

MECHANICAL BIOLOGICAL WASTE TREATMENT IN SOUTH-EAST ASIA - PROCESS FEATURES AND TREATED WASTE PERFORMANCE

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ABSTRACT

Pre-treatment prior to landfilling under tropical condition has been implemented on a typical landfill in Central Thailand. The process comprises homogenization and shredding followed by static pile composting. An intensive test phase has been performed being accompanied by a comprehensive on-site and off-site research program. The first implementation stages have been evaluated concerning performance of the process, degree of stabilization and future emissions potential. The behavior of the treated waste has been tested in lab-scale and semi-scale lysimeters. Additionally the loss of mass and the improved compaction due to the reduced moisture and break down of organic matter has been determined. In order to observe closely the liquid and gaseous emissions of treated waste and compare it with common waste disposal various samples of pre-treated waste have been disposed of in lysimeters. The dominance of the waste composition, high moisture and an extreme plastic content as well as the variations of the climatic conditions governs the intended aerobic degradation. An open static pile composting without eventual turning will run at risk of an advancing an-

aerobic degradation. However, within a reasonable time and under controlled conditions a satisfactory stabilization according to given criteria can be obtained. The revised and extended considerations based on the latest results and their extrapolation show that under the given circumstances a pre-treatment is obviously an option to massively reduce the emission potential thus encouraging a further implementation in the region.

Within the chosen pretreatment period overall gas formation potential can be reduced significantly 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 85 and 70% respectively. With the on-going semi-scale lysimeter information that tendency is clearly proven. A properly controlled pre-treatment is needed in order to reduce the total emissions significantly. 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 has to be made and suitable stabilization criteria being developed.

INTRODUCTION

The Asian and in particular the South-East Asian landfill management urgently calls for 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. Theoretical considerations based on European experiences could provide convincing support. A prediction over a timeframe of 20 years indicates the benefits of a reasonable emission reduction by such a

pre-treatment process. The cumulative pollution load from leachate shall be diminished for carbon and nitrogen compounds by 75-90%. The overall gas formation shall be reduced by more than 35 % and the global warming potential will be abated by more than 50%. 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, reduction 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 as well as the performance of processed waste disposed of in lysimeters are reviewed.

PRETREATMENT IN TROPICAL SETTINGS

Consideration and general conclusions on the potential of MSW pre-treatment shall be drawn from the sanitary landfill of Phitsanulok in Central Thailand. The incoming municipal solid waste's composition demonstrates around 60% LOI at moisture content in a high range of 62%. A remarkable plastic content in a wide range of 24 -56% (average 38.7% wt) has to be noticed. The pre-treatment process at place comprises an uncomplicated homogenization combined with some crushing namely to break up plastic bags most frequently used as multi-purpose repository. Waste is piled up to trapezoidal shaped windrows of around 20-25 m breadth, 40-60 m length, and a variable height of 2.0-2.5m. The windrows are naturally ventilated, which is supported by a bottom layer of pallets and maintained by perforated pipes detached at defined distance and working only with natural draft (Maak, 2000) 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 shall 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 Soye, 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 during the composting phase 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 and 2003).

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 and despite a distinct dry season 220–250 days per year show up with no rain at all. Throughout the year high evaporation rates can be observed. Both the rainy and dry season will have a distinct impact on the performance of the composting

process as core of pre-treatment. Given the very specific composition of waste with little bulking agents the performance of composting will be endangered. Due to the lack of void space, compaction and blocking plastic layers complete aeration and oxygen supply will not be guaranteed. Especially during the rainy season's intensive downpours the situation will aggravate and worsen the supposed to be aerobic degradation. Given these facts static pile windrow composting runs 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 using the temperature development and the off-gas composition as an indicator for a suitable aerobic performance. The windrows observed have been built up in May 2002 (windrow C) and middle of August 2002 (windrow D) respectively. During three successive days in early September 2002 rainfall accounted for a total of 290 mm. Although the temperature of the windrows sustained at an optimum temperature level the downpour literally extinguished the fire and caused an immediate temperature drop of more than 20 degrees for windrow C. This windrow didn't recover from that tremendous decline. Furthermore the temperature fell close to 50 degree and increased slightly only after 5 months time. In contrary windrow D faced during the phase of intensive exothermic reaction only a slight temperature drop but thereafter the composting temperature increased. 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 mean methane formation during that period. Starting with a low methane concentration in the off-gas windrow C turned within one month after the particular 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). 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 ob-

servation of either intensive rainfall events or droughts has to be part of the basic 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 with respect to process control.

