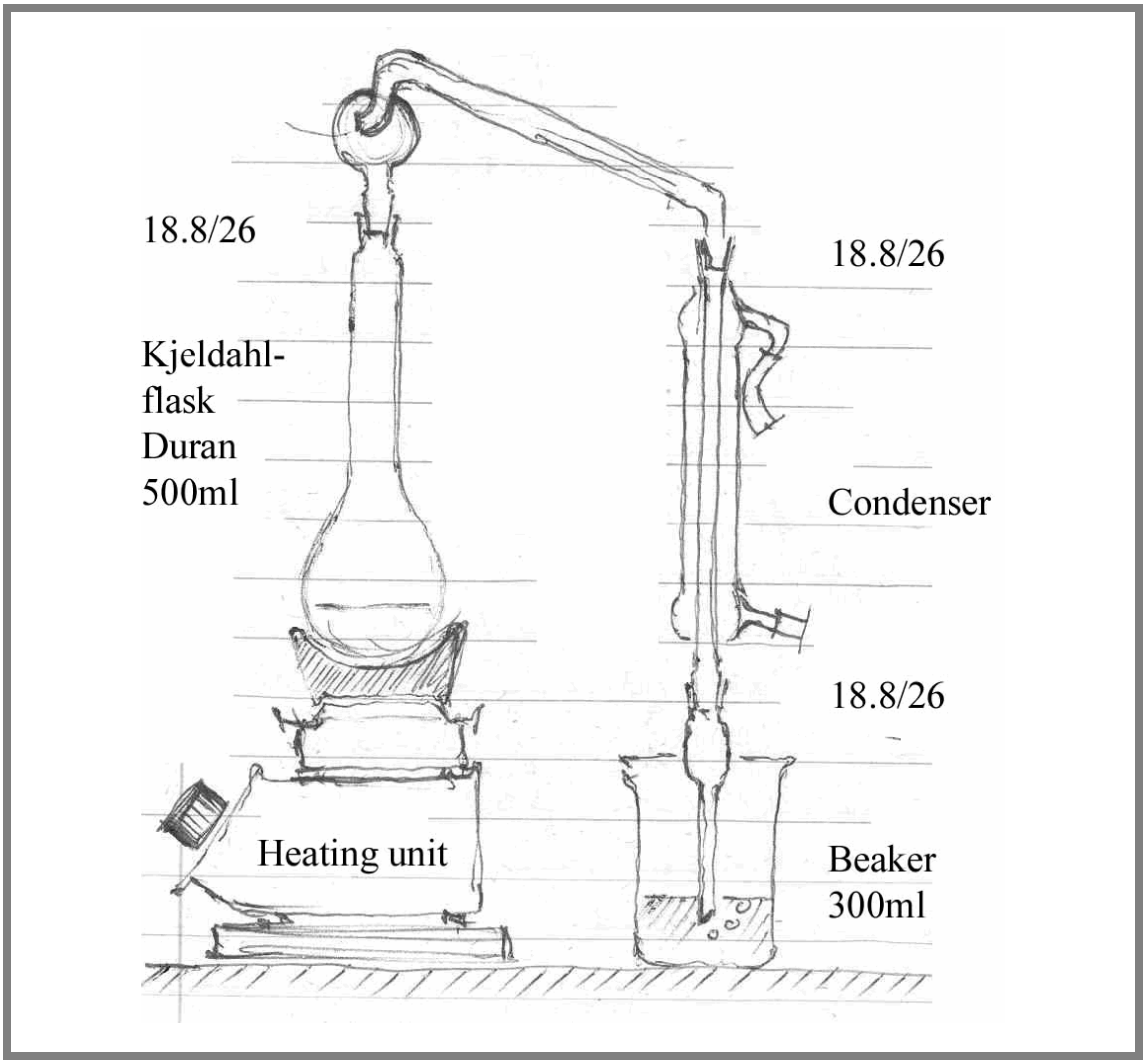
Nitrogen in Co-compost

and other chemical compost analyses

Report of a field study in Kumasi, Ghana, from March to November 2003



Macro Kjeldahl Apparatus used for determination of $NH_{3/4}$ and N_{org}, drawing: Tanner

SANDEC, December 19th 2003

Martin Tanner

1 Introduction

The main topic of this study was research on the methods for chemical analysis on compost and a chemical analytical monitoring of composting processes. Beside chemical analyses a rainwater harvesting system was constructed which is supposed to ensure constant water availability for composting and plant maintenance. Details about the rainwater can be found in the Appendix.

1.1 The project background

The outlines of this project on waste management in Kumasi, Ghana, are given in the report on the first phase of the project by Olufunke Cofie from February 2003 [6]:

"This project on co-composting was developed by the Department of Water & Sanitation in Developing Countries (SANDEC) of the Swiss Federal Institute for Environmental Science and Technology (EAWAG). Collaborating were the International Water Management Institute (IWMI), Kwame Nkrumah University of Science and Technology (KNUST), and the Waste Management Department (WMD) of Kumasi Metropolitan Assembly (KMA).

The Pilot Co-composting Project will provide the vital information for the planning and implementation of the large-scale project at the new landfill site. The KMA plans to utilise the compost in two ways. Some will be sold to farmers to be used as soil conditioner to improve agricultural activities and the rest will be used as cover materials on the landfill. The primary objective of the composting project as far as KMA is concerned is to reduce the quantity of waste to be landfilled thereby increasing the life of the landfill facility.

The overall goal is to gain scientific and technical knowledge on the options of co-composting Solid Waste (SW) and Feacal Sludge (FS) to be used as decision support and for the benefit of municipal authorities and farmers.

The expected output of the pilot project is decision support for municipal authorities on the mode of operation of a co-composting station.

The approach used was to first set up a multidisciplinary team of engineers, agronomist, environmental scientist and biologist from SANDEC, IWMI, KNUST and KMA. This team met together for a roundtable discussion to plan and review project activities. A memorandum of agreement was signed with the municipal authority that later offered a piece of land for the establishment of a pilot co-composting plant at Buobai, Kumasi."

1.2 The co-composting pilot plant

The heart of the co-composting pilot plant consists of a roofed concrete platform of 12 x 19m surface. This platform provides space for 6 compost heaps of $3m^3$ each, space for storing dried feacal sludge and sorting market waste and place for sieving and bagging of the final product. Feacal sludge is dried on two sand filter beds of $25m^2$ each, enabling the drying of $15m^3$ of feacal sludge per drying cycle (initially 30cm depth of feacal sludge). The drying beds are fed via a sludge storage tank where the loads of three sludge trucks, each $5m^3$, are mixed and sampled before loading the sand beds. Percolate gathered with a drainage system under the sand and gravel layers of the drying beds flows into the percolate storage tank where the daily volume is measured and samples are eventually taken. Cofie [6] and Strauss [18] give more detailed descriptions of plant and processes.

1.3 Limitations of earlier studies, low data quality

Many different people and institutions were involved in the chemical and biological analyses so far. Several bachelor and master students as well as people rendering national service were working in the lab of Civil Engineering of KNUST. Most of these people had no or just few lab experience before their commitment for this project. Furthermore earlier reports on the project don't name investigators and lack of detailed descriptions of the methods used. Some analyses, especially all analyses of compost samples, were carried out at the Soil Research Institute in Kumasi. No records or method description of these analyses are given and hence reproduction of these experiments is not possible though would often be desirable. Results of the heavy metal analyses for example indicate too high values and led already to the search of eventual sources of lead in the raw materials (analyses of the well water on site). Expectations of too high lead values came after observations during compost cycle 3 where increasing lead contents by 1 to 2 orders of magnitude were observed. But in the same heaps the copper values dropped about one order of magnitude [6]. These results indicate nothing but severe problems in the analytical procedure. If further investigations are based on such doubtful data, valuable resources are bound which could eventually be invested in goals that are more promising.

1.4 Objectives on chemical Compost characterisation

Three main objectives on chemical analysis were given this study:

1. **Evaluation of chemical analytical methods for compost and establishing of a standard procedure of the analyses**. Compost monitoring should lead to the proposition of a set of chemical parameters for future monitoring and compost characterisation in Kumasi. Standard procedure together with a limited set of parameters should ensure quality of future analyses and make results of different project stages comparable among each other. The proposed analyses should take in account

the possibilities of the civil engineering lab. Standardised methods are supposed to ensure a start of analyses after just a short introduction time even for a person with little lab experience. A minimum quality level of the chemical data should be ensured in order to satisfy the necessities of the project.

2. **Study of the influence of the turning frequency on the chemical properties of co-compost**. Together with the evaluation of chemical parameters a first experiment on the composting performance was carried out. The frequency of the compost turning was varied. This is of interest for a future scale-up since turning frequency influences workload and subsequent manpower required.
3. **Balance of Nitrogen during the sludge drying process**. Beside the performance of composting, nitrogen conservation during sludge drying process was studied. Nitrogen is the most important factor for the fertilising quality of compost. High Nitrogen contents in feacal sludge led to the assumption that addition of dried feacal sludge could improve compost quality.

2 Materials and Methods

2.1 Sludge drying performance

2.1.1 Set-up

In each sludge drying cycle about $15m^3$ of fresh feacal sludge, a mixture of public toilet sludge and sludge from septic tanks (1:2 by volume) were dried on a sand filter bed. The sand filter beds have no roof but can be covered in case of rainfall. Since the start of the project in 2001 these coverings lost a big part of there covering qualities and must be covered themselves with a canvas cover. But in case of heavy rainfall during the raining seasons in June or August/September even this double cover was not able to protect the drying sludge to get wet again. Partially dewatering of sludge with initial TS of about 3% leads to a dried sludge with a TS of >20%. At this stage the sand filter beds are desludged with shovels getting about 1 to 2t of dewatered sludge (DWS). A detailed description of the plant and the facilities for sludge dewatering used in this study can be found in [6].

2.1.2 Sampling and Analysis

Two drying cycles were monitored by chemical analysis. Samples of fresh sludge were taken from the sludge storage tank after mixing the load of 3 trucks, equal a total of about $15m^3$. Samples of the percolate were taken from the percolate tank together with the daily measurement of the percolate volume. After desludging of the drying beds, the dewatered sludge (DWS) was stored under the shade roof of the composting plant. As soon as enough market waste (MW) was brought to the composting site by KMA and sorted by the two workers, the MW was mixed with DWS and the composting process started. Sampling and chemical characterisation of the DWS was done just before forming the compost heaps. The following parameters of fresh FS, Percolate and DWS were analysed: Volume/mass, TS, NH_4-N and N_{org}.

2.2 Composting performance

2.2.1 Experimental set-up

For every composting cycle, two heaps of compost were formed. Each of the heaps consisted of $2m^3$ of Market waste (MW) mixed with $1m^3$ of dried sludge (DWS). Both of these raw materials were weighed before forming the heaps and a wooden box of $1m^3$ was used in order to control the volume. The resulting heaps were of $3m^3$ volume and about 1.5t weight each. The composting cycles monitored in this study were numbered 5 and 6 resuming previous cycles of the same project which are described in [6].

The two heaps of every cycle were turned with two different frequencies. Heap1 was turned according to temperature. This means turning about twice a week during the first four or five weeks and about once a week until the end of the thermophilic phase after 8 weeks. Heap2 was turned every 10 days.

2.2.2 Sampling and Analysis

Samples were taken with every turning and the following chemical parameters were measured: TS, TVS, pH, EC, NH_3-N, N_{org}, NO_3-N.

2.3 Analytical Methods

2.3.1 Total Solids (TS)

The amount of Solids was determined by drying samples at 105°C for 24h [13]. Samples with low TS, like untreated feacal sludge, were first dried on a water bath in a fume hut in order to minimize smell in the laboratory.

2.3.2 Total Volatile Solids (TVS), Total organic Carbon (TOC), Sand

The amount of the volatile solids was determined by ignition of dried sample at 550°C for 3h [13].

2.3.2.1 Relation between TVS and TOC?

Barnal give in [5] the values for TVS and TOC of 28 different compost samples at different degradation stages. For 16 of the samples sewage sludge was one of the raw material. The relation TOC.TVS varies from 0.49 to 0.58 with an average of 0.53.

Zorpas e.a. give 9 values of TOC and Organic Matter for different raw materials and mature compost. All of the samples contained sewage sludge as raw material in different amounts. The relation TOC.TVS varies between 0.52 and 0.58 with an average of 0.57.

The California Compost Quality Council [1] mentions the possibility to estimate the amount of TOC from TVS data with a factor between 0.5 and 0.58.

The Verband Kompostwerke Schweiz (VKS) mentions a factor of 0.58 in its guidelines and the Methodenbuch zur Analyse von Kompost of the Bundesgütegemeinschaft Kompost e.V., Köln [13] gives the same value of 0.58.

2.3.2.2 Difficulties in the determination of TVS

The main difficulty in getting reproducible results of the TVS was a generally high sand content in the compost which influenced the TS results and therefore the TVS results too. The sand content was estimated after washing the ashes of the TVS measurement through a filter with mesh number of 80. 25 samples of compost at different maturation stages showed sand contents of 5 to 51%TS with an average of 37%TS. This uncertain sand "background" has an influence on all measurements since the samples were taken by weight. The high sand content is also reflected in a generally low TVS. In cycle 6 the compost showed an average of 40%TVS compared to 66% average of the Bernal data. High sand content is typical and unique for this compost due to the sludge treatment on drying beds of sand. This makes comparisons with literature data for TVS difficult.

2.3.3 Total organic Carbon (TOC)

Samples of heap2 of cycle 6 and samples of the final products of cycle 5 and 6 were brought to Switzerland, ground and analysed with an auto analyser: Nitrogen Analyzer 1500 of Carlo Erba Strumentazione. This apparatus is meant to analyse Nitrogen, Carbon and Sulphur but just the carbon analyses gave reliable results.

2.3.4 Conductivity (EC) and pH

Electrical Conductivity (EC) and pH of dried feacal sludge and compost were determined in a blended 1:10 extract (w/w) [17]. pH of fresh feacal sludge was determined by direct measurement in solution.

