# MECHANICAL BIOLOGICAL PRETREAT-MENT IN SOUTH-EAST ASIA – THEORET-ICAL AND PRACTICAL APPROACH

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**SUMMARY:** A sanitary landfill under operation has been the objective of a theoretical and practical appraisal of mechanical biological pre-treatment under tropical conditions. Since February 2002 pre-treatment prior to landfilling has been implemented. The process comprises homogenization and shredding followed by static pile composting. An intensive test phase has been performed being accompanied by a comprehensive research program. Variations of the climatic conditions in combination with a very specific waste composition adversely affect the aerobic degradation. Intensive downpours cause irreversible shifts from aerobic to anaerobic status hampering the entire degradation. Static pile composting without periodically turning will run at risk of massive methane formation. Based on the German ordinance on "Environmentally compatible landfilling of domestic waste" the process' efficiency is discussed. Within 300 days an adapted process will guarantee a reasonable stabilization appraised by leaching characteristics, TOC reduction, oxygen consumption, and biogas formation of the remainders.

## 1 LANDFILLING IN SOUTH-EAST ASIA

In the South-East Asian region waste containing eminent organic matter combined with high moisture content is predominantly dumped in non-engineered landfills; leachate and landfill gas treatment is not in place and aftercare considerations are if at all neglected. The regional landfill management urgently requires suitable approaches to tackle present and future problems. As been published earlier basic considerations emphasized the emission reductions by biological pre-treatment under given conditions (Ranaweera et al., 2001). Pre-treatment, i.e. mechanical biological processing or simple composting of MSW (not for the production of quality compost) has been suggested as a feasible option for improving the landfill performance in the tropical region by reducing landfill emission.

Concerning landfilling most Asian countries face similar problems most landfills are just open dumps. However, landfilling is considered to be the most effective method of solid waste disposal in developing countries if adequate sites are available. The upgrading of existing sites and the sound operation as well maintenance will be major issues of future solid waste management system. The cost associated with landfill construction and operation practiced in developed countries, and indefinite post closure control of gas, and leachate require substantial amount of money and technical skills for post closure activities. Therefore, the design of an appropriate landfill technology calls for a comprehensive approach on alternatives. Suitable and feasible landfill operations are most sought after and especially those to curtail the operational costs for leachate treatment as well as post closure aftercare period. Biological pretreatment of solid waste by a simple homogenization and composting is one reasonable option.

Biological pre-treatment of solid waste is claimed to have advantages such as shortening the monitoring period, production of lower concentration leachate requiring simpler treatment, re-

duction in landfill gas production rates and space conservation due to fast degradation and consequently better compaction. In the following investigation the benefits of such a pre-treatment are discussed and first results of the process' implementation are reviewed.
Theoretical considerations and a prediction over a timeframe of 20 years prove the benefits of a reasonable emission reduction by a pre-treatment process. The cumulative pollution load from leachate can be diminished for COD and nitrogen compounds by 75-90%. The overall gas formation can be reduced by more than 35 % and the global warming potential will be abated by more than 50%. The total waste mass will be diminished saving landfill volume and achieving a lifetime extension of the landfill. Landfill aftercare will thus be reduced significantly.

## 2 IMPLEMENTATION OF MECHANICAL BIOLOGICAL PRETREATMENT

Consideration and general conclusions on the potential of MSW pre-treatment shall be drawn from the sanitary landfill of Phitsanulok in Central Thailand. The selected site is very typical for the region. It features a design of bottom liner and final cover both of compacted clay of reasonable low permeability, and an efficient leachate drainage system but no gas drainage system. The incoming municipal solid waste's composition illustrated in Table 1 demonstrates around 60% LOI at high moisture content in the range of 62%. A remarkable plastic content in a range of 24 - 56% average 38.7% wt. has to be noticed. The high plastic portion restricts the compaction to solely 300-400 kg/m³. The specific situation of the said landfill serves as input to evaluate various approaches on how to reduce the overall gaseous and liquid emissions by mechanical biological pretreatment.

Table 1: Domestic waste composition

| **Waste composition** | **Phitsanulok** | | | **Thailand** |
|---|---|---|---|---|
| | **May 1999** | **February 2002** | **April 2002** | **Average** |
| | [%] | [%] | [%] | [%] |
| Plastics | 27 | 21.1 | 38.4 | 13.7 |
| Biowaste | 33 | 43.1 | 45.7 | 59.8 |
| Fines < 20mm | | 30.1 | 10.8 | |
| Textiles | 5 | 2.5 | - | 2.7 |
| Metal | | 1.5 | 1.3 | 3.1 |
| Glass | | 0.6 | 1.1 | 4.3 |
| Paper | 18 | 0.4 | 0.7 | 7.7 |
| Stones, ashes, inerts | 18 | 0.8 | 2.0 | 5.0 |
| Moisture content | 55.8 | 61.9 | 62.8 | |
| LOI | 72 | 54.6 | 65.1 | |

The pretreatment process comprises an uncomplicated homogenization combined with some crushing namely to break up the plastic bags most frequently used as multi-purpose repository. Waste is piled up to windrows, which are naturally ventilated and if deemed necessary irrigated. The mechanically processed waste is supposed to undergo a degradation process without further turning over 9-12 months. Thereafter no further processing is intended and the waste should be disposed of in the landfill. It is expected that during the degradation process organic matter is stabilized and a minimum of liquid and gaseous emissions might occur.