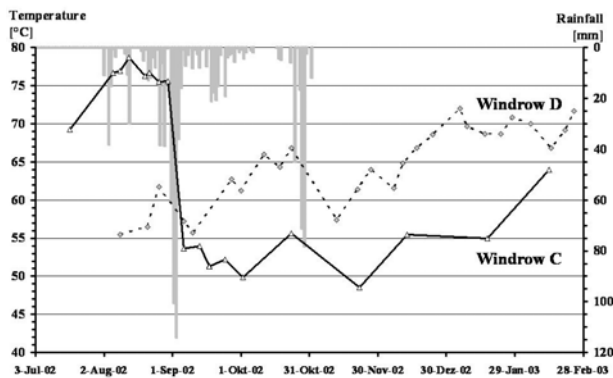


Figure 1: Temperature gradient windrows C and D

Degradation efficiency

Main purpose of the biological pre-treatment 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 of organic matter. However, due to the weather impact an entire aerobic process cannot be guaranteed. Moreover under ambient conditions the anaerobic degradation might run uncontrolled that means the decomposing process is retarded and consequently incomplete. Besides that the anaerobic process is emitting in a non-controlled manner a reasonable amount of greenhouse gases.

The remaining total organic content of the solids, loss of ignition (LOI) and the final dry matter content are specific parameters that determine the degree of degradation. Over a timeframe of more than one year the degradation has been carefully observed. Specimens have been regularly taken 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.

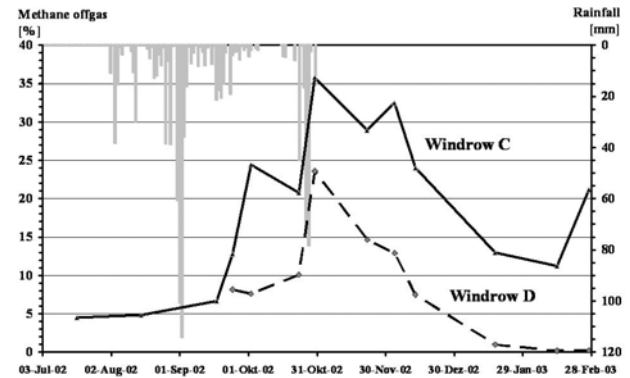


Figure 2: Methane off-gas concentration

The assessment of 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. 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 at a reasonable bandwidth of 25-40% being achieved. As far as LOI is considered it is rated 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.

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.