2.3.5 Ammonium (NH_4)

Ammonium was determined by distillation according to Standard Methods [7]. 2ml of feacal sludge and 10ml of percolate of the sludge drying process respectively were analysed without pre-treatment. Compost was extracted with distilled water (1:10 by weight) and 30ml of this extract were used for analysis.

2.3.6 Organic Nitrogen (N_{org}) and Total Kjeldahl Nitrogen (TKN)

Residues of the Ammonia determination of feacal sludge and percolate were analysed according to Standard Methods after digestion in sulphuric acid [7]. 3ml of the compost extract were digested without Ammonia distillation first, giving the amount of Total Kjeldahl Nitrogen (TKN). The amount of N_{org} was then calculated by subtracting the Ammonia from the TKN value.

Bremner writes in the chapter about Kjeldahl Nitrogen in Methods of soil analysis [16] that high concentration of K_2SO_4 in the digestion solution has the complication that the digest is likely to solidify on cooling. They suggest that a ratio of less than 0.8g K_2SO_4 / ml H_2SO_4 should be used to avoid this. Therefore the digestion solution as it is described in Standard Methods 134g K_2SO_4 + 134ml H_2SO_4 per litre H_2O_{dest} was changed to 100g K_2SO_4 + 135ml H_2SO_4 per litre H_2O_{dest}.

2.3.7 Nitrate (NO_3)

2.3.7.1 Methods for nitrate determination in compost

The nitrate content in the samples was determined by measurement of the UV absorption at 220nm of a 1:500 extract (w/v) with a CECIL CE 1021 UV photo-spectrometer and Plastibrand UV cuvettes of 1.5ml content. No method for direct nitrate determination by UV measurement in compost extract is described in literature. The method for determining nitrate in water and wastewater described in [7] was adapted to the specific needs of composts analyses. Interference due to the colour of the extract and suspended solids was minimised by acidification and consequent centrifugation. Advantage of the method is the low needs concerning chemicals and equipment (HCl, centrifuge and UV-spec.) and that a decolourising step with active carbon can be avoided. Active carbon could eventually adsorb nitrate and though effect the results. Presence of Chloride is not interfering with NO_3, therefore HCl can be used for decolourising.

Optical methods based on colour developing reactions and subsequent absorption measurements are often used. A basic disadvantage of all of these methods is their sensitivity to sample colour and ions, especially chloride, effecting the chemical colour reaction. Another disadvantage is chemical consumption with subsequent disposal of eventually hazardous waste like cadmium compounds.

Fast test kits like the ones of Merck or Hach need specific chemicals and equipment which are often not available on local markets in developing countries or lead to waste generation.

2.3.7.2 Basic information on the proposed UV-Spectrophotometric method

2.3.7.2.1 The law of Beer Lambert

The Beer-Lambert law states that the amount of light absorbed is proportional to the number of molecules of absorbing substance in the light path; i.e. absorption is proportional both to the concentration of the chromogen in solution and to the length of the light path through the solution. This relationship can be expressed as follows:

$$-\log_{10}\frac{I}{I_0} = K \cdot conc \cdot l$$

I, I_0 Intensity of transmitted light in the presence and absence of the chromogen, respectively

conc	Concentration of the chromogen.
l	Length of the light path through the solution.
K	Constant, characteristic for an absorbing substance at a specific wavelength of light and in a specified solvent

The ratio I/I_0 is called the light transmission and in usually measured in percent. The absorbancy (Abs) is the quantity more frequently used, and is given by

$$Abs = -\log_{10} \frac{I}{I_0}$$

On substitution of this definition into the Beer-Lambert law follows

$$Abs = K \cdot conc \cdot l$$

In this form the Beer-Lambert law states that doubling of either the concentration of the absorbing substance or doubling of the depth of solution leads to a doubling of the absorbancy (Abs) [24]. And therefore a calibration curve of (Abs) against (conc) for a given chromogen gives a constant slope (sensitivity) equal $(K \cdot l)$.

2.3.7.2.2 Sample preparation, reducing colour of the compost extract

Photometric analyses are sensitive to unspecific interference due to light scattering of particles or light absorption of compounds others than the analysed chromogen. Extracts of compost show generally a brown colour of different intensity, which decreases during compost maturation. By applying of the proposed method for sample preparation for photometric nitrate measurement in Standard Methods [7] a significant reduction in colour intensity was observed after acidifying the samples. Consequent centrifuging led to almost decolourised solutions with compact pellets. This observation can be explained by the solubility of organic acids, like humic acids, which are partly responsible for the extract colour. The solubility of organic acids decreases with decreasing pH. Therefore colouring agents tend to fall out of solution after adding a strong acid like HCl.

Sample preparation and standard addition for internal calibration are described in Figure 1.

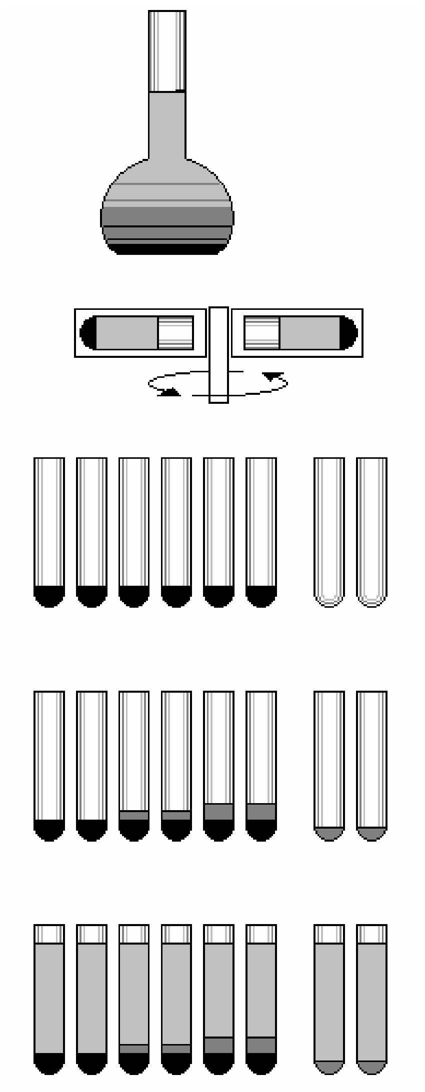
	1. Acidifying, first dilution 2ml HCl 1M is given to 10ml of blended extract and the mixture is made up to 100ml with H2Odist (dil=1:10).
	2. centrifuging About 40ml of acidified extract is centrifuged at 800G for 10min.
	3. Preparation of test tubes: 5ml of acidified and centrifuged extract were given into 6 of 8 test tubes. 2 test tubes were left empty for tests of analytical quality.
	4. Addition of standard: 0, 1 and 2 ml of Nitrate standard (50mg NO3-N/l) were added to the sample tubes (each in duplicate) and 2ml were added to the quality test tubes.
	5. Second dilution: All test tubes were made up to a total volume of 25ml with HCl (0.02N).

Figure 1: Preparation of samples for Nitrate measurement.

2.3.7.2.3 The cuvettes

Measurements in the UV range need special cuvettes since glass is not transparent in the far UV range (see Figure 2). Usually quartz cuvettes are used for measurements in the UV range, but they are fragile and expensive. As an alternative PMMA cuvettes are transparent in the UV as well. In the presented work disposable Plastibrand cuvettes with 10mm light path were used. Disposable cuvettes can be used several times if handled with care (avoiding scratches) and if the results are checked frequently (measurement of standards). Figure 3 show the absorption spectrum of a Plastibrand cuvette with the range of used wavelengths highlighted.

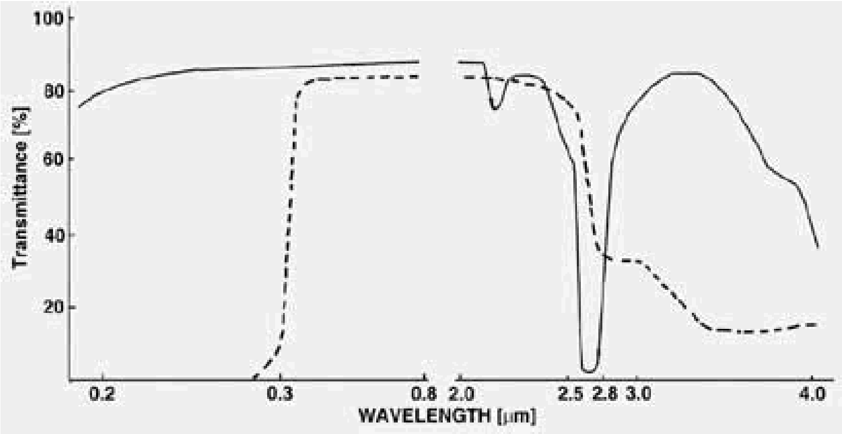


Figure 2: Transmission spectrum of glass from 190nm to 4mm (dotted line) and synthetic quartz (line) cuvettes.

Source [23]

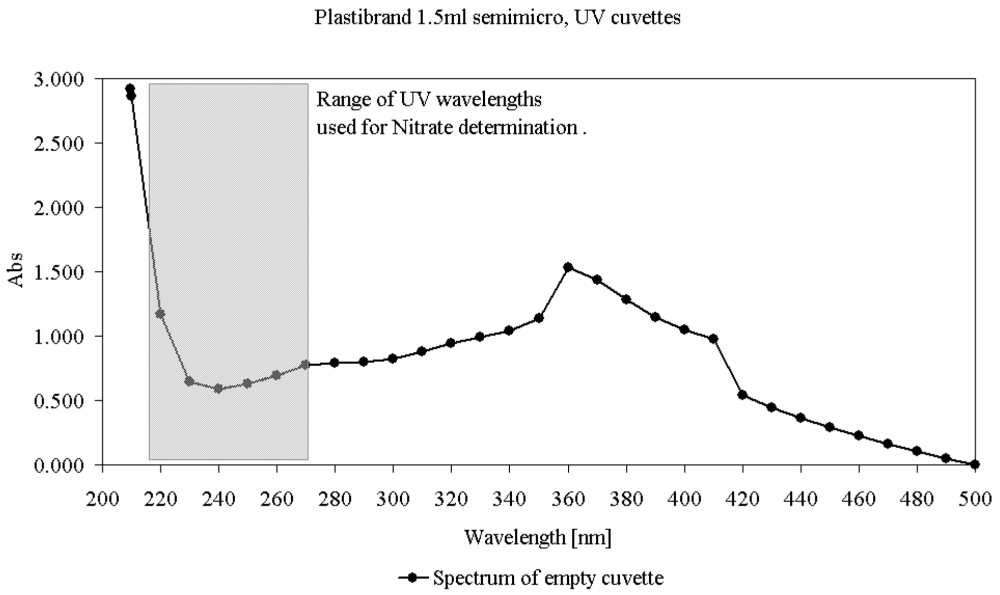


Figure 3: Absorbancy spectrum of an empty Plastibrand UV cuvette.

2.3.7.3 The wavelength

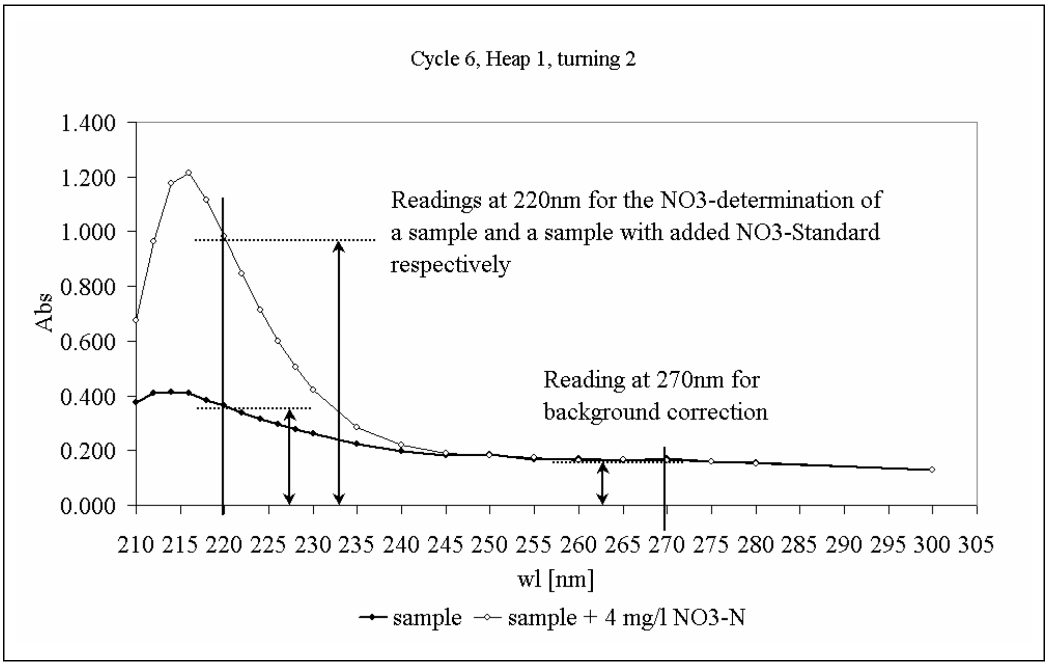


Figure 4: Absorption band of the nitrate ion. Spectrum measured of a compost sample with and without addition of a nitrate standard. Indicated are the wavelengths used for the nitrate determination in compost.

Figure 4 shows the absorption spectrum of a compost sample with and without addition of nitrate standard. Indicated are the wavelengths used for nitrate determination (220nm) and for background determination (270nm). Hoather mentions in [12] an absorption maximum of the nitrate ion at 193.6nm. The peak, observed with the Plastibrand cuvette, shows a maximum at about 215nm. This means that the observed decrease of absorbancy between 215 and 210nm is not an expression of a decrease of the nitrate absorbancy but is an artefact of the limited transparency of the cuvette, see Figure 3. Hoather e.a. [12] and Navone [15] used the absorption at 210nm for nitrate measurement. Goldmann e.a. [11] measured nitrate at 220nm which is the wavelength proposed in Standard Methods [7].

In this study the reading at 220nm was used for nitrate determination together with a background correction reading at 270nm.

