

Composting of a mixture of VFG waste and used paper diapers

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Summary

Waste disposal in the Netherlands has come under great pressure in recent years. The policy of the Dutch government is directed towards radically restricting on the domestic waste to be dumped on the basis of social, spatial and environmental-protection considerations. The key point of this policy is to make possible and promote the exploitation (re-use and useful application) of domestic waste and the sole application of waste incineration for the - greatly reduced - residual fraction. The utilization of waste is made possible by the separation of waste at source, for example through waste paper collection, bottle banks and VFG tanks. As well as the above considerations, there is a cost saving in this integrated approach to waste treatment over the dumping or incineration of waste, partly in view of the sharp rise in the price of these ways of waste treatment. Although the scales of charges differ from one municipality to another, it can be stated that the costs of composting VFG waste at present are equal to or lower than the costs of dumping or incineration. The composting of VFG waste will be increasingly cheap in the near future in relative terms as a result of the policy being conducted. In view of the integrated approach to waste treatment in the Netherlands, the composting of used paper diapers, i.e. moving diaper waste from the residual fraction to the VFG waste stream, will be a logical step to take.

At present, however, paper diapers are thrown into the rubbish bin (grey container) and then dumped or incinerated. The used paper diapers largely consist of pulp and are therefore in principle suitable for being composted together with normal Vegetable, Fruit and Garden (VFG) waste.

Various studies on the compostability of a VFG waste/paper diaper mixture have demonstrated that a good-quality compost can be produced from it. The problem in carrying out the composting of the VFG waste/diaper mixture is the fact that the paper diaper is folded up into a plug after use, as a result of which the pulp is screened by the plastic diaper film and is not composted. It is therefore necessary to grind the diaper plug prior to composting, so that the pulp becomes available for composting. However, the used paper diaper also contains approx. 15 wt.% plastic film in addition to the compostable material. This plastic diaper film must not end up in the final product. It is therefore anticipated that an adjusted process route will be necessary for composting VFG waste/diaper mixtures.

The Department of Environmental Technology of the Institute of Environmental and Energy Technology (TNO-ME) in collaboration with the Research and Development Department of VAM has carried out a study on behalf of the Dutch Association of Paper Diaper Manufacturers (Nederlandse Vereniging van Papieren-Luierfabrikanten) to develop an adjusted process route for composting VFG waste/diaper mixtures. The point of departure for this adjusted process route is the composting process applied at VAM. The following process steps have been added to this VAM process and studied.

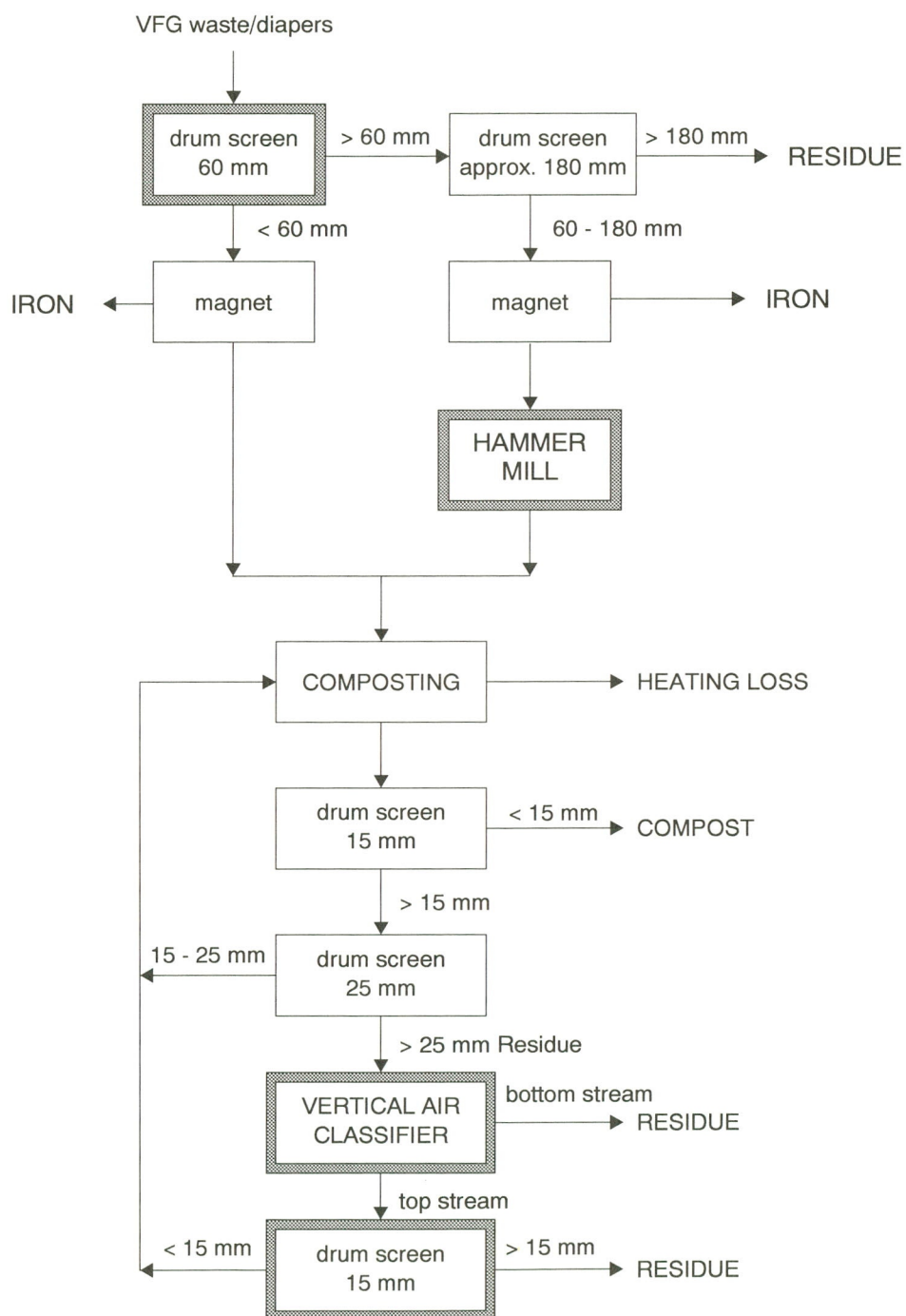
Prior to composting:

- Screening of the VFG waste/diaper mixture over a 60 mm screen to remove all diapers from the VFG waste.
- Grinding of the screen fraction > 60 mm (mixture containing all paper diapers and coarse VFG waste).

After composting:

- Airclassifying/screening of the screen fraction > 25 mm to remove the plastic diaper film.

Process diagram for the composting of a mixture of VFG waste and used paper diapers



The boxes with a grey surround are additional process steps.

Composting of a mixture of VFG waste and used paper diapers

Approximately 5,000 kg of used paper diapers was collected twice for this study, and the mixtures of VFG waste/diapers (90 wt.%/10 wt.%) were created with this. This weight ratio was chosen on the basis of international figures indicating that if used paper diapers are added to VFG waste, the percentage of used paper diapers in this will be between 2.5% and 10 wt.%. By choosing the maximum concentration, it is expected that any positive or negative effects on composting will become more clearly apparent. These mixtures were used for the study, which was largely carried out at VAM's Wijster site.

The results of this study are as follows:

- Mixtures of VFG waste and used paper diapers can be composted without difficulty by introducing additional process steps.
- The quantity by weight of used paper diaper waste to be dumped or incinerated is reduced by approx. 84% as a result of the composting of the used paper diapers. What remains as waste after composting of the used paper diaper is the plastic diaper film. This accounts for approximately 16% of the weight of the used paper diaper. The plastic diaper film can be separated out as residue to 98% as a result of the introduction of the additional process steps. At a weight ratio between VFG waste to used paper diapers of 90/10, the residue after composting as a result of the plastic diaper film is therefore 1.6% of the weight prior to composting.
- The quality of the agricultural compost produced from the VFG waste/diaper mixture via this adjusted process route is good, and the quantity of plastic diaper film in this final product is very low (0.04%) and not visually disturbing.
- The additional process steps prior to composting (screening and grinding) have a positive effect on the composting process for both normal VFG waste and VFG waste/diaper mixtures. These positive effects are as follows:
 - The yield of final product (agricultural compost < 15 mm) is increased. The residue (screen fraction > 25 mm) content is reduced.
No final figures can be established on the basis of this single trial. It is expected that as a result of introducing a grinding step prior to composting for the fraction > 60 mm, the increase in the yield of final product will be more than 10%, whilst the quantity of residue can decrease by more than 25%.
- The addition of the extra process step of air classifying/screening after composting does not contribute to the further removal of plastic diaper film. However, a quantity of compostable material can be recovered from the residue as a result of this additional process step, so that the quantity of residue to be dumped can be reduced by a further approx. 20%.

The introduction of additional process steps causes a limited rise in the costs of the composting process. However, it is anticipated that this rise will be (more than) offset by savings in processing costs due to the reduction of the residue content in the composting process. The final reduction in residue as a result of adding the additional process steps can be established after several experiments have been carried out.

In the context of integrated waste treatment in the Netherlands, the benefits resulting from the composting of used paper diapers can also be presented as reduced dumping or incineration costs. This can signify a cost saving of up to 70% on the waste treatment of used paper diapers, and a further increase in the future. The composting of used paper diapers can in this way lead to a real cost saving in waste treatment in the future of between ten and twenty million guilders per year.

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1 Introduction

The Department of Environmental Technology of the Institute of Environmental and Energy Technology (TNO-ME) in collaboration with the Department of Research and Development of VAM has carried out a study on behalf of the Dutch Association of Paper Diaper Manufacturers (Nederlandse Vereniging van Papieren-Luierfabrikanten) to develop process routes and techniques for composting used paper diapers together with normal Vegetable, Fruit and Garden waste (VFG), followed by the most complete removal possible of the plastic diaper film particles.

Previous studies [1] had demonstrated that a mixture of 90 wt.% VFG waste and 10 wt.% used paper diapers can be composted well and produces a good- quality compost, but that the quantity of plastic diaper particles remaining in the compost that is produced, although low in weight, is assessed as causing a visual disturbance.

The process route tried out in this study was chosen, in consultation with the client and those carrying it out, from a number of process routes drawn up by TNO-IMET at the start of this study.

The basic principles for these process routes are as follows:

- The composting of the paper diapers takes place in one process run-through.
- The paper diapers are reduced in size prior to composting.
- Removal of the plastic diaper film particles takes place after composting.

The following process components were investigated in order to put these basic principles into practice:

1. Selective removal of used paper diapers from VFG waste-diaper mixture.
2. Grinding of the selectively removed paper diaper fraction.
3. Composting of a mixture of VFG waste and used paper diapers.
4. Removal of plastic diaper film from compost by screening.
5. Removal of plastic diaper film from compost by air classifying.

Assessment criteria were drawn up in consultation with the client for these phases of the study. These are mentioned in the discussion of the various process components.

This report contains the data and results from the study which has been carried out. The process components enumerated above are explained in sequence in sections 2 to 7. The conclusions and recommendations arising from this study are finally presented in section 8.

2 Selective removal of used paper diapers from VFG waste/diaper mixture

2.0 Assessment criteria

- > 90% of the used paper diapers must be removed from the mixture by screening.
- The screen oversize must contain no more than 67% VFG waste.

2.1 Purpose of process component

In practice, the paper diaper is folded up after use into a kind of plug with the protective plastic film on the outside. Previous research shows [1] that if such diaper plugs are added to VFG waste untreated, the diaper plugs are virtually unaffected after this mixture has been composted and the pulp present in the diaper has not been composted. It follows that before the pulp present in the diaper is composted, the diaper plug must be ground/broken open, so that the pulp becomes available for composting. In the composting process for VFG waste employed at VAM, however, no grinding step is used prior to composting. The grinding of the VFG waste/diaper mixture in its totality is unattractive in terms of energy. In addition, the air permeability necessary for composting may be adversely affected. An attempt was therefore made to develop a process step by which the diapers are selectively removed from the VFG waste/diaper mixture and can afterwards be ground/broken open.

A screening step was tried out for this selective removal of the paper diapers from the VFG waste/diaper mixture.

2.2 Collection of used paper diapers

The client collected a quantity of approx. 10,000 kg used paper diapers through a targeted action in the northern part of the country within a period of about two weeks. This batch of used paper diapers was subsequently transported to VAM's Wijster site, where the screening trials with VFG waste/diaper mixtures were performed after mixing with VFG waste.

2.3 Mixing of VFG waste and used paper diapers

In the present situation, used paper diapers are not added to the VFG waste, in accordance with the 'VFG Waste Order'. It was therefore not possible to obtain the mixture of VFG waste/diapers through collection, and this mixture had to be put together by mixing the separate components.

The assumed quantities of used paper diapers in VFG waste vary from one study to another. In Germany it has been assumed that paper diapers account for approx. 2.8 wt.% and in Switzerland approx. 2 - 3 wt.% of the VFG waste [1, 2, 3]. In the Netherlands, the National Institute of Public Health and Environmental Protection

(RIVM) has published the finding that used paper diapers in VFG waste in practice will amount to between 2.5 and 10 wt.%. Approximately 800 million paper diapers are consumed in the Netherlands. The dry weight of these is approx. 55 grams and the wet weight approx. 180 grams. Approx. 150,000 tonnes of used paper diaper waste thus arises annually. In order to be certain that the trials took place at real contents of paper diapers, the composting trials were therefore carried out with a content of 10 wt.% used paper diapers. By opting for the maximum concentration in this study, the effects of this on the composting process are accentuated better.

