PhD dissertation thesis

Examination of degradation processes of composts based on various wastes

Hunyadi Gergely

Supervisor: **Prof. Dr. Tamás János**

UNIVERSITY OF DEBRECEN
Kerpely Kálmán Doctoral School of Crop Production, Horticulture and Regional Sciences

Debrecen, 2012

1. BACKGROUND AND AIMS OF THE DISSERTATION

The political, economical and social changes of regime at the end of the '90s considerably affected the agriculture and resulted huge changes in the proprietary and farm system in Hungary. The large companies were replaced by micro-, small and medium enterprises and individual farmers which generated the separation and shot of land-ownership (*Molnár and Farkasné, 2003*).

Due to the changes of land-ownership the too main fields of agriculture – plant production and animal husbandry – has separated, which diminished the profitableness of each enterprise. The decreasing efficiency was coupled with the drastic decline of livestock. Comparing with the '70s the cattle- and also the pig-livestock decreased more than 40% (*Baranyai and Takács, 2007*).

The negative changes of livestock resulted the diminution of the amount of organic manure. In the '70s approximately 15 million ton of organic manure per year was used. This value until 2000 decreased to 5 million ton (*KSH, 2000*). These changes – until the beginning of the '90s - were accelerated by the incursion of chemical fertilizer utilization too. The increase of the used amount of chemical fertilizers not only increase yield but affect the properties of soil and soil ecology.

The amount of chemical fertilizers which is determined by nutrient-demand of crops may ensure this need but does not assist the long term sustainment of the organic matter content of soil. Furthermore, during planning the utilised amount of active agents we do not consider the nutrient need of the microorganisms and soils which need to ensure their needs from the reserves of soil decreasing the nutrient base and nutrient supply ability of soil. The stripping of organic compounds and humus materials may cause decrease of soil properties or soil degradation which may result impossible soil-tillage (*Dobos, 1999*).

To avoid the consequences mentioned above and to preserve the advantageous characteristics of soil the supplement of extracted organic materials is essential. Composting is one of the possibilities to ensure organic matter demand. With the use of optimal raw materials, the control of degradation processes and the continuous checking of deterministic parameters we can produce a stable final product that can be effectively used in nutrient cycle (*Filep, 1999*). The wide range of raw materials of composting makes the disposal of organic waste possible – only with the exact adherence of conditions.

By fulfilling the aims of the National Communal Sewage Water Collection and Treatment Program in the next few years we have to count with increasing amount of sewage sludge – produced as a co-product by the different wastewater treatment technologies (*Petróczki, 2005*). The problem of the disposal and the deposition of the increasing amount have to be solved because the 1999/31/EC direction of the European Commission and the National Waste-management Plan II. unequivocally defies that the deposition of biodegradable organic wastes – as valuable energy sources – in waste disposal plants has to be decreased. To fulfil requirements of legislations the produced organic wastes have to be utilized in agriculture, biogas production or composting.

The sewage sludge has a very good nutrient potential, but its direct utilization as organic fertilizer is limited by its hazardous heavy metal content and its pathogenic agents (*Szili-Kovács, 1985; Tamás, 1990; Simon et al, 2000)*. Otherwise, generally it can be used as raw material in composting because as an effect of aerobic degradation processes and high temperature suwage sludge loose its disadvantageous characteristics – except heavy metal content – and its organic contents are transformed to useful humus-materials (*Uri, 2007*).

Consequently, the aerobic degradation of sewage sludge is a possibility during which next to the stabilization and disposal of sludge we can produce a final product that can be used in agriculture. The only use of sewage sludge during composting is not feasible because its low C/N ratio and high moisture content. Due to this, we should use sewage sludge in aerobic biodegradation technologies with different bulking agents. *Amlinger et al.*, (2004) highlights with the use of the different types of communal wastes (wastes of park maintenance, selectively collected communal wastes, food wastes, etc.) and other bulking agents such recipe and technology variants should be determined which produce a stabilized final product with the disposal of these wastes.

Thanks to the stricter national and EU legislation – sharpened because the BSE disease – the disposal of slaughter house and animal wastes also have to be solved. According to the *71/2003 (VI.27.)* ministry regulation we cannot produce a final product that can be used in forage from the dead animals and slaughterhouse wastes; consequently, the previous protein-processing technologies will be used during the disposal of these hazardous wastes. The incineration technologies that processing slaughterhouse wastes, are not only energetically inefficient and uneconomical, but they mean some problems related to environmental production too (*Kádár et al., 2009*). The composting technologies after pre-treatment methods of he second and third class wastes – as they are determined in the mentioned law – are not just only more economical processes, but not as hazardous to the environment too and also adapted to the natural nutrient cycle. There is no established standard composting technology for the treatment of these kinds of wastes which produces a stable final compost material which fulfils the requirements of animal health care. The low C/N ratio of slaughter wastes needs to build up recipes that can produce a deposable compost material and fuilfils all the requirements of legislation, animal healthcare and composting (*Ragályi and Kádár, 1998*).