2.3.7.4 Sensitivity

Organic compounds can influence the sensitivity of the Absorption of Nitrate in solution. Therefor internal standardisation was used for calibration. The complete procedure of sample preparation is described in Figure 1. The 22 nitrate determinations of cycle 6 showed an average sensitivity of 0.159 ± 0.010 (mg NO_3-N /l extract)$^{-1}$. Measuring of Nitrate without internal standardisation and using 0.159 as sensitivity instead would lead to an error of 6%.

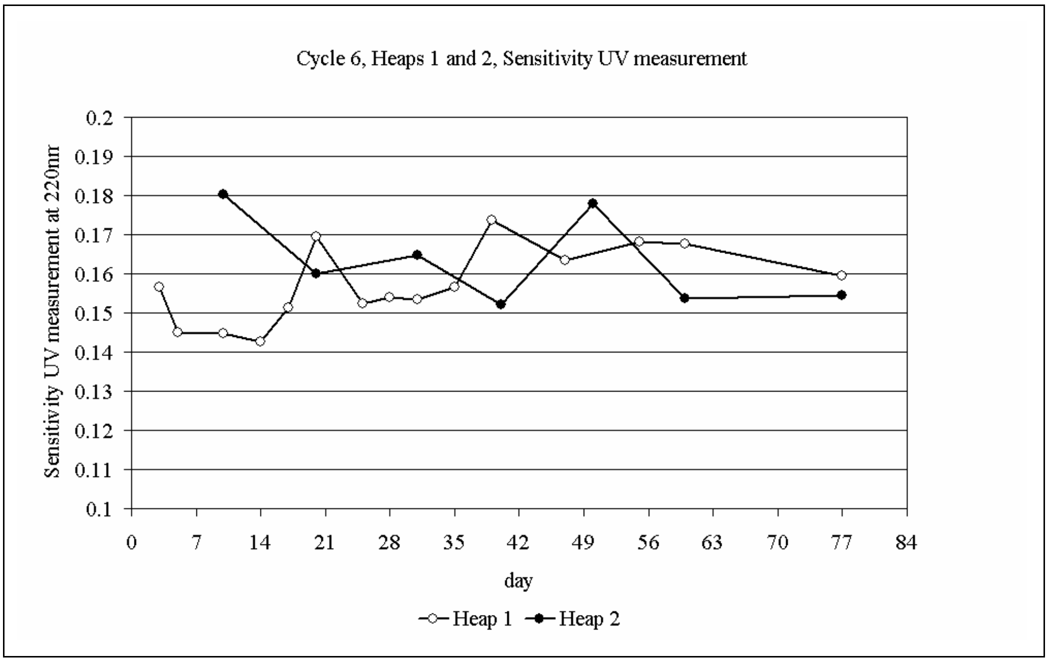


Figure 5: Sensitivity of UV measurement at 220nm for cycle 6, Heaps 1 and 2

2.3.7.5 Background correction

According to Standard Methods [7] an error due to an eventual background of the signal, caused for example by organic compounds, could be corrected by subtracting twice the reading at 275nm from the reading of 220nm, Goldman e.a. mention a factor of 2.5 for the same correction [11] and Hoather e.a. give in [12] a factor of 4 for correcting the reading at 210nm with the reading at 275nm. These suggestions are meant for samples with low reading at 275nm (less than 10% of the 220/210nm readings) and the factors of 2, 2.5 and 4 respectively are not justified in these references but given as empirical values.

The centrifuged compost extracts analysed in this study showed background readings at 275nm, which were generally much higher than the suggested maximum of 10% of the readings at 220nm. In some cases the use of a correction factor of 2 would already lead to negative results, which is not reasonable and therefore none of the suggested correction procedures could be used. Instead a correction factor of 1 was used and is justified as follows:

Since the signal of the sample and the sample with added standard are almost horizontal in the range of 250 to 280nm (Figure 4) we assumed a constant background in the range from 210nm to 280nm. If this was true, measuring with standard addition at three different wavelengths (values corrected by the reading at 270nm) should lead to the same result for all measurements. This was found for several compost samples with different background levels. One example is given in Figure 6.

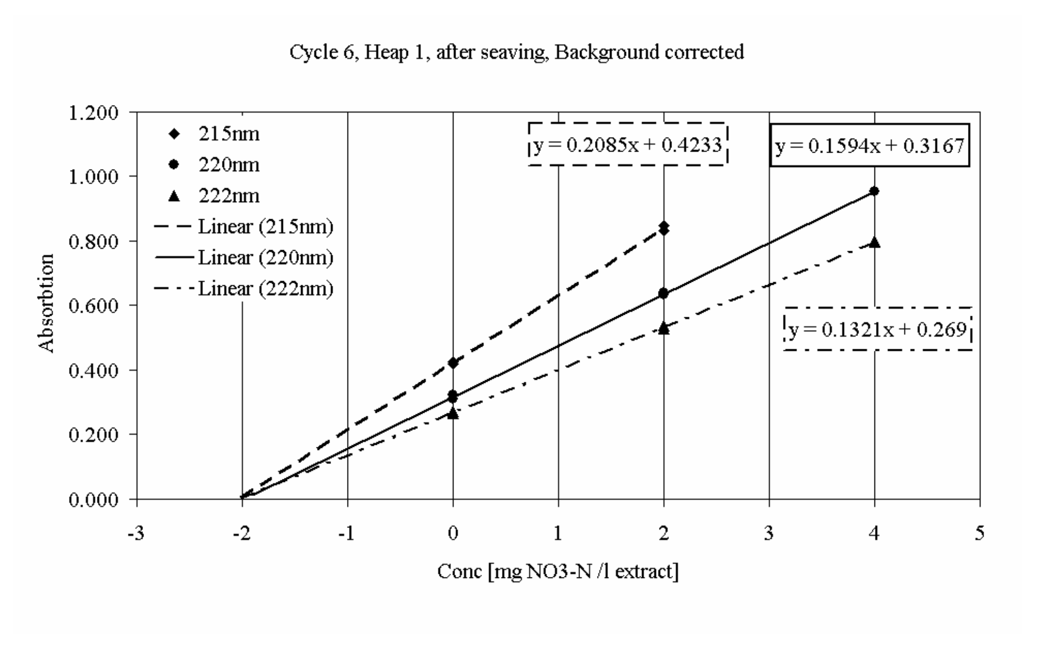


Figure 6: Standard addition and UV measurement at three different wavelengths. After subtracting of background.

The background values of cycle 2, heap 2 (Figure 7), are ranging from 0.058 to 0.163. This corresponds to corrections for the nitrate concentrations in the compost of 0.4 to 1g/kgTS. These values are in the range of the finally reported results and would completely cover changes in nitrate concentration. But the nitrate changes found, showing continuous development with time (Figure 23), correspond well to the behaviour described in [17]. This is a second indication for a correct background treatment.

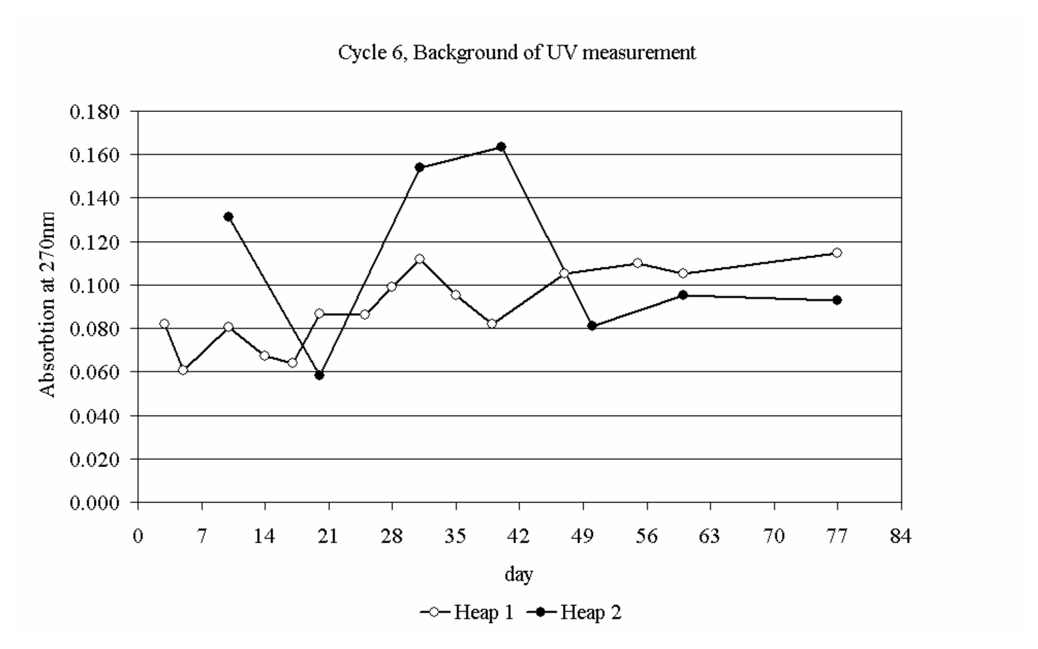


Figure 7: Background of UV measurement of cycle 6 measured in 1:500 diluted compost extracts.

The 22 nitrate determinations of cycle 6 showed an average absorption at 270nm of 0.097 ± 0.027. Further experiments could be done in order to increase reliability of the nitrate measurements: Reduction of nitrate in the extract with Zn/Cu to determine background values [15] [2], Measurement with Nitrate electrode for comparison of absolute value [7].

3 Results and Discussion

3.1 Mass balance of the sludge drying process

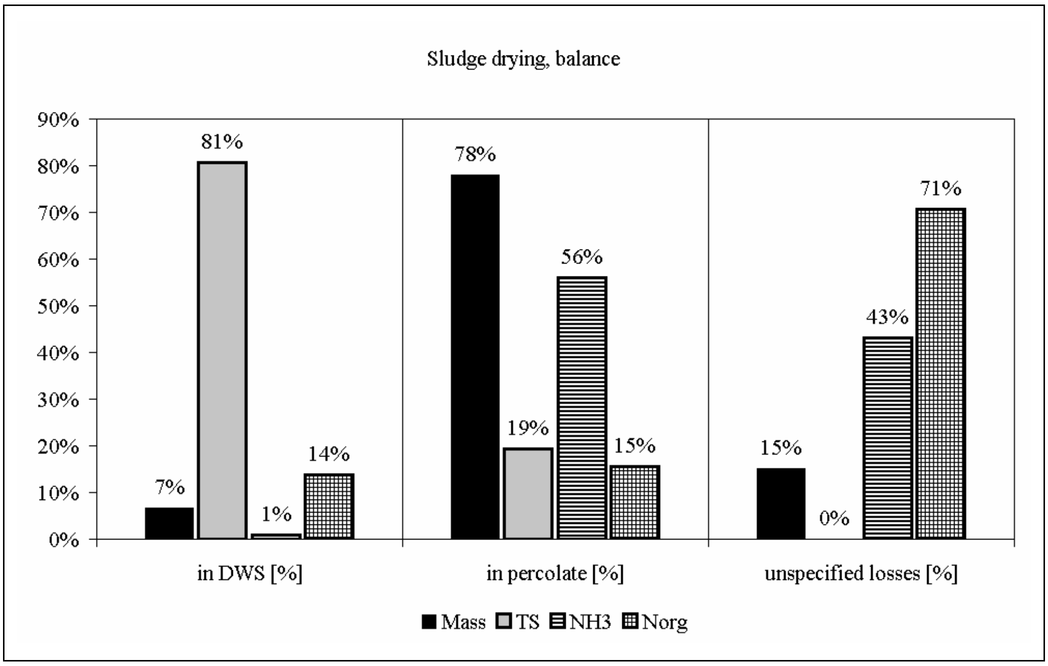


Figure 8: Balance of the components of feacal sludge found in percolate and in the dewatered sludge for composting cycle 5. (Values are mean of two cycles)

The two sludge drying cycles monitored in this study were not effected by rainfall. Therefore feacal sludge can be estimated as the only source of the measured percolate val.

The water content mainly causes the mass of fresh feacal sludge and percolate. Since the two monitored drying cycles were done in a period with no or almost no rainfall, we can interpret the findings in Figure 8 as follows: The liquid part of the fresh sludge mainly go to the percolate (78%) and evaporation is less important for the drying process (15%).

Feacal sludge has a TS of about 3%, Percolate about 0.7% and the dried sludge of this monitoring about 54%. It is difficult to establish a balance for the TS of the drying process. Critical is the fact that the filter material of the drying beds (sand) mixes partly with the loaded liquid sludge. After desludging parts of the sludge remain in the sand layer and parts of the sand are removed with the dewatered sludge. As a first assumption the loss of initial TS brought in by the feacal sludge was set to zero. The relation between initial TS found in the DWS and the percolate was then calculated as about 4:1 (81%:19%). The effective TS found in DWS was about 40% higher than expected out of the difference between initial TS in fresh sludge and TS found in percolate. This gain in TS can be related to the sand brought in during desludging.

The high water-solubility of Ammonia is represented in the data where we find 56% of initial Ammonia washed out with the percolate. In the final product, the DWS, we found just about 1% of initial Ammonia. The difference of 43% can be related to evaporation.

High incertitude is in the quantities of organic nitrogen. About 15% of initial organic nitrogen was found in the percolate. This would well correspond to the TS found in the percolate (19%) assuming that the organic nitrogen is mainly present in the solid parts of the sludge. But the amount of organic nitrogen in the DWS is much lower than expected (14%), leaving 71% unexplained. Parts of this nitrogen have to be searched for in the sand bed (not analysed). The analysis of the organic nitrogen in the percolate was always done with just 10ml of sample (TS: 0.7%=> sample dry weight about 0.07g) which means that the incertitude in this balance may be caused by analytical incertitude.