Based on the actual pre-treatment performance consequences of simple windrow composting for final disposal are evaluated. Specific criteria compulsory for German mechanical-biological treatment plants according to national ordinances (BMU, 2001 and Soyez, 2000) are used to appraise the degree of stabilization and accordingly the rating of final disposal quality. In order to predict the overall emissions available information served as an input for detailed analysis under given boundaries. Both off-gas analyses, leachate sampling plus extra measurements like temperature and a regular solid sampling have been carried out in order to obtain best available information about the composting process under local climatic conditions. Additional results obtained from semi-scale lysimeters and lab-tests have been used to refine the comparison with respect to the forecast of leachate production and gaseous emission of both pretreatment and final disposal influenced by monsooning conditions (Tränkler et al 2001, 2002).

## 3 PERFORMANCE UNDER TROPICAL SETTINGS

### 3.1 Composting performance

Thailand ails monsoon conditions, which are best characterized by a rainy season of eventually high intensity rainfall. However, it has been observed that under the local conditions 220–250 days per year show up with no rain at all and a distinct arid period of about 4 months. An average temperature of 28 ° C and high solar radiation result in high evaporation rates. Both the distinct rainy season and the more or less arid period have a distinct impact on landfilling as well as impel to a high extent the performance any kind of composting pre-treatment.

Given the very specific composition of waste (table 1) with little bulking agents the performance of composting will be endanger. Due to the lack of void space, compaction and blocking plastic layers complete aeration and oxygen supply will not be guaranteed. Especially during rainy season intensive downpours will aggravate the situation and worsen the supposed to be aerobic degradation. Additionally a reasonable portion of food waste is packed in plastic bags thus not being accessible for aerobic degradation. Given these facts static pile windrow composting run risk to turn over into an anaerobic status emitting methane at high level. This might occur in particular under extreme weather conditions but even under non-favorable circumstances an obvious hazard exists that windrows turn anaerobic.

In the following figures 1 and 2 such a specific case is presented. During three successive days in early September 2002 rainfall accounted for 290 mm. The windrows observed have been built up in May 2002 (windrow C) and middle of August 2002 (windrow D) respectively. Although the temperature of windrow sustained at an optimum level the downpour literally extinguish the fire and caused an immediate temperature drop of more than 20 degrees. This windrow didn’t recover from that tremendous decline. Furthermore the temperature fell close to 50 degree and after 5 month increased slightly. In contrary windrow D faced during the phase of intensive exothermic reaction only a slight temperature drop but improved the composting temperature. However, it took nearly three month most likely always hampered by rainfalls to attain a constant temperature around 70 degrees (figure 1). Parallel to the temperature changes the status of degradation has been altered. This is more than obvious from the methane formation during that period. Starting with a low methane concentration in the off-gas windrow C turned within one month after the rain event into an anaerobic status. During the following three months the off-gas concentration maintained above 25 % and thereafter decreased only slightly. Similar to that windrow D showed an increase in off-gas methane concentration but witnessed only a short-term peak concentration and returned to a predominantly aerobic degradation indicated by the temperature level obtained and a drop of the methane concentration close to zero. Nevertheless, it took nearly four month to regain that status (figure 2).