The general aim of my dissertation at on side is the examination of those composting technologies based on sewage sludge and slaughterhouse wastes which may give a solution to the environmentally friendly disposal of these wastes – next to the utilization of their advantageous characteristics. On the other hand, is introducing and developing new measurement methods of parameters that determine degradation process and the characteristics of the final product.

The aims of my work in details:

1. analyses of the composting technologies based on sewage sludge and slaughterhouse wastes,
2. the evaluation of the effects mixing rates and raw materials on the final products during open air windrow composting,
3. the control of mixing rate, analyze compost homogeneity,
4. the causes of the different temperature of different points on the surface of compost pile, exploring the connection between inside and surface temperature,
5. following the degradation processes of composting, establishing in-situ measurement methods of deterministic parameters,
6. introducing a new in-situ method th determine compost-maturity.

2. RESEARCH METHODS

2.1. Characteristics of the examined raw materials

The used raw materials of composting can be divided int three groups indenpendently of the utilized composting technology – primary (sourced from plants), secondary (sourced from animals) and tertiary materials.

The aim of the use plant residues and by-products was optimizing the conditions of degradation. The plant sourced materials can be used to set the C/N ratio and stabilize the optimal moisture content.

Because in of the technologies sewage sludge, and in the other slaughterhouse wastes were given as disposable waste, the primary bulking agents and their rate were chosen according to the disadvantageous characteristics of these wastes.

From the range of animal manure, cattle manure and poultry liquid manure were used to optimize the C/N ration and the moisture content of compost. The quality and contents of manure is determined by the used husbandry and manure treatment technology.

The third group contains the by-products of industrial technologies that were wanted to be disposed.

The quality of sewage sludge is determined by the technology process and the characteristics of the treated wastewater. During the research we used a pre-digested sewage sludge (the anaerob treatment took place at the wastewater treatment plant of Debrecen) with 70-75% moisture content.

The characteristics of the used sewage sludge fulfil the limiting requirements of *50/2001. (IV.3.)* regulation. The legislation does not limit the use of sewage sludge. The standard deviation in the case of some parameters was high (e.g. copper, zinc). According to this before set of mixing rate we have to examine the chemical compounds of sewage sludge.

In the case of the technology based on animal wastes before set the mixing rate of raw materials we analysed the characteristics of those wastes that need special treatment processes (placed to group 2. according to the *71/2003. (VI. 27.)* legislation) and the poultry feather (placed to group 3. to according to the *71/2003. (VI. 27.)* legislation).

After the pre-treatment (sterilization) of the slaughterhouse wastes the liquid phase is used during the biogas production in the biogas plant of the BátorTrade Ltd. in Nyírbátor, meanwhile the solid phase and residual phase are used during composting.

2.2. Used experiments and technologies

Because of the different degradability and characteristics of the two main wastes I examined two composting technologies:

1. open air windrow composting in the case of sewage sludge,

2. and GORE Cover active aerated prism composting in the case of slaughterhouse wastes.

In the case of slaughterhouse waste composting the closed system is essential because of the retention of the produced gases and odours and the active aeration helps the degradation of the difficultly degradable compounds.

The open air windrow composting is explained by the large produced amount of easily degradable sewage sludge.

Open air windrow composting

The open air windrow composting based on sewage sludge was set the composting plant of the A.K.S.D. Ltd. The aim of the corporation is to sell the produced final material as compost or mixing with peat as black-mould. At the composting plant set of 25 piles is possible. The machinery of the corporation contains a mixing machine, a loader, a sorting machine and a winnower.

At the plant with different rates of the raw materials we set 7 prisms. During the establishment of the mixtures the aim was to use the maximal amount of sewage sludge and set 13-15:1 C/N ratio, because of the higher nitrogen-content the prism heats up faster as the degradation processes.

To increase the efficiency of the degradation in some mixtures we used COFUNA inoculum. The retention time of degradation was 8 weeks independently of the mixing rate. In the case of the first 4 prisms the aim was to compare the final products given by the different mixing rates – the prisms were set at one time. The aim of set the other prisms was the examination of degradation and determination of compost homogeneity and maturity.