This study indicate that most of the high potential of feacal sludge as a nitrogen source for co-composting is lost during the drying process. A mass balance of the sludge drying process is given in Table 1.

	mass	TS	NH_3-N	N_{org}
	[kg]	[kg]	[kg]	[kg]
Fresh sludge	**32170**	**865**	**70**	**26**
Air	*4800*	*0*	*30*	*0*
Dewatered Sludge	*2200*	*650*	**0.5**	**3**
Sand layer	*?*	*?*	*<0.5*	*?*
Percolate	**25120**	**168**	**39**	**4**

bold: measured values, *italic: estimated values*

Table 1: Balance of different parameters during sludge drying process.

3.2 Composting

3.2.1 Temperature

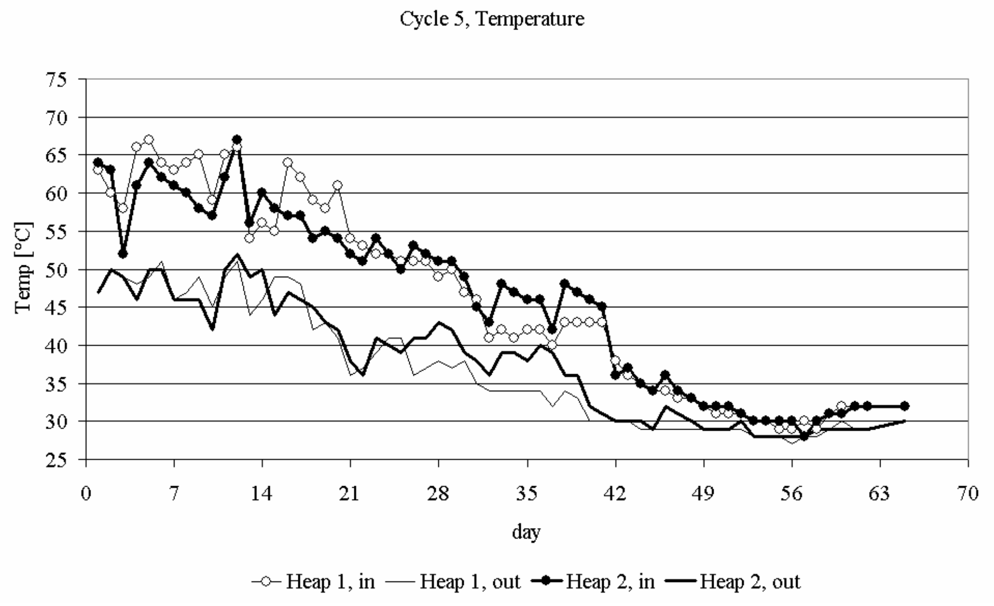


Figure 9: Temperature development in the compost heaps of cycle 5

Figure 9 show the development of the two compost heaps of cycle 5. As expected, the internal temperature of the heaps is always higher than the outside temperature. After the thermophilic phase (8 weeks) the inside and the outside temperatures confirm to the ambient temperature. The two different treatments of the heaps are not reflected in the temperature. During the 8 first weeks differences between the daily inside temperatures show an average value 0.04°C.

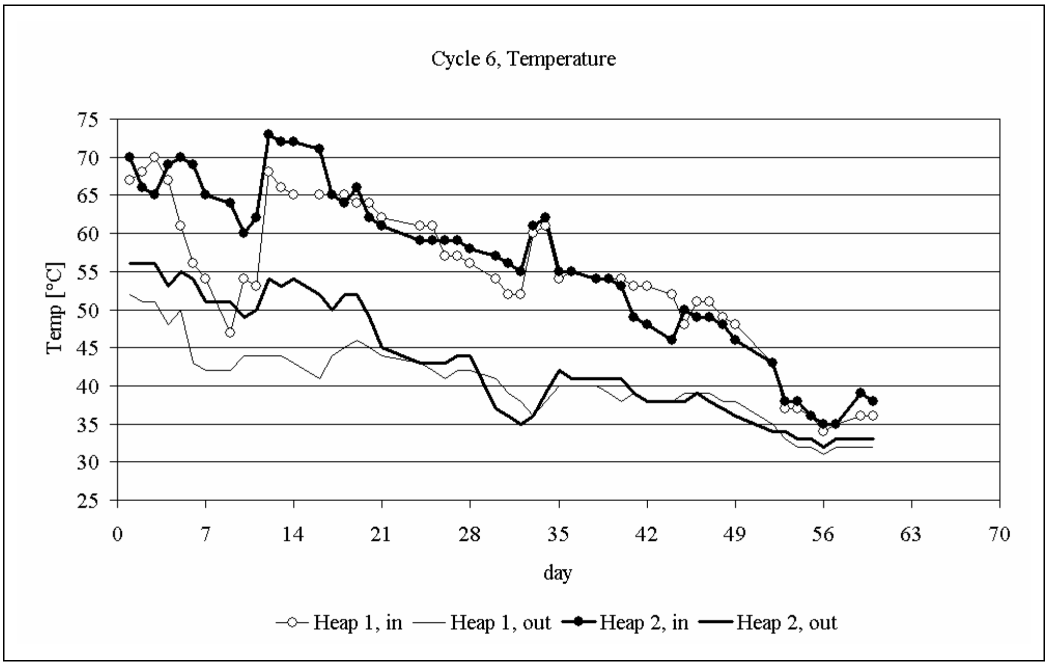


Figure 10: Temperature development in the compost heaps of cycle 6

Figure 10 show the development of the two compost heaps of cycle 6. The internal temperature of the heaps was always higher than the outside temperature. After 8 weeks the inside temperatures were still slightly elevated compared to the outside temperatures. Remarkable was the drop in inside temperature of heap 1 during the first 9 days. It is an indication for a temporary low microbial activity. This behaviour is unique within the four monitored heaps and can't be related to other measured parameters in heap 1. After two weeks, the temperature of heap 1 rose again to over 65°C and after that the two heaps showed no more different temperature development. During the first 8 weeks differences between the daily inside temperatures show an average value of 0.9°C.

The general trend in temperature development, a continuous decrease over 2 to 3 months from initially about 70°C to ambient temperature, corresponds well with data in literature. An example of Tiquia is given in [19]. But more replicates of composting are necessary in order to establish relationships between temperature development and chemical parameters as Tiquia did there.

3.2.1.1 Influences of the turning frequency?

0.4 and 0.9°C difference between heap 1 and 2 of the co-composting cycle 5 and 6 indicate that the turning frequencies have no or just marginal effect on the temperature development during co-composting. In contrast, differences in the raw material and/or environmental conditions seem to have an effect on the temperature development. The mean value of two heaps of the daily inside temperatures show a higher value of 8°C for cycle 6 compared to cycle 5 during the first 8 weeks of composting.

3.2.2 TS

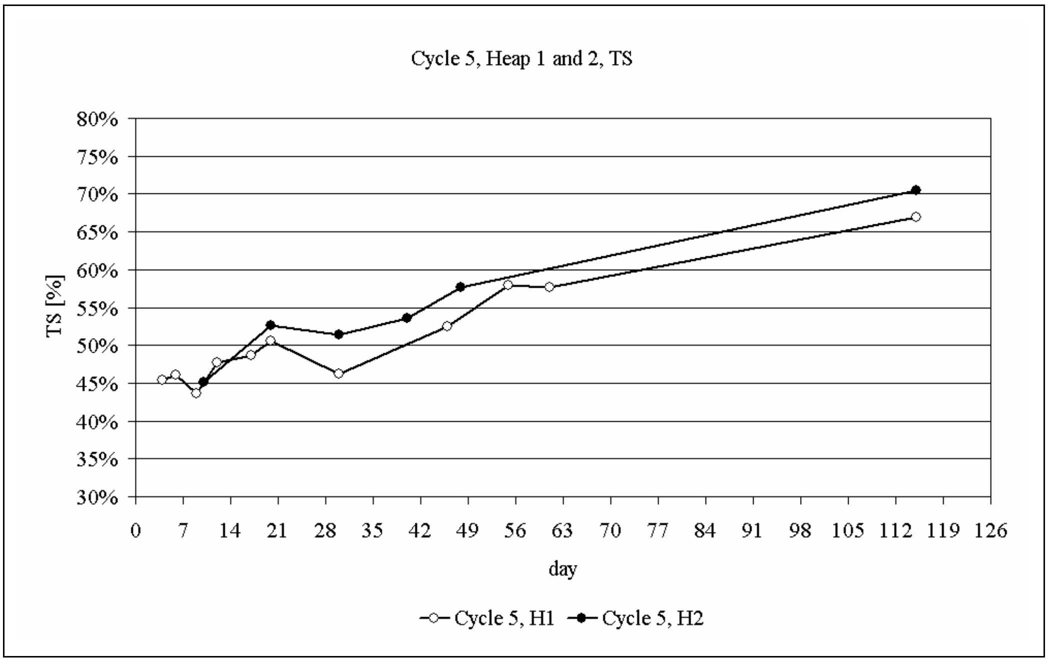


Figure 11: The development of the TS in the two heaps of cycle 5.

The data given in Figure 11 show an average TS in thermophilic phase, until the end of week 8, of 50%. During the maturation phase the heaps were not turned any more nor watered which is visible in the data. TS of heap 2 increased up to 70% in week 17.

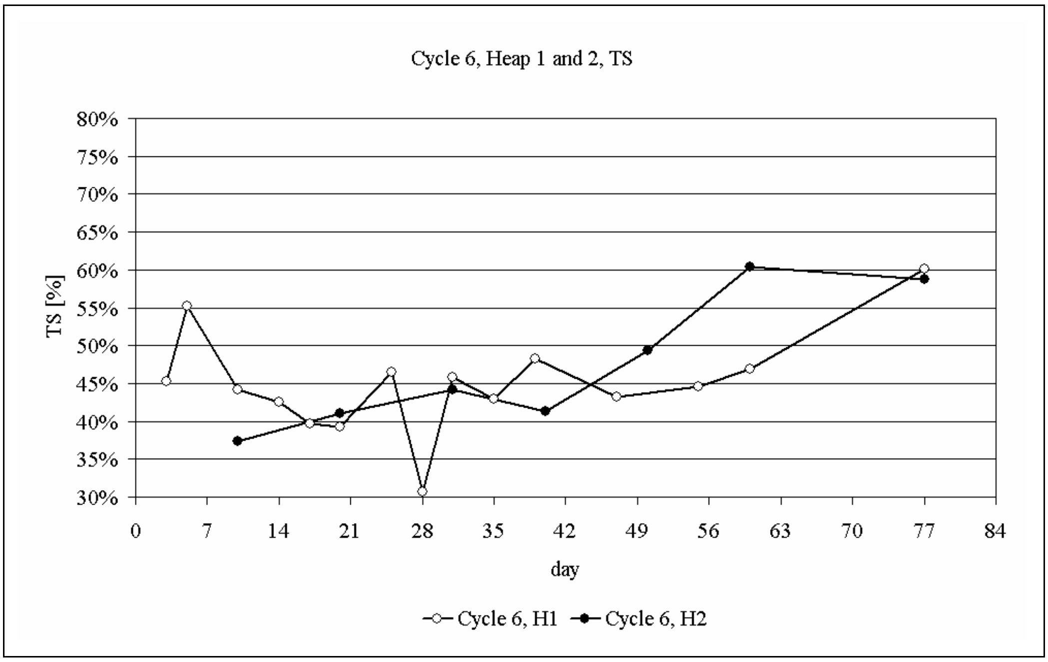


Figure 12: The development of the TS in the two heaps of cycle 6.

The data given in Figure 12 show an average TS of 43% in thermophilic phase, until the end of week 8. The final product shows a TS value of 60%.

High moisture content of over 50% would result in high biological activity [14] but very high moisture content over 70% also inhibits aeration of the compost heaps or leads to leaking of water [21].

Compared with these recommendations cycle 5 has to be qualified as being quite dry already during thermophilic phase and certainly too dry during maturation phase. The moisture content of both heaps of cycle 6 was good for the thermophilic phase but also too low for the maturation phase. This means that the conditions were not ideal for biological activity during cycle 5 and the maturation phase of cycle 6.

3.2.2.1 Influence of the turning frequency?

In order to check on a possible influence of the turning frequency on the TS value it is necessary to be able to ensure constant moisture conditions. After that measuring of the water consumption of the different heaps could answer the question whether evaporation is increased due to a higher turning frequency.

3.2.3 TVS, TOC, Sand

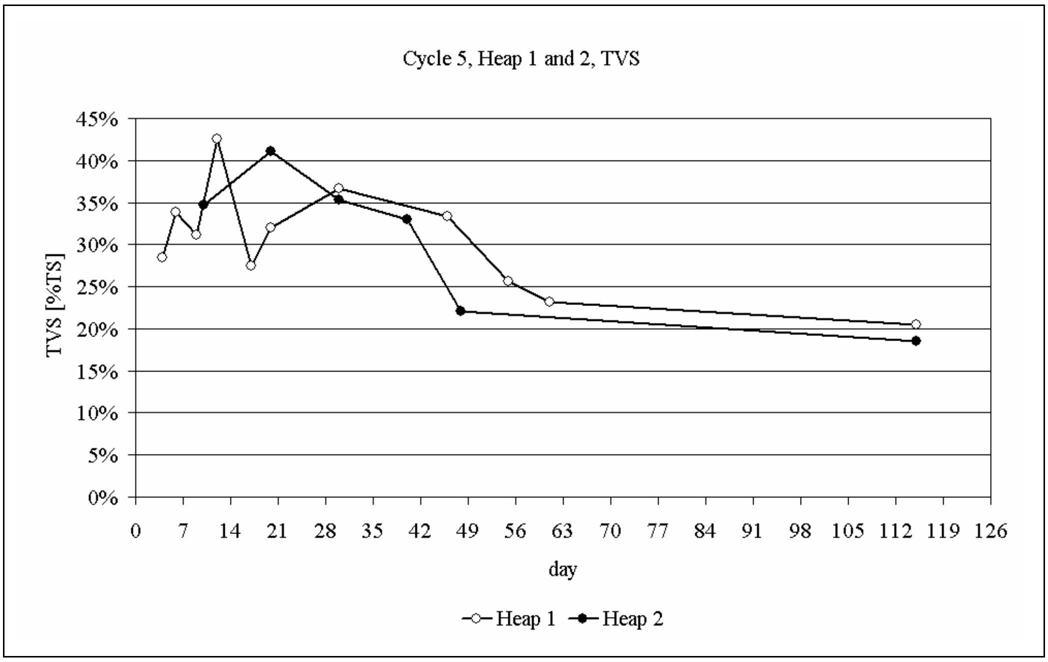


Figure 13: The development of the TVS in the two heaps of cycle 5.