The VFG waste used in the trials came from the daily delivery and was then screened in accordance with the normal process route over a drum screen with holes 150 mm round and the iron was then removed using a top-belt magnet. In this way large pieces of stone, wood and metal were removed from the VFG waste with a view to preventing damage to the apparatus used in the composting process.

Composition of mixture:

VFG waste < 150 mm round 89,140 kg (90%)

Used paper diapers 9,840 kg (10%)

It was assumed that if the used paper diapers were delivered already mixed with VFG waste, virtually no used paper diapers would be removed from the VFG waste/diaper mixture by using a screen with holes 150 mm round. In a trial with approx. 4,000 kg VFG waste/diaper mixture, only > 0.5% of the diapers was found to be removed from the mixture by screening over 150 mm round holes.

2.4 Screening of VFG waste/diaper mixture

The VFG waste/diaper mixture put together from the separate components was then screened using a mobile drum screen with a screen opening of 60 mm square.

The performance requirements to be met by this screening step are:

- The removal to more than 90% of the used paper diapers from the VFG waste/diaper mixture.
- In order to limit the grinding costs, the selectively removed paper diaper fraction (screen oversize) must consist to no more than 2/3 (67%) of coarse VFG waste.

The results of this screening step are presented in Tables 1 and 2 below and in Figures 1 and 2.

Table 1 Composition of the screening fractions after screening with a screen opening of 60 mm square

	Diapers wt. %	VFG wt. %	Total wt. %
Screen undersize	0%	100%	78%
Screen oversize	46%	54%	22%

Composting of a mixture of VFG waste and used paper diapers

Table 2 Material distribution over the screen fractions after screening with a screen opening of 60 mm square

	Diapers % of total	VFG % of total
Screen undersize	0%	87%
Screen oversize	100%	13%

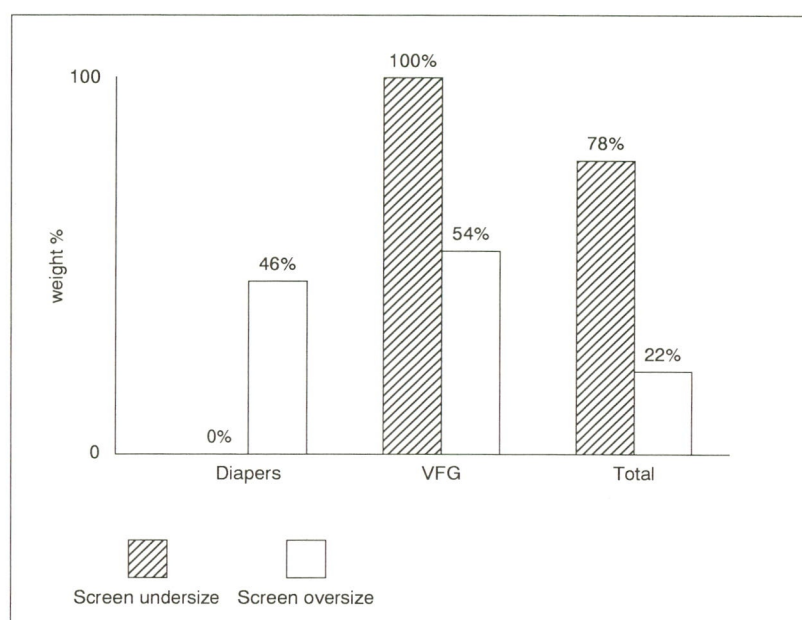


Figure 1 Composition of the screen fractions after screening with a screen opening of 60 mm square

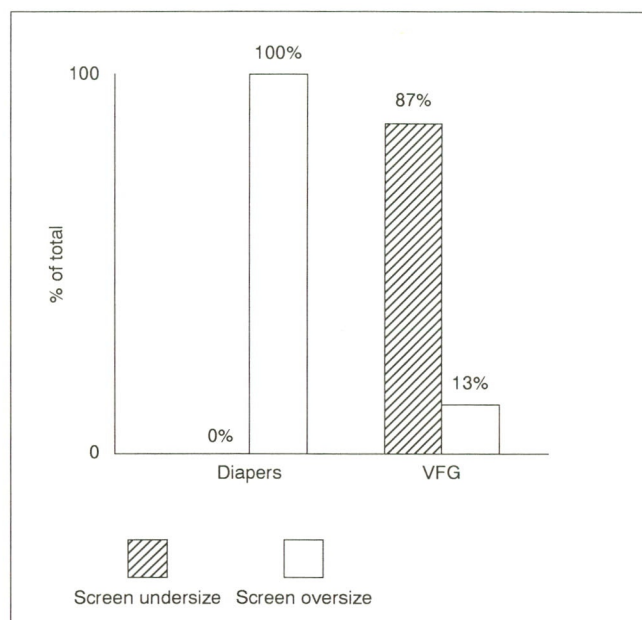
Composting of a mixture of VFG waste and used paper diapers

Figure 2 Material distribution over the screen fraction after screening with a screen opening of 60 mm square

Conclusions on screening trials

The specified requirements are amply met by applying the chosen screening step.

The used paper diapers are removed to 100% from the VFG waste/diaper mixture (requirement more than 90%).

The screen oversize consists to 46 wt.% of used paper diapers and to 54% of coarse VFG waste (requirement max. 67 wt.% VFG waste).

The screen oversize (selectively removed paper diaper fraction), 22 wt.% of the original quantity of VFG waste/diaper mixture, was used for performing the grinding trials.

3 Grinding of the selectively removed used paper diaper fraction

3.0 Assessment criteria

- Plastic diaper film; 100% > 50 mm.
- Organic compostable material; 100% < 16 mm.
- Energy consumption maximum 35 kWh/tonne.

3.1 Purpose of process component

The principal purpose of grinding the selectively removed paper diaper fraction is:

To separate the compostable pulp present in the diaper plug as completely as possible from the non-compostable plastic diaper film.

In addition, the following must be achieved after grinding of the diaper fraction:

The plastic diaper film remains substantially coarser than the organic compostable material. The purpose of this is to make it possible to screen out the plastic diaper film effectively after composting.

The following are aimed for:

Separation/opening up of compostable diaper portion to 100%.

Plastic diaper film; 100% > 50 mm.

Organic compostable material; 100% < 16 mm.

The grinding apparatus which best approximates this optimum is selected for the continued study.

3.2 Procedure for grinding experiments with diaper fraction

Two groups of mills are selected for the grinding experiments.

The first group of mills are what are known as low-speed mills with a rotor speed < 100 rpm. The action of these mills is based on a cutting principle in which the materials are reduced in size between pairs of knives. The dimensions and shape of the knives determine the size of the fragments of reduced material. A screen is sometimes placed at the bottom of the grinding chamber, so that materials are only allowed through after a particular fragment size has been reached.

The advantages of low-speed mills are:

- Low noise level.
- Low dust generation.

The drawbacks of low-speed mills are:

- Low capacity in relation to investment.
- Susceptibility to wear of the knives.

Composting of a mixture of VFG waste and used paper diapers

The second group of mills are what are known as high-speed mills with a rotor speed > 500 rpm. The action of these mills is based on an impact/collision principle. Fixed or mobile hammers are mounted on a fast-rotating rotor. The material is beaten/torn apart by these hammers. There are sometimes dies or cams in the grinding chamber which support the breaking-apart of the materials by the hammers. A screening structure may be positioned at the bottom of the grinding chamber, the apertures in which partly determine the fragment size of the reduced material.

The advantages of high-speed mills are:

- High capacity in relation to investment.
- Relatively simple replacement of wearing parts.

The drawbacks of high-speed mills are:

- High noise level.
- Substantial dust generation.

The makes and types of grinding mills tested are as follows:

(for technical specifications, see Annex 1).

Low-speed mills	
Make	Type
HAMMEL 450 MALIN 400*1400 KARA KLASMANN	2-axis machine with 11 knife discs Machine with 3 separately driven cutting rollers 1-axis wood shaper with cutters on rotor and counter-knife in grinding chamber 2-axis turf breaker with cams on rotors
High-speed mills	
Make	Type
JENZ AZ 50 JENZ HEM 7 and 12 WILLIBALD 3500	Hammer mill with open rotor and moving hammers Hammer mill with closed rotor and fixed hammers Hammer mill with open rotor and moving hammers

All the mills were operated without a screen structure in the grinding chamber. The reason for this was that it is anticipated that grinding capacity would be adversely affected and blockages/smearing may occur. In addition, if a screen is used, an unwanted reduction in the size of the plastic diaper film may occur. In the case of the high-speed hammer mills JENZ AZ 50 and WILLIBALD 3500, trials were performed at several machine settings. This was done in order to optimize the fragment size of the diaper film. The duration of the experiment for a visually acceptable result is approx. 5 minutes, at which time quantities of diaper fraction of between approx. 100 kg and approx. 1000 kg have been ground, depending on the capacity of the mill.

3.3 Assessment of grinding trials with diaper fraction

It is first of all determined during the trials to what extent the mill sufficiently damages/reduces the diaper plugs. If less than 50% of the diaper plugs are visually damaged, the grinding experiment is stopped and the ground product does not undergo further analysis. The mill concerned is not regarded as suitable. This is the case for the following mills:

Unsuitable mills for the size reduction of the diaper fraction:

HAMMEL 450	- approx. 80% of the diaper plugs are not damaged
MALIN 400*1400	- approx. 50% of the diaper plugs are not damaged
KLASMANN	- approx. 100% of the diaper plugs are not damaged

The particle size distribution of the ground products from the mills with which reasonable to complete damage of the diaper plugs was achieved was then determined by screening and the distribution of organic material and plastic diaper film over the fractions was determined by hand picking. The sample size in these analyses was 10 kg minimum.

The materials are divided into the following categories in hand picking:

film	- this is plastic diaper film without other attached material
film + pulp	- this is plastic diaper film with attached or enclosed material (a non-ground diaper also falls into this category)
organic	- these are all VFG wastes and the pulp coming from the diaper
residue	- this is everything which does not fall under the other three categories and thus contains among other things stone, glass, plastics not coming from diapers and metals

The data from the screen and sorting analyses is presented in Tables and Figures 2a to 2g which are contained in Annex 2 of this report.

This analytical data is assessed in relation to two aspects:

- The compostable pulp portion of the paper diaper must be separated as well as possible from the plastic diaper film. This is presented as:
percentage opening-up of the compostable diaper portion.
- Plastic diaper film must remain coarser after grinding than the compostable organic material. This is presented as:
percentage of plastic diaper film > 50 mm and > 16 mm
percentage of organic material < 50 mm and < 16 mm

The calculation of the percentage opening-up of the compostable diaper portion is:
(Assumption: The quantity of plastic diaper film in wet diapers is 12 wt.%)

$$\frac{\% \text{ diapers in mixture to be ground} - \text{measured } \% \text{ film/pulp in ground product}}{\% \text{ diapers in mixture to be ground} - \text{theoretical } \% \text{ film in ground product}} \times 100\%$$

The analytical data used for the assessment is summarized in the following table and Figure 3.

Composting of a mixture of VFG waste and used paper diapers

Table 3 Results of grinding trials on VFG waste/diaper mixture

Mill type	% Opened up compostable diaper portion	Plastic diaper film		Organic material	
		% ¹⁾ > 50 mm	% > 16 mm	% < 50 mm	% < 16 mm
KARA	28	91.5	98.5	95.5	63.0
JENZ HEM 12	35	97.5	99.8	89.5	56.5
JENZ HEM 7	79	98.5	99.9	90.0	52.0
JENZ AZ 50 MAX ²⁾	89	66.5	98.0	96.5	72.5
JENZ AZ 50 MIN ²⁾	91	73.0	98.5	97.5	70.0
WILLIBALD 3500 MAX	96	71.0	98.0	96.0	78.5
WILLIBALD 3500 MIN	98	80.5	98.0	94.5	76.5

1) Percentage of the total quantity by weight present in the ground product of a particular material which is present per screen fraction.

2) The additions MAX and MIN signify the maximum and minimum size reduction respectively. This is attained by changing the grinding chamber construction.

