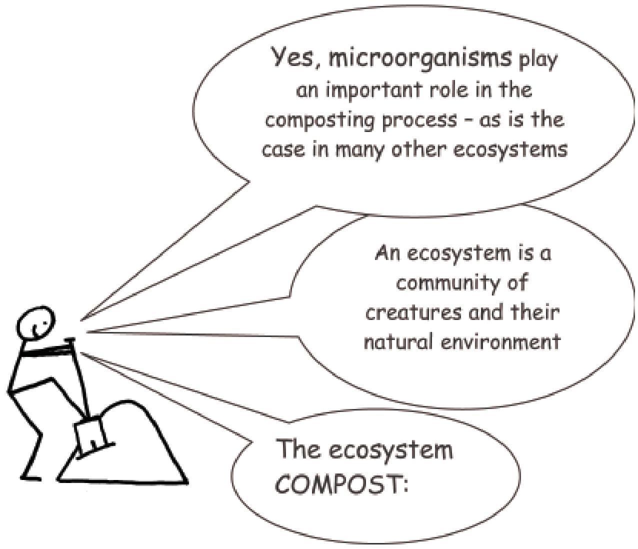
Humic acids represent a stable fraction of humic substances. There are two ideas how to imagine the molecule structure.

- One model suggests a network of a large molecule.
- The other one is of the opinion that smaller molecule entities are combined to form an aggregate that is called “micelle”.

Humification is a very complex biological - chemical process. Mechanisms are not known in detail. Due to the lack of a stoichiometric formula a technical synthesis is not known that could replace the biological process. Composting can be considered a “humification technology”.

In order to yield a high amount of humic acids two items have to be kept in mind:

- the composition of the input material and
- process operation.


Yes, microorganisms play an important role in the composting process – as is the case in many other ecosystems
An ecosystem is a community of creatures and their natural environment
The ecosystem COMPOST:

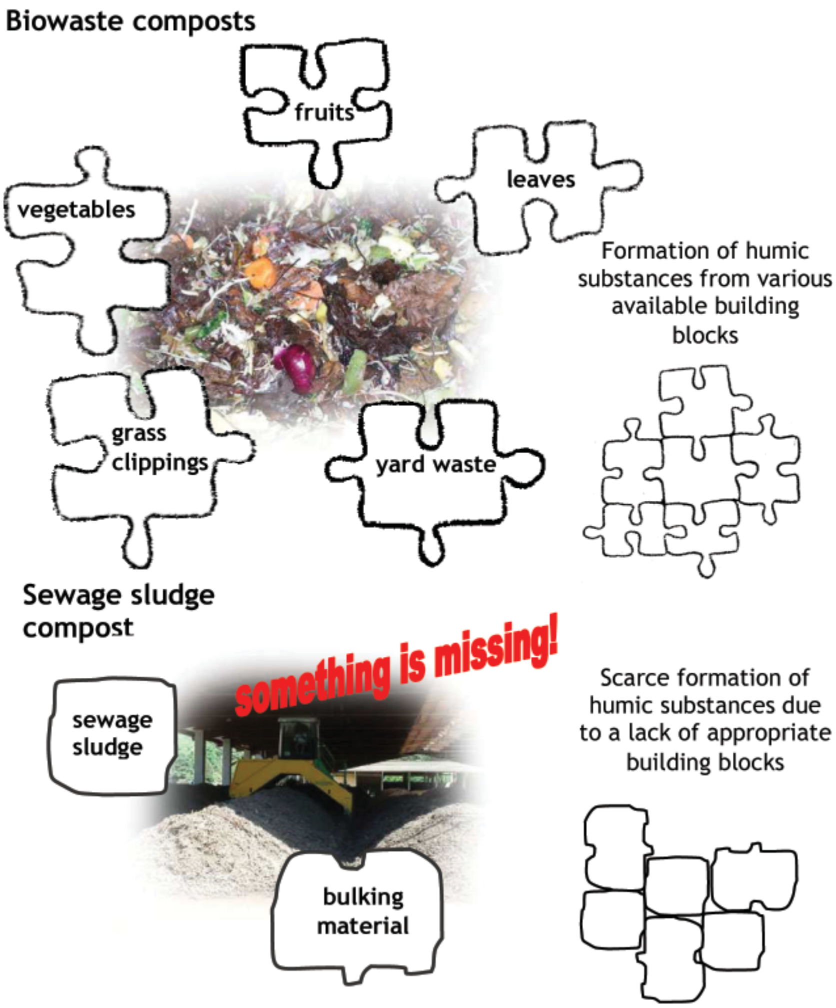

oxygen
(O_2)
oxygen
(O_2)

Microorganisms play a crucial role in all ecosystems. A diversity of bacteria and fungi is found in the compost, each in a large number. The majority of these microorganisms have not yet been identified. Degradation and transformation are mainly performed by microorganisms.

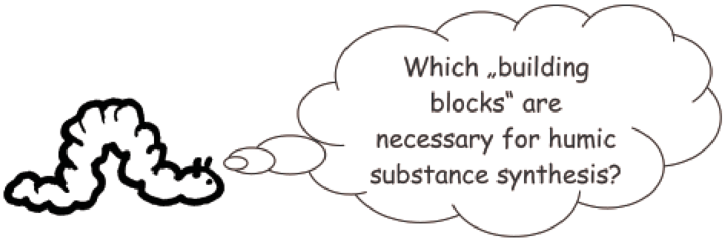
Such transformation processes may result in humic acids among other metabolic products.

Humic acids contain aromatic moieties that should be present in the input material. Aromatic compounds are characterized by a specific molecule structure. They are part of woody ingredients and of many other chemical components. The input material should comprise a diverse, well balanced mixture of easily (e. g., fruits and vegetables), moderately and hardly degradable (e. g., wood) substances, in order to maintain microbial activity over a longer period of time. This enables participation of scarcely degradable components in transformation processes.

Building blocks that are available for humic acid synthesis



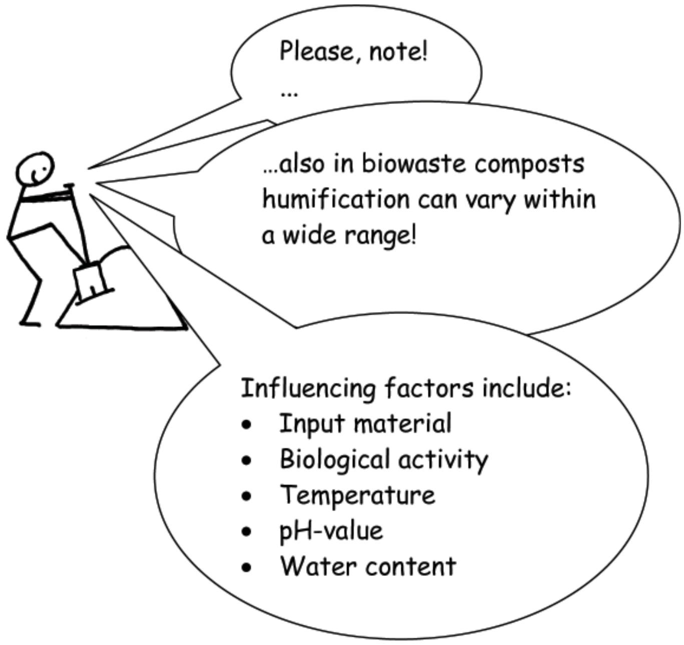
Due to degradation molecule moieties, suitable building blocks used for humic substance synthesis, are generated. If suitable moieties are not available due to the lack of input materials or predominant mineralization, humic substance formation is rather poor.