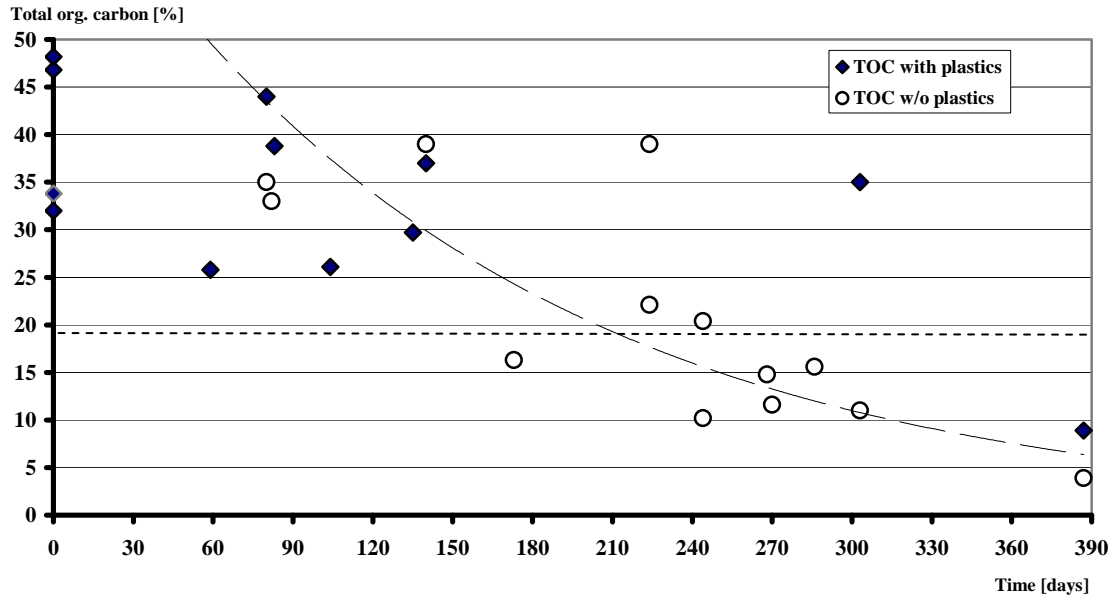


Fig. 3: Time dependent reduction of organic matter

FINAL DISPOSAL PERFORMANCE

The pre-treatment aims at the generation of lower leachate load requiring uncomplicated treatment technique over a limited timeframe, the reduction in landfill gas production rates that rather require natural attenuation methods than intensive collection and disposal systems, and finally due to the mass reduction and better compaction saving valuable landfill space. Consequently, these advantages shall allow the shortening of a nowadays unpredictable after closure monitoring period. However, the final disposal performance depends on various issues, of which some cannot be determined in advance. As a substitute some commonly agreed parameter like a minimum of organic matter expressed as TOC (see fig. 3), the respirometric activity, biogas generation capacity, and leaching potential are applied. Such parameter will be reviewed in the following. Additionally full-scale investigation like compaction and semi-scale viz. leachate generation under ambient condition in lysimeter trials are discussed in order to assess the final disposal performance of processed waste.

The reduction of mass due to decomposition and the evaporation of moisture have been determined for some windrows under full scale trials. The wet weight of the input as well as the output of processed waste has been determined. Further to that the LOI of selected samples of both the input and the output were analyzed to get an overview on the reduction of organic matter (GTZ 2003). The findings indicate a loss of wet mass of 53% due to evaporation. The loss organic matter is approximated to 19%. The decomposition rate is comparable to what is provided in relevant references. A further im-

provement of reduction of organic matter shall be feasible by an improved composting process as been indicated before.

Aside of the mass reduction it is reported that a volume reduction is additionally achieved by an improved compaction. Usually the ordinary MSW is hardly compactable and under common condition a compaction at a density of less than 300 kg/m³ is obtained. Given the density of the windrows after degradation of 530, which is already above the commonly achieved values a further mechanical compaction, finally achieved a compaction rate of 1.100 kg/m³ for processed waste, which is double wet density of the windrows. Related to the dry mass it is even a four fold density. Consequently it has been testified that landfill volume can be conserved. However, it has to be indicated that this expression is valid for dry weather conditions only as the experience shows that under rain weather condition compaction becomes difficulty and sometimes nearly not feasible..

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 determine the anaerobic biogas formation potential. This method applied will provide reasonable information about the material's status prior to landfilling and has to meet the limiting

values in Germany prior final disposal of pretreated waste (BMU 2001 and Soyeyz at al).

An effective reduction of biogas throughout the pre-treatment period is demonstrated. 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

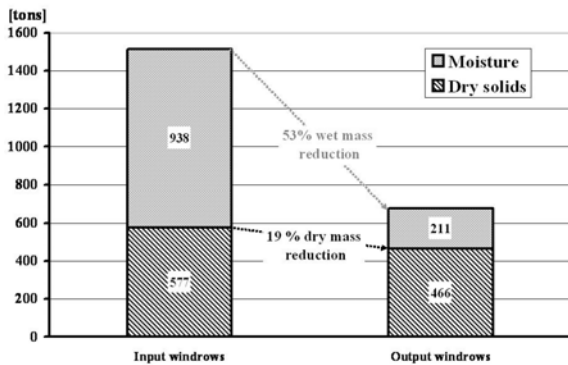


Figure 4: Mass reduction full scale experiment

Leachate generation potential

Aside of landfill gas polluted leachate is produced during the course of disposal. The effect on leachate generation (both quantity and composition) depends not only on pre-treatment but also design criteria like top layer systems, landfill operation and rainfall. Consequently a forecast of leachate production and composition of processed waste is nearly impossible to be made. Therefore on a first sight leaching procedures according to German DEV S4 standard are applied and shall illustrated the pre-treatment's potential to diminish specific leachate compounds.