Active aerated prism composting

The intensive aerated prism composting technology was elaborated in the composting plant of BátorTrade Ltd. In Nyírbátor. The composting building is closed from every side. The composting procedure takes place in separated composting cells. The building contains 14 composting cells. Each cell is able to degrade 150 ton raw material. The set of mixture is made with a loader and organic fertilizer spreader. The retention time in each cell is approximately 4 weeks – each cell can be set 12 times per year. The air is injected with aeration pipes which are built in the floor. The scheduled work of ventilators is controlled by the oxygen and temperature probes that are put in the prism.

The degradation of the mixtures is carried out with GORE Cover technology.

The system contains 3 main elements:

1. active aeration system which ensures the oxygen demand of microorganisms,
2. aeration controlling system with the use of oxygen and temperature probes in the pirsm,
3. the coverage of the prism which is a semi-permeable membrane.

In the case of the active aerated technology the aim was the examination of temperature and gas distribution inside the compost prism.

2.3. Measurements and used equipments

During the research measurement points were determined in the cross and longitudinal-section in different heights and depths. For sampling we used an EIJKELKAMP soil auger.

The gas-concentration was examined by OLDHAM MX 21 portable mobile multigas-analyzer. The concentration of carbon-dioxide, oxygen and ammonia was measured.

With the gas-analyzer we can measure the concentration of the following gases: explosive gases (methane, propane, butane, etc.), toxic gases (carbon-monoxide, hydrogen-sulfide, chlorine, ammonia, etc.), carbon-dioxide and oxygen. The equipment can measure 4 gases simultaneously – one explosive and three optional – with special sensor-blocks. The measurement method is based on infrared-refraction.

The tool is equipped with pump system and gas-injector cap, so it can measure the gas-concentration at where difficult to get. The gas levels are displayed on an alphanumeric LCD screen, in ppm (in the cases of toxic gases) and V/V% (in the case of explosive gas).

To measure the gas-components directly in the compost prism a special supplement was needed. The supplement (which was innovated by our department) is an acid-proof, stainless steel pole, which's inner diameter is 14 mm, and the maximal measurement depth is 1,5 m. The pole because of the easier application ends in a spike, and supplied with a special gripe. To avoid contamination a special steel filter was added.

The relative moisture content was analyzed in the samples taken from the prism. The samples were dried at 105°until constant weight. The relative moisture content was calculated by the mass-loss.

For the heavy metal measurement the samples should be prepared. The samples were mixed, spread and dried. After the drying process the compost was grained and chopped. After the chopping the sample was sifted on a strainer with 2 mm diameter. The prepared sample was taken into bags and hermetically closed (*Shefsky, 1997*).

The heavy metal content of the sample was determined with FPXRF NITON XLt 700 which based on second generation spectrometry. The instrument contains a miniature x-ray tube. The instrument is able to measure complete element content and takes the matrix effects into consideration (*Nagy et al., 2006*).

Calibration and control measuring forerun the measurement. We used compact samples and measured them for 60 seconds that determine by the instrument. Each measurement was repeated three times and we took the average of the results. The instrument gives mistake-factors but with did not use them during the data-processing (*Kalnicky és Singhvi, 2001*).

The temperature was measured by a stack thermometer. The thermometer was supplied with a stainless steel, acid-proof 150 cm ling probe for the direct measurements. The equipment ensures 0.1 °C accuracy. The temperature was measured in 3 depths 50, 100 and 150 cm.

To examine the surface temperature we used PYROLATER 12 thermo-camera which is produced by HEXIUM Ltd. In the stainless steal cover box there is 7800 microbolometer sensor (320X240 grid), which does not need cooling. The sensitivity of the sensor is approximately 0.05 °C. The measuring interval is between -20 and 120 °C, but the optimal working temperature is in between -15 and 60 °C (*Nagy, 2005*).

The camera can be used optimally, when the temperature of the environment is lover than the temperature of the analyzed material.

Determining the reflectance of the samples and ALTA II on-field, portable spectrophotometer was used. The equipment measures in different wavelengths between 470 and 940 nm. The different wavelengths are produced by the bulbs on the backside of the equipment.

The carbon and nitrogen content and the C/N ratio were measured with a CNS element-analyzer of the Institute.

The organic material content, the phosphate, potassium, calcium and element content of the taw materials were measured in the laboratories of the Institute of Food Processing, Quality Assurance and Microbiology.

2.4. Statistical data evaluation methods and used software

SPSS 15 statistical software and Microsoft Office Excel software were used for statistical evaluation of data. The data was processes at 5 and 10% significance level because the measurements can be repeated fast and the values of different parameters support each other.