The composition of the input material is a crucial issue, because metabolic products of these substances serve as building blocks for humic acids.

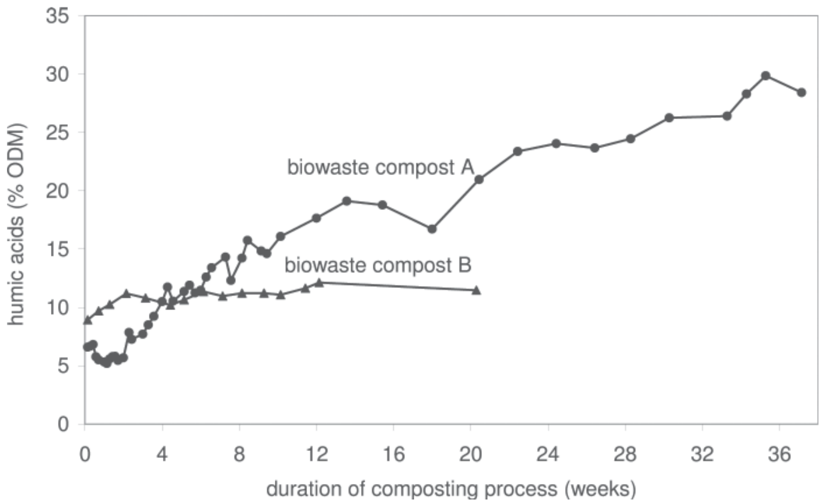
The mixture of biowaste materials obtained from the source separated bin collection provides a variety of aromatic components that are suitable substrates for humic substance synthesis under adequate process conditions.

By contrast, sewage sludge provides sparsely suitable aromatic building blocks for humic substance synthesis due to its one-sided composition.


Please, note!
...
...also in biowaste composts humification can vary within a wide range!
Influencing factors include:
• Input material
• Biological activity
• Temperature
• pH-value
• Water content

PROCESS CONDITIONS

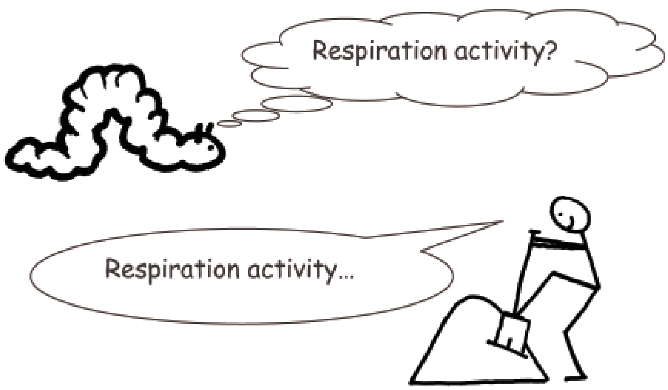
The figure below displays the development of humic acid contents under different conditions of degradation.
Biowaste compost A yields conspicuously higher humic acid contents compared to biowaste compost B.



Development of humic acid contents during composting (processes A and B)

In process B the intensive rotting phase was forced. Such process operation led preferentially to mineralization.

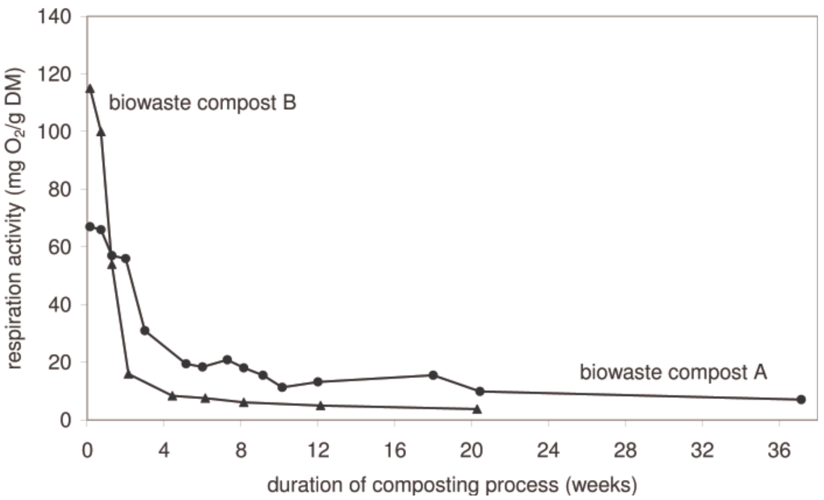
The development of the process can be assessed by measuring the respiration activity of the material during composting.



… is a measure of the current microbial activity. It is higher if more degradable substances are present in the material. The oxygen uptake is recorded over a period of 4 days. Respiration activity is reported as oxygen uptake (O_2) in milligrams (mg) per gram (g) dry matter (DM).

The following figure illustrates the evolution of respiration activities of the composting processes A and B. In process A respiration activity decreases slowly and remains at a more „biologically active“ level for a longer period of time. In process B, values of respiration activity fall to a low level very fast.

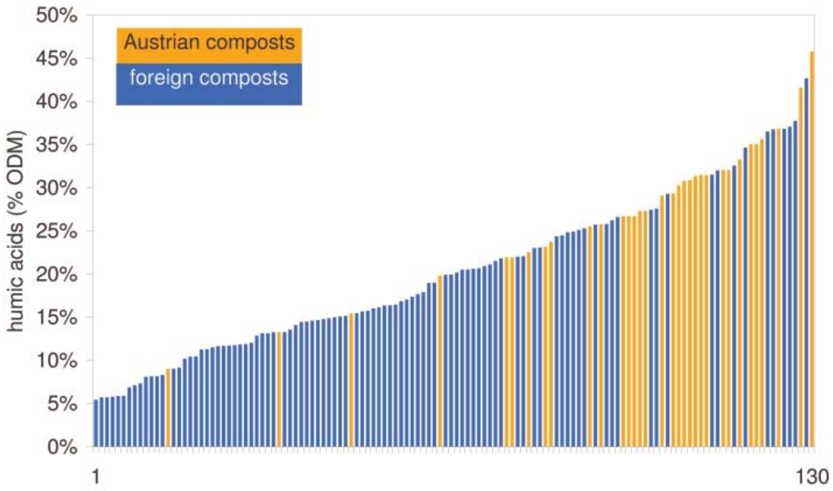
This fact clearly visualizes the quick mineralization. Therefore building blocks were no longer available for humic substance synthesis.