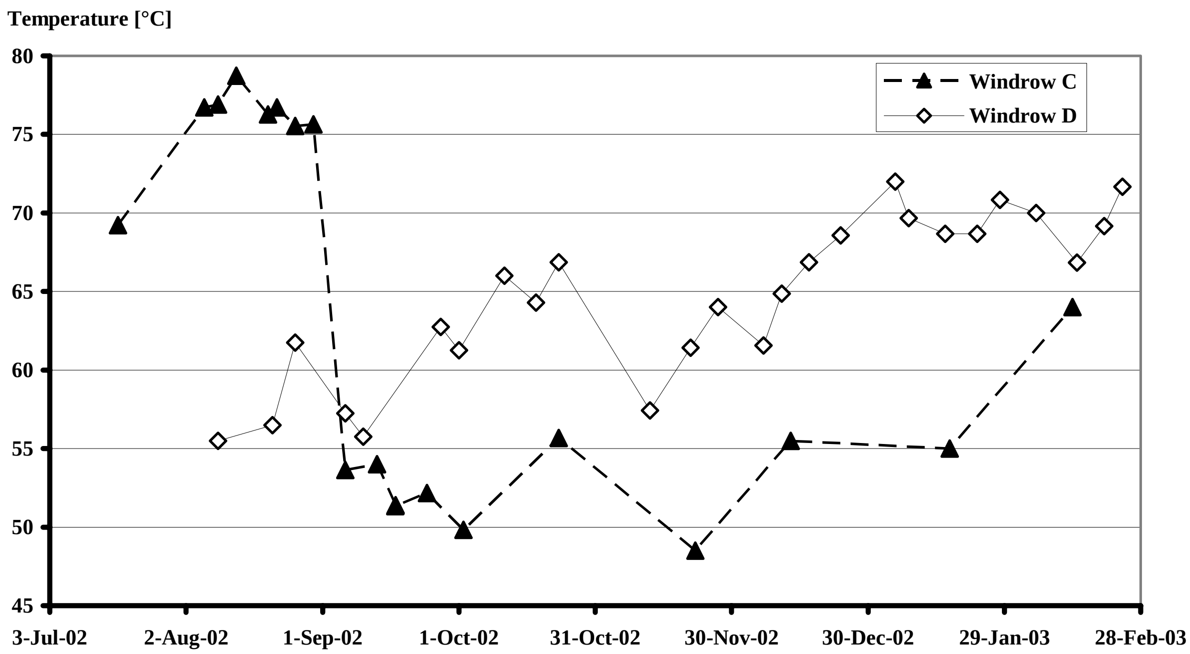


Figure 1: Temperature development after an extreme rainfall event

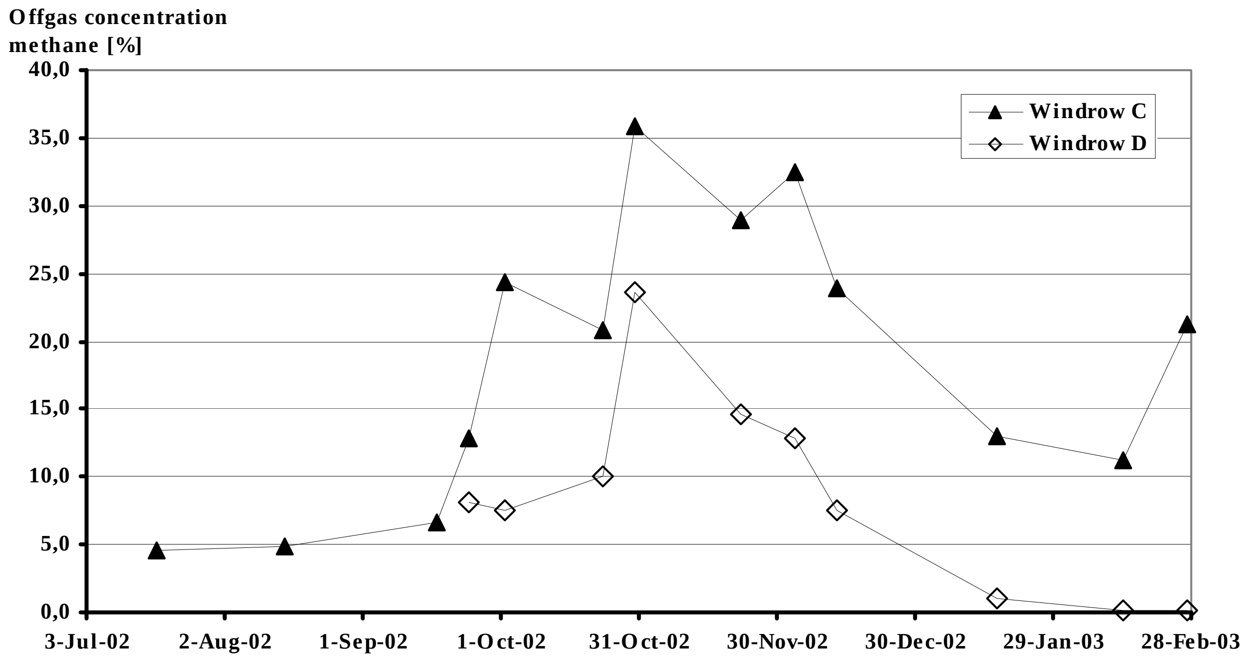


Figure 2: Off-gas concentration in the aftermath of an extreme rainfall event

Based on the fact that extreme rainfalls occur regularly consequences for the design and the operation of windrows are required. Primarily due to the given composition an extensive compaction has to be avoided. This limits the windrows' height and requires a top layer, which works as gas permeable but water impermeable barrier. With available natural material these requirements are hardly to achieve, accordingly a sub-optimum has to be aimed for. An essential feature is an effective bottom layer, which guarantees an optimum of drainage and likewise a top layer with an optimum of run-off properties. Intensive downpours are matter of fact in tropical settings you have to cope with. Proper design is indispensable but control of temperature in combination with the observation of either intensive rainfall events or droughts has to be part of the operation. Corollary irrigation and/or rebuilding windrows have to be planned and decided in time. More experience is needed for reliable effective and efficient decision making.