Modelling the degradation processes mass-balance model was used in which the organic material and moisture content of the input material were calculated from the weighted used amount of the raw materials. In the model 50% efficiency of degradation was assumed. The output result s of the model were compared with the amount and characteristics of input materials and the degradation process of the model in which only sewage sludge was used as raw material.

Tukey-test was used to determine those wavelengths where the different mixing rates can be separated significantly. To explore the connection between the mixing rate and reflectance we used a linear regression analysis. During the examination of compost-homogeneity to produce isometric distribution-profiles Golden Software Surfer 9 software was used. To compare the different distribution-profiles correlation-analysis of the datasets was used.

During the analysis of temperature and gas-concentrations of different mixing rates and different maturity-stages the datasets of the prisms were compared also with correlation. The coherences between inside temperature and the respiration-index, the respiration-index and ammonia-concentration and the ammonia-concentration and temperature were analyzed vith regression-models.

To process the thermo-photos IRPlayer software – developed by HEXIUM Ltd. – and Golden Software Surfer 9 were used. To explore the coherences between the surface temperature and the values of pixels regression-analysis was used. To determine the cause factors of the temperature of different points also regression was used.

The connections between surface temperature and the temperature of different layers were determined with correlation. To analyze the curve of temperature-change curve estimation and function-analysis was used.

To find out the role of gas-concentration changes and reflectance during compost-maturity determination correlation was utilized.

3. MAIN OBSERVATIONS OF DISSERTATION

The general aim of my dissertation at on side is the examination of those composting technologies based on sewage sludge and slaughterhouse wastes which may give a solution to the environmentally friendly disposal of these wastes – next to the utilization of their advantageous characteristics. On the other hand, is introducing and developing new measurement methods of parameters that determine degradation process and the characteristics of the final product.

The main part of the research was related to the evaluation of the open air windrow composting technology – based on sewage sludge – but some experiments were connected to the analysis of the active aerated prism composting of slaughterhouse and animal wastes.

To examine the effects of mixing rate on the characteristics of the final product we set 5 compost prisms. The final product and the characteristics of the raw materials were compared. According to the results we can conclude that we can produce compost with closely constant characteristics from each starting mixture. The different bulking agents not affected considerably the quality of the final product – they nutrient content and heavy metal concentration dilution ability appeared. The characteristics of the final product are determined by the quality of the sewage sludge. Due to this, during establishing the compost-recipe we should maximize the amount of the used sewage sludge as 50% percent considering the optimal C/N ratio and moisture content. Instead of the utilization of the total amount of bulking agents at the starting mixture it is better to add them continuously, especially at beginning of degradation. Thanks to the high nitrogen-content of the grass-cutting, the temperature of the windrow rises faster – it is better to add it to the starting mixture. With the continuous adding the organic material need of microorganisms is ensured. The produced final product has large copper content- it is suitable to utilize it on soils with low copper-content. The potassium content needs supplement by an additive such as zeolit.

The volume of the prism containing the mature compost decreased with 30-40% which is a result of two main effects – the degradation processes and the decrease of moisture content. The moisture content and the organic matter content also decreased by 10-15% until the end of degradation.

I examined the changes of degradation at the case of different mixing rates with a mass-balance model. According to the models we can conclude the effectiveness of degradation, the amount of produce carbon-dioxide and water vapour is nor determined by the quantity of the organic matter but its quality. Reflected to 100 g raw material the amount of produced carbon-dioxide and water vapour by the different mixtures does not show high differences but if we calculated with the real amount of the used raw materials the differences can be more hundred kilograms. The adsorption, utilization and reuse of carbon-dioxide and water vapour are on of the main goals of the composting technologies of the future.

Examining the active aerated intensive technology we can conclude that retention time is too short to degrade these kinds of difficultly degradable organic materials. To optimize retention time more experiments are needed. During the process – because of the high protein content – large amount of ammonia is produced - it is important to measure not just only the oxygen concentration but the ammonia nd to mix the prism more frequently.

Bíró et al. (2007) and *Mézes et al.* (2007, 2008) were working on the improvement of the poultry feather – with high keratin content - pre-treatment technology. Using their results it is more suitable to use poultry feather after bacterial pre-digestion than directly.