Evolution of respiration activity during composting processes A and B

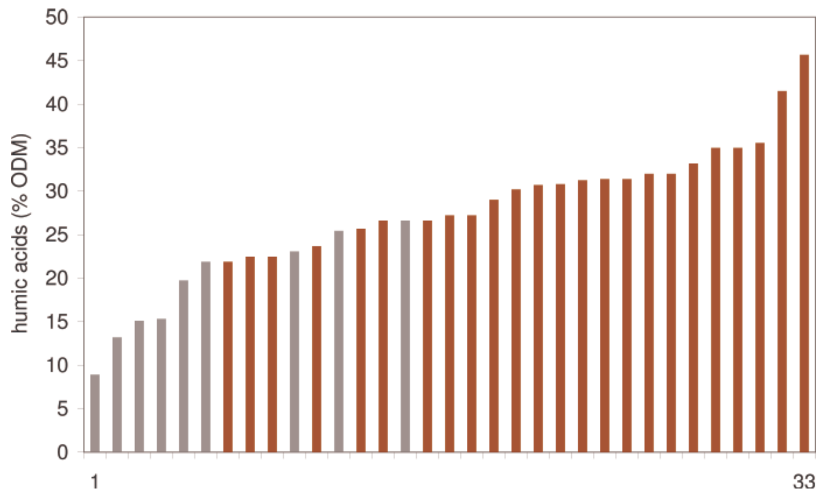
Comparison of Austrian and foreign composts

Austrian composts feature a top quality!



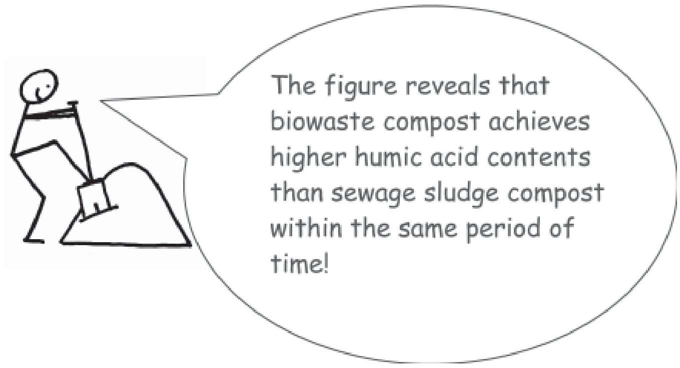
SEWAGE SLUDGE (BIOSOLIDS) COMPOST

The next figure displays humic acid contents of 33 Austrian composts. Humic acid contents in gray belong to sewage sludge composts. The data clearly show that biowaste composts tend to build up more humic acids than sewage sludge composts.

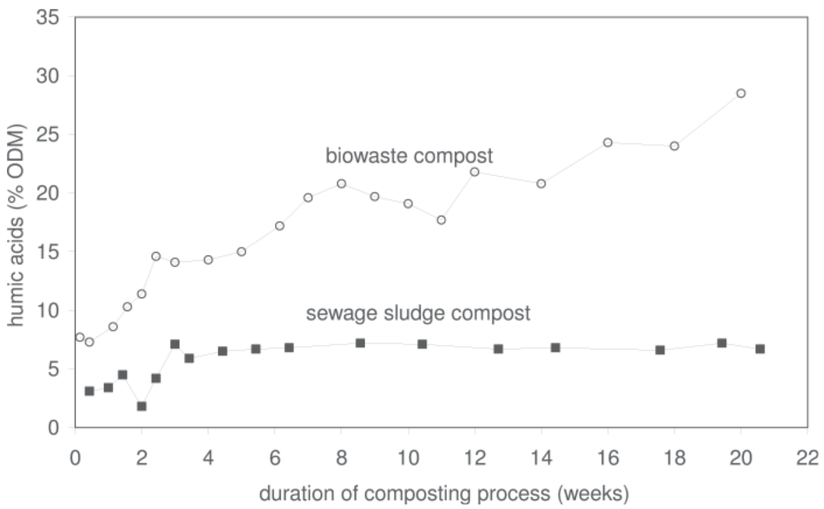


Humic acid contents found in sewage sludge composts (gray) and biowaste composts (brown)

Humic acid formation can be improved by the addition of other waste materials (e.g., biowaste) that provide appropriate building blocks.


The figure reveals that biowaste compost achieves higher humic acid contents than sewage sludge compost within the same period of time!

The following figure shows the formation of humic acid in composts made from biowaste and from sewage sludge. After 21 weeks of composting the humic acid content accounts for 29 % of organic dry matter in biowaste and for about 6 % in sewage sludge.



Humic acid content in biowaste and sewage sludge compost (% of humic acids referring to organic dry matter)

These composting processes exemplify the effect of the input material on the formation of humic acid.

Determination of extractable humic substances (HS)
According to Gerzabek et al. (1993):

For humic acid analysis several grams of an air-dried, ground, sieved through < 0,63 mm sample are extracted by means of an alkaline solution over 24 hours. Depending on their solubility at different pH values different fractions are obtained by such procedure.
Humic acids are precipitated at pH of 1, fulvic acids are soluble in acidic and alkaline solution. Quantification is performed by photometric measurement.
In order to extract humic acids as completely as possible the extraction procedure is repeated four times.

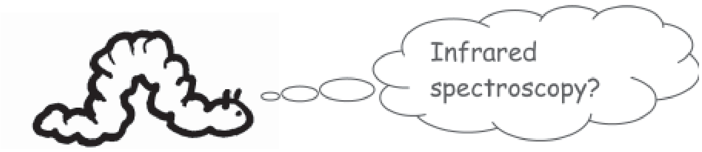
METHODS FOR QUALITY ASSESSMENT

As mentioned before, commonly applied parameters are not sufficient to describe comprehensively the quality of composts.

Humic acids are usually determined by a chemical method. Humic substances are extracted using an alkaline solution. Different humified fractions are separated by means of this procedure according to their behavior under acidic or alkaline conditions.

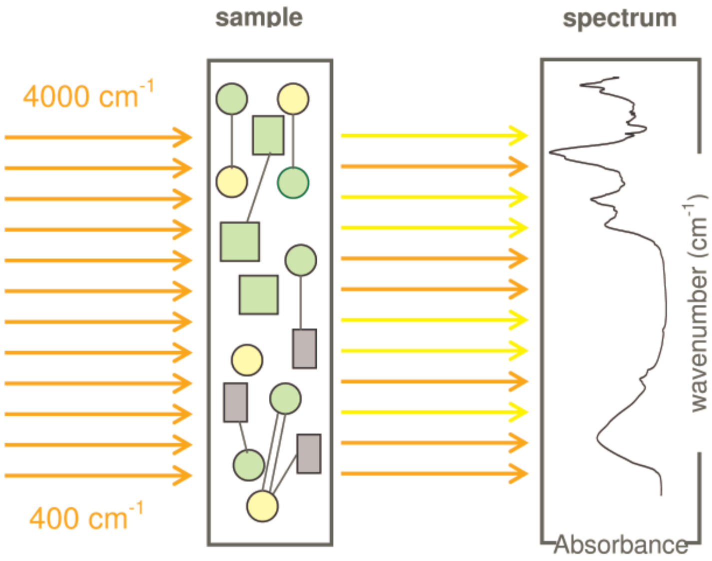
This procedure is very time consuming (4 days). Faster analytical methods would be preferable.

Such advantage is made available by infrared spectroscopy.



Theoretical approach

Infrared spectroscopy is based on interactions of infrared radiation with molecules, especially with functional groups of molecules. Molecules are caused to vibrate using energy of infrared radiation. The energy uptake is recorded within the scanning area (wavenumber 4000-400 cm^{-1}). It results in a “spectrum” that displays absorption bands of the sample. These bands can be assigned to specific molecules or molecule groups, respectively.