### 3.2 Degradation efficiency

Main purpose of the biological pretreatment is the reduction of organic matter thus minimizing future liquid and gaseous emissions. It is a prerequisite that composting works under optimum condition in order to achieve a maximum reduction. However, due to the weather impact an entire aerobic process cannot be guaranteed. Moreover under ambient conditions the anaerobic degradation runs uncontrolled that means the decomposing process is retarded and incomplete. Besides that the anaerobic process is emitting non-controlled a reasonable amount of greenhouse gases.

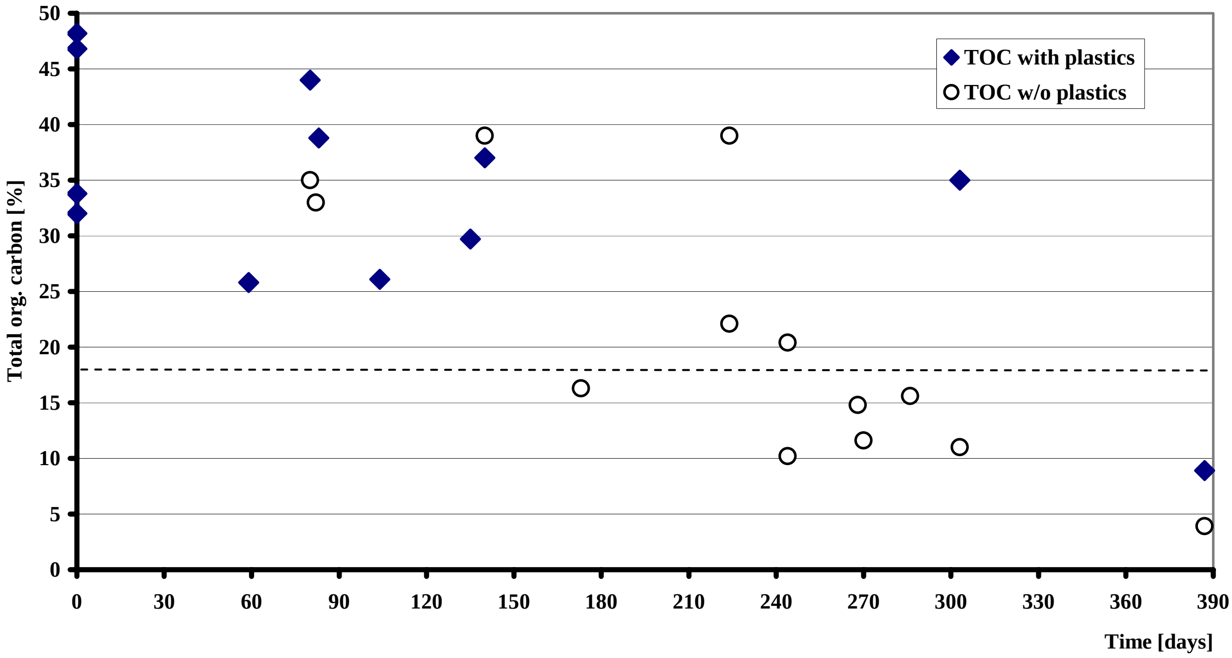


Figure 3: Degradation of organic carbon (solids)

The remaining total organic content of the solids, loss of ignition (LOI) and the final dry matter content are several parameters that determine the degree of degradation. Over a timeframe of more than one year the degradation has been carefully observed taking regularly samples for solids analyses. The effect on prolonged decomposing time is obvious concerning the reduction of moisture content. Irrespective the high evaporation capacity as well as rainfall intensity a continuous increase of dry substance content from initial 35% to a final 65-70% was noticed. The latter one might not favorable for composting but occurred at the final stage when loss of volatile solids are phasing out. For the overall decomposition lack of moisture hasn't been a limiting factor. However, rating the loss of volatile solids proved to be more complex due to the extraordinary plastics content of the waste. Both the simpler LOI and TOC can hardly testify in the presence of available but non-degradable plastics the degradation of native organic matter. For example the LOI of original waste remained throughout the entire test period in a range of 40-70%. Consequently, plastic particles have been sorted out and parallel analysis has been performed. The findings indicate for the LOI of composted waste a reasonable degradation but a reasonable bandwidth of 25-40%. As LOI is considered an inadequate standard to evaluate the loss of volatile solids TOC has been introduced as a yardstick (BMU, 2001). The German ordinance requires pre-treated waste to prove a TOC content of less than 18%. Figure 3 demonstrates the progression of organic carbon decomposition over the testing period. Generally speaking only those samples without plastic will reach a TOC content of less than 18% and if they do so a composting duration of 9 months deems to be appropriate to accomplish that target. Besides that selected samples (mainly organic matter) will be enabled to obtain a similar decomposition rate. Therefore it is recommended to screen the pretreatment remainders and use the low-value recycling fraction as RDF at least to recover the calorific value.