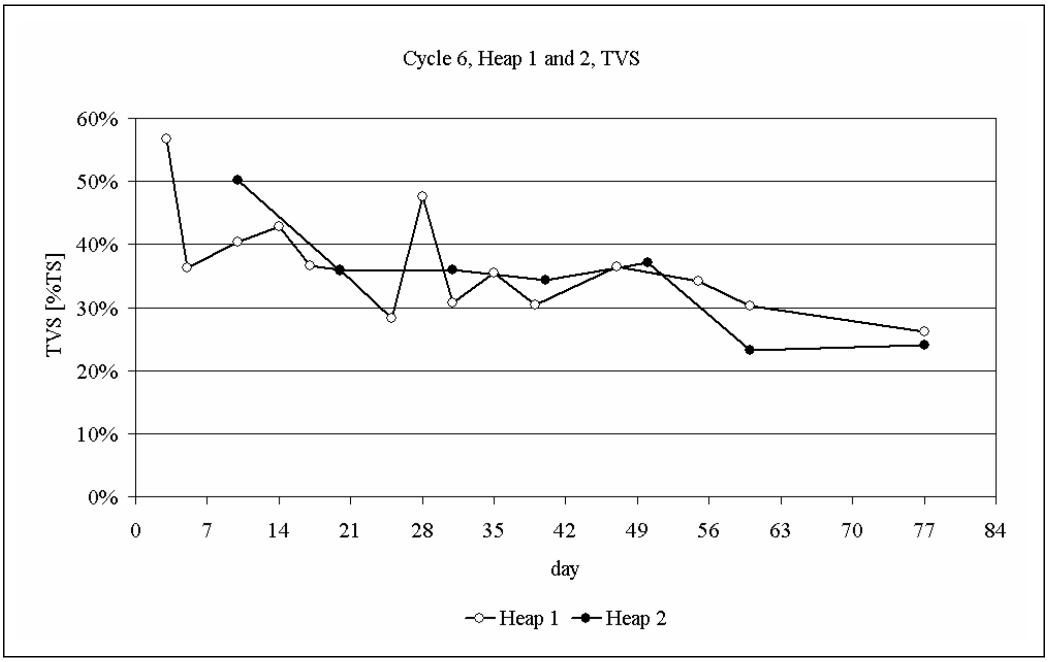


Figure 14: The development of the TVS in the two heaps of cycle 6.

Figure 13 and Figure 14 show the development of the Total Volatile Solids (TVS) with maturation time of the compost during cycles 5 and 6. Taking in account uncertainties due to difficult representative sampling, the heaps of cycle 5 show a fall of TVS from about initial 40%TS to final 20%TS. The TVS of the raw materials of cycle 6 show slightly higher values, about 50%TS, compared to cycle 5. At the end of the composting the values reach about 25%TS. The relative loss in all 4 heaps is about 50% of initial organic material.

Bernal e.a. [5] give values of Organic Matter (OM) for 7 different composts made of sewage sludge, poultry manure, pig slurry, cotton waste, olive-mill wastewater sweet sorghum bagasse and maize straw in different mixing ratios. The amount of OM was determined by measuring the loss on ignition at 430°C for 24h. These mixtures showed an average of 79%TS initial OM. After loosing 27% they reached an average of 57%TS OM.

The composts of this study showed much lower initial and final TVS values compared with the ones described by Bernal. This can be explained by the high sand content of our compost (30-40%) which lowers relative the loss on ignition.

3.2.3.1 TOC

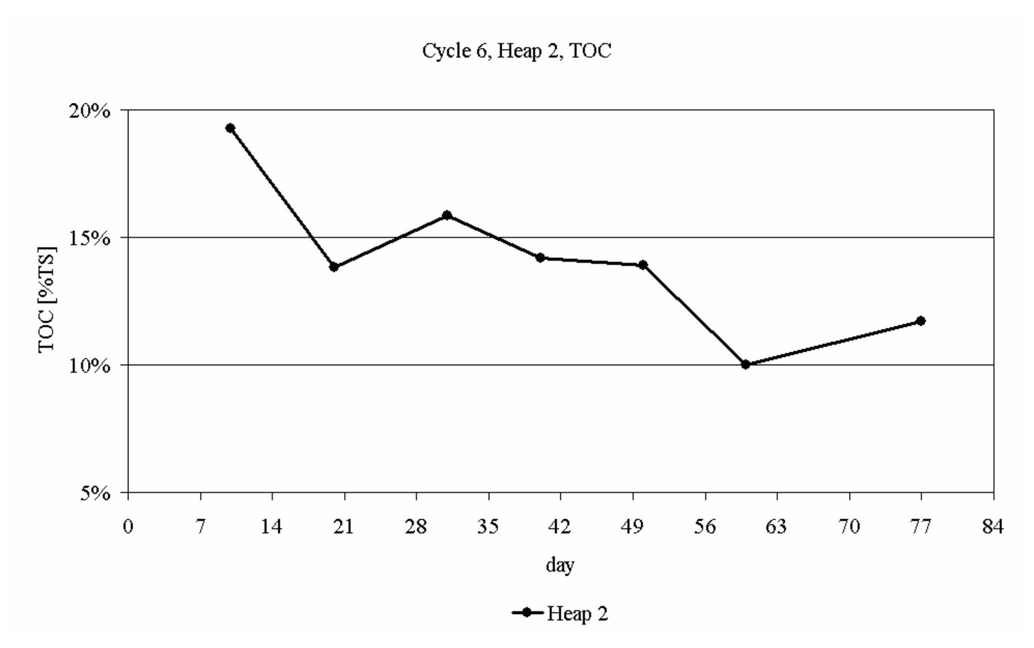
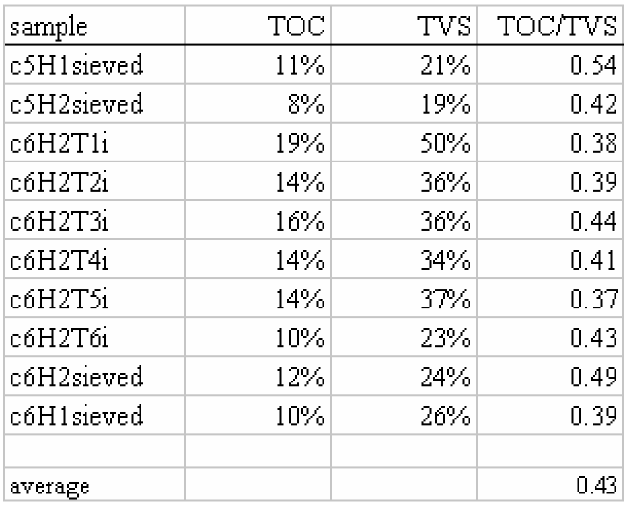


Figure 15: TOC values of Heap 2 of cycle 6, analysed with a CNS analyser.

The values for TOC found with the CNS analyser are given in Figure 15. They show a trend like it is expected in comparison with data in literature. In Table 2 TOC values are compared with TVS values. The TOC/TVS values show an average of 0.43. This is lower than the values given in literature but the variation between the values are small. May be these values indicate a characteristic difference of Kumasi co-compost to the composts described in literature or they are low due to analytical incertitude either for the TVS or the TOC determination. Either way the constancy of the values indicates that a TOC/TVS ratio can be used to give at least a qualitative description of the compost.



sample	TOC	TVS	TOC/TVS
c5H1sieved	11%	21%	0.54
c5H2sieved	8%	19%	0.42
c6H2T1i	19%	50%	0.38
c6H2T2i	14%	36%	0.39
c6H2T3i	16%	36%	0.44
c6H2T4i	14%	34%	0.41
c6H2T5i	14%	37%	0.37
c6H2T6i	10%	23%	0.43
c6H2sieved	12%	24%	0.49
c6H1sieved	10%	26%	0.39
average			0.43

Table 2: TOC values from CNS analyser and TVS values from loss on ignition at 550°C. Comparison between 10 different samples.

3.2.3.2 Influence of the turning frequency?

There is too much incertitude within the data in order to state whether there is or is no difference between the two observed of the turning frequencies on the degradation of organic matter.

3.2.4 pH and Conductivity

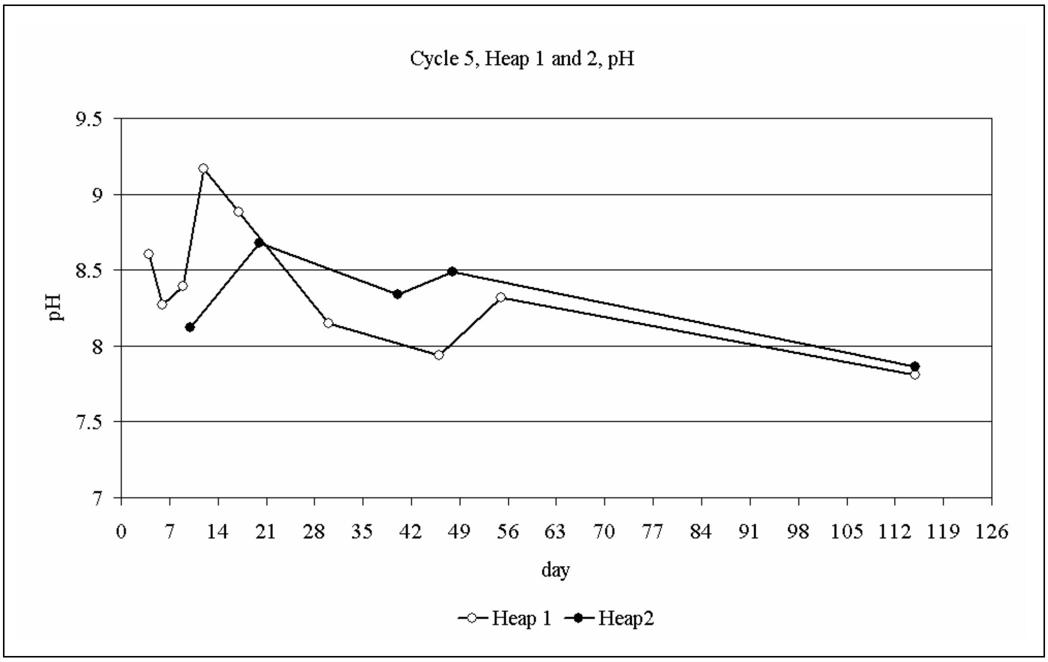


Figure 16: Changes in pH during co-composting of cycle 5.

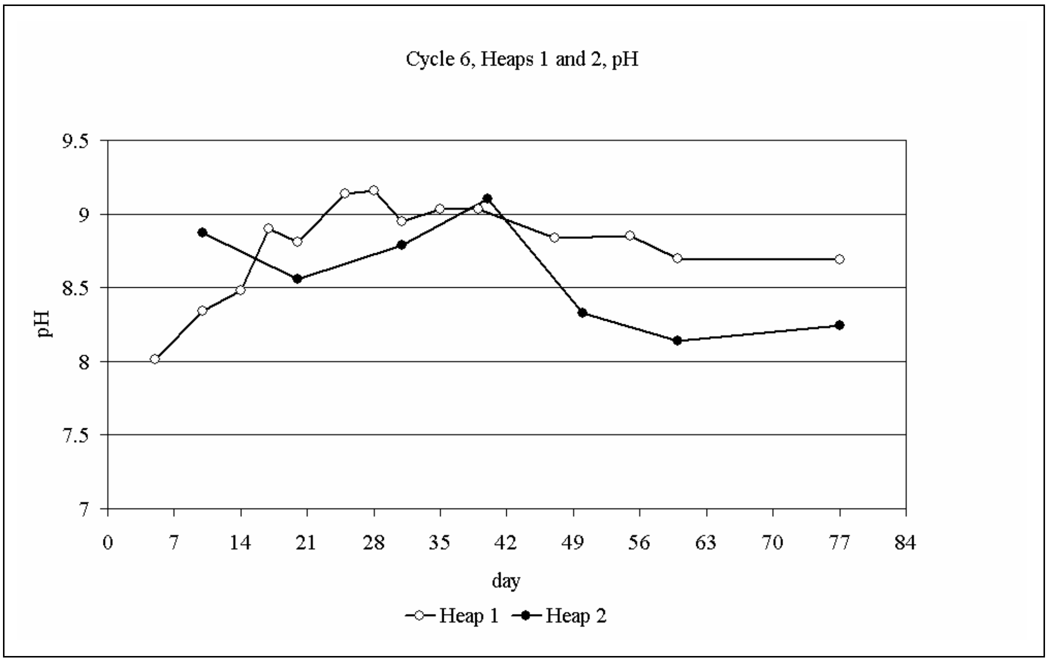


Figure 17: Changes in pH during co-composting of cycle 6.

The behaviour of pH over time corresponds well to the behaviour Sanchez-Monedero e.a. describe [17] and which they relate to the formation and degradation of NH_3 during the composting process. Initial production of NH_3 lead to an increase of the pH, whereas the following degradation of NH_3 is followed by a decrease in pH too.