Provided the fact that during pre-treatment 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 pre-treated waste is lowered with extension of the treatment period. However, for the chemical oxygen demand (COD) an extensive fluctuation over a long period can be noticed. Few analyses of dissolved organic matter (DOC) illustrate a straightforward reduction with treatment time (figure 6). It is quite obvious that under thorough aerobic conditions pretreatment improves the leachate characteristics. At a final stage low concentrations might be expected. Nevertheless, the lab procedure will offer only a tendency but given the decline a concentration reduction by roundabout 80% for organic

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.

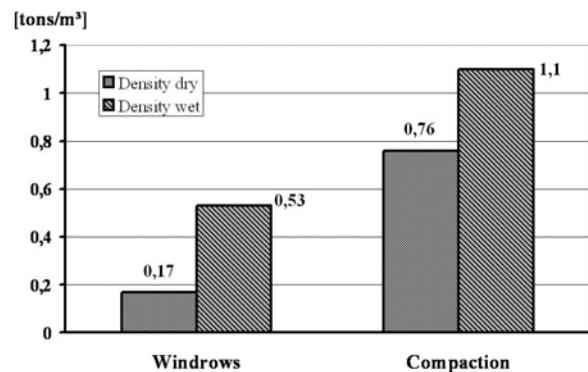


Figure 5: Improved compaction (GTZ 2003)

constituents might be expected.

Given the time variations a similar result is to be anticipated for the nitrogen compounds characterized by TKN. 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. Parallel to an extended pretreatment period ammonium-nitrogen drops below 50 mg/L. Thus requirements of a leachate ammonium concentration below 200 g /L (BMU, 2001) are easily to be fulfilled. 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 remind that real concentration might differ from those generated under lab conditions but a comparison points out a reduction by a factor of 10. In the following chapter the data from semi-scale lysimeters and leaching procedures are compared and shall provide a complete picture.

In combination with a decent organic pollution load it is likely that the nitrogen compounds are easier treatable. However, even at lower pollution load an appro-

priate leachate treatment system is required. Though, the application of low technology treatment systems

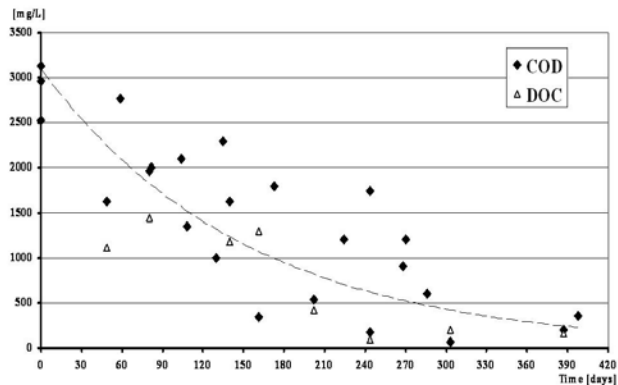


Figure 6: Reduction of COD/DOC leachability

Leachate generation –lysimeter investigations

In order to provide a better understanding under ambient conditions two specimens of processed waste have been selected and disposed of in lysimeters as described by Visvanathan et al, 2002. The variability of leachate flow and concentration can be well observed and compared with a reference system, which consists of non processed municipal solid waste. The said waste is of different origin and already emplaced in the lysimeter for more than one year. But it is assumed that basic performance is similar and tendencies are quite obvious.

The selected specimens underwent slightly different conditions. Whereas the specimen C3 obtained a partially anaerobic/aerobic degradation over roughly 9 months (see the chapters above). The specimen G7

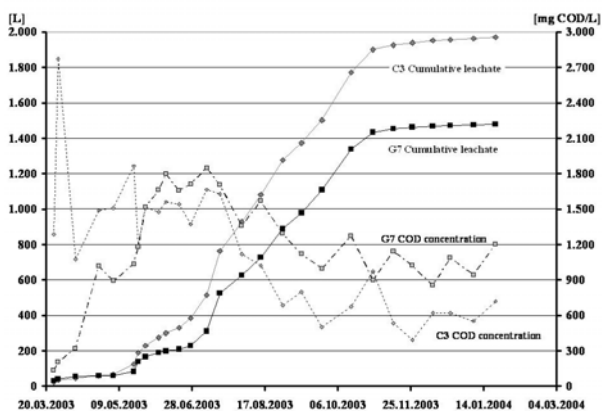


Figure 8: COD concentrations during lysimeter tests (right axis) and cumulative leachate generation (left axis)

like wetlands might be more suitable and adequate notwithstanding the appearance of priority pollutants.