To check the mixing rate of compost we developed a method which is fast and analyze the samples directly from the compost prism. The method is based on reflectance measurements. The basis of the measurement is given by the different characteristics of the raw materials. According to the results we can conclude that in the case of rape-straw and sewage sludge mixture the more suitable wavelengths intervals are in the infrared zone. In those cases when more than 60% sewage sludge was used there is no significant difference between the reflectance of the different mixing rates. This does not considerably affect the utilization possibility of the method, because in practice – to reach the maximal effectiveness of degradation and waste disposal – the rate of sewage sludge is never higher than 50%. The increasing rate of rape straw increased reflectance. The moisture content affected the reflectance negatively, after drying the reflectance increased. The method can be used with wet and dry samples, but in the case of wet samples there is no need for sample preparation and drying so it is possible to measure directly from the prism.

By statistical analyses we can build up a model which makes the determination of mixing rate of different samples possible after measuring reflectance. The regression model can be used at 5% significance level. With the use of the regression model we can calculate the mixing rate of samples of the compost prism and we can examine homogeneity.

To measure the homogeneity of open air compost prism I used ex-situ and in-situ measurement methods. The ex-situ methods were C/N ratio, relative moisture content and heavy metal content measurements. The in-situ methods were direct measurements of ammonia-, carbon-dioxide and oxygen-concentration. To measure the gas components we developed a special equipment which makes direct measurements possible as the stack thermometer. The given OLDHAM MX21 portable, onsite gas-analyzer was supplied with an acid-proof, stainless steel probe. It is better to handle the oxygen and carbon-dioxide concentration together as O_2/CO_2 ratio. The given results were presented on graphs and as isometric distribution maps.

Comparing the mentioned measurement methods and their results, we can conclude that the ex-situ methods need time many samples as the determination of the particle size distribution. The determination of C/N ratio and heavy metal content is economically not cost-effective and the preparation of samples is complex. Furthermore, the distribution profiles of heavy metals do not give an overview of the actual state of the degradation. The method based on moisture content is simple and cheap, needs only mass measurements. The preparation of samples in this case includes the measurement too. The error factor of the ex-situ methods is relatively high, because until the measurement many steps are need: sampling, transport of samples, sample-preparation. Sampling takes time and the characteristics of the samples not always reflect the real situation of the prism. The most effective method is the measurement of gas-concentration. However, it has a special equipment demand nut the measurement dos not need sampling and sample preparation it takes place directly in the compost prism. More advantages are the possibility of immediate actions and the value of ammonia and oxygen concentration confirm each other.

In the case of open air windrow composting I made temperature-mapping of the prism based on the temperature and gas-concentration measurements. In the case of the active aerated technology because of the coverage I could only examine the temperature distribution vertically.

At the active aerated compost according to the measure gas-content and temperature the prism can be divided into 3 zones. The temperature of the lower zone is affected by the temperature of the floor and the injected air. The temperature of the higher zone is determined be the temperature of the environment. The central zone is the zone of intensive degradation. The results in the case of the oxygen are not realistic because the accuracy of the measurement was affected by the oxygen-content of the injected air.

In the case of open air windrow composting based on the gas concentrations and also the temperature we can dived the prism to 3 zones: the lower zone is affected by the floor, the higher zone by the environment. The central zone is the zone of intensive degradation. By the temperature, the cross section can be divided into 3 zones horizontally too: an outer "crustzone", a central zone of intensive degradation and an inner "corezone". With the optimization of the size of the compost prism the size of "corezone" can be lowered. The ammonia-concentration increased through the prism to the core, while the rate of oxygen and carbon-dioxide decreased.

I introduced the utilization of the thermocamera to evaluate the surface temperature in the case of open air windrow composting. With the help of the thermocamera we can get an overview from those points where the characteristics of compost are different. To explore the causes of the different temperature we took samples from the points that have different temperature than the average and also from the points which have the average temperature and determined the organic material content, C/N ratio and moisture content. The surface temperature only correlated strongly with the organic material content. As a result, we can conclude the temperature was affected by the organic matter content.

Intermediately the C/N ratio and the moisture content also can be connected to the surface temperature. According to this, we can conclude the temperature differences are resulted from the improper mixing. With the use of the thermocamera we can determine the parts that have to be mixed by the exploration of the points with different temperature.

I examined the effects of surface temperature distribution on the temperature of the inner layers. Before the comparison an establishment of a data process methodology was needed with which we can calculate and connect the temperature values to the pixel values of the thermo-photo. The surface temperature affects the temperature of the inner layers but it depends on the type of the used bulking agent. In the case when we used wood-clipping a crust forms which width is 20-320 cm. Because of this crust the temperature of the inner layers does not follow the temperature of the surface. In the case when we used straw as bulking agent the inner temperature followed the surface temperature until 60 cm depth. It is more suitable if more composting plants use one thermocamera because the high acquisition cost.