Even under unfavorable climatic conditions simple windrow composting will achieve a reasonable decomposition of organic matter. However, operation has to be adjusted and a final treatment is recommended. Sifting or screening, which is much easier to be performed after decomposition and natural drying might suitable processes to recover at least plastics for energy generation.

## 3.3 Final disposal performance

### 3.3.1 Degradation and final gaseous emissions

The pretreatment process is not in a position to completely diminish the organic content therefore it is rather evident that although the gas generation is significantly reduced emissions will occur. In view of that specific analyses are used to determined on one hand the oxygen consumption better to say the respirometric activity of the pretreated waste and on the other hand the anaerobic biogas formation potential. Both methods applied will provide reasonable information about the material's status prior to landfilling and one of them has to meet the limiting values in Germany prior final disposal of pretreated waste (BMU 2001 and Soyez at al). In the following both methods are used to illustrate specific features of pretreatment under tropical conditions.

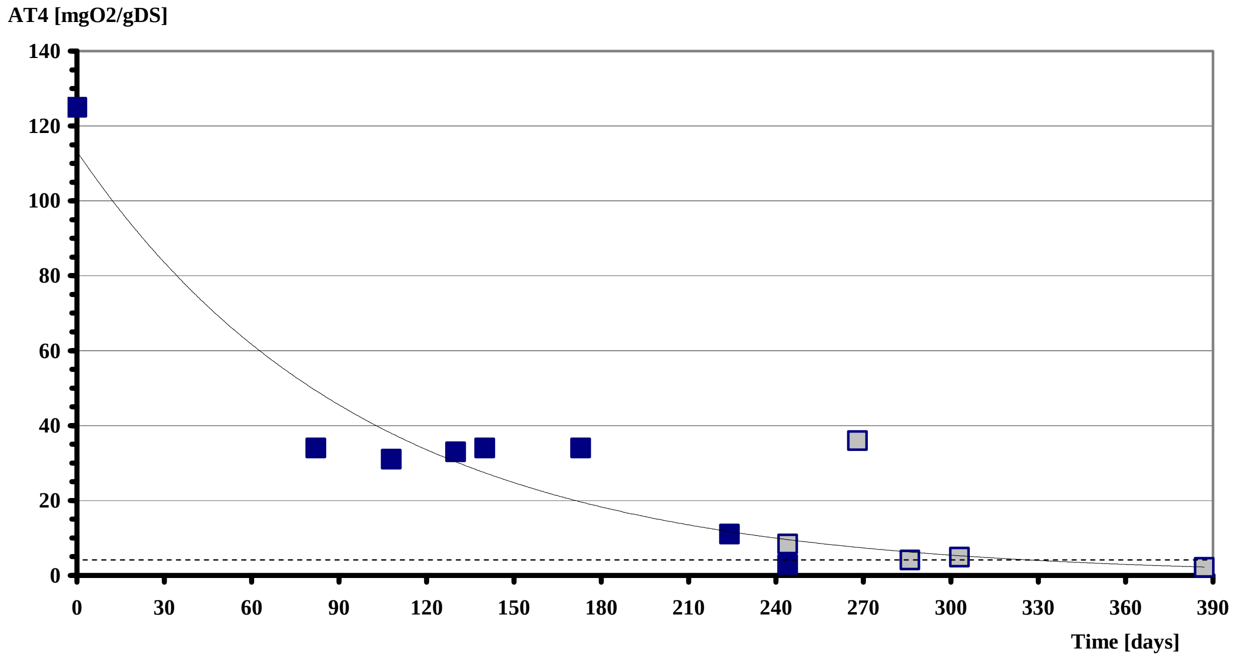


Figure 4: Specific oxygen consumption over degradation time (grey squares indicate a second stage of composting – curing- over 23 -53 days)

Compared to fresh waste the pretreated materials demonstrate a reasonable lower oxygen demand, which can accomplish after 240 -300 days of composting a set standard of 5 $mgO_2$/g DS consumption. However, this accomplishment is linked with some operational modifications. Over a period of more than 90 days the oxygen consumption remained stagnant (figure 4). That fact of an incomplete conversion might be due to the high organic matter and a certain probability of anaerobic phases due to nature's impact. A short curing or post treatment has to ensure an aerobic degradation to the greatest possible extent. This post treatment period needs at least 6 weeks because in some exemplary cases with a shorter post treatment phase oxygen consumption accounted for 9 and 34 mg/g respectively

These sensitive measurements prove that under favorable conditions a sole pretreatment can achieve a very low oxygen consuming matter, which will not run risk to turn anaerobic. If circumstances are less positive a post treatment by a second stage composting will be most suitable to guarantee equivalent results.