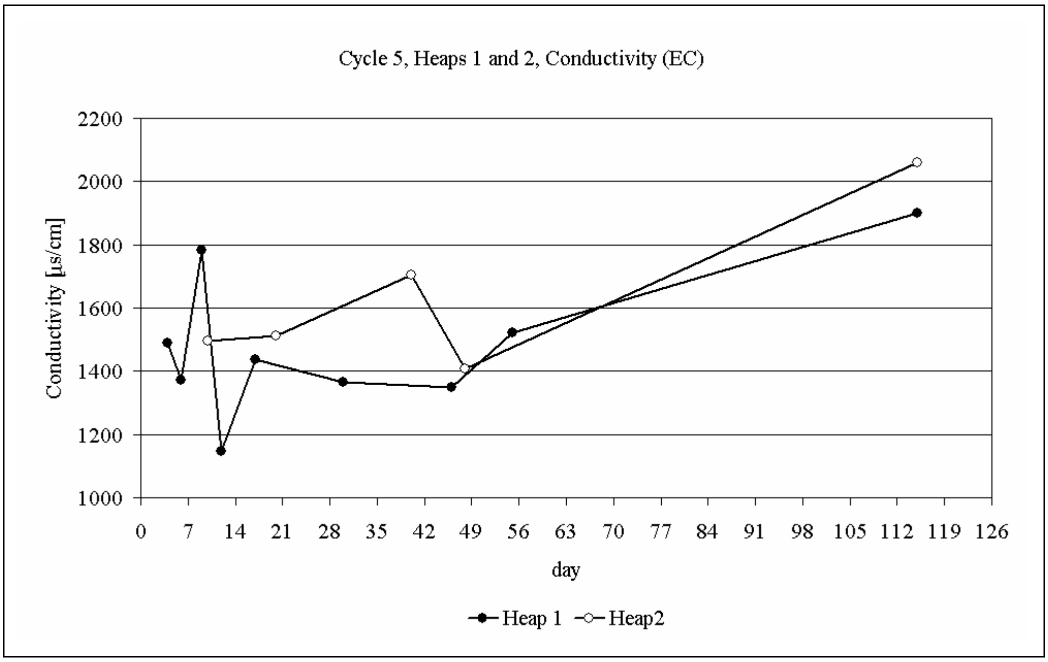


Figure 18: Changes in conductivity during co-composting of cycle 5.

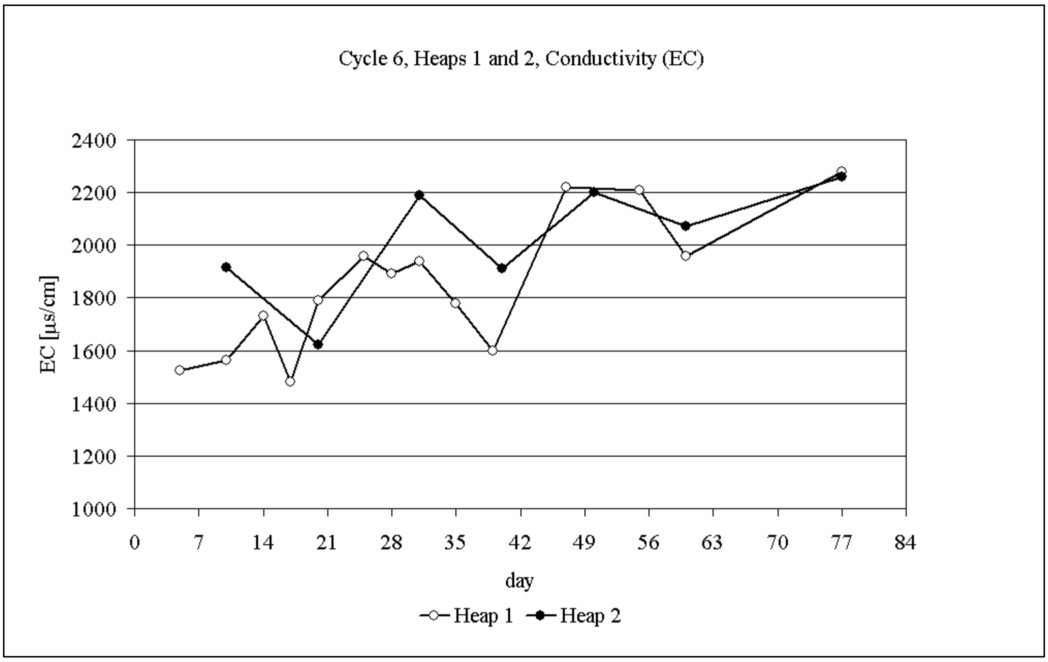


Figure 19: Changes in conductivity during co-composting of cycle 6.

Sanchez-Monedero e.a. [17] found a direct correlation between the increase of electrical conductivity and the formation of Nitrate (NO_3) in composts. This behaviour was also observed in the four heaps of this study. Fuchs e.a. [9] give a value of 2.5mS/cm as a maximum value of conductivity in compost extracts (1:2 by volume) to ensure successful plant growth. Since the conductivity of a solution depends strongly on the concentration and the actual electrolytes in solution [3], measurements in extracts which were prepared differently can’t be compared. Kehres e.a. mention in [13] that the determination of osmotically active ions like Na+, K+ or Cl- would be of more significance than measurement of the conductivity.

3.2.4.1 Influence of turning frequency

Within the observed compost cycles no indication was found that the two turning frequencies would lead to different behaviour in pH or conductivity. But the two cycles showed variations which indicate an influence of the raw materials and the external conditions on the composting process.

3.2.5 NH_4, NO_3

3.2.5.1 Ammonia and Nitrate development with time

Initial production in week 2 to 4 and decreasing content with maturation was observed in all 4 heaps. In cycle 5 the maximum ammonia content was observed after 1 to 3 weeks where the maximum in cycle 6 was after 4 weeks in both heaps.

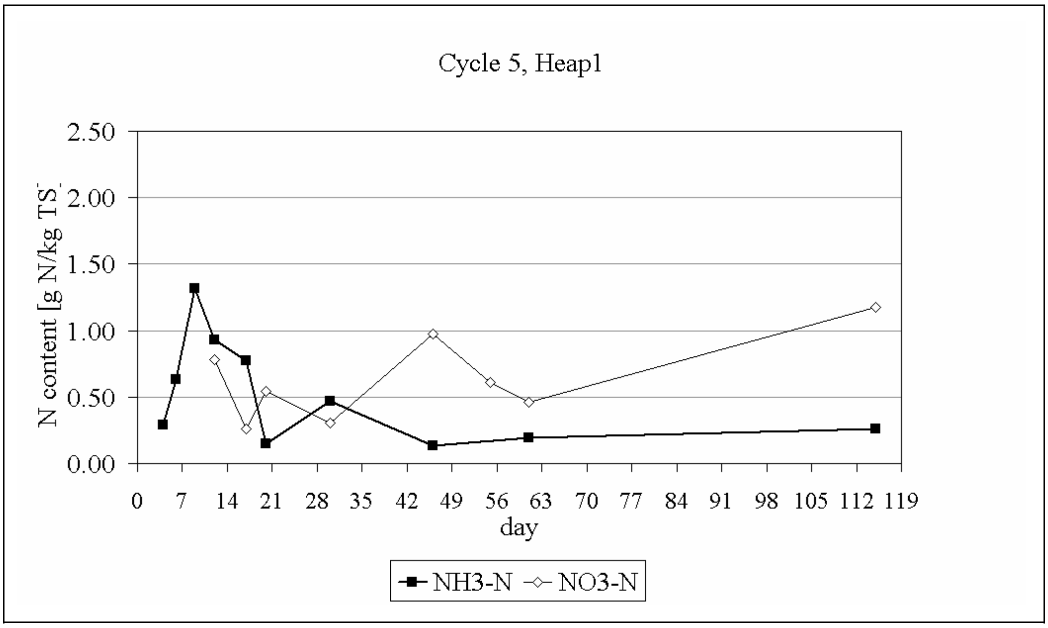


Figure 20: NH_4-N and NO_3-N contents in Heap 1 of cycle 5

Heap 1 of cycle 5 (Figure 20) showed a fast Ammonia development with a maximum concentration in the second week after forming of the heap. Initial incertitude in the measurement of Nitrate may be caused by analytical problems since the method for nitrate determination was developed during cycle 5. The basic trend of Nitrogen mineralisation, described by Sanchez-Monedero in [17] and by Fang in [8], can nevertheless be observed. Initial increase and subsequent decomposition of Ammonia lead to the formation of the final Nitrogen species, Nitrate. High nitrate content, 1.2g NO_3-N/kg TS, and a low Ammonia level, 0.26g NH_3-N/kg TS, with an NO_3-N/NH_3-N ratio of 4.5 at the end of Maturation are indicators of a mature product. Fuchs e.a. [9] give a minimum NO_3-N/NH_3-N ratio of 2 for open land application of compost.

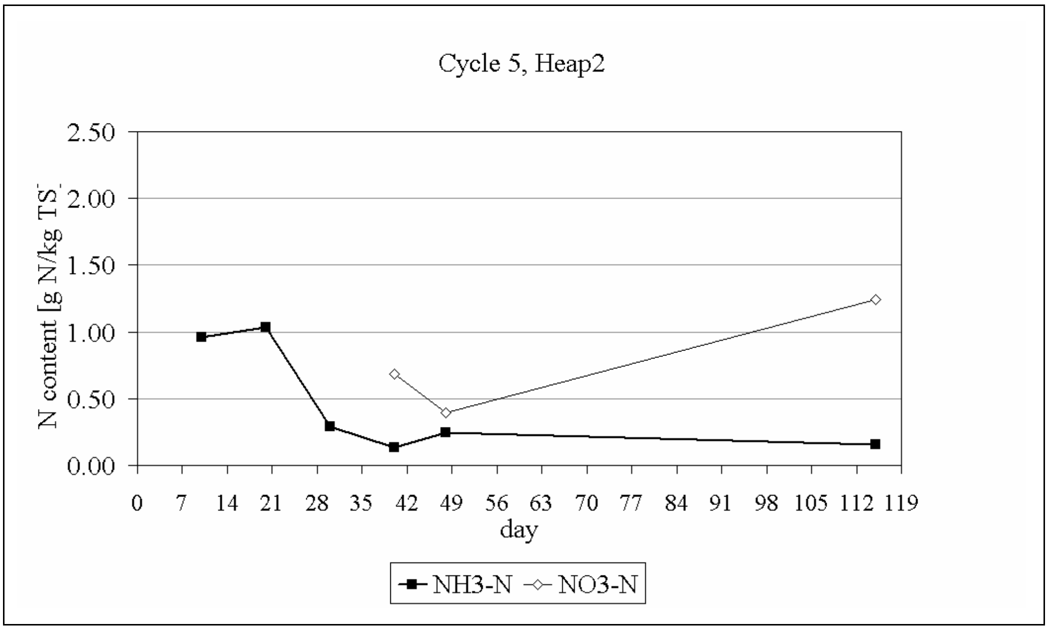


Figure 21: NH_3-N and NO_3-N contents in Heap 2 of cycle 5

Heap 2 of cycle 5 (Figure 21) shows the same trends as heap 1. A maximum of NH_3 could be observed after 3 weeks. At the end of maturation 1.2g NO_3-N/kg TS and 0.15g NH_3-N/kg TS with an NO_3-N/NH_3-N ratio of 8.1 indicate a mature product.

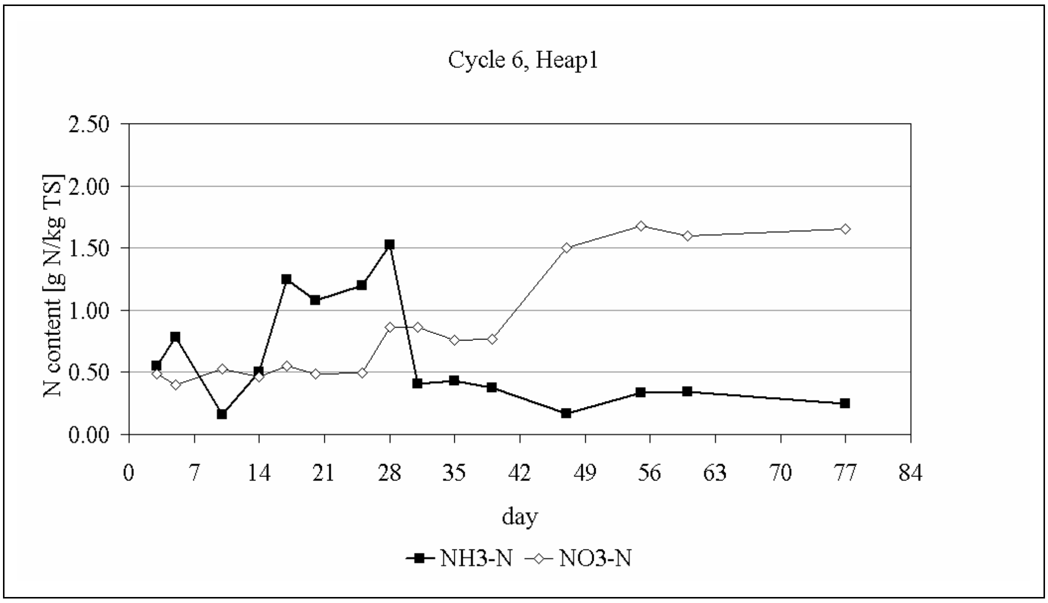


Figure 22: NH_3-N and NO_3-N contents in Heap 1 of cycle 6

Heap 2 of cycle 5 (Figure 22) shows the same trends as heap 1. A maximum of NH_3 could be observed after 4 weeks. At the end of maturation 1.7g NO_3-N/kg TS and 0.25g NH_3-N/kg TS with an NO_3-N/NH_3-N ratio of 6.7 indicate a mature product.