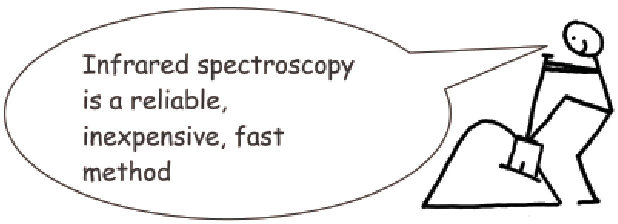
Schematic graph of infrared spectroscopic analyses (measurement in transmission mode)

INFRARED SPECTROSCOPY (FTIR)

The energy uptake by the sample is recorded within a wavenumber range (4000 - 400 cm^{-1} mid-infrared area). The majority of molecules interact with infrared radiation and yield a „chemical“ fingerprint of the sample.

This fingerprint (characteristic pattern of absorption bands) provides information on composition and stability of the material.

Many investigations have been performed at the Institute of Waste Management (BOKU – University), to assess compost maturity. Changes of spectroscopic characteristics indicate changes during the composting process.



The next figure shows infrared spectra of the input material for composting and the mature compost. Differences are clearly visible. Interpretation is given below

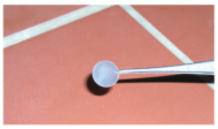
From sample preparation to the spectrum of the sample

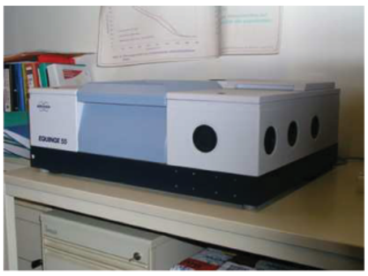
1. Weighing
200 mg Potassiumbromide + 2 mg sample; Potassiumbromide is the carrier material of the sample

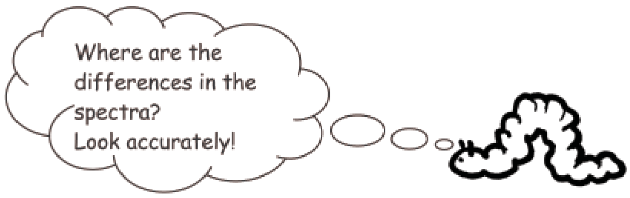
2. Homogenizing
with pestle and mortar

3. Pressing
for 3 minutes with a pressure of 10 tons

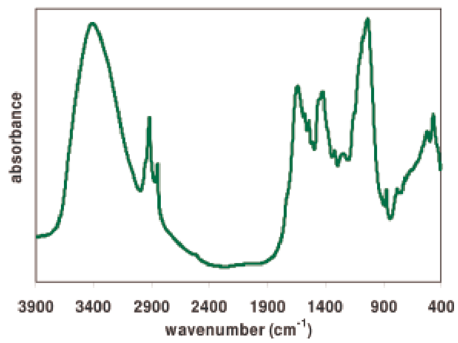
4. Measuring
The pellet is fixed; infrared radiation is transmitted through the sample (Transmission mode)



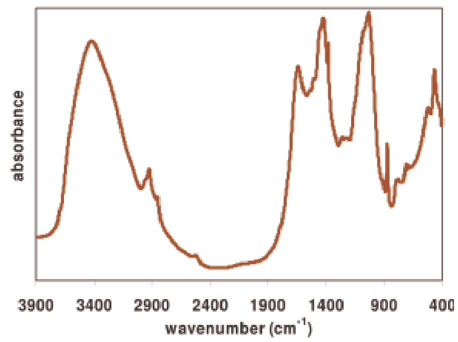




Fresh biowaste



Final product -
Biowaste compost



Infrared spectroscopic characteristics of compost

Characterization can be performed in different ways:

Characteristics:

Sex: male
Size: 178 cm
Hair color: gray
Eye color: blue

Characteristics:

Product: vegetables
Ingredients: corn, carrot, peas
Calories per 100 g: 300 kcal
Price: 5 € / kg

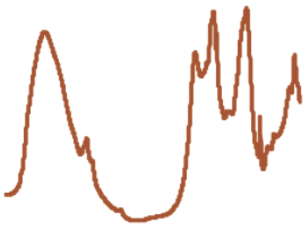
4 002903 021386

Characteristics:

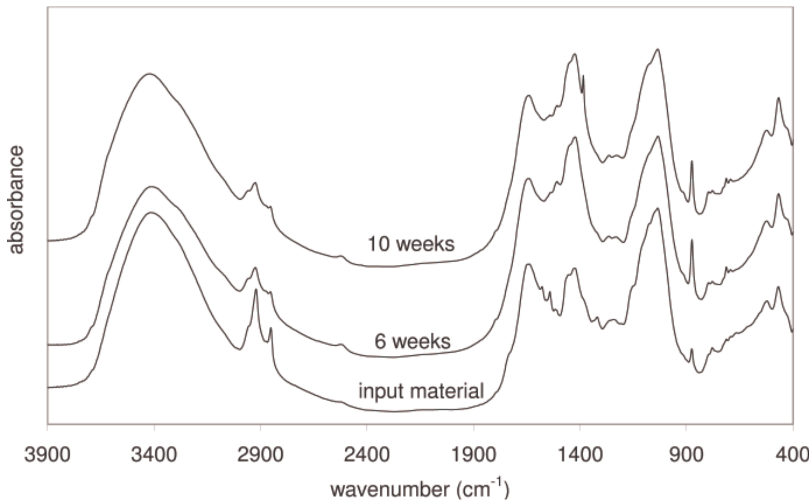
Color: green
Length: 45 cm
Width: 55 cm
Height: 105 cm

Characteristics:

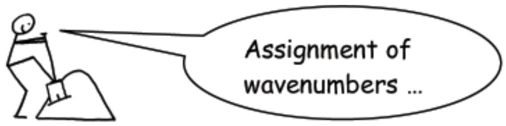
Loss of ignition: 28,8 %
TOC: 14,9 %
Humic acid content: 30 % ODM
Maturity: V



The next figure represents changes of infrared spectroscopic characteristics:

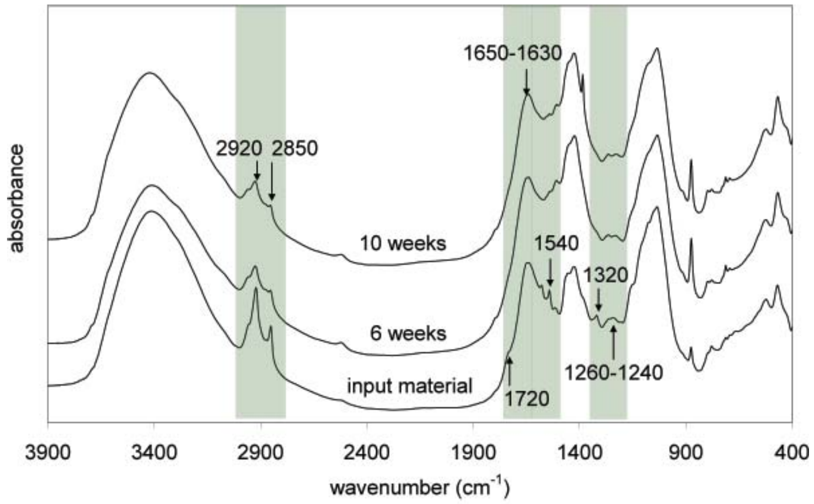


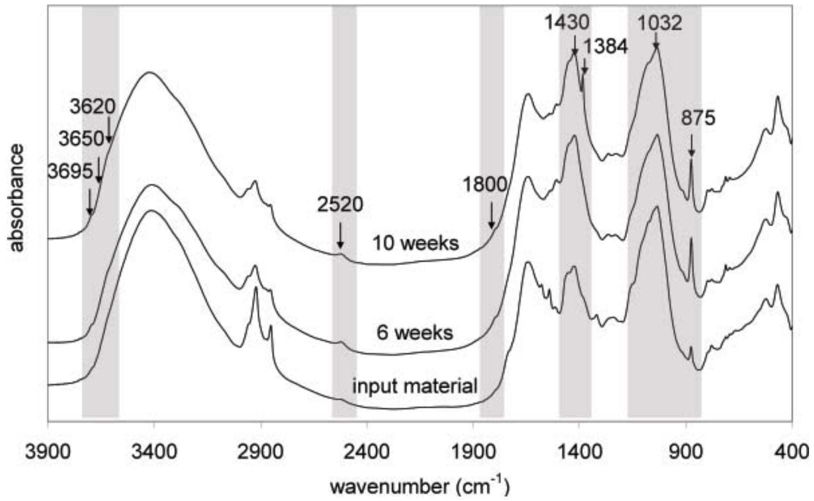
In the following graphs the significant areas in the spectrum are marked. To support evaluation and interpretation, band areas are highlighted in green (assigned to organic compounds) and in gray (inorganic compounds). These areas are called „indicator bands“ as they reflect changes in the material. Evaluation of these bands allows a fast and simple visual assessment of stability and material composition.

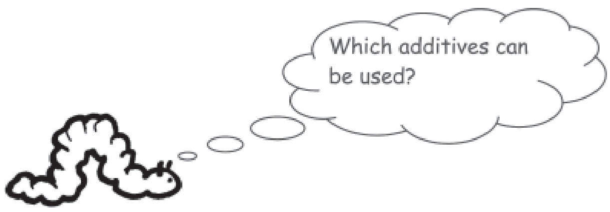


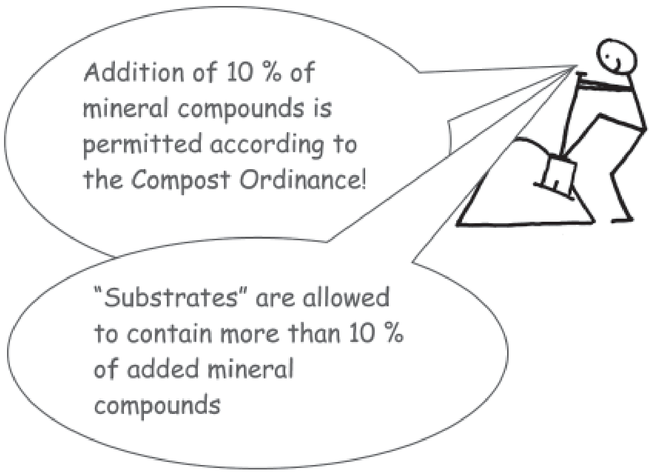
Wavenumber (cm^{-1})	Development and assignment of wavenumbers (wavenumber regions) in composts
2920 2850	Aliphatic methylene bands decrease during composting due to the breakdown of molecule structures.
1740-1720	Bands of aldehydes, ketones, carboxylic acids and esters are only visible in the spectra of fresh materials. They disappear after a short composting time.
1650-1630	Within this wavenumber area several bands are overlapping (Carboxylates, amides, alkenes and aromatic compounds).
1540	Amides are decomposed during composting and cause therefore band intensities to decrease.
1510	Within this wavenumber area ligno-cellulosic materials (wooden compounds) display a small characteristic band. It is a suitable indicator for biowaste.
1320	Aromatic primary and secondary amines increase at the beginning due to metabolic activities. They disappear with increasing maturity and stability.
1260-1240	Carboxylic acids and amides absorb in this wavenumber area. The band decreases with age.
3695, 3650 and 3620	This group of three bands can be assigned to kaolin.
2520 and 1800	These weak bands are assigned to carbonates.
1430	The intensity of the carbonate band increases during composting due to mineralization that causes the relative increase of inorganic components.
1384	The nitrate band appears in general at a later stage of composting in correspondence to the increasing nitrate content.
1032	Bands of clay minerals increase with time due to mineralization.
875	As mentioned above, carbonate bands increase due to mineralization.

Support for „reading“ wavenumbers



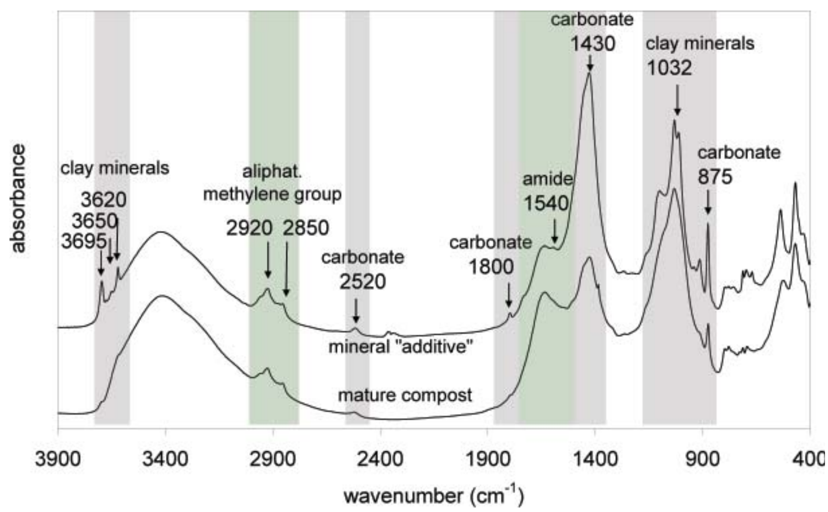



Which additives can be used?


Addition of 10 % of mineral compounds is permitted according to the Compost Ordinance!
“Substrates” are allowed to contain more than 10 % of added mineral compounds

Infrared spectroscopic investigations provide additional information:

Addition of mineral compounds is detected by characteristic infrared spectra. Intensities of inorganic bands in mature composts increase due to mineralization. At the same time organic band intensities decrease due to degradation of organic compounds. Immature compost that is "diluted" by mineral compounds displays relatively strong organic bands and huge inorganic bands. The figure below demonstrates spectra of the mature compost and the immature compost with added mineral compounds. Bands that are assigned to inorganic components are conspicuous (gray areas) and bands that indicate reactivity are still present (green). The latter are weaker or absent in the mature compost.



Infrared spectra of a mature compost and of an immature compost "diluted" by addition of mineral compounds


...because I am using
EVALUATION TOOLS!
EVALUATION TOOLS?
Tell me more about it!

„Dilution is no solution“ to pretend maturity or to comply with limit values of pollutants.
It is not possible to detect addition of mineral compounds by conventional parameters.