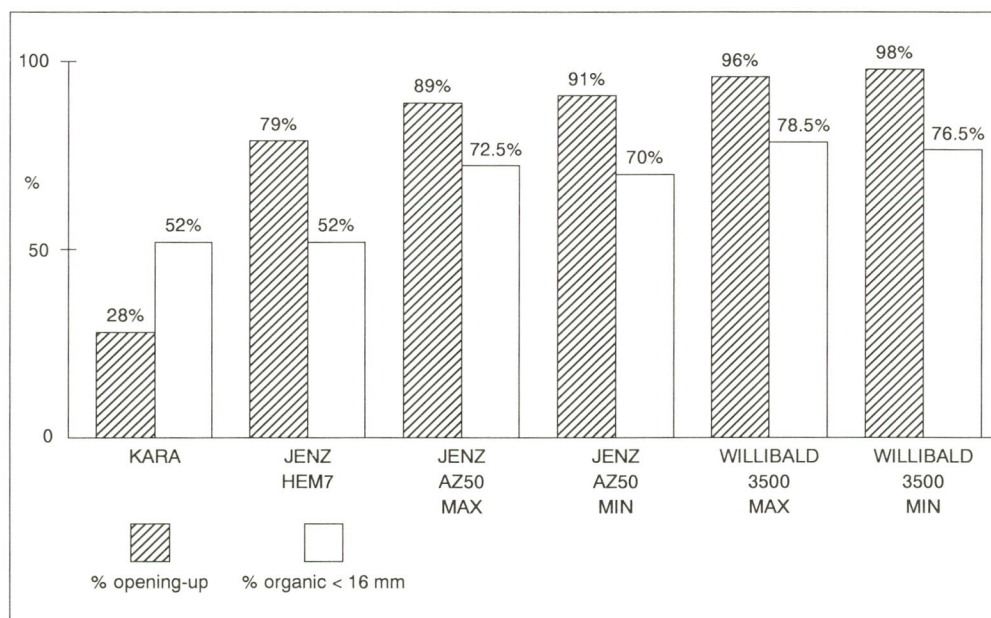


Figure 3 Results of grinding trials on VFG diaper mixture

Conclusions on grinding trials

The percentage opening-up of the compostable diaper portion is the most important assessment aspect. If this is lower than approx. 90%, the ground product still contains too many incompletely damaged diaper plugs. The compostable material present in the diaper plugs will not compost and is removed as residue after the composting process.

Composting of a mixture of VFG waste and used paper diapers

The second assessment aspect, the particle-size distribution of the plastic diaper film and the organic material, is secondary to opening-up. It is when the compostable diaper portion is not completely opened up that the plastic diaper film remains quite coarse. It should be borne in mind, however, that the plastic diaper film in this case still contains a great deal of attached and enclosed compostable material which will not compost or will not compost completely. The effect of the grinding step can therefore best be assessed on the percentage of organic material present after grinding with a particle size < 16 mm. This portion of the organic material will be completely composed and end up in its totality in the final product.

The energy consumption in these grinding trials was difficult to establish (see Annex 1). For the Jenz AZ50 and Willibald 3500 it was < 15 kWh/tonne.

On the basis of these assessment aspects, the best grinding results are obtained with the Willibald 3500. This grinding mill was also used for the continued study.

4 Composting of a mixture of VFG waste and used paper diapers

4.0 Assessment criteria

- Quantity of residue to be dumped (> 25 mm) no greater than in the present composting system.
- In the final-product compost, < 15 mm, the quantity of plastic diaper film present must not cause visual disturbance.

4.1 Preparations

A composting experiment was conducted by NV VAM as part of the project entitled 'Composting of a mixture of VFG waste and used paper diapers'. The experiments were performed at VAM in Wijster. Two experimental batches were put together and offered for composting on the basis of the results of the preliminary study (phases 1 and 2).

Preliminary treatment was as follows:

1. Screening of 100 tonnes of fresh VFG waste with a screen opening of 180 mm round.
2. The undersize (approx. 98 tonnes) is split into two batches of approx. 50 tonnes each. One batch serves as reference and goes directly to composting.
3. Approx. 10 wt.% paper diapers is added to the other batch and mixed, after which this batch is screened with a screen opening of 60 mm square.
4. The oversize of the screen (5,460 kg used paper diapers and 8,640 kg VFG waste 60 - 180 mm) is reduced in size using a grinding mill, Willibald 3500 type (chosen after the completion of phase 2, see section 3). The results of this grinding step are presented in Annex 4. The results of this grinding step are virtually in agreement with previous data. The energy consumption is approx. 7 kWh/tonne.
5. The size-reduced oversize fraction is mixed again with the fraction 0 - 60 mm and the mixture is composed as a trial heap.

4.2 Method

Composting took place in the open air. Both heaps of approx. 50 tonnes each were set up in the shape of a dike on aeration channels, using a crane. The height of the heaps varied between 2 and 3 metres. Composting was carried out using forced (blowing) aeration. The aeration was temperature-controlled and the process data was established using a data-acquisition system. Composting took seven weeks, and the heaps were turned three times during this time.

No re-moistening took place owing to the weather conditions. After composting, the material was screened using a drum screen with 15 mm and 25 mm square openings one after the other. Mass balances were drawn up from the screen oversizes and undersizes. The final product (screen fraction < 15 mm) was examined and tested against the assessment guidelines for VFG compost.

4.3 Results

Process

The composting process proceeded normally. The temperature variation during composting is presented for both compost heaps in Figure 5a in Annex 5. The results of earlier research conducted by VAM [4] demonstrated that the composting of similar heaps in the open air is quite possible, provided precipitation is not too high. Unfortunately an enormous amount of rain fell during this composting trial. This influenced the results to some extent. It was noticeable that the heap with paper diapers suffered virtually no adverse effects from the rainfall, but that the reference heap did suffer such effects. This was evident in the moisture content of the compost and the mass balances.

There are two explanations for the difference between the reference heap and the heap with paper diapers:

- effect of the diapers on the moisture management;
- effect of the grinding step on the moisture management.

It was not investigated which of the two had the most significant effect. It is found from the measured data, however, that after grinding of the screen fraction > 60 mm (mixture of coarse VFG waste and all paper diapers) approx. 75% of the compostable portion of this fraction has a particle size of < 16 mm square (see Annex 4). After composting, it is anticipated that this material ends up in the final product compost < 15 mm in its entirety. This is confirmed by the measured weight ratios between the compost fractions 0 - 25 mm and > 25 mm and the quantity of organic material in the final product compost < 15 mm.

For the non-ground reference VFG waste, after composting 70% is smaller than 25 mm and the final product (compost < 15 mm) contains 34% organic material.

For the VFG waste with paper diapers, the screen fraction > 60 mm of which was ground prior to composting, after composting 79% is smaller than 25 mm and the final product (compost < 15 mm) contains 41% organic material (see Annex 5).

The mass balances of the composting trials are presented in Table 4.

Table 4 Mass balances for composting of VFG waste without and with paper diapers

	Reference VFG waste		VFG waste with paper diapers	
	kg	%	kg	%
VFG waste 0 - 180 mm	50120	100	48980	90
Used paper diapers			5460	10
Total before composting	50120	100	54440	100
Heating loss	22540	45.0	29240	53.7
Total after composting	27580	55.0	25200	46.3
Compost 0 - 15 mm	14380	28.7	15887	29.2
Fraction 15 - 25 mm	5043	10.0	4024	7.4
Fraction 0 - 25 mm	19423	38.7 (70)	19911	36.6 (79)
Fraction > 25 mm	8157	16.3 (30)	5290	9.7 (21)

Residue, > 25 mm

VAM supplied information for the period from week 18 to week 40 in 1992 on the results of open-air composting of VFG waste at Wijster. The quantity of compost fraction > 25 mm (residue) in this period was:

Average 10.3% of the weight before composting

Minimum 3.2% of the weight before composting

Maximum 27.5% of the weight before composting

95% confidence interval: 3.9 to 16.7% of the weight before composting.

It must be noted here that in 1992 the VFG waste before composting was not screened over an 180 mm round screen. In the present trials it was found that approx. 2.2 wt.% was removed by this screening step. If it is assumed that after composting this quantity ends up in its totality in the fraction > 25 mm and the heating loss during composting is 55%, the 1992 average must be reduced by approx. 1%.

It is found from the composting experiment data that the measured values for the quantity of compost fraction > 25 mm (residue) lie within the 95% confidence interval of the Wijster 1992 data.

Quality of the final product compost, < 15 mm

In the composting route now applied for VFG waste with paper diapers, the final product compost contains only a very small quantity of plastic diaper film, which is not visually disturbing.

The final product, the fraction < 15 mm, of both batches was tested against the assessment guidelines for VFG waste. The results of this are presented in Annex 5. The standard for the VFG compost assessment guidelines is also presented in this annex.

The data shows among other things that:

- The composting process proceeded well. Stability was sufficient.
- Apart from the dry matter and the organic matter contents, there were hardly any differences between the properties of the reference VFG compost and the compost formed from VFG waste with used paper diapers.
- The germination test with barley was below the standard for both products. The likely explanation for the moderate germination is that the germination test was performed on compost which had composted for only seven instead of eight weeks and had not been post-composted as is usually done.
- The organic matter content of the compost formed from VFG waste with used paper diapers is higher than that of the reference VFG compost. This is caused firstly by the pulp coming from the diapers and secondly by the enrichment of the fraction < 15 mm with organic material obtained after grinding of the fraction 60 - 180 mm.
- The grinding of the fraction 60 - 180 mm before composting does not cause any increase in the content of contaminants and stone in the final product compost, < 15 mm.

5 Removal of plastic diaper film from compost by screening

5.0 Assessment criteria

- Approx. 95% of the plastic diaper film must end up in the screen oversize (residue).
- In the final product compost, < 15 mm, the quantity of plastic diaper film present must not be visually disturbing.

5.1 Procedure for screening experiments

A usual process step after composting VFG waste is screening.

This is carried out in order to separate fine composted material from coarse insufficiently composted material. At VAM Wijster, screening is first of all performed using a 15 mm square screen. The undersize from this screen is the final product and is sold as agricultural compost. The oversize from the screen, which consists of coarse compostable material and a non-compostable residual fraction (stone, glass, plastics etc.) is screened again using a 25 mm square screen. The undersize from this screen (15 - 25 mm), which consists chiefly of compostable material, is returned to composting. The oversize from the screen (> 25 mm), which in addition to a quantity of coarse compostable material contains virtually all the non-compostable residual materials, is at present still dumped.

This screening sequence was also at first used for the trials.

The chemical compositions of the screen fractions < 15 mm (final product compost) were measured. These are discussed in section 4.3.

The screen fractions > 15 mm were then screened using a 25 mm and 35 mm square screen one after the other. The following screen fractions were obtained:

15 - 25 mm

25 - 35 mm

> 35 mm

The organic, diaper-film and residue contents were determined in these fractions by hand picking. A calculation was also made, using these compositions of the fractions, of what percentage of the total quantity by weight present after composting of a particular material is present per screen fraction.

5.2 Results of screening experiments

The results of the screening experiments with reference VFG compost and compost obtained from VFG waste with paper diapers are presented in Annexes 3a and 3b. The results are summarized in Tables 5 and 6.

The distribution of the total quantity of diaper film present over the screen fractions is presented in Figure 4 (page 22).

Composting of a mixture of VFG waste and used paper diapers

Table 5 Composition of screen fractions

	Organic		Plastic diaper film		Remainder	
	Reference compost wt. %	Compost from VFG waste + diapers wt. %	Reference compost wt. %	Compost from VFG waste + diapers wt. %	Reference compost wt. %	Compost from VFG waste + diapers wt. %
< 15 mm	99.74	99.77	-	0.04	0.26	0.19
15 - 25 mm	99.37	98.66	-	0.35	0.63	0.99
25 - 35 mm		95.86	-	1.38		2.76
> 25 mm	98.09	78.26	-	16.26	1.91	5.48
> 35 mm		40.12		48.5		11.38
Total	99.18	95.08	-	3.49	0.82	1.43

Table 6 Distribution of the materials over the screen fractions

	Organic		Plastic diaper film		Remainder	
	Reference compost % ¹⁾	Compost from VFG waste + diapers %	Reference compost %	Compost from VFG waste + diapers %	Reference compost %	Compost from VFG waste + diapers %
< 15 mm	52.4	66.1	-	0.8	16.4	8.3
15 - 25 mm	18.3	16.6	-	1.5	14.7	11.1
25 - 35 mm		14.5	-	5.7		27.8
> 25 mm	29.3	17.3	-	97.7	68.9	80.6
> 35 mm		2.8	-	92.0		52.8

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is present per screen fraction.

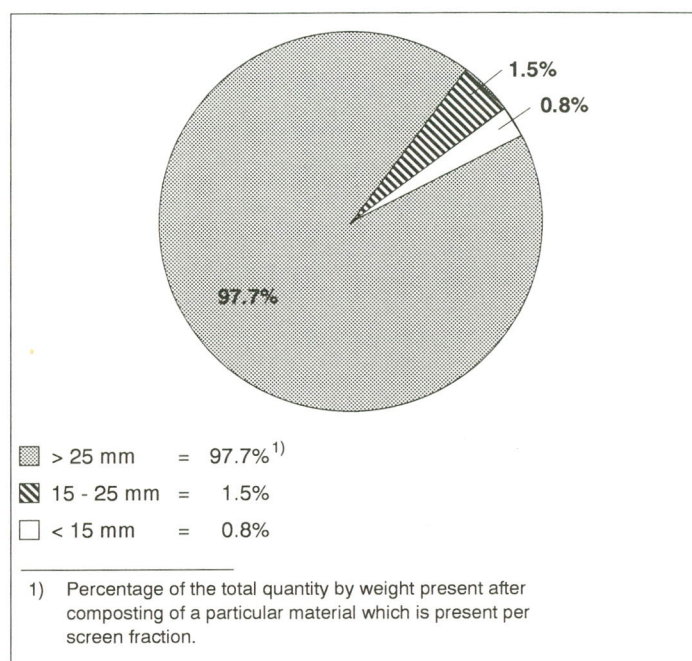


Figure 4 Distribution of the plastic diaper film between the screen fractions

5.3 Discussion of results of screening experiments

The difference in composition between reference compost and compost with diapers in principle consists solely of plastic diaper films. The measured differences in the residual fractions are based on chance and are caused among other things by non-homogeneities in the screen fractions, as a result of which representative sampling is difficult. In addition, the determination of the compositions of the screen fractions was only performed on one sample, whilst in the case of the compost with diapers particularly for the screen fractions > 25 mm the compositions were calculated from the results of measurements on more than five samples.