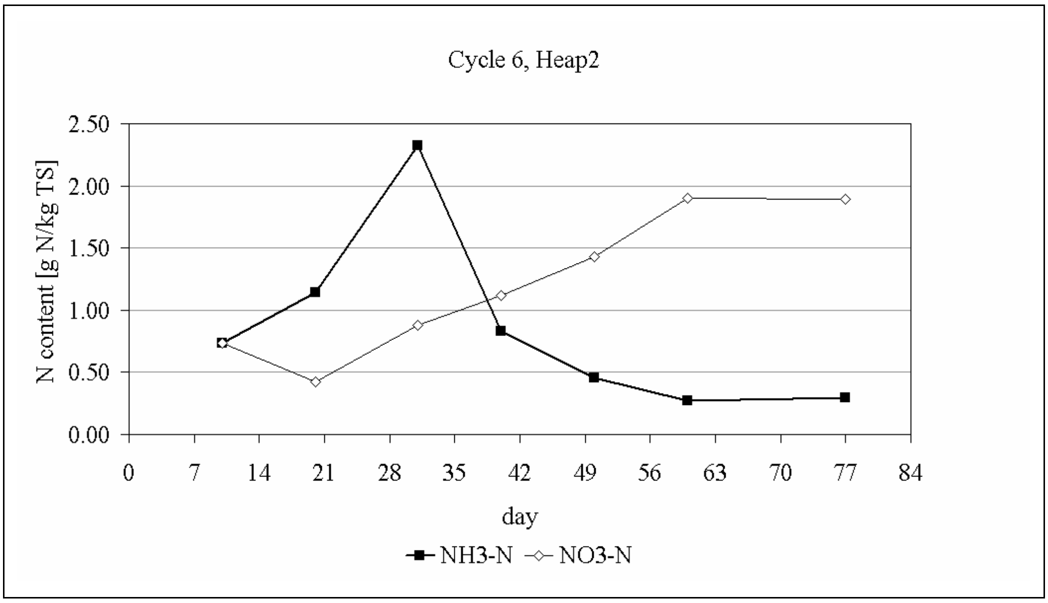


Figure 23: NH_3-N and NO_3-N contents in Heap 2 of cycle 6

Heap 2 of cycle 5 (Figure 23) shows the same trends as heap 1. A maximum of NH_3 could be observed after 4 weeks. At the end of maturation 1.9g NO_3-N/kg TS and 0.30g NH_3-N/kg TS with an NO_3-N/NH_3-N ratio of 6.3 indicate a mature product.

3.2.5.2 Influence of turning frequency?

The main variation between different compost heaps is the time and intensity of ammonia production. No correlation can be stated to the turning frequency. But the behaviour of the heaps of one cycle was similar indicating that raw material and external conditions had an influence on the nitrogen mineralisation.

3.3 Organic Nitrogen

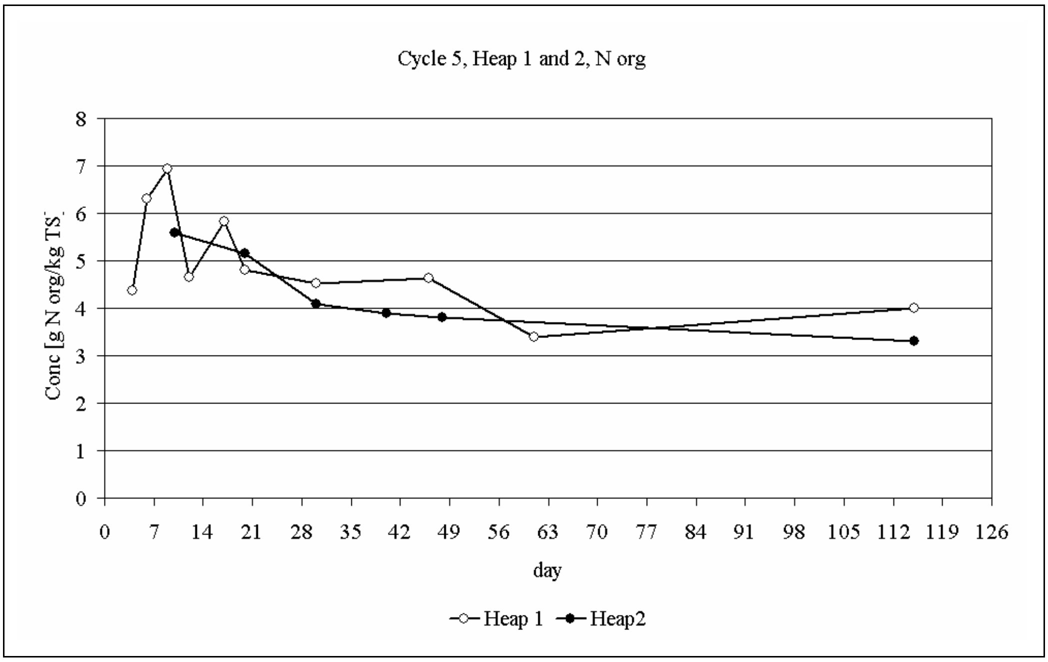


Figure 24: Content of organic Nitrogen (N_{org}) in Heap 1 and 2 of cycle 5.

The DWS used for cycle 5 showed a N_{org} content of 3.05g N/kg TS. This value would be just half the value found in the compost after wards (see Figure 24).

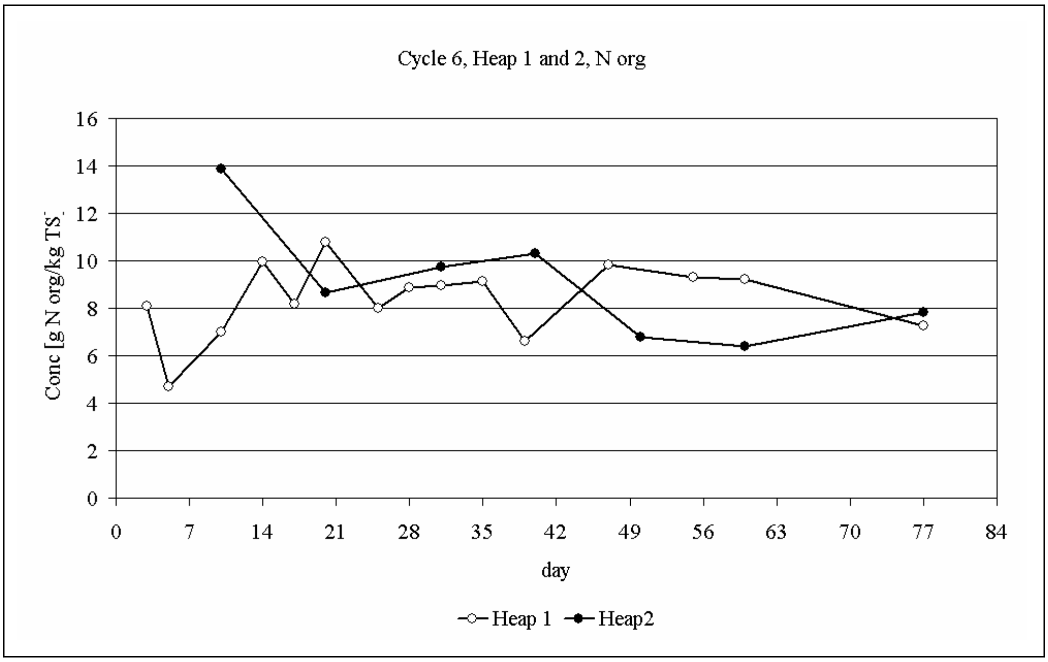


Figure 25: Content of organic Nitrogen (N_{org}) in Heap 1 and 2 of cycle 6.

The DWS used for cycle 6 showed a N_{org} content of 5.40g N/kg TS. As for cycle 5, this value is just half the value found in the compost (see Figure 25).

In contrast to the assumption that DWS has higher nitrogen content than Market waste (MW), the co-compost made of a mixture of DWS and MW show double the nitrogen content compared with DWS. This would imply that most of organic nitrogen would be brought into the compost with MW fraction. These observations would be against expectations. More analyses have to be done and the analytical procedure must be cross-checked with other methods, like a total CNS analyser, should be used to gain more certainty about the absolute nitrogen results.

4 Conclusions

4.1 Nitrogen loss during the sludge drying process

The high nitrogen content of feacal sludge is a very promising quality regarding the fertilising capacities of eventual co-compost. Unfortunately the majority of Nitrogen in feacal sludge is in the form of Ammonia. Ammonia is lost during the drying process with the percolate or due to evaporation. In the remaining dried solid sludge the main form of nitrogen is the organic nitrogen. This study could not answer to the question of where this form of nitrogen goes during the process. The incertitude in the balance is mostly due to incertitude in the chemical analysis. Generally can be said that the major part of initial nitrogen is lost in form of Ammonia during the drying process with sand filter beds.

4.2 Recommendations for future composting

4.2.1 Watering

In order to get reproducible conditions for composting trials, the moisture content should be given more attention for smaller variability from one composting cycle to another. W. Bakx give in [4] a detailed description of the squeezing test which he compared with laboratory analyses of moisture content:

“Take a sample of compost in your hand…make sure there are no sharp objects in the sample. Squeeze tightly. If water flows freely out of your hand, the moisture content is 65 percent or higher – too wet. If a few drops of water are visible between your fingers, you are right at 60 percent – the upper limit. If you don’t see any water, open up your hand and if a sheen is clearly visible, moisture content will be at 55 to 60 percent. If no sheen is visible and a ball remains in your hand, tap the ball gently. If the ball stays intact, moisture content is 50 to 55 percent. If a ball forms but breaks apart during tapping, moisture content will be 45 to 50 percent. When opening your hand and the compost dos not remain in the ball, moisture is 40 to 45 percent or less. If, when discarding the material from your hand, a dry talcum-like feeling remains on your hand and no ball had formed, moisture content is likely below 40 percent, which slows down composting process.”

These observations may be slightly different for co-composting and have to be verified. But once such a relation between observation and laboratory analyses is established, the plant manager should be able to adjust moisture in the composting heaps between 50 and 60% for the whole thermophilic and maturation phase.

Watering should be continued until the end of the maturation in order to keep the microorganisms alive (see TS data). Up to now the watering was halted after thermophilic phase in order to get a product that was dry enough to be sieved with a simple sieve made out of a wire net. Sieving of the final product of cycle 6, which had moisture content of 40%, led already to clogging of the sieve. For improvement of the composting process it would be useful to invest in a new sieving facility for compost with moisture content of 40%. A copy of the drum sieve shown in Figure 26 with suitable mesh size could be manufactured at Suame Magazine, the quarter of mechanics in Kumasi.

Figure 26: German made compost sieve for small scale composting.

4.2.2 Turning

Turning should be continued until the end of the maturation phase in order to aerate the windrows, which is necessary for nitrate production and removal of ammonia rests.

The two turning frequencies compared in this study didn't lead to different compost quality. A turning frequency of once a week or less is suggested in order to decrease the workload on the plant and introducing a standard procedure for composting. If turning would be done just every 14 days, sampling every week for monitoring would still be wishful. For this purpose sampling without turning according to [10] could be appropriate which would require an Edelman Auger.

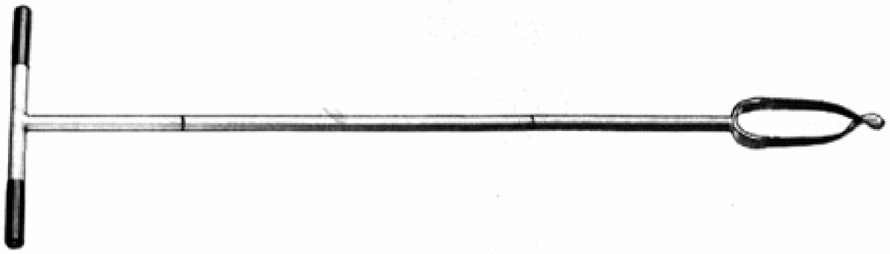


Figure 27: One Piece Edelman Auger (Eijkelkamp)

4.2.3 Compost monitoring

Monitoring is supposed to give information about the different stages of the composting process, like intensity and end of thermophilic phase or the end of the maturation phase. The chemical parameters chosen for this purpose must be measurable with good reproducibility.

- **Do measure Temperature**: This is an important parameter, which gives an impression on the actual biological activity in the compost heaps. It is easy to measure and give good and **immediate results**.
- **Do measure TS**: The total solids or the moisture content respectively are critical for good biological activity during the composting process.
- Don't measure TVS: TVS could be a useful parameter to observe a decrease in organic matter. Due to variations in the sand content of the co-compost in Buobai, this parameter can not be measured with enough precision.
- **Do measure pH**: The pH can be correlated with the process of production and degradation of Ammonia. pH is easy to measure but the reaction on changes in the compost are slow. pH is therefore no reliable indicator for characteristic stages of the compost like the end of thermophilic or maturation phase.
- Don't measure Conductivity: Conductivity show a constant increase with time, but it gives no distinct value indicating end of thermophilic or maturation phase.
- **Do measure NH_4**: production and degradation very characteristic for thermophilic phase, possible determination by distillation and titration.
- **Do measure NO_3**: The start of NO_3 production indicates the end of thermophilic and the beginning of maturation phase. In order to decrease the workload UV photometric measurement can be done without standard addition but by using a constant value of 0.159 for sensitivity.

Temperature, Ammonia and Nitrate are varying during the thermophilic and maturation phase in a characteristic manner, which make the intensity and pace of a particular composting process visible. TS and pH need to be observed in order to ensure optimal conditions for composting. These parameters are measurable on site or in the Civil Engineering lab.

4.2.4 Compost qualification

To describe the final product the following parameters are essential according to the VKS-Richtlinie Qualitaetseigenschaften von Komposten [9]:

- **TS**: The TS value should exceed 55%.

- **TVS**: The TVS is an indicator for the amount of organic matter in the compost. TOC can be estimated from TVS value by multiplication TVS with a factor of 0.58.
- **pH, Conductivity and NH_4**: These parameters are essential to describe the **plant compatibility** which is important for planting trials and use of the compost by farmers. In order to get comparable results, the pH and conductivity should be measured in compost extracts which are prepared according to guide lines.
- **N_{org} and NO_3**: Together with the NH_4 value the total nitrogen content can be estimated. This is a key parameter to describe the **fertilising quality** of the compost. Due to low analytical precision of the N_{org} value, this measurements provide just approximate values of total nitrogen.
- **NO_3/NH_4 and C/N ratios**: These values can be calculated from above parameters and give an indication about the **maturation stage** of the compost. The NO_3/NH_4 ratio has higher reliability due to higher precision in the measurement of the two parameters used. The C/N ratio is more influenced by incertitude due to sand content in the compost and therefore less useful for compost quality description.

These are parameters that can be determined in the civil engineering lab. The following parameters would be nice to have as well but for these ones more investigation and/or better equipment would be required: **P**, **K**, **sulphide**, **colour of compost extract** and **heavy metals**.

Biological tests like the **kresse test** would complete the compost qualification.