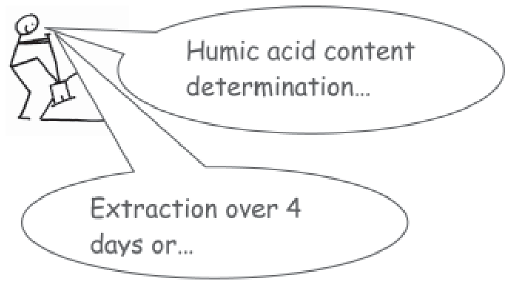
Spectra interpretation requires considerable experience. Evaluation methods using statistical models and adequate software tools enable, in a simple way, spectral data interpretation of the composts investigated.

„EVALUATION AND INTERPRETATION TOOLS“ FOR USERS

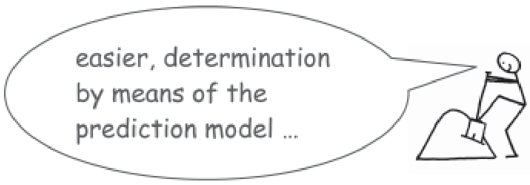
...because additional tools are provided for users to support interpretation of data generated by this innovative analytical method. By means of these tools and the computer, self-interpretation of data is facilitated.

These tools developed at the Institute of Waste Management enable e. g.:

- Prediction of humic acid contents by means of infrared spectroscopic investigations (prediction model for humic acid determination „InfraHUM“).
- Differentiation of quality composts (Classification model „InfraKLASS“).



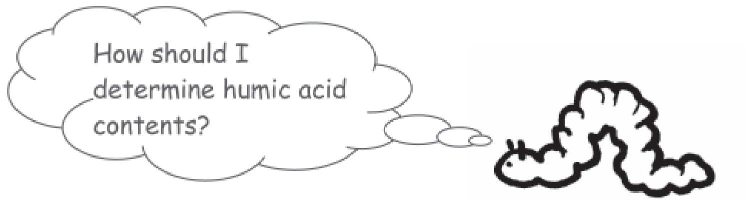
…The chemical extraction method for humic acid determination according to Gerzabek et al. (1993) is decribed in the section „Humic substances“



Humic acid prediction model „InfraHUM“:
The model is based on multivariate statistical methods. The regression calculated displays the relationship between the dependent variable (humic acid contents) and many independent variables (data points of the infrared spectrum). The prediction model „InfraHUM“ includes 360 samples. The correlation coefficient (R^2) of the regression is 0.87, the error of prediction is 2.4 % HA ODM.
The correlation coefficient is an indicator of the correlation between variables. If R^2 is zero, no correlation exists, whereas if R^2 is 1, a proper linear correlation is present. This means that R^2 is in a range between 0 and 1.

The development of the prediction model „InfraHUM“

As stated above, compost quality can be defined according to the humic acid content. The humic acid content also reflects the portion of stable organic matter in composts.



Determination of humic acid contents can be performed in a chemically by means of an extraction method (Gerzabek et al., 1993) and, using a modern analytical tool such as infrared spectroscopy. If infrared spectroscopy is used for humic acid analysis, the prediction model („InfraHUM“) is applied. Humic acid contents in the composts are reflected by specific wavenumber regions 1745 – 1685 cm^{-1} and 1610 – 1567 cm^{-1} in the spectrum. The prediction model is based on this correlation.

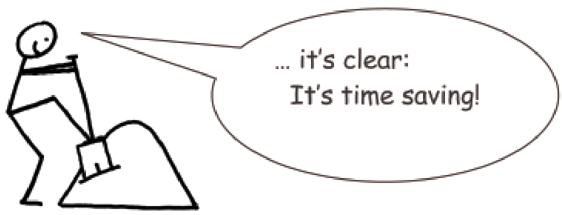
For the development of the model, humic acid contents of 360 composts were determined by means of the extraction method. Infrared spectra of the same sample set were recorded. Based on these investigations and multivariate statistical methods, a model was developed to predict humic acid contents by means of the infrared spectrum.

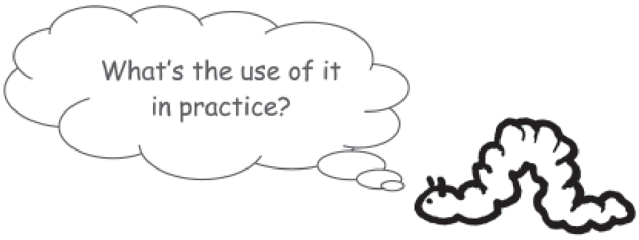
Humic acid analysis
„Extraction method“

duration: **4 days**

Recording of the infrared spectrum
& humic acid prediction „InfraHUM“

duration: **15 minutes**



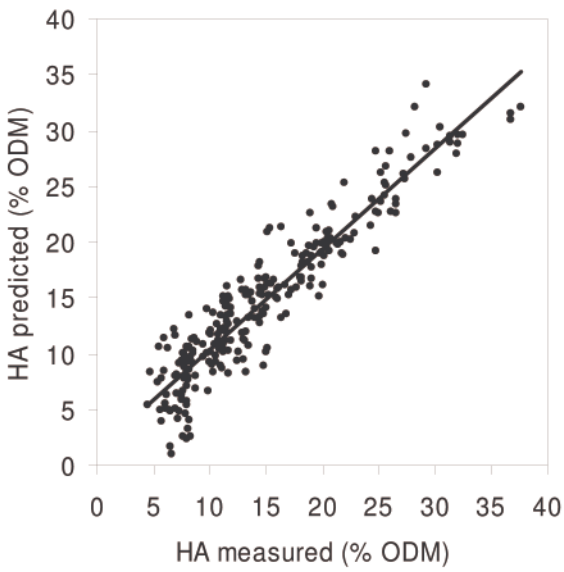


The model „InfraHUM“ was developed and validated at the Institute of Waste Management (University of Natural Resources and Applied Life Sciences). It enables the determination of humic acid contents within a few minutes and time consuming analyses are no longer necessary.

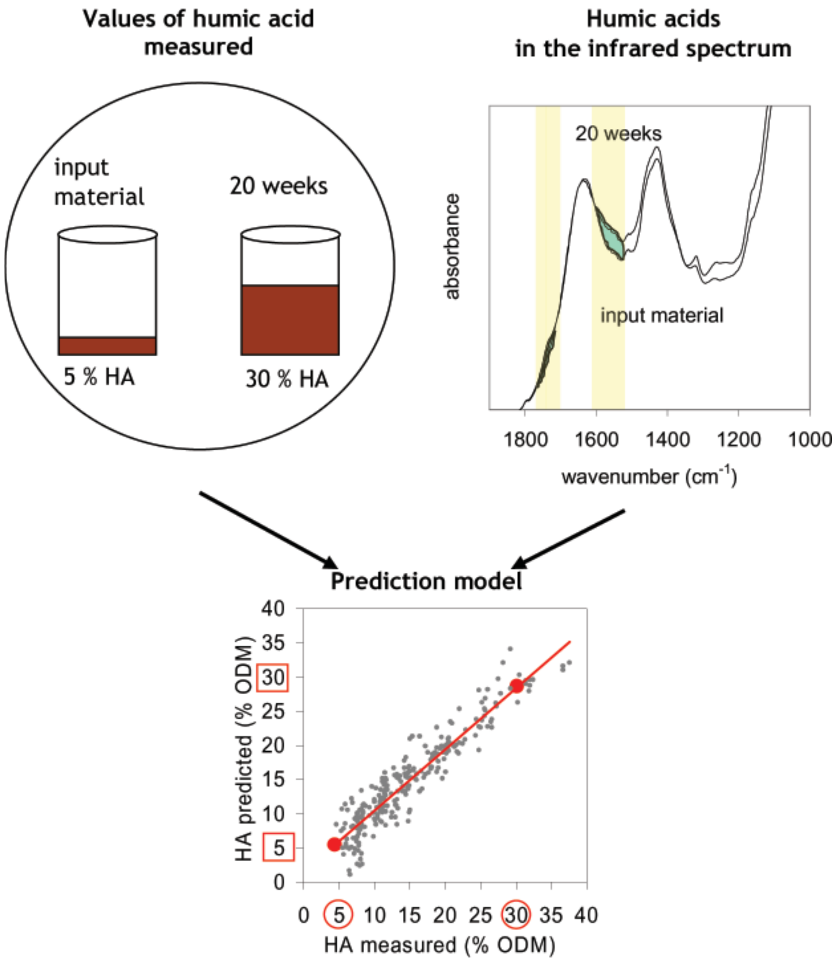
For application in practice it is absolutely necessary to validate the model.