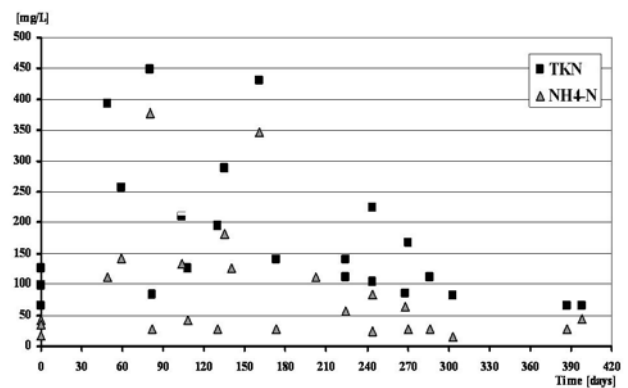


Figure 7: Reduction of TKN/NH-N₄ leachability

underwent a similar degradation plus an additional 2 months curing under strict aerobic conditions. As been indicated by figures 8 and 9 the effect of different kind of pre-treatment operation resulted in a slightly different performance related to leachate generation and the related concentrations of the COD and TKN. Further to that it has to be noticed that the concentration differ from the ones expected from the leachability results. Matter of fact is that for the lysimeter a specific load has to be compute and compared to the leaching test. The cumulative results are presented in figure 10. Compared to the leaching tests a much lower specific load is obtained for both parameter. The ongoing experiments shall resolve at what level and within which timeframe we will arrive at.