Final product, compost fraction < 15 mm

The plastic diaper-film content in the compost fraction < 15 mm, obtained from VFG waste with paper diapers, is very low (0.04 wt.%) and not visually disturbing. The compost (fraction < 15 mm) obtained from VFG waste with paper diapers contains, mainly as a result of the grinding step prior to composting, a higher percentage of the total quantity by weight of the organic material present after composting. A difference of 14% compared with the reference VFG compost was measured in this single trial. This results in a higher yield of agricultural compost per tonne of composted VFG waste and/or in a higher content of organic material in the agricultural compost. The range of the difference between the composting of VFG waste with or without a grinding step prior to composting can only be established after several experiments have been performed.

*Composting of a mixture of VFG waste and used paper diapers**Recycled material, compost fraction 15 - 25 mm*

The plastic diaper film in the compost fraction 15 - 25 mm, obtained from VFG waste with paper diapers, is low (0.35 wt.%). This fraction can therefore be returned to composting in exactly the same way as the reference VFG compost. The fractions 15 - 25 mm of the reference VFG compost and the compost obtained from VFG waste with paper diapers contain almost equal percentages of the total quantities by weight of organic material present after composting.

Residue, compost fraction > 25 mm

The compost fraction > 25 mm obtained from VFG waste with paper diapers contains 98% of the total quantity of plastic diaper films present after composting. The quantity of plastic diaper film, including attached dirt, which remains as residue after the composting of paper diapers is approx. 16% of the paper-diaper weight prior to composting. For a 90/10 mixture of VFG waste and paper diapers, the residue after composting due to the plastic diaper film is therefore 1.6% of the weight before composting.

The measured percentages of residue in this single trial are:

Reference VFG compost 16.3% of the weight before composting.

Compost obtained from VFG waste with paper diapers 9.7% of the weight before composting.

In addition, the fraction > 25 mm of the reference VFG compost is 12% less than the total quantity by weight of organic material present after composting.

Both differences are again chiefly caused by the grinding of the fraction > 60 mm prior to composting. It is found from the measured data of the ground product (Annex 4) that only approx. 15% of the compostable organic material in the screen fraction > 60 mm after grinding has a particle size of > 25 mm. It can be deduced from this that the quantity of compost residue is reduced by the grinding of the fraction > 60 mm before composting. The residue quantity of the reference VFG compost in this single trial is 40% higher than that of the compost obtained from VFG waste with paper diapers, where the fraction > 60 mm was ground prior to composting.

This is despite the fact that all the plastic diaper films are also contained in this.

The final positive effect of the grinding step prior to composting on the residue content present after composting must be established on the basis of several experiments.

In the long term, however, dumping of the screen fraction > 25 mm is not desirable in view of government policy. This fraction, in addition to approx. 98% of all the plastic diaper film and 70 - 80% of the residual materials, still contains approx. 15 - 30% of all the compostable (organic) material present.

It is therefore appropriate to post-treat the screen fraction > 25 mm with the aim of separating plastic diaper film and remaining material from the compostable (organic) material. In this way, organic material can be returned to composting and the quantity of residue to be dumped can be reduced.

The results of the investigation on the post-treatment of the screen fraction > 25 mm are presented in the following section 6.

6 Removal of plastic diaper film from compost by air classifying

6.0 Assessment criteria

- Approx. 95% of the plastic diaper film must be separated as residue.

6.1 The principle of air classifying

The principle of air classifying consists in the separation of particles on the basis of differences in density, shape and size.

Air classifying is a technique in which particles are separated on the basis of their difference in falling behaviour in an air current.

There are many different types of air classifiers. Devices with rectangular, round and zigzag-shaped channels occur. In all types of air classifiers, the mixtures of materials to be separated are brought into an adjustable air current. This air current is across or against the flow of material; combinations of cross and counter-current also occur. Air classifiers are often used as a first coarse separating step with the purpose of pre-concentrating in a separation process.

6.2 Procedure for air classifying trials

Three different types of air classifiers were used for the air classifying trials:

- zigzag air classifier;
- vertical air classifier;
- drum air classifier.

The principle of these air classifiers is illustrated in Figure 5.

For the technical specifications of the air classifiers used, see Annex 6.

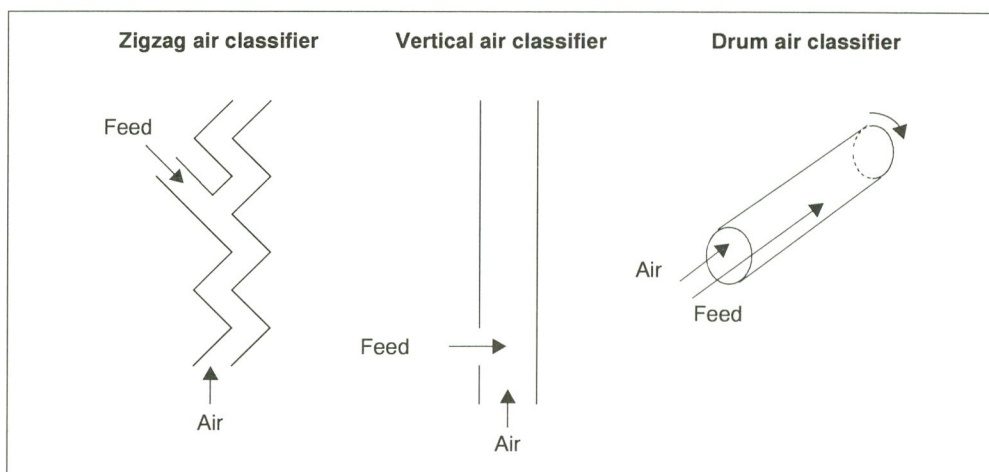


Figure 5 Principle of air classifiers

The purpose of the air classifying experiments is to separate the compostable (organic) material as well as possible from the non-compostable materials (plastic diaper film, stone, glass, plastics and so on).

The materials used for the air classifying experiments are the screen fractions > 25 mm from the compost obtained from VFG waste with paper diapers. The percentages of the materials per screen fraction are shown in Table 7.

Table 7 Percentages of the total quantities by weight present after composting of a particular material which is present per screen fraction

	Organic	Plastic diaper film	Remainder
25 - 35 mm	14.5%	5.7%	27.8%
> 25 mm	17.3%	97.7%	80.6%
> 35 mm	2.8%	92.0%	52.8%

These figures show that if the recovery of organic material is the main purpose, the air classifying of the screen fraction > 35 mm is not very useful because only a small quantity of the organic material present after composting is in this. Consideration can even be given to disposing of the fraction > 35 mm untreated as residue. However, the problem is the screen fraction 25 - 35 mm. This fraction contains approx. 15% of all the organic material present after composting combined with approx. 6% of the plastic diaper film and approx. 28% of the remainder materials. This screen fraction therefore cannot be returned to composting because in the long run unacceptable enrichment of the compost heaps with plastic diaper film and remainder materials would take place as a result. It is therefore not appropriate to screen the materials with 25 and then 35 mm screens after composting. One screening step with a 25 mm screen is sufficient.

However, in the air classifying trials the screen fraction > 35 mm was also tested.

6.3 Mutual comparison of air classifier performance

Preliminary air classifying trials were first carried out with all three air classifiers. These experiments were performed with the screen fractions 25 - 35 mm, > 35 mm and > 25 mm. The results for the screen fraction > 25 mm for the zigzag and vertical air classifiers were calculated from the results for the screen fractions 25 - 35 mm and > 35 mm.

The air velocities in the air classifiers were visually adjusted to the optimum for these preliminary experiments. This optimum was at an air velocity of approx. 8 m/s for all the air classifiers. After the air classifying experiments, it is established by hand picking how the organic material, the diaper film and the residual materials are distributed between the bottom stream and the top stream. The aim is to separate 100% of the plastic diaper film in the oversize and 100% of the organic material in the undersize. The results of these air classifying experiments are presented in Annex 7. Figure 6 summarizes the results of the air classifying of the screen fraction > 25 mm.

Composting of a mixture of VFG waste and used paper diapers

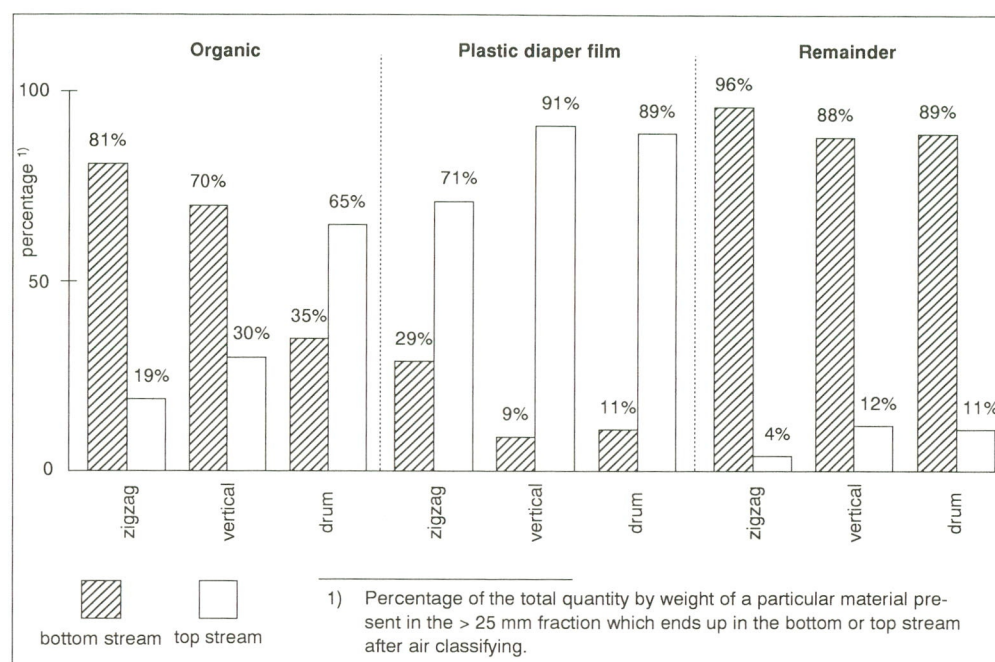


Figure 6 Distribution of the materials after air classifying of the screen fraction > 25 mm

It can be seen from this figure that the vertical air classifier best approaches the target values of 100% plastic diaper film in the top and 100% organic material in the bottom stream.

It should be noted that the design of the drum air classifier used is far from optimum for the separation of organic material and diaper film. This drum air classifier was designed to separate metals and insulating material such as occur in underground cables. The angle of repose and the transport of material in the drum must be optimized for the separation of organic material. As a consequence of this, the trials with the drum air classifier were performed with a feed of approx. 700 kg/hour, whilst the design capacity is approx. 3 tonnes/hour.

An adverse phenomenon noted in the air classifying of the screen fraction > 25 mm is that as well as a particular percentage of the organic material, virtually all the remainder materials such as stone, glass and thick-walled plastics end up in the bottom stream of the air classifier. If the bottom stream fraction of the air classifier is returned to composting, unacceptable enrichment of the compost heaps with non-compostable remainder materials will take place in the long run. A process route must therefore be looked for in which, as well as the plastic diaper films, the remainder materials must also be separated from the compostable organic material to be returned.

6.4 Effect of the air velocity in the vertical air classifier on the distribution of the materials over the bottom and top stream

It can be seen from the results presented in 6.3 that the vertical air classifier brings about the best separation between organic material and plastic diaper film. The vertical air classifier also merits preference because of the simplicity of its construction and the consequent small likelihood of breakdowns.

In order to determine how the distribution of material over the bottom and top stream will change at increasing velocities between 7 and 13 m/s, supplementary experiments were performed with the screen fraction > 25 mm. The results of these experiments are presented in Annex 8. The effect of air velocity on the percentages of organic material, plastic diaper film and the total (organic + diaper film) in the top stream is shown in Figure 7.