The graph on the next page clearly demonstrates the need of a big number of samples to establish a reliable model.

The next page visualizes the correlation between the chemical analysis and infrared spectroscopic characteristics.



Regression analyses of the measured humic acid contents (% HA) referring to organic dry matter (ODM), obtained by extraction and infrared spectroscopic investigation

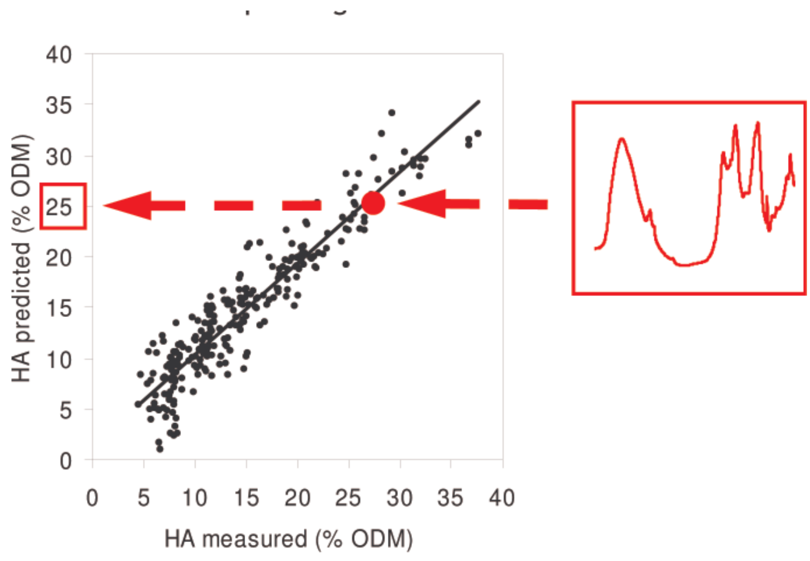


Schematic graph of the correlation „HA measured“ and „HA predicted from the spectrum“ (wavenumber areas for model calculation: 1745 – 1685 cm^{-1} and 1610 – 1567 cm^{-1})


Humic acid -
prediction?

As mentioned above, humic acid contents can be predicted from the infrared spectrum. For this purpose the model **„InfraHUM“** was developed.

The figure below displays an example. The infrared spectrum of the compost sample is like a „fingerprint“. The model „InfraHUM“ evaluates the spectrum and reveals where the sample is located („red dot“) along the regression line. It indicates the corresponding humic acid content.



Prediction model for humic acid determination „InfraHUM“

1. Model development:
Infrared spectra of a very large number of composts and MBT materials were recorded. After definition of classes models for each class are generated. Areas that are highlighted in colors (see figure) represent the class membership with a probability of 95 %.

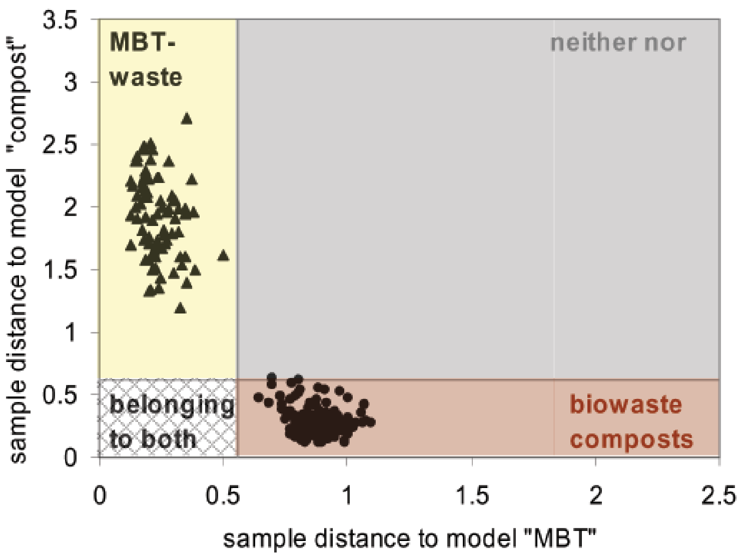
2. Testing the models (Model validation):
In order to verify the reliability of the models, unknown samples are tested by the model. If class assignment based on conventional parameters and on infrared spectroscopic characteristics correspond, the model is considered reliable and valid. The validated model is applicable in practice. It is called „InfraKLASS".

3. Applicability in practice:
Infrared spectra of samples to be analyzed are recorded and classified by means of the validated model. Classification is performed by the model „InfraKLASS" and by the computer.

Additional details may be found in the literature (Smidt et al.: Classification of waste materials using Fourier Transform Infrared spectroscopy and Soft Independent Modeling of Class Analogy)

Development of the classification model - „InfraKLASS“

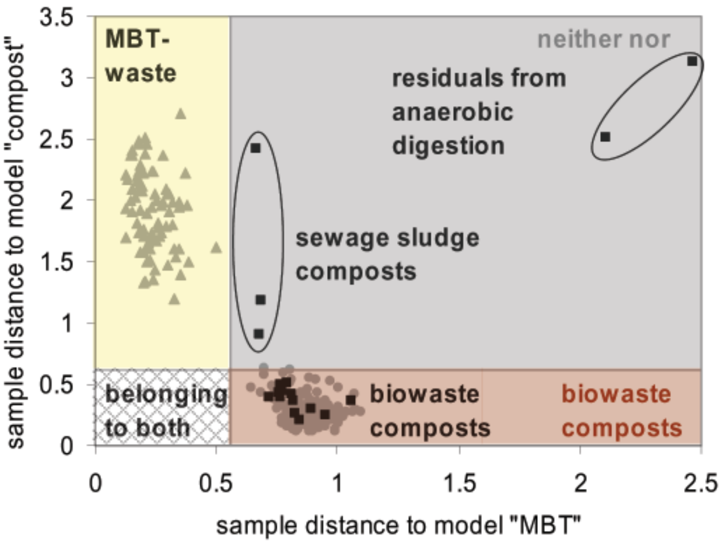
Classes have to be defined for sample classification. For the class “biowaste compost” only infrared spectra of biowaste from separate collection were used. For the MBT waste model, typical municipal solid waste materials (MBT waste) served as representative samples. The figure below shows both models. The brown colored area constitutes the class „biowaste compost“, the yellow area denotes the class „MBT-material“. The gray corner is reserved for samples that do not belong either to biowaste compost or to MBT-material. The striped corner is assigned to materials featuring characteristics of both composts and MBT-materials. These models were developed and validated at the Institute of Waste Management



Classification models („InfraKLASS“) for biowaste compost and MBT-material

The figure below demonstrates the application of the classification model **„InfraKLASS“**.