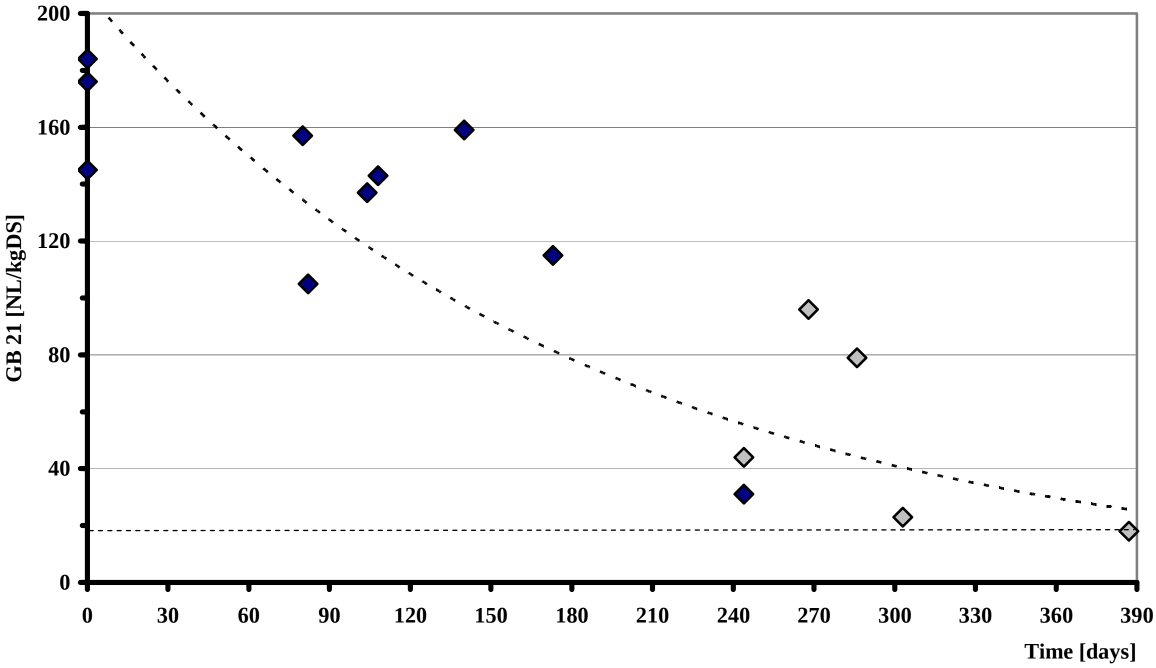


Figure 5: Specific biogas production ((grey squares indicate a second stage of composting – cur ing- over 23 -53 days)

The quality of pretreated waste with respect to a subsequent landfilling is best explained by the residual biogas formation potential. An effective reduction of biogas throughout the pretreatment period is demonstrated (figure 5). It is quite obvious that pre-treatment can reduced the biogas production; however, complying with set standard (20 NL/ kg DM) it deems that it can only be achieved in exceptional cases, so far. At least a period of 300 days deems to be appropriate to obtain a low biogas formation profile.

Although during some phases of pretreatment the process turns into an anaerobic status it is not surprising that still a reasonable gas potential remains. As been pointed out earlier and shown in figure 2 the anaerobic degradation runs uncontrolled and reaches methane concentrations, which indicate an incomplete degradation process. In case of partial anaerobic composting only an extended post treatment period will provide a low biogas potential, which might be suitable for a final disposal without gas collection systems but a methane oxidation layer.

3.3.2 Degradation and consequences for leachate production

Aside of landfill gas polluted leachate is produced during the course of disposal. The effect of pretreatment on leachate generation depends on design criteria of top layer systems, landfill operation and rainfall. A prediction of leachate production and composition after pretreatment is nearly impossible therefore a leaching procedure according to German DEV S4 standard shall illustrated the pretreatment's potential to diminish specific leachate compounds.