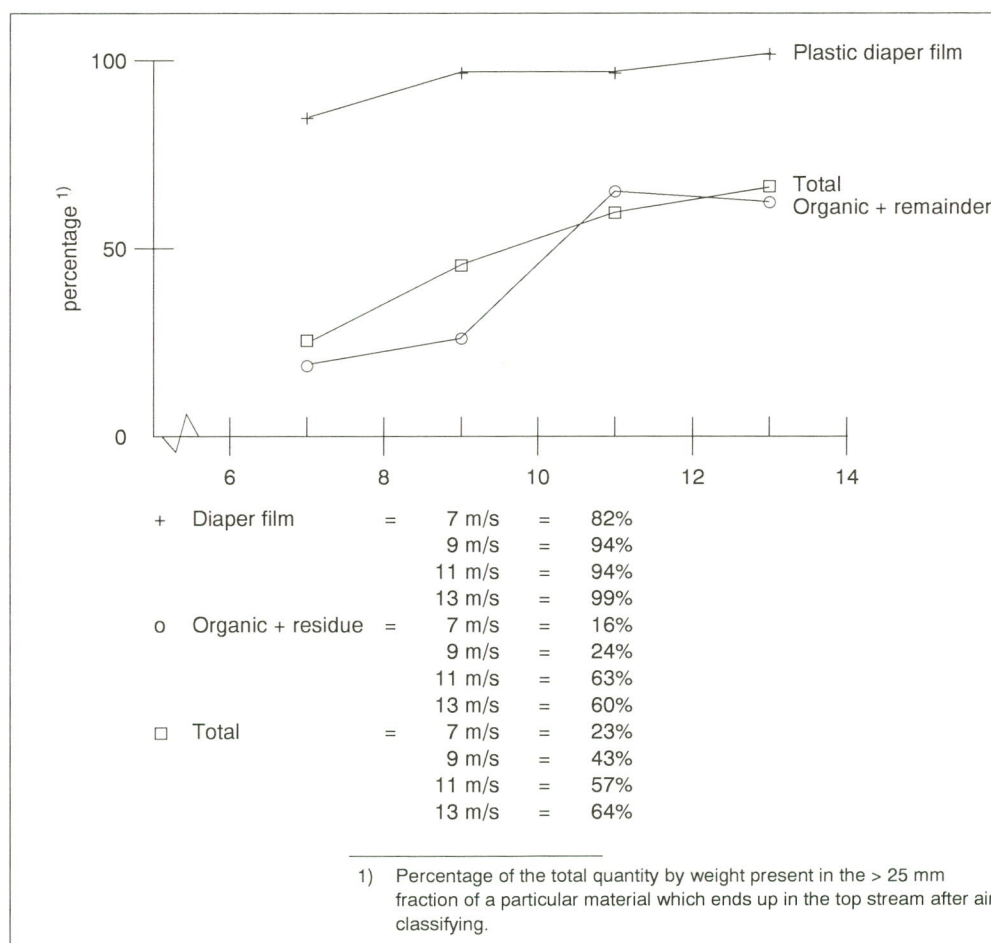


Figure 7 Air velocity versus percentage and total of the materials in the vertical classifier top stream

It can be seen from the figure that at an air velocity of 13 m/s virtually all the plastic diaper film (99%) ends up in the top stream fraction. In addition, however, the top stream contains approx. 50% of the organic materials.

Composting of a mixture of VFG waste and used paper diapers

The following is observed after visual inspection of the bottom stream and top stream fractions of the vertical air classifier (at an air velocity of 13 m/s).

The bottom stream fraction contains:

Remainder materials such as glass, stone and thick-walled plastics.

Very coarse organic material which will not compost sufficiently without intensive size reduction.

The top stream fraction contains:

In addition to the plastic diaper films fairly fine organic material which on average is considerably smaller in terms of particle size than the plastic diaper films.

The following is proposed on the basis of this:

- Dispose of the bottom stream fraction of the air classifier as residue.

The composition (wet) of this residue and the percentages of the materials in this residue are:

	Composition wt. %	of total ¹⁾ after composting %
Total	100	6.9
Organic	87.1	6.4
Plastic diaper film	0.3	0.6
Stone, glass, plastics etc.	12.6	61.5

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (air classifier bottom stream).

- Screen off the air classifier top stream to separate the compostable fine organic material from the plastic diaper films.

The results of the screening of the air classifier top stream are presented in section 6.5.

6.5 Screening of the top stream fraction of the vertical air classifier for the removal of plastic diaper film

The composition (wet) of the top stream fraction of the vertical air classifier (13 m/s) and the percentages of the materials in it are:

	Composition wt. %	of total ¹⁾ after composting %
Total	100	13.9
Organic	73.7	10.8
Plastic diaper film	24.4	97.5
Stone, glass, plastics etc.	1.9	18.4

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is present in the air classifier top stream.

Composting of a mixture of VFG waste and used paper diapers

This top stream fraction was then screened with the screen opening 16 mm square. The composition (wet) of the screen undersize and screen oversize and the percentages of the materials in it are:

	Composition wt. %		of total ¹⁾ before screening %	
	Undersize	Oversize	Undersize	Oversize
Total	100	100	50	50
Organic	99.2	47.6	68	32
Plastic diaper film	0.6	48.7	1.2	98.8
Stone, glass, plastics etc.	0.2	3.7	3	97

¹⁾ Percentage of the total quantity by weight present in the air classifier top stream of a particular material which ends up in the screen undersize or screen oversize.

The screen undersize is returned to composting.
The screen oversize is removed as residue. The percentages of the materials in it are:

	of total ¹⁾ after composting %
Total	6.9
Organic	3.5
Plastic diaper film	96.3
Stone, glass, plastics etc.	17.9

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (screen oversize).

For further information, see Annex 9.

6.6 Residue quantities and materials

Reference VFG compost

In the process employed at present at VAM Wijster for the composting of VFG waste, the screen fraction > 25 mm is removed as residue. In the trial which is now being conducted, the residue content of the reference VFG compost was 16.3% of the weight before composting.

Composting of a mixture of VFG waste and used paper diapers

The composition (wet) of this residue of the reference compost and the percentages of the materials in it are:

	Composition wt. %	of total ¹⁾ after composting %
Organic	98	29
Stone, glass, plastics etc.	2	69

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is disposed of as residue (> 25 mm).

A relatively large quantity of organic material is consequently removed as residue.

Compost obtained from VFG waste with used paper diapers

The following process steps are added to the process route for the composting of VFG waste with paper diapers compared with the process route for the reference VFG waste.

Before composting:

- Screening over 60 mm square.
- Grinding of the screen fraction 60 - 180 mm with high-speed hammer mill.

After composting:

- Vertical air classifying with the screen fraction > 25 mm square.
- Screening of the top stream fraction of the vertical air classifier over 16 mm square.

If only the extra process steps before composting are introduced, the residue (> 25 mm) content is 9.7% of the weight before composting. This is in relative terms 40% less than the residue content of the reference experiment, despite the fact that the plastic diaper film causes a rise of approx. 1.6% in the residue quantity.

The composition (wet) of this residue of the compost obtained from VFG waste with used paper diapers and the percentages of the materials in it are:

	Composition wt. %	of total ¹⁾ after composting %
Organic	78.3	17.3
Plastic diaper film	16.3	97.7
Stone, glass, plastics etc.	5.4	80.6

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (> 25 mm).

The substantial reduction in the residue content and the relatively smaller quantity of organic material in it are chiefly the result of the grinding of the screen fraction 60 - 180 mm. However, it is anticipated that the pulp in the diapers also has a positive effect on the composting process.

Composting of a mixture of VFG waste and used paper diapers

If the extra process steps after composting are applied, the residue content is 6.4% of the weight before composting. This is 60% less than the residue content obtained when the reference experiment is performed.

The residue is obtained after carrying out two process steps as follows:

- bottom stream fraction of the vertical air classifier arising in the air classifying of the screen fraction > 25 mm square.
- oversize fraction of the 16 mm screen, arising in the screening of the top stream fraction of the vertical air classifier.

The composition (wet) of this residue of the compost obtained after composting VFG waste with paper diapers and the percentages of the materials in it is:

	Composition wt. %	of total ¹⁾ after composting %
Organic	67.4	9.8
Plastic diaper film	24.4	97.0
Stone, glass, plastics etc.	8.2	79.2

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue.

The application of the extra process steps of air classifying and screening after composting thus only make a contribution towards lowering the residue content and the quantity of organic material in the residue. These extra process steps are not necessary for the removal of plastic diaper film and remainder materials.

The residue contents and the percentages of materials in this residue for the reference composting process and the optimized composting process for the composting of VFG waste with paper diapers are presented in overview in Figures 8 and 9.

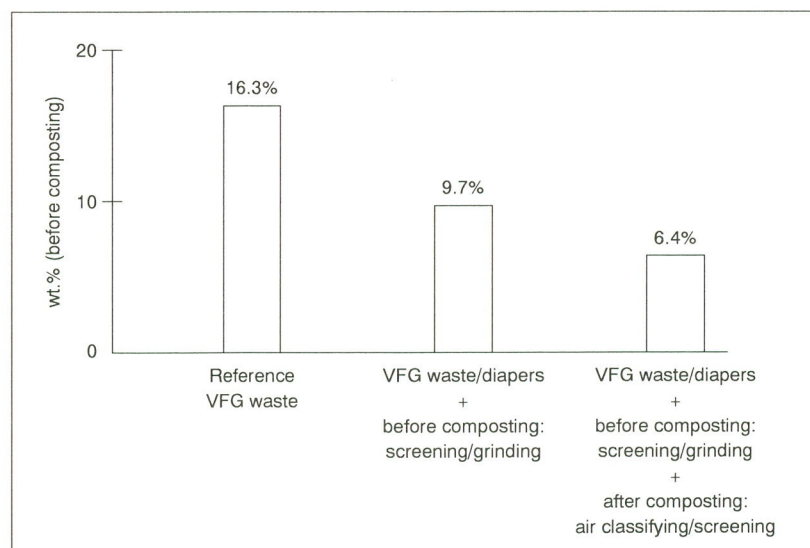


Figure 8 Residue contents after carrying out the composting processes

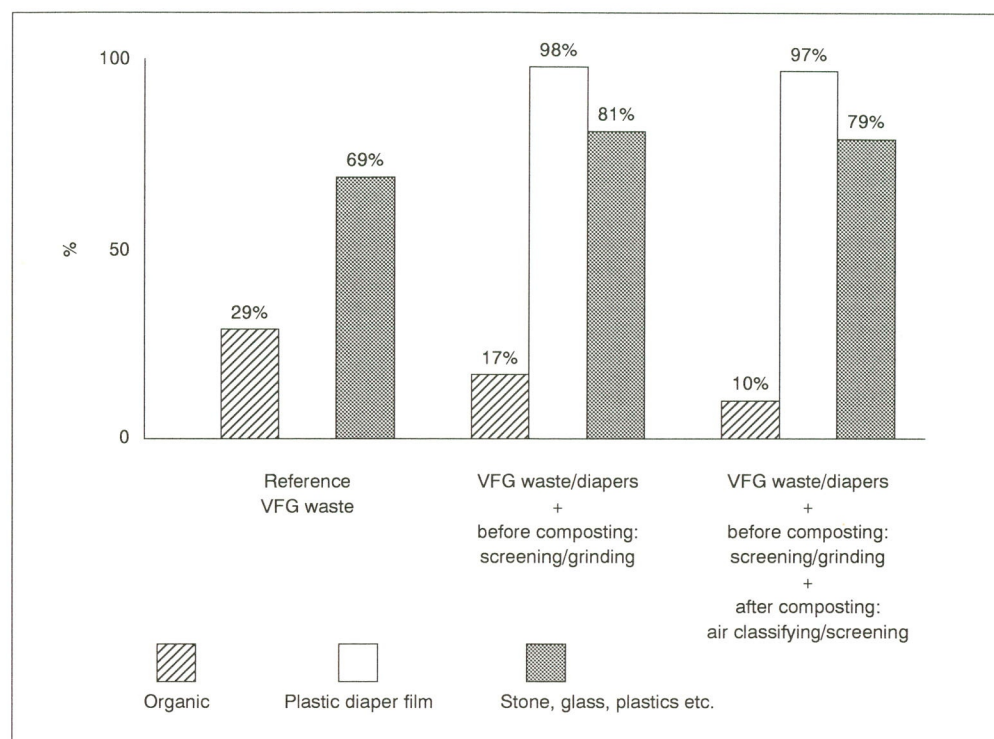
Composting of a mixture of VFG waste and used paper diapers

Figure 9 Percentages of the total quantities by weight of a particular material present after composting which is removed as residue

7 Financial aspects of process adjustments and composting of diapers

7.1 Costs/benefits of the process modification

Costs

The extra process steps added to the VAM composting process consist of:

- a. The screening before composting of the VFG waste over 60 mm square. Consideration is to be given to combining this 60 mm screening step with a 200 mm square opening screening step.
The purpose of this is to reduce the residue content further in comparison with the present screening step over 150 mm round opening.
- b. The grinding of the screen fraction > 60 mm prior to composting. Maximum 30% of the material per tonne VFG waste is > 60 mm.
- c. The air classifying/screening of the compost fraction > 25 mm after composting. After composting approx. 10% of the material per tonne VFG waste is > 25 mm.

The costs of these extra process steps have been estimated by VAM at NLG 3.00/tonne VFG waste. The following assumptions have been made:

- Composting unit with capacity of 60,000 tonnes VFG waste/year.
- Investments for extra process steps NLG 700,000.
- Operating costs: NLG 180,000/year.

The costs of dumping and incinerating wastes differ from one municipality to another. The following have been used in the calculations:

- Dumping (excluding storage) NLG 80/tonne waste.
- Incinerating NLG 270/tonne waste.

Benefits

The benefits of the extra added process steps within the composting process chiefly consist in the reduction of dumping or incineration costs. If the quantity of waste to be dealt with is reduced by 1% of the waste weight before composting, the benefits are:

- dumping: NLG 0.80/tonne waste;
- incineration: NLG 2.70/tonne waste.

It is anticipated that, in view of the national development towards residual waste exclusively being incinerated, the reduction in residue will certainly neutralize the rise in costs.

It is not possible to give a final figure for the reduction in the residue content per tonne composted VFG waste as a result of the addition of the extra process steps on the basis of this single trial.

Composting of a mixture of VFG waste and used paper diapers

If it is assumed that the reduction in residue per tonne composted VFG waste varies between 1.5 - 4%, it is possible to calculate what the benefits minus costs are at the present dumping and incineration prices.

This is illustrated in Figure 10.