To determine the compost maturity I established a method which can be used directly in-situ, fast and cost-effectively. To analyse compost maturity I used reflectance and gas-concentration measurements.

The degradation process can be divided into 4 periods based on the temperature and reflectance. The change of reflectance is just the opposite as the temperature. Namely, the intensive degradation results an increase of the temperature but the degradation of the carbon-chains decrease reflectance. If we compare the degradation curves of the different prisms we did not experienced significant differences. There was no difference between the results of different wavelengths; accordingly any of them can be used to evaluate compost maturity.

According to the regression-model of reflectance and temperature we can conclude the reflectance-analysis can be used effectively for determine compost maturity. More suitable if we use reflectance together with temperature measurement so we can receive more accurate results. The frequency of the measurements has to be increased at the end of the degradation (from the 25^{th} day) because experiencing the increase then the decrease of reflectance we can deduce the built up of humus components and the end of degradation.

Based on the ammonia, carbon-dioxide and oxygen measurements we cannot separate the 4 degradation periods, but the continuous decrease of the concentrations indicates the end of degradation, the mature of compost. According to the results we should increase the frequency of measurements in the last period of degradation. The continuous measurement of gas-concentration is suggested because of exploring compost homogeneity and aerob/anaerob conditions.

4. New scientific results of dissertation

1) The changes of temperature during the degradation process can be represented by three mathematical functions: the initial stage with an exponential function, the degradation and transformation stage together with a cubic function, and the maturity stage also with and exponential function. The end of the degradation stage and the beginning of the transformation stage is described by the inflexion point of the cubic function. The exponential function of the maturity stage is converging to a linear function which's value is equal with the value of the actual temperature.

2) In case of open air windrow composting the oxygen-carbon dioxide ratio continuously decreases ahead to the inner sections of the prism. The change of the ammonia concentration is the inverse of this. The vertical zonation of the prism is observable in the case of ammonia, carbon dioxide and oxygen concentration. The vertical layers emerge during active aerated composting too. The change of ammonia concentration has a medium correlation with the change of temperature. A strong correlation appears between the inner temperature and the carbon dioxide concentration. The concentration of carbon dioxide increases by the growth of inner temperature.

3) The degradation process based on reflectance measurements can be divided into 4 stages like in the case of temperature. The change of reflectance coheres with the changes of temperature. The increase of temperature results the decrease of reflectance.

5. PRACTICAL UTILIZATION OF RESULTS

1) In the case of open air windrow composting during the set of mixing rate the characteristics of sewage sludge have to be considered next to the relative moisture content and C/N ratio. To produce a good quality final product the rate of sewage sludge has to be maximized as 50% according to the results.

2) The retention time in the case of the examined active aerated technology is too short if we use these kinds of raw materials. With more frequent mixing of compost we can reduce the amount of the produced ammonia. It is more effective if we measure the carbon-dioxide and ammonia-concentration together with the oxygen.

3) I developed an equipment which is suitable to determine the gas-concentrations in the compost prism directly. With the measured gases we can follow the degradation process and analyse homogeneity and maturity.

4) By measuring reflectance and using the regression equation we can estimate the actual mixing rate of samples on site and determine homogeneity.

5) The used homogeneity measurements give the possibility to check the compost prism. The in-situ methods are suggested from the evaluated methods. The

determination of relative moisture content - as and *ex-situ* method- may give a solution because the measurement involves sample-preparation too.

6) I introduced the utilization of thermocamera for estimating the surface temperature of the compost prism. By the use of thermophotos we can explore the points with different temperature and we do not need to mix the whole prism. It is more suitable if more composting plants use one thermocamera because the high acquisition cost.
7) The reflectance and continuous and direct measurements of gas-content can give an overview of the maturity of the compost prism. It is suitable to make the measurements more frequent at the last period of degradation and measure the ammonia and oxygen concentration together.