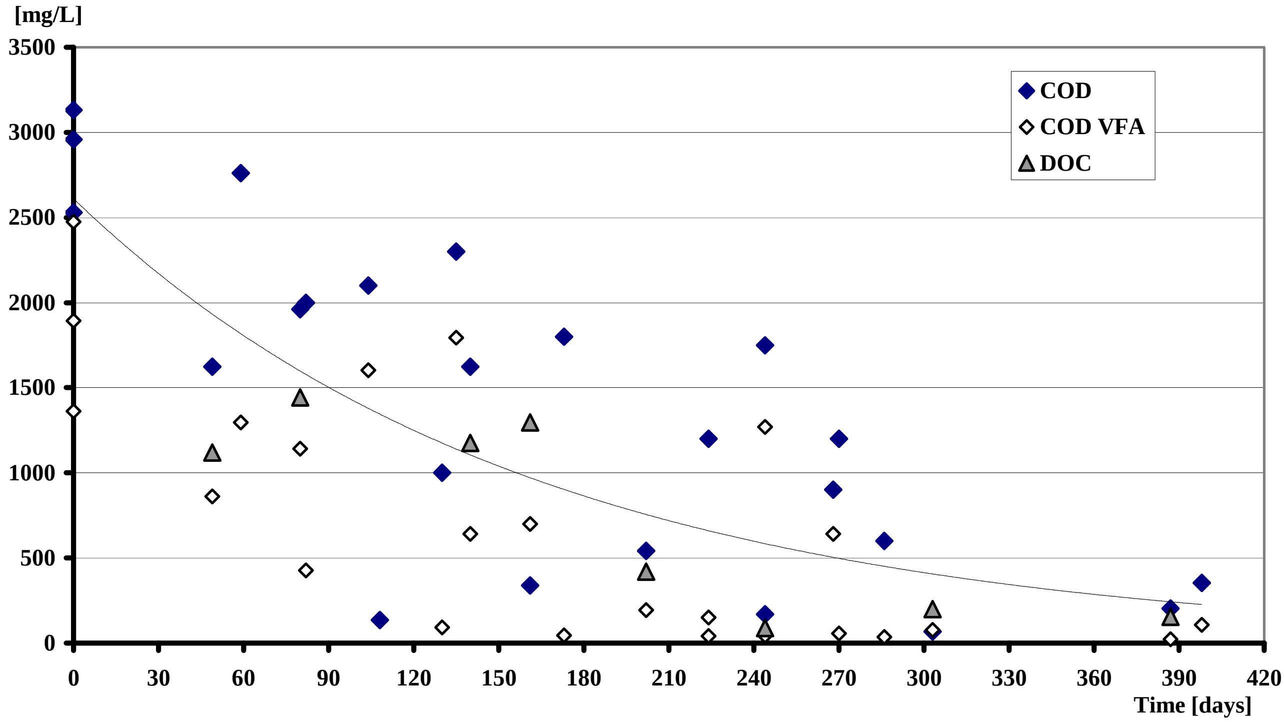


Figure 6: Leaching characteristics of COD and volatile fatty acids (transformed into their chemical oxygen demand $COD_{VFA}$)

Provided the fact that during pretreatment a significant reduction of organic matter occurs an artificial leaching of processed waste will attain most probably a similar decline. In fact the leaching potential of pretreated waste is lowered with extension of the treatment period. However, for chemical oxygen demand an extensive fluctuation can be noticed over a long period. Few analyses of dissolved organic matter (DOC) illustrate a straightforward reduction with treatment time. Further to that the share of easy degradable matter characterized by $COD_{VFA}$ varies accordingly. Volatile fatty acids are typical for an acidogenic phase viz. undersupply of oxygen or partially anaerobic conditions at certain stages of the pretreatment process. Comparable low $COD_{VFA}$ values indicate prevailing aerobic conditions whereas higher values imply facultative settings with more non-degradable breakdown products. Further to that it is quite obvious that under straight aerobic conditions post treatment improves the leachate characteristics. At a final stage low concentrations might be expected. Nevertheless, the lab procedure will offer only a trend but given the decline (figure 6) a concentration reduction by roundabout 80% for organic constituents might be expected.

Given the time variations a similar result like the organic parameters is to be anticipated for the nitrogen compounds. Although inorganic nitrogen constituents are only little affected by anaerobic degradation the decrease in both organic and ammonium nitrogen is more than obvious (figure 7). Under strict aerobic conditions oxidation of ammonium is likely to happen consequently with an extended pretreatment period ammonium-nitrogen drops blow 50 mg/L. Thus requirements of an ammonium concentration below 200 g /L (BMU, 2001) are easy to fulfill. Commonly high-level nitrogen compounds govern the leachate composition of conventional landfills until a non-predictable final stage. Compared to such conditions the leachate from pre-treated waste arrives at a reasonable level within a foreseeable timeframe. Again we have to re-mind that real concentration might differ from those generated under lab conditions but a com-parison points out a reduction by a factor of 10.

In combination with a decent organic pollution load it is likely easier treatable. However, even at lower pollution load an appropriate leachate treatment system is required. Though, the applica-tion of low technology treatment systems like wetlands might be more suitable and adequate not withstanding the appearance of priority pollutants.