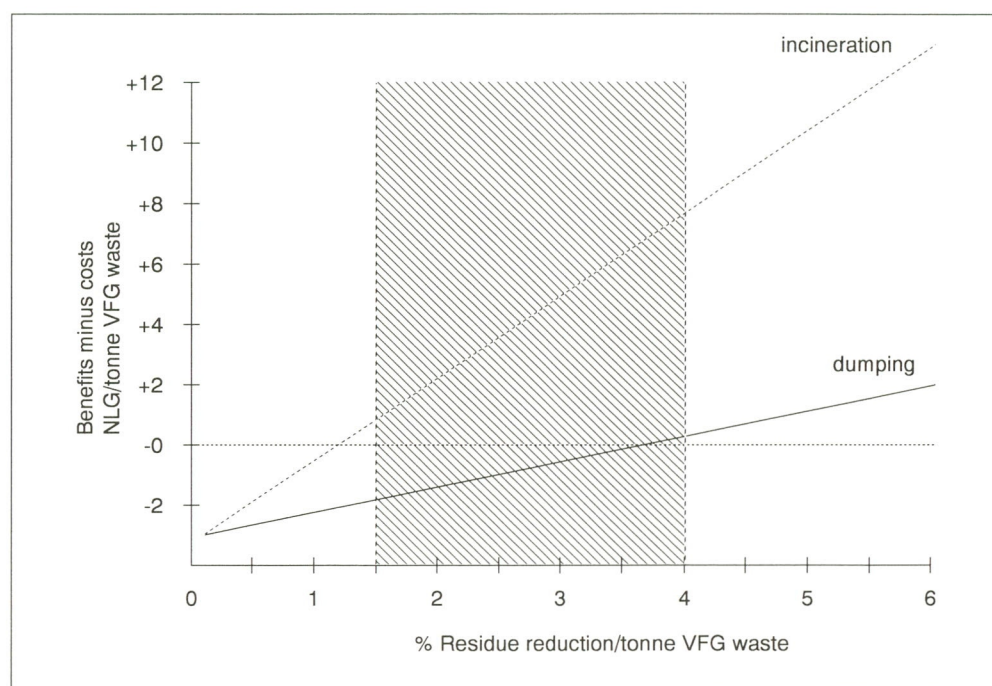


Figure 10 Benefits minus costs versus % reduction in residue per tonne VFG waste

7.2 Cost saving due to integrated waste treatment

In the context of the integrated waste treatment of domestic waste in the Netherlands with separate waste streams of VFG waste and 'residual waste', the benefits of composting used paper diapers can also be presented as reduced dumping or incinerating costs (and in the near future exclusively incineration costs). The processing of the VFG waste stream is at present 70% cheaper than the processing of 'residual waste'. In the future this difference will increase further. This means that the composting of used paper diapers in the future may lead to a real cost saving in waste treatment of 10 to 20 million guilders per year.

8 Conclusions

Process

Mixtures of VFG waste/used paper diapers (weight ratio 90/10) can be composted without difficulty if extra process steps are added prior to composting. These extra process steps are:

The screening of the VFG waste/diaper mixture with a 60 mm (square) screen.

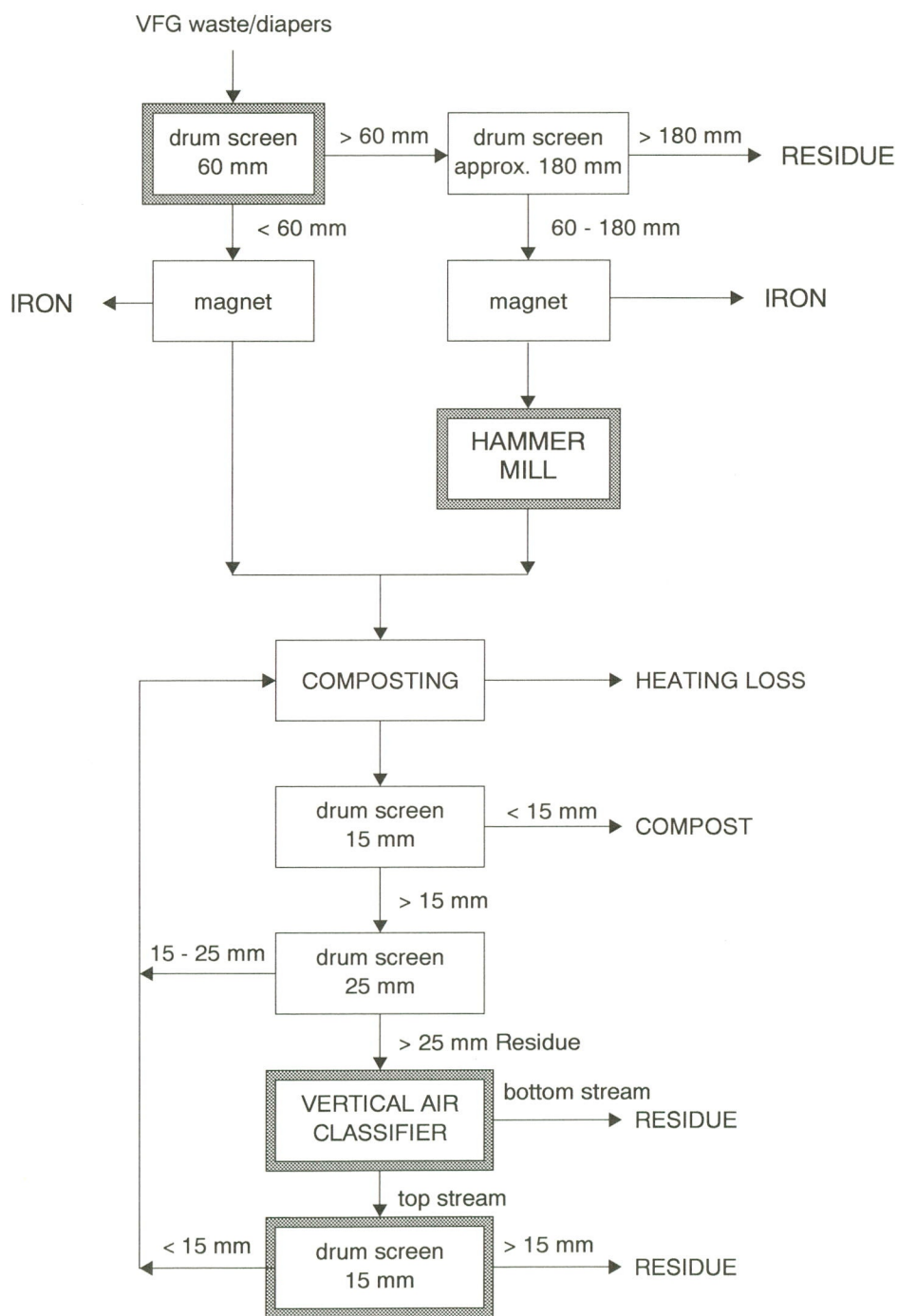
The grinding of the screen fraction > 60 mm (mixture of coarse organic material and all diapers).

The quantity by weight of used paper diaper waste to be dumped or incinerated is reduced by approx. 84% by the composting of the used paper diapers. Approx. 16% of the paper diaper weight therefore remains as waste after composting, in the form of plastic diaper film.

These extra process steps have a positive effect on the composting process of both VFG waste and VFG waste/diaper mixtures. They increase the yield of final product and reduce the residue content per tonne of composted material. This is chiefly caused by the reduction in size of organic compostable material by the grinding step. It is anticipated that the pulp from the paper diapers will also have a favourable effect.

The addition of extra process steps after composting, such as air classifying/screening, is not necessary in order to produce a good-quality compost from the VFG waste/diaper mixture. On the other hand, a quantity of compostable material is recovered from the residue in this way and the residue quantity to be dumped is reduced.

Process diagram for the composting of a mixture of VFG waste and used paper diapers



The boxes with a grey surround are additional process steps.

Product quality

Final product (agricultural compost < 15 mm)

The addition of 10 wt.% used paper diapers to VFG waste does not have any adverse effect on the composition of the compost produced from this, via the adjusted process route. The quantity of plastic diaper film in the final product is very low (0.04 wt.%) and not visually disturbing. In addition, the adjusted process route does not result in an increase in other impurities, such as stone, glass and plastics.

Recycled material (screen fraction 15 - 25 mm)

The quantity of plastic diaper film in the compost fraction 15 - 25 mm, obtained from VFG waste with paper diapers, is low (0.35 wt.%), and this fraction can therefore be recycled without difficulty. The 15 - 25 mm fraction of the reference VFG compost and the compost obtained from VFG waste with paper diapers contain almost equal percentages of the total quantities by weight of the organic material present after composting.

Residue (screen fraction > 25 mm)

The compost fraction > 25 mm obtained from VFG waste with paper diapers contains 98% of the total quantity of plastic diaper films present after composting. The residue of the reference VFG compost contains a higher percentage of the total quantity by weight of organic material present after composting. Dumping of this relatively organically rich fraction results in a lower compost yield per tonne of composted VFG waste.

Product quantity

It is not possible to establish ranges on the basis of this single trial. Several experiments are required for this purpose.

It is anticipated that as a result of the introduction of a grinding step for the fraction > 60 mm prior to composting, the increase in the yield of final product will be more than 10%, whilst the residue quantity can be reduced by more than 25%.

If the extra process step of air classifying/screening is introduced after composting, a quantity of compostable material can be recovered from the residue, so that the quantity of residue to be dumped can again be reduced by approx. 20%. The quantity of plastic diaper film which is left behind as residue after the composting of paper diapers (screen fraction > 25 mm) is approx. 16% of the paper diaper weight before composting. At a weight ratio of VFG waste/used paper diapers of 90/10, the residue after composting due to the plastic diaper film is therefore 1.6% of the weight before composting.

Costs/benefits

The costs associated with the application of the extra process steps have been estimated at NLG 3.00/tonne VFG waste. Within the composting process, the benefits consist in savings on dumping or incineration costs as a result of the reduction in the residue content. To offset the costs, at the prices currently applicable to dumping and incineration the residue content in dumping must be reduced by approx. 4% and in incineration by approx. 1%.

The benefits of composting used paper diapers can also be presented as reduced dumping or incineration costs.

At a difference in treatment costs between composting and incineration of used paper diapers (150,000 tonnes/year) for example of NLG 100/tonne, a saving of NLG 12,600,000 is attained.

9 References

- [1] Onderzoek naar de composteerbaarheid van papieren luiers (Study on the compostability of paper diapers);
T.D. Brethouwer and H.J. Doddema, April 1992.
- [2] Co-Kompostierung von Höschenwindeln und Bioabfall im Kompostwerk Stockerau (Co-composting of diapers and bio-waste in the Stockerau composting plant);
Thomas Obermeier et al., July 1991.
- [3] Elimination der Kunststoffbestandteile von Höschenwindeln aus Grobkomposten (Elimination of the plastic constituents of diapers from coarse composts);
Thomas Obermeier et al., September 1991.
- [4] NOVEM report number 9226.

10 Authentication

Name and address of the principal

Nederlandse Vereniging van Papieren-Luierfabrikanten
(Dutch Association of Paper Diaper Manufacturers)
Attn J.J.G.M. Glansbeek
P.O. Box 1345
3000 BH Rotterdam

Names and functions of the cooperators

P.C. Tuinman, project officer
J.F. van Middelkoop, project officer
C. Verschut, project leader

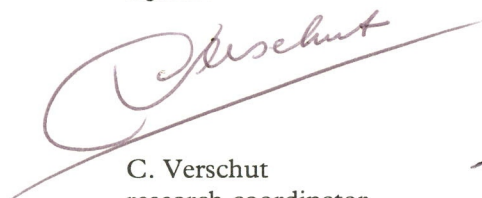
Names of establishments to which part of the research was put out to contract

NV VAM, Department of Research and Development, Hilversum:
T.D. Brethouwer, project leader
NV VAM, Wijster site: Mr. de Visser and staff
Fuhler B.V. Emmen: Mr. J. Fuhler and staff
TNO-IMW: Dr. H.J. Doddema

Date upon which, or period in which, the research took place

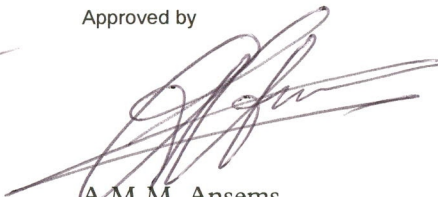
May 1993 to December 1993 inclusive

Signature



C. Verschut
research coordinator

Approved by



A.M.M. Ansems
section leader

Annex 1 Technical specifications of grinding equipment

Low-speed mills

Make/type	MALIN 400x1400	HAMMEL 450	KARA
Rotor diameter mm	400	450	250
Rotor width mm	1400	1400	800
Rotor speed rpm	38 and 90	33	105
Rotor construction	3 open-screw	2 with 11 knives	rotor with cutters
Feed system	top two rotors	funnel	loading slide
Grinding chamber facilities	counter-knives	-	counter-knife
Motor power kW	150	110	18.5
Capacity tonnes/hr	20	15	< 1
Energy consumption kWh/tonne VFG waste	approx. 7	approx. 7	> 15

High-speed mills

Make/type	WILLIBALD 3500	JENZ HE 7/28	JENZ HEM 12	JENZ AZ 50
Rotor diameter mm	750	320	320	1040
Rotor width mm	1500	280	400	1500
Rotor speed rpm	1100	1200	600	1100
Rotor construction	3 rows mobile hammers	fixed knives	fixed knives	3 rows mobile hammers
Feed system	roller	funnel	roller	roller conveyor
Grinding chamber facilities	counter-rake post-reducer	-	-	adjustable base
Motor power kW	280	10	-	270
Capacity tonnes/hr	40	< 1	1	40
Energy consumption kWh/tonne VFG waste	approx. 7	approx. 15	-	approx. 7