6. REFERENCES

1. *Amlinger, F. - Favoino, E. - Pollak, M.*: 2004. Heavy metals and organic compounds from wastes used as organic fertilisers, Compost – Consulting and Development, Technical Office for Agriculture, Wien, Austria. 60-65.
2. *Baranyai Zs. - Takács I.*: 2007. A rendszerváltás hatása a mezőgazdasági termelés hatékonyságára Magyarországon. AVA Nemzetközi Konferencia. Debrecen. Konferencia CD. 1-15.
3. *Bíró T. - Mézes L. - Tamás J.*: 2007. The examination of poultry feather digestibility for biogas production. *Cereal Research Communications*. 35. 2: 269-272.
4. *Dobos E.*: 1999. Talajtan. Ökológiai Intézet a Fenntartható Fejlődésért Alapítvány. Miskolc.
5. *Filep Gy.*: 1999. Talajtani alapismeretek I. Általános talajtan. DATE Mezőgazdaságtudományi Kar. Kari Jegyzet. Debrecen. 64.
6. *Kádár I. - Petróczki F.- Hámori V. – Morvai B.*: 2009. Kommunális szennyvíziszap, illetve vágóhídi hulladék komposzt hatása a talajra és a növényre szabadföldi kísérletben. *Agrokémia és Talajtan*. 58. 1: 121-136.
7. *Kalniczky, D. J. - Singhvi, R.*: 2001. Field portable XRF analysis of environmental samples. *Journal of Hazardous Materials*. 83. 93-122.

8. *Kovács E. - Tamás J.*: 2002. Terepi röntgen-floreszcens spektrofotométer megbízhatóságának elemzése. [In: Proc. Innováció, A tudomány és a gyakorlat egysége az ezredforduló agráriumában]. Környezetvédelem. Debrecen. 11-17.
9. *KSH.:* 2000. Magyar Statisztikai Évkönyv, 1999. Budapest.
10. *Mézes L. - Bíró T. - Petis M. - Tamás J.*: 2008. Keratin-tartalmú hulladékok üzemi méretű biológiai előkezelése. *Acta Agraria Debreceniensis*. 30. 59-65.
11. *Mézes L. - Bíró T. - Tamás J. - Petis M.*: 2007. Baromfi toll hőkezelése és mikrobiális előkezelése biogáz célú hasznosításhoz. *Agrártudományi Közlemények*. 27. 113-118.
12. *Molnár J. - Farkasné Fekete M.*: 2003. A makrogazdasági környezet néhány meghatározó elemének hatása az agrárgazdaságra. Birtokviszonyok és mérethatékonyság. Agroinform Kiadó és Nyomda Kft. 9-26.
13. *Nagy A. - Kovács E. - Kovács E. - Tamás J.*: 2006. Heavy metal pollution mapping of abandoned mining site by airborne hyperspectral image analysis. *Cereal Research Communications*. 34. 53-57.
14. *Nagy T.*: 2005. A termokamera, avagy a csörgőkígyó stratégiája II. Tanulmány a Hexium Műszaki Fejlesztő Kft. részére. Hexium Kft. Budapest.
15. *Petróczki F.*: 2005. Kommunális szennyvíziszapból készült komposzt hatása a növényi fejlődésre és beltartalomra. Doktori értekezés. Veszprémi Egyetem. Georgikon Mezőgazdaságtudományi Kar. Keszhely.
16. *Ragályi P. - Kádár I.*: 2008. Processed slaugterhouse waste application on calcareous sandy soil. *Acta Agronomica Ovariensis*. 50. 1: 95–101.
17. *Shefsky, S.*: 1997. Comparing Field Portable X-Ray Fluorescence (XRF) to laboratory analysis of heavy metals in soil. International symposium of field screening methods for hazardous wastes and toxic chemicals. Las Vegas. Nevada. USA.
18. *Simon L. - Prokisch J. - Győri Z.*: 2000. Szennyvíziszap komposzt hatása a kukorica nehézfém-akkumulációjára. *Agrokémia és Talajtan*. 49. 247-255.
19. *Szili-Kovács T.*: 1985. A szennyvíziszap elhelyezés talajmikrobiológiai problémái. *Agrokémia és Talajtan*. 34. 486-493.
20. *Tamás J.*: 1990. Szennyvíziszap elhelyezés és hatása a környezetre. Debreceni Agrártudományi Egyetem. *Tudományos Közlemények*. Debrecen. 1-125.

21. *Uri Zs. E.*: 2007. Települési szennyvíziszapok termesztett növényekre és talajra gyakorolt hatásának vizsgálata. Debreceni Egyetem. Debrecen. (Doktori értekezés)

7. Publications related to the dissertation

Publication in foreign language in reviewed journal

- **Hunyadi, G**. - Tamás, J. - Bíró T.: 2009. Reflectance as a Possible Method to Determine Mixing Rate and Homogeneity of Compost Prisms. *Analele Universitatii Din Oradea. Fascicula: Protectia Mediului*. 14:163-173. ISSN: 1224-6255

Publication in foreign language in national reviewed journal

- **Hunyadi, G. –** Bíró, T. – Mézes, L. – Burai, P.: 2008. Establishing the conditions of agricultural utilization of rotted sewage sludge with composting. *Cereal Research Communications.* 36.5:807–810**.** ISSN: 0133–3720.
- **Hunyadi, G. –** Bíró, T. – Tamás, J. – Csatári, G.: 2008. Examination of the temperature distribution of compost prisms according to the recipe and the retention time. *Acta Agraria Debreceniensis.* 283–287. ISSN: 1588–8363.
- **Hunyadi G.**: 2010. Evaluation of sewage sludge based composting technology to increase soil buffering capacity. *Növénytermelés.* 59:49–52. ISSN: 0546–8191.