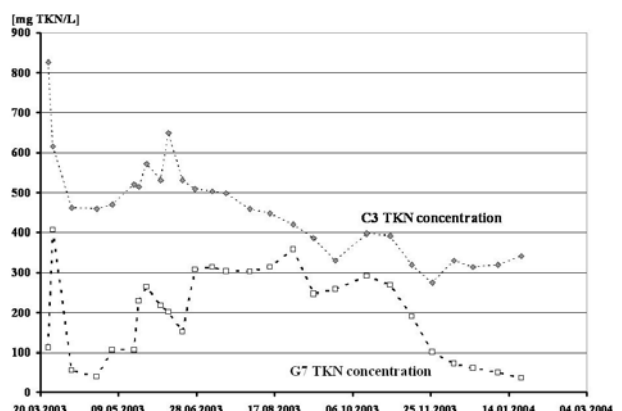


Figure 9: TKN concentrations during lysimeter tests

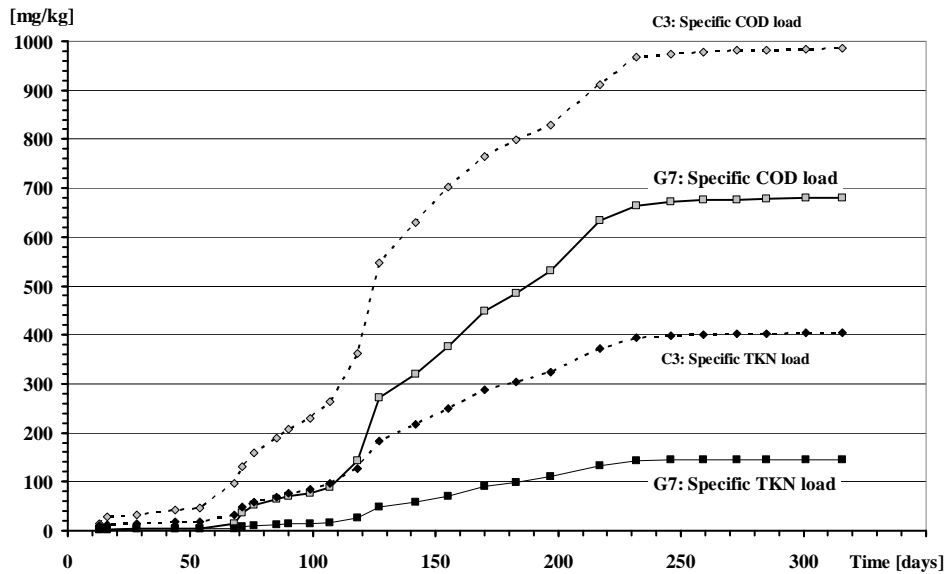


Figure 10: Specific leachate load from pre-treated MSW

The forecast indicates for the G7 specimen for COD a 5 times higher and for TKN a 4 times higher load. Whereas the sample C3 will reach for COD 10 times and TKN 2 times higher load. Considering the starting level of 'year one' it verifies how important an entire degradation process will become (see figure 10).

The afore-mentioned comparison shall give an indication at what level of total load originating from more or less pre-treated waste we might arrive at. Further to that a preliminary assessment has been made based on the first year's parallel run of reference and pre-treatment system. As been pointed out the experiments didn't run parallel and there are further differences however, the comparison given in figure 11 and 12 reveals the benefits of pre-treatment. A conventional landfill will most likely generate a 7 times higher cumulative COD load compared to one consisting of pre-treated waste. This statement is even valid for material that could not be treated as required. However, fundamental distinctions are to be realized for the TKN. The influence of thorough pre-treatment is more evident and the differences to the reference system are neglectable (C3) or reach a doubling of the load (G7).

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.

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 degradation. 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 satisfactory stabilization according to given criteria can be obtained. Thus an improved compaction can be achieved and additional landfill volume being saved.

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. During the first year of operation the leachate's pollution load can most likely be diminished for COD by 85% and nitrogen compounds by 70 % respectively. Further improvement shall be achieved in maintaining the composting process in a more strict aerobic status. Given the composition of the waste, and the fact of eventual intensive rainfalls static pile composting shows its limitation. Either forced aeration over a certain period or turning might render the problem. 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.

The revised and extended considerations based on the latest results and their extrapolation show that under the regional circumstances a pre-treatment is obviously an option to massively reduce the emission potential thus encouraging a further implementation in the region. Pre-treatment technology has the advantage of

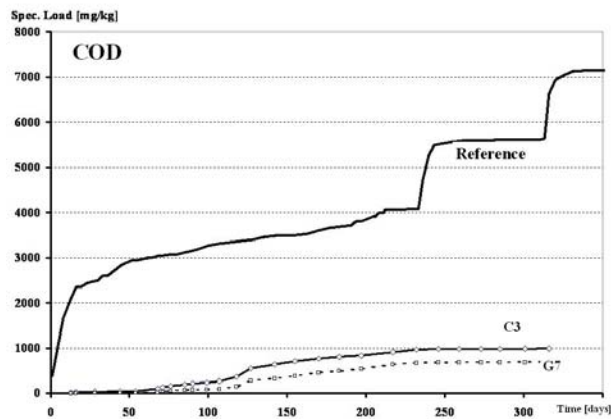


Figure 11: Comparison specific COD loads

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selecting its components according to the requirements of particular waste stream, climate conditions, desired quality of output and economy. More work has to be invested to investigate appropriate stabilization criteria, which suit the region best.

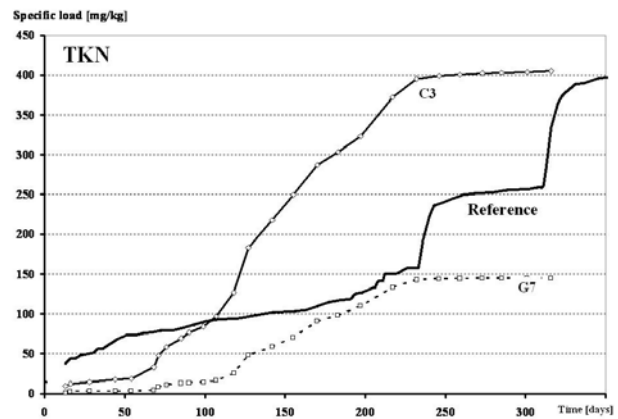


Figure 12: Comparison specific TKN loads

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