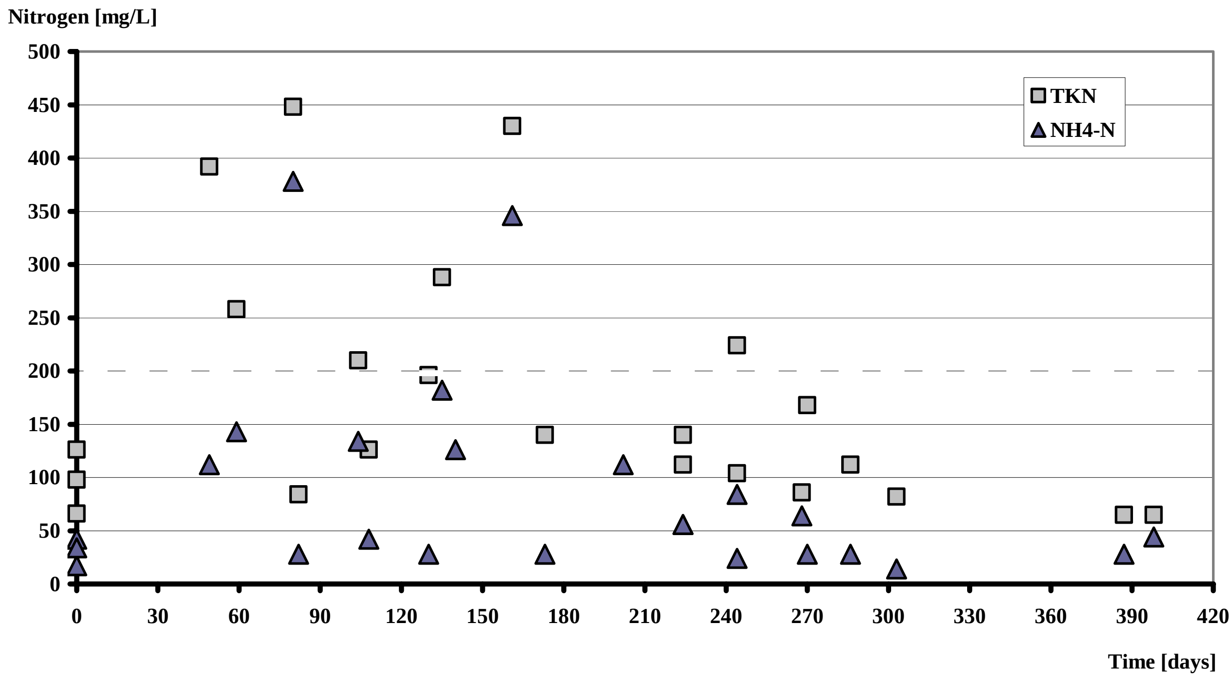


Figure 7: Leaching characteristics of nitrogen compounds

## 4 CONCLUSIONS

The first implementation stages of domestic waste pre-treatment prior to landfilling has been evaluated concerning performance of the process, degree of stabilization and future emissions potential. Under tropical climatic condition are discussed. Criteria of the German ordinance on “Environmentally compatible landfilling of domestic waste“ namely leaching characteristics, TOC reduction, oxygen consumption, and gas formation have been used and their applicability under local conditions are reviewed.

The dominance of the waste composition, high moisture and an extreme plastic content as well as the variations of the climatic conditions adversely affect the intended aerobic degrada-tion. An open static pile composting without turning will run at risk of an advancing anaerobic degradation. At least every 3 months -during rainy season even on demand at shorter intervals - windrows should be turned to avoid a massive methane formation and to a certain extent the slow-down of the degradation process. Nevertheless, within a comparable short time a satisfac-tory stabilization according to given criteria can be obtained. The revised and extended consid-erations based on the latest results and their extrapolation show that under the regional circum-stances a pre-treatment is obviously and option to massively reduce the emission potential thus

encouraging a further implementation in the region. Pre-treatment technology has the advantage of selecting its components according to the requirements of particular waste stream, climate conditions, desired quality of output and economy. The advantages of the pre-treatment could be stressed by looking more closely in the pollution load originating from landfill leachate and greenhouse gas emissions. By properly controlled pre-treatment of MSW, landfill emissions can be reduced significantly even farer than expected by previous theoretical considerations.
Within the chosen pretreatment period overall gas formation potential can be reduced by more than 80% and the global warming potential will be abated to a high extent. The pollution load from leachate can most likely be diminished for COD and nitrogen compounds by more than 80 and 90% respectively. Further improvement shall be achieved in maintaining the composting process in a more strict aerobic status. Given the moisture content of the waste, intensive rain-falls, a minimum of void space plus a reasonable plastic fraction static pile composting shows limitation. Either forced aeration over a certain period or turning might render the problem. However, additional efforts have to be made and more energy will be consumed. With the on-going full-scale operation information will be more and more available, which allow a further fine-tuning of the process and future deliberations on the overall assessment of the combination of pre-treatment and a subsequent landfilling under specific tropical conditions

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