Publication in Hungarian, national reviewed journal:

- **Hunyadi, G**. – Bíró, T. – Piskolczi, M. – Tamás, J.: 2008. Termékorientált szennyvíziszap komposztálási technológiák kidolgozása az AKSD Kft. gyakorlatában. *Acta Agraria Debreceniensis*. 30:33–36. ISSN: 1587–1282.
- **Hunyadi, G**. – Bíró, T. – Mézes, L. – Tamás, J.: 2009. A komposzt–homogenitás vizsgálatának új lehetőségei szennyvíziszap alapú komposztprizmák esetében. *Acta Agraria Debreceniensis*. 35:49–52. ISSN: 1587–1282.
- **Hunyadi, G. –** Bíró, T. – Tamás, J. – Mézes, L. – Kosárkó, M.: 2008. Rothasztott szennyvíziszap felhasználásával kialakított komposztrecepturák tápanyagtartalmának vizsgálata. *Talajvédelem*. 395–402. ISSN: 1216–9560.
- **Hunyadi, G.**: 2010. Komposzt keverési–arány meghatározásának módszertani kidolgozása. *Acta Agraria Debreceniensis*. 42:29–33. ISSN: 1587–1282.

- **Hunyadi, G. –** Tamás, J.: 2010. Hőfelvételek és interpolációs eljárások alkalmazhatósága komposztprizmák felszíni hőmérsékletének vizsgálatára. *Acta Agraria Kaposváriensis*. 14.3:293–302.
- **Hunyadi, G**. – Bíró, Gy. – Tamás. J.: 2012. Reflektancia alkalmazhatósága a komposztérettség meghatározására. *Acta Agraria Debreceniensis*. 46:31–36.

Publications in foreign language in international reviewed conference proceedings

- **Hunyadi, G. –** Bíró, T. – Tamás, J. – Mézes, L.: 2008. The effect of C/N ratio and fraction distribution on oxygen–consumption of compost prisms during slaughtered waste composting. [In: Koutev, V. (ed.) Potential for simple technology solutions in organic manure management. 13th RAMIRAN International Conference.] Albena, Bulgaria. 413–416. ISBN: 978–954–9067671–6–3.
- **Hunyadi, G. –** Bíró, T. – Mézes, L. – Tamás, J.: 2009. Changes of temperature and gas–concentration of compost prisms during slaughtered waste composting. [In: Kuntz, A. (ed.). I. International Symposium on Animal Waste Management.] Florianópolis, Santa Catarina State, Brazil. 79–83.
- **Hunyadi, G. –** Tamás, J.: 2010. New methods to analyze the degradation process of composting. [In: Lasaridi, K., Manios, T., Bidlingmaier, W., Abeliotis, K., de Bertoldi, M., Diaz, L., Stentiford, E., I. (ed). 7th ORBIT International Conference. Organic Resources in the Carbon Economy.] Thessaloniki, Greece. 1201–1208. ISBN: 978–960–6865–28–3.

Publications in foreign language in international not reviewed conference-proceedings

- **Hunyadi, G.** – Bíró, T. – Mézes, L. – Tamás, J.: 2008. New methods of compost homogeneity determination in sewage sludge based compost prisms. [In Proc.: IV. World Congress of Agronomists and professional in Agronomy.] Madrid, Spain. 128–132.
- **Hunyadi, G.** – Tamás, J. – Kosárkó, M.:2010. Coherences between the inside and surface temperature in sewage sludge based compost prisms [In Proc: ECSM 2010. 2nd European Conference on Sludge Management.] Budapest, Hungary.1–8.

Publications inHungarian in national not reviewed conference-proceedings

- **Hunyadi, G. –** Bíró, T. – Tamás, J. – Thyll, Sz. – Mézes, L.: 2008. Komposztálási technológiák hatása a szennyvíziszap mikroelem tartalmára. [In: Tóth G. (szerk.). 50. Jubileumi Georgikon Napok.] Keszthely.1–6. ISBN: 978–963–9639–32–4.