Unknown compost samples are characterized by black quads. The model „InfraKLASS“ tests which class the samples are assigned to, according to their infrared spectroscopic pattern. The result indicates that the majority is attributed to the class „biowaste compost“. Five samples are assigned to the area „neither-nor“. According to background information these samples are sewage sludge composts and residues from anaerobic digestion.



Classification of unknown samples (black quads)

If you have any questions, please do not hesitate to contact us:

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C. GLOSSARY

Absorption (A)
Absorbed radiation (energy) necessary to cause vibrations of molecules. It becomes visible by absorption bands in the spectrum
$A = \log (I_0 / I)$
I_0 = light intensity without the sample
I = light intensity with the sample

Respiration activity (RA):
Measurement of the oxygen uptake in the course of the aerobic degradation process; RA is indicated as milligram (mg) oxygen uptake (O_2) per gram (g) dry matter (DM)

Humin
Insoluble fraction of humic substances

Humic acids
Fraction of humic substances soluble in alkaline solutions and insoluble under acidic conditions

Humic substances
Stable, organic re-synthesized matter of high molecular weight with a slow turnover rate

Indicator bands
Characteristic bands in the infrared spectrum of the material

Infrared spectroscopy
Analytical method for identification and determination of constitution of chemical compounds

Mineralization
Complete degradation of organic matter to carbon dioxide (CO_2), water, and salts.

Phytosanitary effect
Suppression of plant diseases and support of defense mechanisms against plant diseases

KBr Pellets
For infrared spectroscopic investigations the sample is pressed with KBr as carrier material to a pellet

Regression
Correlation between a dependent and one or more independent variables

Spectrum
Recording of absorption intensities in dependence of a specific wavenumber within a defined wavenumber region

Measurement in the transmission mode
The beam of infrared radiation goes through the sample (pellet)
$T = I/ I_0$
I = light intensity with the sample
I_0 = light intensity without the sample

Wavenumber (ν)
Energy level for characterization of infrared radiation (in former times rather wavelengths (λ) were indicated (ν = 1/λ); Conversion: ν (cm^{-1}) = 104/λ (μm))

D. LITERATURE

BGBl. 68/1992: Verordnung zur getrennten Erfassung von Bioabfällen (1992)

BGBl. II 292/2001: Verordnung über Qualitätsanforderungen an Komposte aus Abfällen (Kompostverordnung) (2001)

Gerzabek M.H., Danneberg, O. und Kandeler, E. (1993): Bestimmung des Humifizierungsgrades, Bodenbiologische Arbeitsmethoden, Springer Verlag, Wien, S. 107-109

ONR 192123: Probenaufbereitung von Abfallproben

OE-NORM S2022: Qualitätskriterien für Müllkompost

OE-NORM S2023: Untersuchungsmethoden und Güteüberwachung von Komposten (1993)

OE-NORM S2200: Qualitätskriterien für Komposte aus biogenen Abfallstoffen (1993)

OE-NORM S2201: Kompostierbare biogene Abfälle – Qualitätsanforderungen (1993)

OE-NORM EN 15002: Charakterisierung von Abfällen – Herstellung von Prüfmengen aus der Laboratoriumsprobe

ADDITIONAL LITERATURE

FIBL – Forschungsinstitut für Biologischen Landbau, Hrsg. Fuchs J.G., Bieri M. und Chardonnens M. (2004): Auswirkungen von Komposten und von Gärgut auf die Umwelt, die Bodenfruchtbarkeit, sowie die Pflanzengesundheit

Meissl K., Smidt E. and Schwanninger M. (2007): Prediction of humic acid content and respiration activity of biogenic waste by means of Fourier Transform Infrared (FTIR) spectra and partial least squares regression (PLS-R) models, Talanta Vol. 72, p. 791-799

Smidt E., Meissl K., Schwanninger M. and Lechner P. (accepted): Classification of waste materials using Fourier Transform Infrared spectroscopy and Soft Independent Modeling of Class Analogy, Waste Management

Smidt E. and Schwanninger M. (2005): Characterization of Waste Materials Using FT-IR Spectroscopy – Process Monitoring and Quality Assessment, Spectroscopy Letters Vol. 38, p. 247-270

Compost Quality Society Austria

Targeted tasks in the field of biowaste and composting:

- To provide information and consultant services
- To promote knowledge transfer and experience exchange
- To support scientific research, setting up new activities and disseminating results

- To guarantee quality assurance and control
- To safeguard member interests
- To organize workshops and support other organizations in the field of biowaste matters and composting

- To aid implementation of an European quality assurance system

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The **International Waste Working Group** is an international waste organisation founded in 2002 to serve as a forum for the scientific and professional community.
The IWWG aims to provide an intellectual platform to encourage and support integrated and sustainable waste management and to promote practical scientific development in the field.
The group is conceived as a think-tank, whose work would be based on scientific principles oriented towards practical applications.

iwwg CONFERENCES

- Sardinia International Waste Management Symposium (www.sardiniasymposium.it)
- BOKU Waste Conference (Vienna)
- Hazardous Waste Conference (Crete)
- VENICE, Biomass and waste to Energy Symposium

iwwg BOOKS

- Management and Landfilling of Solid Wastes in Developing Countries
  L.F. Diaz, L.L. Eggerth and G.M. Savage Eds
- The Sustainable Landfill
  R.Cossu and H. Van der Sloot Eds
- Landfill Aeration
  R. Stegmann and M. Ritzkowski Eds
- Landfill Modelling
  A. Haarstrick and T. Reichel Eds

others titles are coming soon…

iwwg TASK GROUPS

With the aim of coordinating interdisciplinary research and discussing controversial aspects, the following Task Groups are actively working:

- Sustainable Landfilling
- Landfill aerobisation
- CLEAR Consortium for Landfilling Emission Abatement Research
- PHOENIX Combustion Residues
- Waste Management in Developing Countries
- HUMOR Compost Quality
- Leaching Assessment Methodology

iwwg OFFICIAL JOURNAL

Waste Management published by Elsevier, Amsterdam, is a refereed journal and serves as the official voice of IWWG and the strategic focal point for the activities of the group.

iwwg MEMBERSHIPS

Associate members

Every professional working in the solid waste field can become an IWWG Associate Members simply by signing up for a membership fee. The benefits are as follows:

- Free subscription to IWWG Scientific Journal Waste Management
- Access to the member only area on the IWWG website (*Conferences Proceedings, Powerpoint presentation, Task Groups outputs and more…*)
- Discount on IWWG events (*Courses, Seminars, Conference and Symposia*)
- Discount on the purchase price of IWWG publications (*Monographs and Textbooks*)
- Discount on Elsevier publications
- Task Groups membership

Fees

Regular membership fee: 150 € /year
Student membership fee: 100 € /year

Registration and Continuously updated information is available on the IWWG web site: **www.iwwg.eu**