5 Literature

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7 Appendix

7.1 Step by step procedure for the chemical analysis

7.1.1 Sample preparation, extraction

Feacal Sludge

1. Shake sample container well and take about 2ml for N-analyses.

Percolate

1. Shake sample container well and take about 10ml for N-analyses.

Compost extract

1. Weigh 20g of sample into a blender, make up to a total weight of 200g with H_2Odest (dilution 1:10).
2. blend for 30s.
3. Take about 30ml of extract and analyse NH_3-N.
4. Take about 3ml of extract and digest without measuring NH_3-N first. The N_{org} is then calculated by subtracting the amount of NH_3 from the TKN value.

7.1.2 Analyses

Kjeldahl (NH_3-N and N_{org})

1. Give sample or extract into a 500ml Kjeldahl flask, note exact weight => **m extract [g]**
2. Add: Pumice stones, 200ml H_2Odest, 25ml Borate Buffer, 2ml NaOH 6N
3. Fill 50ml of Boric acid with indicator into a 250ml beaker
4. Connect the Kjeldahl apparatus and distil 150ml into the boric acid-indicator solution (colour changes from violet to green) to a total of 200ml.
5. Titrate with H_2SO_4 0.02N (change from green back to violet) => **H_2SO_4 [ml]**
6. Calculate the amount of Ammonium in the sample as follows:

NH_3-N [mg/kg fresh comp.] = **H_2SO_4 [ml]** * 280 / **m extract [g]** * 10

(1ml H_2SO_4 0.02N ≡ 0.28mg NH_3-N)

7. Add 50ml of digestion solution to the remaining solution of step 4), make sure that eventual remains on the wall are washed into the solution.

8. Mount the digestion flask on the heating unit with a 45° angle to prevent sample loss due to eventual bumping.
9. Start the hut ventilation and heat for about 2.5h (after about 1h white fume is produced and after a total of about 2.5h remains a clear green solution)
10. Let cool down for about 10min.
11. Add: 200ml H_2Odest. (this solution can be stored over night before distillation),
12. Add: 50ml of $NaOH/Na_2S_2O_3$ solution
13. continue procedure with steps 3) to 6)

N_{org} [mg/kg fresh comp.] = **H_2SO_4 [ml]** * 280 / **m extract [g]** * 10

14. Analyse 5ml multi-N standard at least once a month.

(5ml standard is supposed to give 10ml H_2SO_4 0.02N for NH_3-N and N_{org} respectively)

Nitrate

(An overview of this method can be found in Figure 1)

1. Fill 25ml of the extract into 100ml mass flask, add 2ml of HCl 1N and make up to 100ml with H_2Odest. (dil.= 1:4)
2. Centrifuge about 40ml at 800G for 10min.
3. Decant into a 50ml beaker.
4. Take 8 test tubes of 30ml content, fill 5ml of centrifuged extract in 6 of them.
5. Add 2x 0.0 / 2x 1.0 / 2x 2.0ml of 50mg NO_3-N/litre-standard to the 6 sample test tubes and 2ml of Standard into the 2 remaining test tubes.
6. Make all the test tubes up to 25ml total with HCl (0.02N) (dilution 1:5).
7. Measure Absorption at 220nm and 270nm as follows:
   - Take two cuvettes and label one as the reference
   - Make sure for all measurements that there are no fingerprints or small drops on the cuvette windows.
   - Fill the reference cuvette with H_2Odest, put it into the spectrometer and set the Absorption at 220nm to 0.000.
   - Fill the sample cuvette with H_2Odest, put it into the spectrometer and read the Absorption.
   - Put the reference cuvette into the spectrometer, change wavelength to 270nm and set 0.000.
   - Measure sample cuvette with H_2Odest.
   - Measure in the following order always for 220 and 270nm: H_2Odest (1), H_2Odest (2), Standard (1), Standard (2), Sample1 (0.0), Sample2 (0.0), Sample3 (1.0), Sample4 (1.0), Sample5 (2.0), Sample6 (2.0),

Standard (1), Standard (2), H_2Odest (1), H_2Odest (2). (The changes of the Absorption at 270nm should not be higher than 0.020).

8. Calculate Nitrate concentration as follows (preferable with the help of excel or a similar computer software):
   - Subtract the average of the 4 H_2Odest values from the values of 220 and 270nm respectively.
   - Subtract the corrected values of 270nm from the values of 220nm (background correction)
   - Draw a graph of the background-corrected values of 220nm against the standard concentrations and add a linear regression line.
   - Out of the equation of the linear regression ($y = ax + b$) the concentration x can be calculated as follows: $x = b / a$.
   - The concentration in the compost can be calculated by including the dilution factors into the calculation:

NO_3-N[mg/kg fresh comp.] = x * 20 * 10

pH

1. Measure the pH of the (1:10) extract with a calibrated pH electrode (no filtering necessary).

Conductivity

1. Measure the Conductivity [µs/cm] of the (1:10) Extract with a calibrated electrode (no filtering necessary).

TS

1. Weigh a dry petri plate => **tare [g]**
2. Add 30 to 40g of fresh compost and weigh => **tot fresh [g]**
3. Put the sample into an oven at 105°C for 24h.
4. Weigh dried sample => **tot dried [g]**
5. Calculate the TS as follows:

TS [%] = {tot dried [g] - tare [g]} / {tot fresh [g] - tare [g]} * 100%

TVS

1. Weigh a dry ceramic cup => **tare [g]**
2. Add the dried sample of the TS measurement and weigh => **tot before [g]**
3. Put the sample in a ventilated oven of 550°C for 3h
4. Lt it cool down in a desiccator and weigh => **tot after [g]**
5. Calculate the TVS as follows:

TVS [%TS] = {tot after – tot before} / {tot before – tare} * 100%

7.1.3 Preparation of the solutions for the various analyses

Kjeldahl

1. Borate buffer
   - Dissolve 4.75g of $Na_2B_4O_7 \cdot 10\ H_2O$ in 500ml of H_2O_{dest}.
   - Add 88ml of NaOH 0.1N
   - Make up to 1.0litre with H_2O_{dest}.
2. NaOH 6N
   - Dissolve 120g NaOH pellets in H_2O_{dest} in a beaker and let it cool down.
   - Transfer solution into a mass flask and make up to 500ml with H_2O_{dest}.
3. Boric acid with Indicator
   - Dissolve 200mg Methyl red in 100ml EtOH 95%.
   - Dissolve 100mg Methylen blue in 50ml EtOH 95%.
   - Mix the two solutions.
   - Dissolve 20g H_3BO_2 in H_2O_{dest}.
   - Add 10ml of Indicator mixture.
   - Make up to 1000ml with H_2O_{dest}.
4. H_2SO_4 0.02N for titration
   - Give 7ml of H_2SO_{4conc} to about 100ml of H_2O_{dest}.
   - Make up to 250ml with H_2O_{dest} => H_2SO_4 1N
   - Take 5ml of H_2SO_4 1N and make up to 250ml with H_2O_{dest} => H_2SO_4 0.02N
5. Digestion solution
   - Give into a 1litre beaker: 100g K_2SO_4, 10g $CuSO_4$, 500ml H_2O_{dest}, and 135ml H_2SO_{4conc}.
   - Stir until you get a clear solution, let cool down, transfer into a mass flask and make up to 1000ml with H_2O_{dest}.
6. $NaOH/Na_2S_2O_3$ solution
   - Give into a 1litre beaker: 500g NaOH, 25g $Na_2SO_3 \cdot 5\ H_2O$, 800ml H_2O_{dest}.
   - Stir until you get a clear solution, let cool down, transfer into a mass flask and make up to 1000ml with H_2O_{dest}.
7. N-Standard solution
   - Dissolve in H_2O_{dest}: 1.320g $(NH_4)_2SO_4$, 0.736g Glutamic acid, 2ml HOAc (stabilisation of NH_4)
   - Make up to 500ml with H_2O_{dest}.

Kjeldahl analyses of 5ml Standard gives for:

NH_4-N (560mg/l): 10ml H_2SO_4 0.02N

N_{org} (560mg/l): 10ml H_2SO_4 0.02N

Nitrate

1. HCl 1N
   - Dilute 21ml of HCl_{conc} in H_2O_{dest} and make up to 250ml
2. HCl 0.02N
   - Dilute 4ml of HCl 1N in H_2O and make up to 200ml.
3. Nitrate Standard solution
   - Dissolve in H_2O_{dest}.: 0.7128g KNO_3 (dried at 105°C for 24h)
   - make up to 1000ml => 100mg NO_3-N/litre
4. Take 100ml of the 100mg NO_3-N/litre-standard and make up to 200ml with H_2Odest. => 50mg NO_3-N/litre
5. Add 2ml $CHCl_3$/litre to the storing bottles as stabiliser. The solutions are stable for at least 6 months.

7.2 Rain water harvesting on the co-composting plant

7.2.1 Justification

On the sludge treatment plant of KMA where the co-composting plant is situated, a tank of about 3500litre provides the plant with water. This tank is periodically filled by periodically pumping water out of a well situated on the area as well. During the first two years of co-composting the sludge treatment plant didn’t have started and so the co-composting plant was the only and small water customer. In the second half of March 2003 the sludge treatment in the pond system started and the workers, especially the truck drivers satisfied their water need from the small tank, which consequently ran out of water much faster than before. Within the same time period the pump in the well broke and led to an uncertain water situation and to the idea of collecting rainwater in Buobai.

Kumasi is blessed with rich rainfall throughout the year and the composting plant provides a 260m^2 roof with aluminium covering. Even in January a rain harvest of 3500l can be expected according to long term meteorological data from Kumasi airport, see Figure 28.

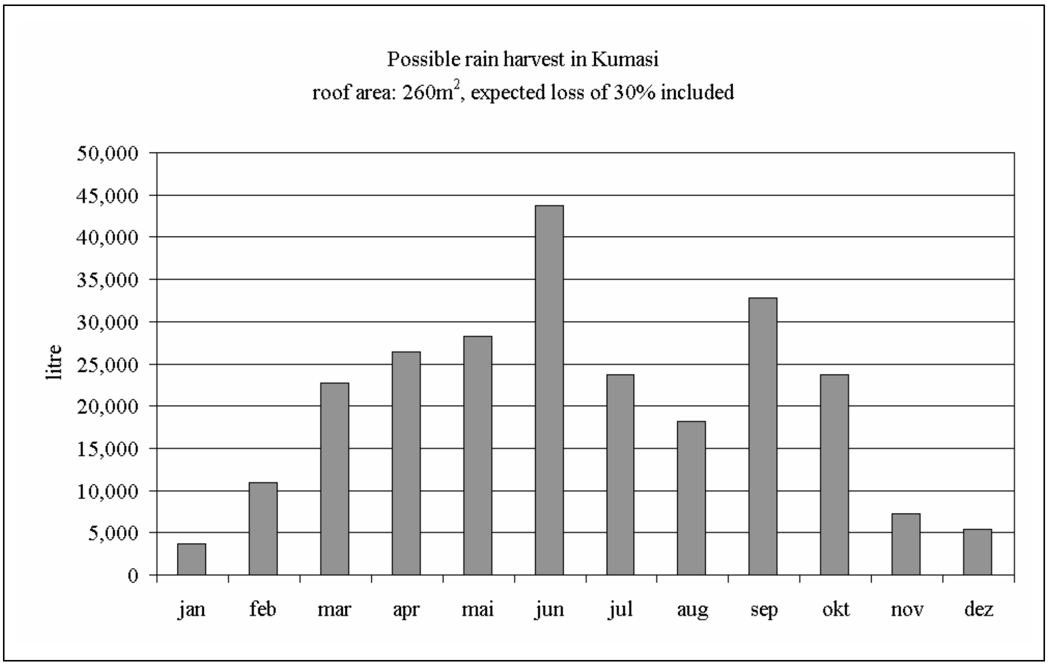

Figure 28: Expected rain harvest in Kumasi. Data calculated with values of the Meteorological service of Kumasi airport.

The water consumption of the co-composting as it is done in Buobai was already studied during the previous composting cycles. One heap of about 3m^3 initial volume needs about 1m^3 (1000l) of water until maturation. Most of the consumption occurs during the first 3 or 4 weeks when the heap is hot and loses a lot of water due to evaporation. A worst case scenario would be if 6 compost heaps would be started at the same time in a dry period like December or January. In such a case the plant would need about 6000l of water for the compost plus water for hygienic purposes of the workers. This consideration led to the evaluation of a 7000l tank made of polyethylene, as they are easy available on the local market. A tank of this volume was as well of the dimension that used the full height available under the roof of the co-composting plant.

7.2.2 Description of the system components

Baseplate

- Circle of cement blocks covered with reinforced concrete, 215 x 215 x 50cm.
- Workers: Esiam and Sam from Civil Engineering Department of KNUST.
- Costs: 1.2mio Cedis.

Metal works

- Rain gutters (8ft each), alu, total 2x20m with hooks.
- Contractor: Kwameh Agyei ("Chairman"), Sofo Line, phone: 34363 or 37627 or 31753 (ask for "Chairman")
- Gutters mounted: Attah Carpenter from Kwadaso, phone 024 287 287.
- Costs: 2.8mio Cedis.

Tanks

- PE Tank Rambo700 (7000l) with 2 connections for 4’ PVC extra, PE (flush-)Tank Rambo030 (300l) with 3 connections for 4’ PVC extra.
- Do-Dive Polytanks Suppliers, Mr. Owusu, Adum Mayfair, P.O.Box R 294, Phone: 020 811 3702 or 024 388 258 or 24309
- Costs of tanks: 5.8mio Cedis.

Plumbing

- Installations of 4’ PVC tubing (total of 15m), flush tank (300l), main tank (7000l) and 2 taps.
- Contractor: Stevo Plumbing works, P.O.Box 810, Sofo Line, Kumasi, phone c/o 22741.
- Costs: 1.3mio Cedis.

Over all costs

Together with variable costs for transport and victuals the over all costs for the rain water harvesting system were 11.6mio Cedis which correspond to 1870 Swiss Franks (1CHF=6200GHC).

Figure 29: The tank system for rain harvesting. 300l flash tank and 7000l water storage tank.