Annex 2 Hand picking analyses of the grinding trials on the VFG waste/diaper mixture

Table 2a KARA wood shaper

Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt. %	wt. %	wt. %	wt. %	wt. %
> 73	100.0	0.0	94.0	3.9	2.1
50 - 73	100.0	1.2	68.4	23.0	7.4
40 - 50	100.0	2.3	30.6	63.2	3.9
30 - 40	100.0	1.8	13.3	84.0	0.8
16 - 30	100.0	0.9	5.5	93.0	0.6
0 - 16	100.0	0.0	1.3	98.6	0.1
> 73 - > 0	100.0	0.4	34.2	64.0	1.4

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re-mainder	Re-mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	27.4	27.4	74.5	74.5	1.7	1.7	39.7	39.7
50 - 73	8.5	35.9	17.1	91.6	3.0	4.7	43.5	83.2
40 - 50	2.0	37.9	1.9	93.5	2.0	6.7	5.4	88.6
30 - 40	3.9	41.8	1.7	95.2	5.1	11.8	2.2	90.8
16 - 30	17.4	59.2	3.2	98.4	25.2	37.0	7.1	97.9
0 - 16	40.9	100.0	1.6	100.0	63.0	100.0	2.2	100.0
> 73 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS KARA WOOD SHAPER

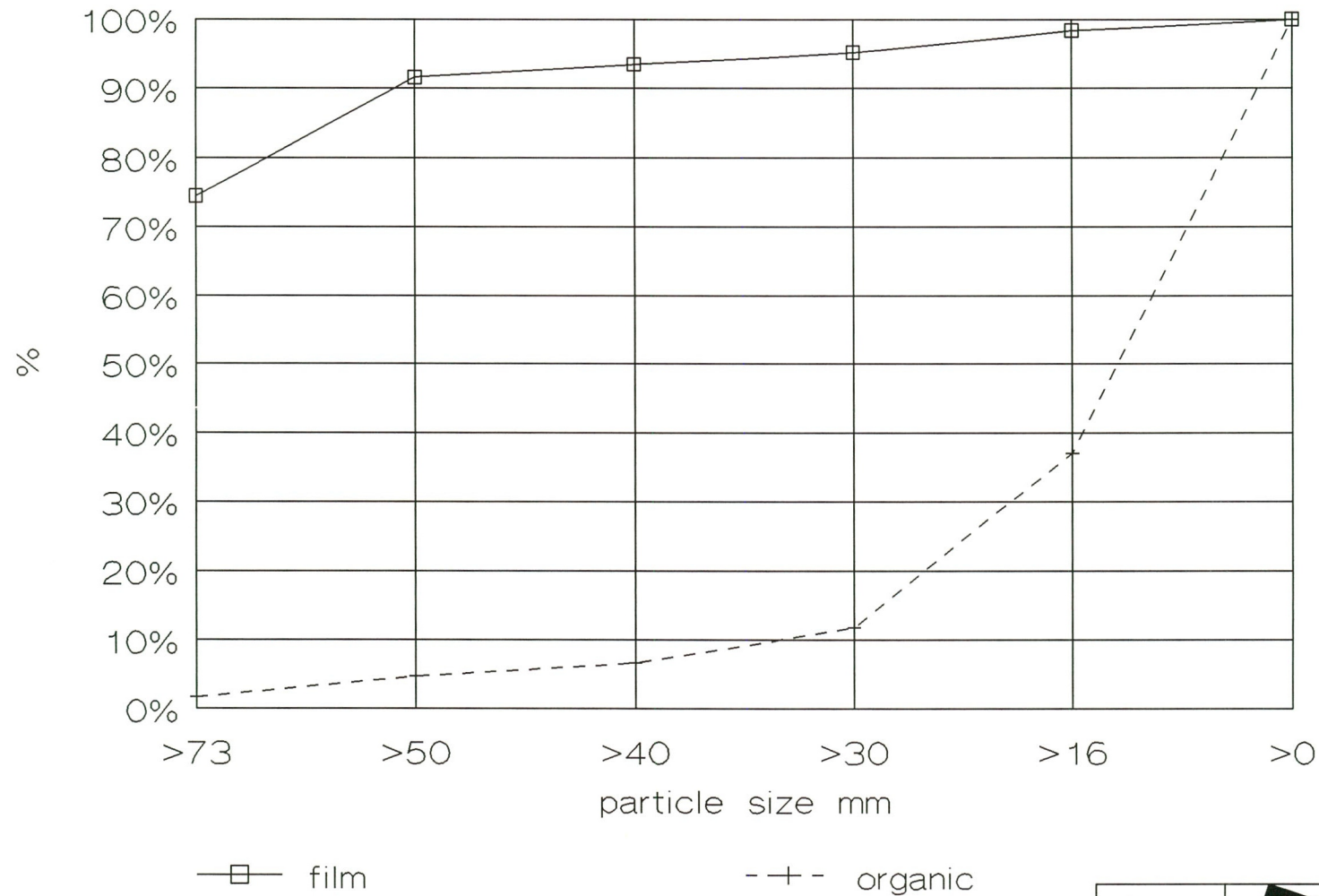


figure
2a



Composting of a mixture of VFG waste and used paper diapers

Table 2b JENZ HEM 12

Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt. %	wt. %	wt. %	wt. %	wt. %
> 73	100.0	0.1	87.5	9.6	2.8
50 - 73	100.0	0.2	44.3	45.2	10.4
40 - 50	100.0	0.4	7.4	86.3	5.9
30 - 40	100.0	0.7	3.1	91.6	4.6
16 - 30	100.0	0.3	1.1	97.3	1.4
0 - 16	100.0	0.0	0.2	99.0	0.8
> 73 - > 0	100.0	0.1	31.8	65.4	2.7

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re- mainder	Re- mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	31.3	31.3	85.8	85.8	4.6	4.6	32.3	32.3
50 - 73	8.5	39.8	11.8	97.6	5.9	10.5	32.5	64.8
40 - 50	3.7	43.5	0.9	98.6	5.0	15.4	8.1	72.9
30 - 40	5.1	48.6	0.6	99.2	7.2	22.6	8.7	81.6
16 - 30	14.1	62.7	0.6	99.8	20.9	43.5	7.1	88.7
0 - 16	37.3	100.0	0.2	100.0	56.5	100.0	11.3	100.0
> 73 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS

JENZ HEM 12

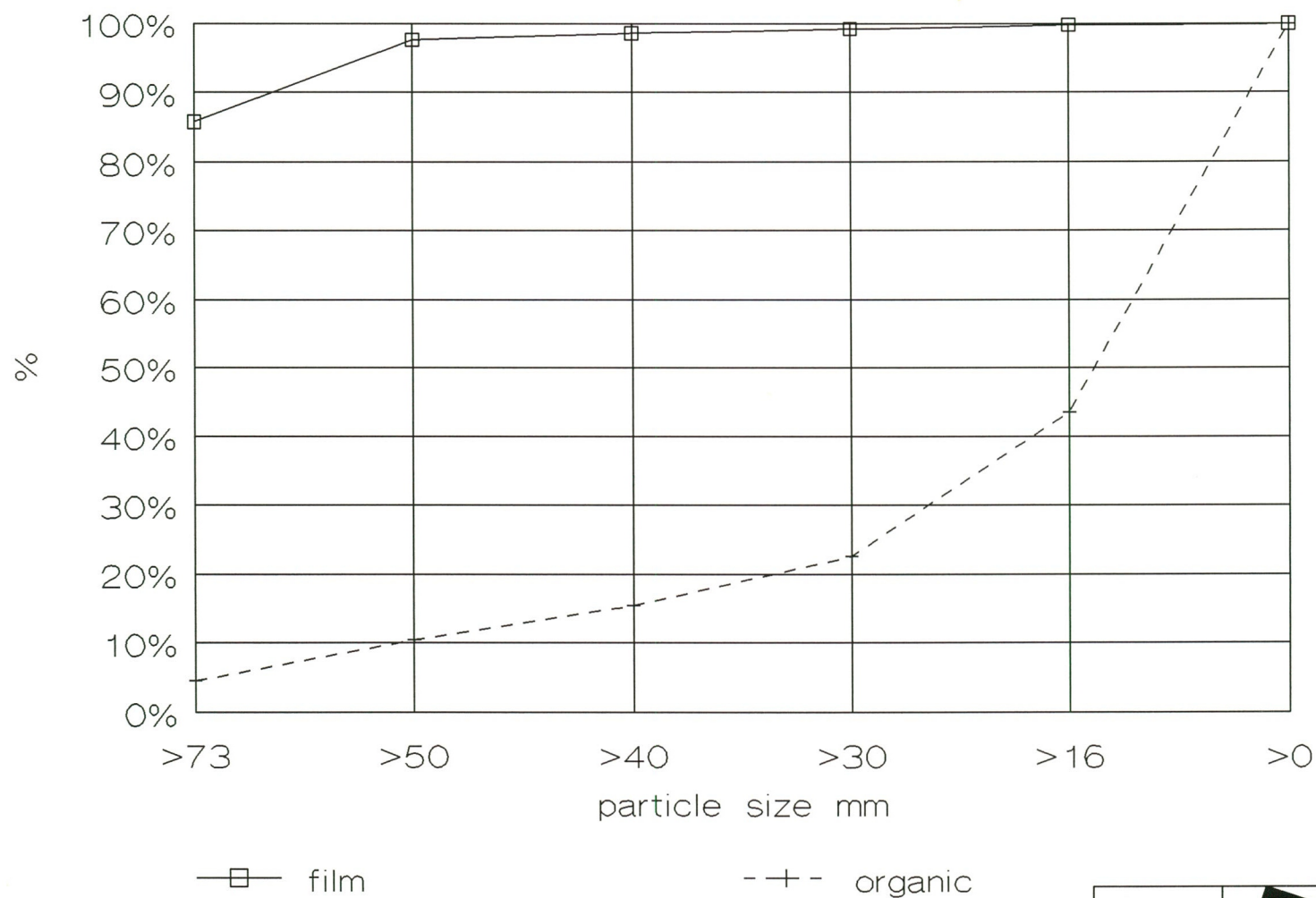


figure
2b



Composting of a mixture of VFG waste and used paper diapers

Table 2c JENZ HEM 7-28TR

Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt. %	wt. %	wt. %	wt. %	wt. %
> 73	100.0	0.0	68.4	27.6	4.0
50 - 73	100.0	0.5	15.5	62.8	21.2
40 - 50	100.0	0.1	0.7	98.4	0.7
30 - 40	100.0	0.2	0.5	97.1	2.2
16 - 30	100.0	0.1	0.3	97.4	2.1
0 - 16	100.0	0.0	0.0	98.5	1.5
> 73 - > 0	100.0	0.1	13.8	83.1	3.0

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re- mainder	Re- mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	19.0	19.0	93.3	93.3	6.3	6.3	25.2	25.2
50 - 73	4.5	23.5	5.2	98.6	3.4	9.8	32.1	57.3
40 - 50	5.1	28.6	0.3	98.9	6.0	15.8	1.2	58.5
30 - 40	6.4	35.0	0.3	99.2	7.4	23.2	4.7	63.2
16 - 30	21.1	56.1	0.7	99.9	24.8	48.0	15.1	78.3
0 - 16	43.9	100.0	0.1	100.0	52.0	100.0	21.7	100.0
> 73 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS

JENZ HEM 7-28TR

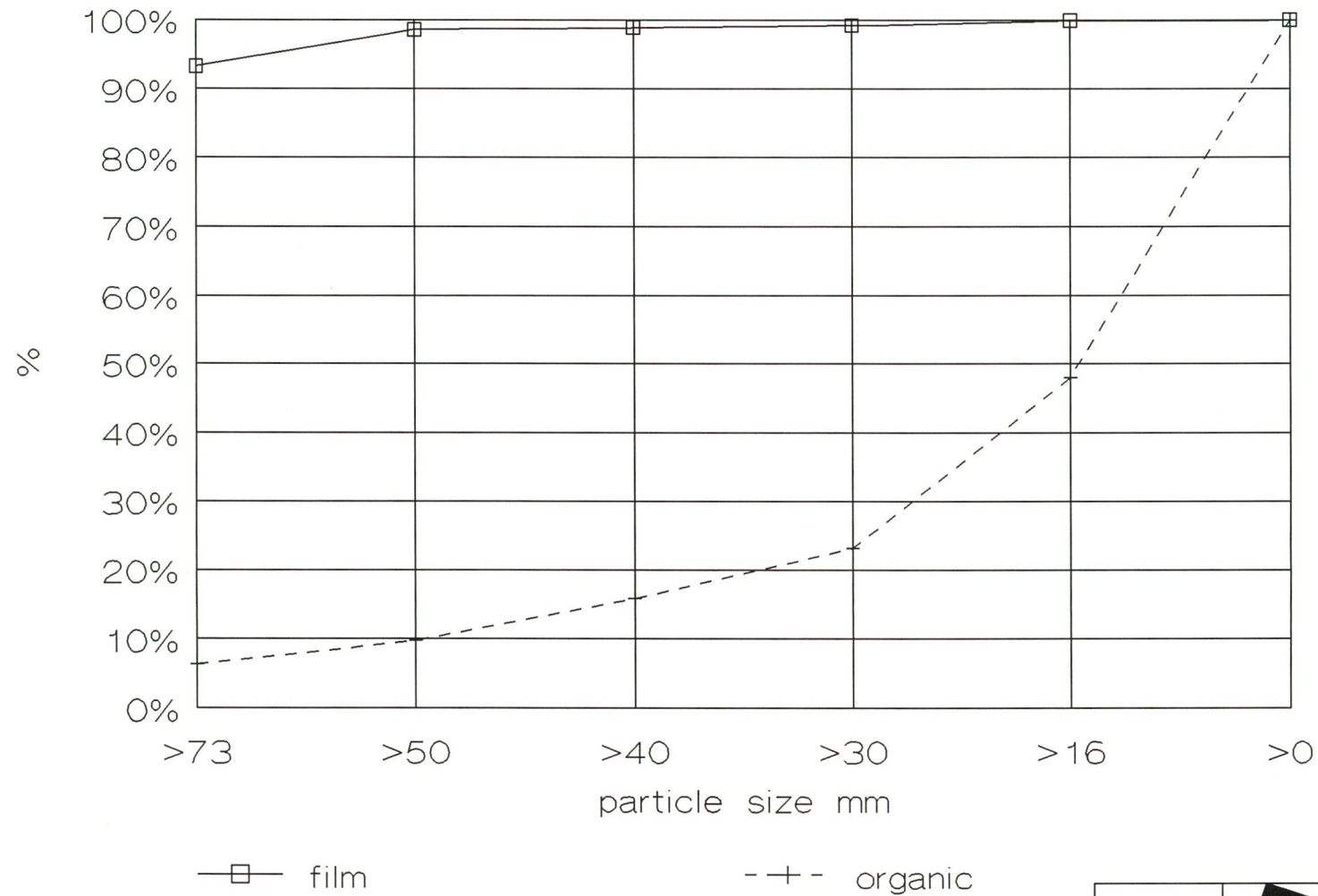


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2c



Composting of a mixture of VFG waste and used paper diapers

Table 2d JENZ AZ 50 maximum size reduction

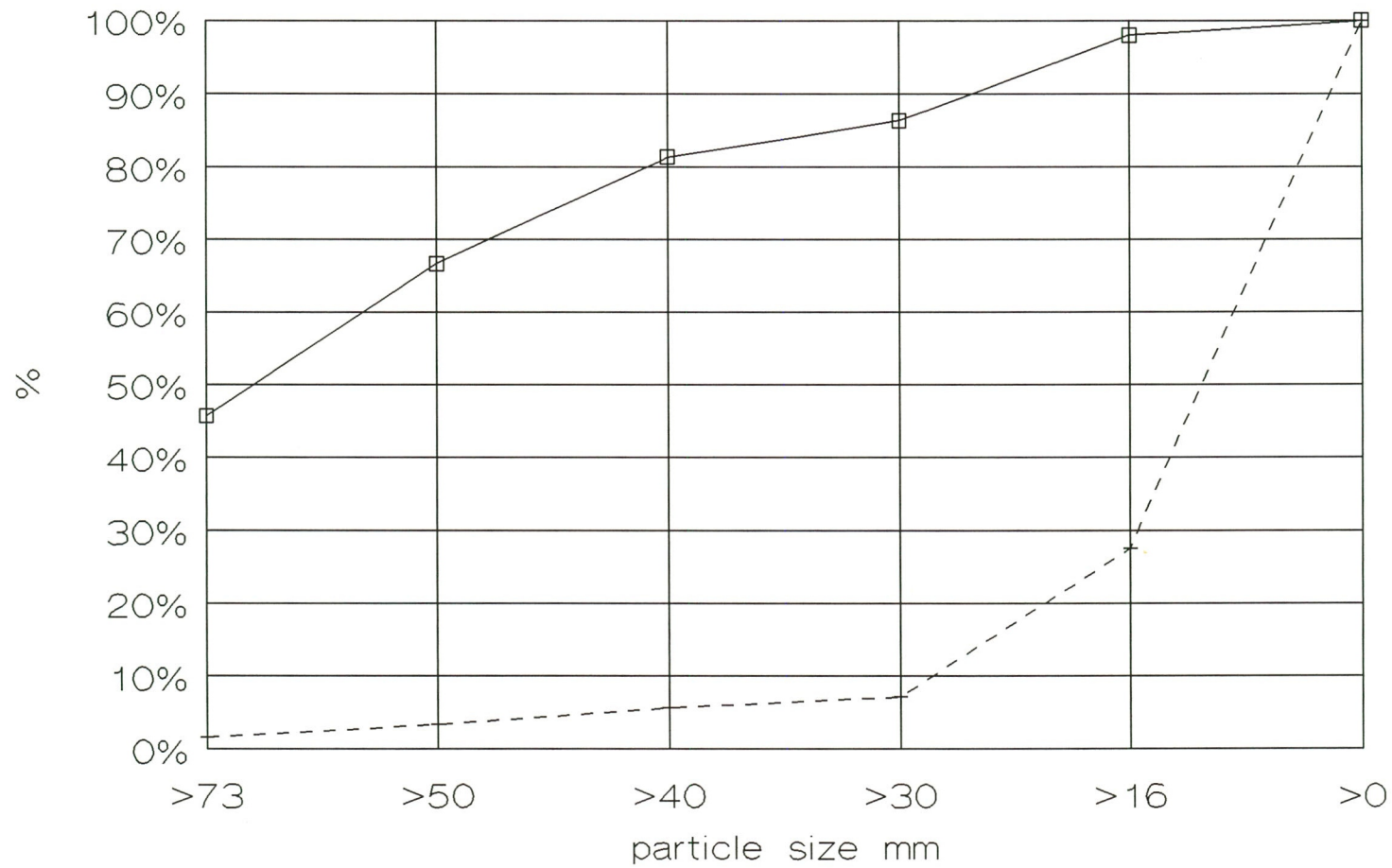
Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt. %	wt. %	wt. %	wt. %	wt. %
> 73	100.0	1.4	56.1	16.7	25.7
50 - 73	100.0	3.5	41.0	33.7	21.8
40 - 50	100.0	3.4	34.1	49.3	13.2
30 - 40	100.0	4.1	19.5	58.0	18.5
16 - 30	100.0	1.9	4.3	92.4	1.4
0 - 16	100.0	0.0	0.3	99.7	0.0
> 73 - > 0	100.0	0.9	9.2	85.6	4.3

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re- mainder	Re- mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	8.0	8.0	45.7	45.7	1.6	1.6	48.0	48.0
50 - 73	4.8	12.8	21.1	66.7	1.9	3.4	24.3	72.3
40 - 50	3.9	16.7	14.7	81.4	2.3	5.7	12.2	84.5
30 - 40	2.1	18.8	5.0	86.4	1.5	7.2	9.3	93.8
16 - 30	18.9	37.6	11.6	98.0	20.4	27.5	6.2	100.0
0 - 16	62.3	100.0	2.0	100.0	72.5	100.0	0.0	100.0
> 73 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS

JENZ AZ 50 maximum size reduction



—□— film

--+- organic

figure
2d



Composting of a mixture of VFG waste and used paper diapers

Table 2e JENZ AZ 50 minimum size reduction

Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt. %	wt. %	wt. %	wt. %	wt. %
> 73	100.0	0.0	79.7	12.1	8.3
50 - 73	100.0	0.7	48.6	32.4	18.2
40 - 50	100.0	1.7	25.6	58.4	14.3
30 - 40	100.0	1.6	14.2	68.8	15.4
16 - 30	100.0	1.0	3.2	92.2	3.6
0 - 16	100.0	0.0	0.2	99.7	0.1
> 73 - > 0	100.0	0.4	8.7	87.7	3.2

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re- mainder	Re- mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	5.4	5.4	47.6	47.6	0.7	0.7	14.2	14.2
50 - 73	4.6	10.0	25.2	72.8	1.7	2.5	26.7	40.9
40 - 50	2.7	12.7	8.1	80.8	1.8	4.3	12.2	53.1
30 - 40	4.5	17.2	7.8	88.6	3.5	7.8	21.8	74.9
16 - 30	21.1	38.3	9.8	98.4	22.2	30.0	24.0	98.9
0 - 16	61.6	100.0	1.6	100.0	70.0	100.0	1.0	100.0
> 73 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS

JENZ AZ 50 minimum size reduction

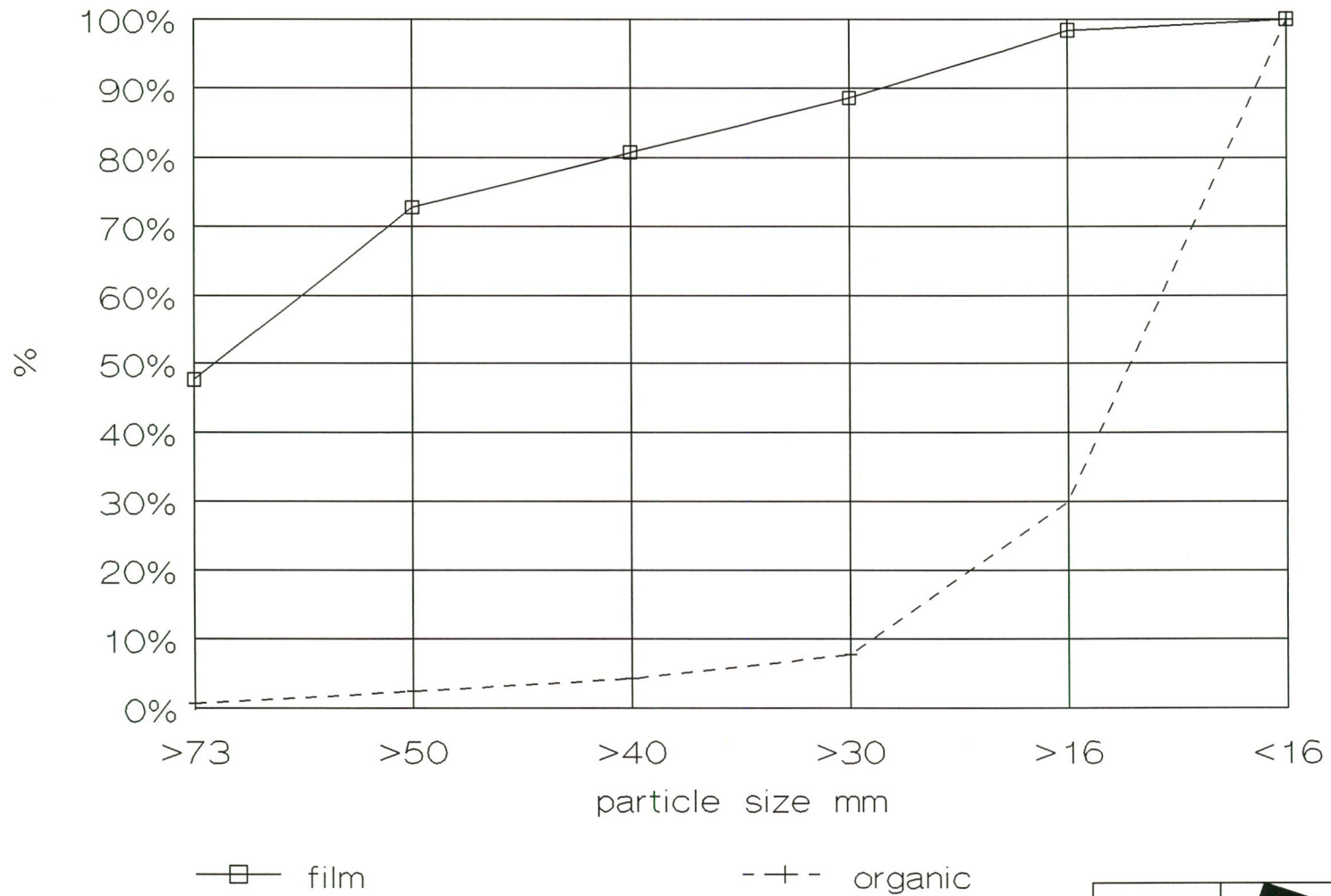


figure
2e



Composting of a mixture of VFG waste and used paper diapers

Table 2f WILLIBALD 3500 maximum size reduction

Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt. %	wt. %	wt. %	wt. %	wt. %
> 73	100.0	2.6	49.5	41.2	6.8
50 - 73	100.0	7.8	47.6	35.7	9.0
40 - 50	100.0	9.6	18.9	58.1	13.4
30 - 40	100.0	4.5	12.3	77.7	5.5
16 - 30	100.0	1.6	3.2	92.3	2.9
0 - 16	100.0	0.0	0.2	99.5	0.3
> 73 - > 0	100.0	1.1	6.0	91.0	1.9

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re- mainder	Re- mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	4.7	4.7	34.6	34.6	2.1	2.1	17.0	17.0
50 - 73	4.7	9.4	36.3	70.9	1.8	4.0	22.1	39.1
40 - 50	2.6	12.0	10.4	81.3	1.7	5.6	18.3	57.4
30 - 40	3.4	15.4	8.0	89.4	2.9	8.5	9.8	67.2
16 - 30	12.7	28.1	8.6	98.0	12.9	21.4	19.6	86.8
0 - 16	71.9	100.0	2.0	100.0	78.6	100.0	13.2	100.0
> 73 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS

WILLIBALD 3500 maximum size reduction

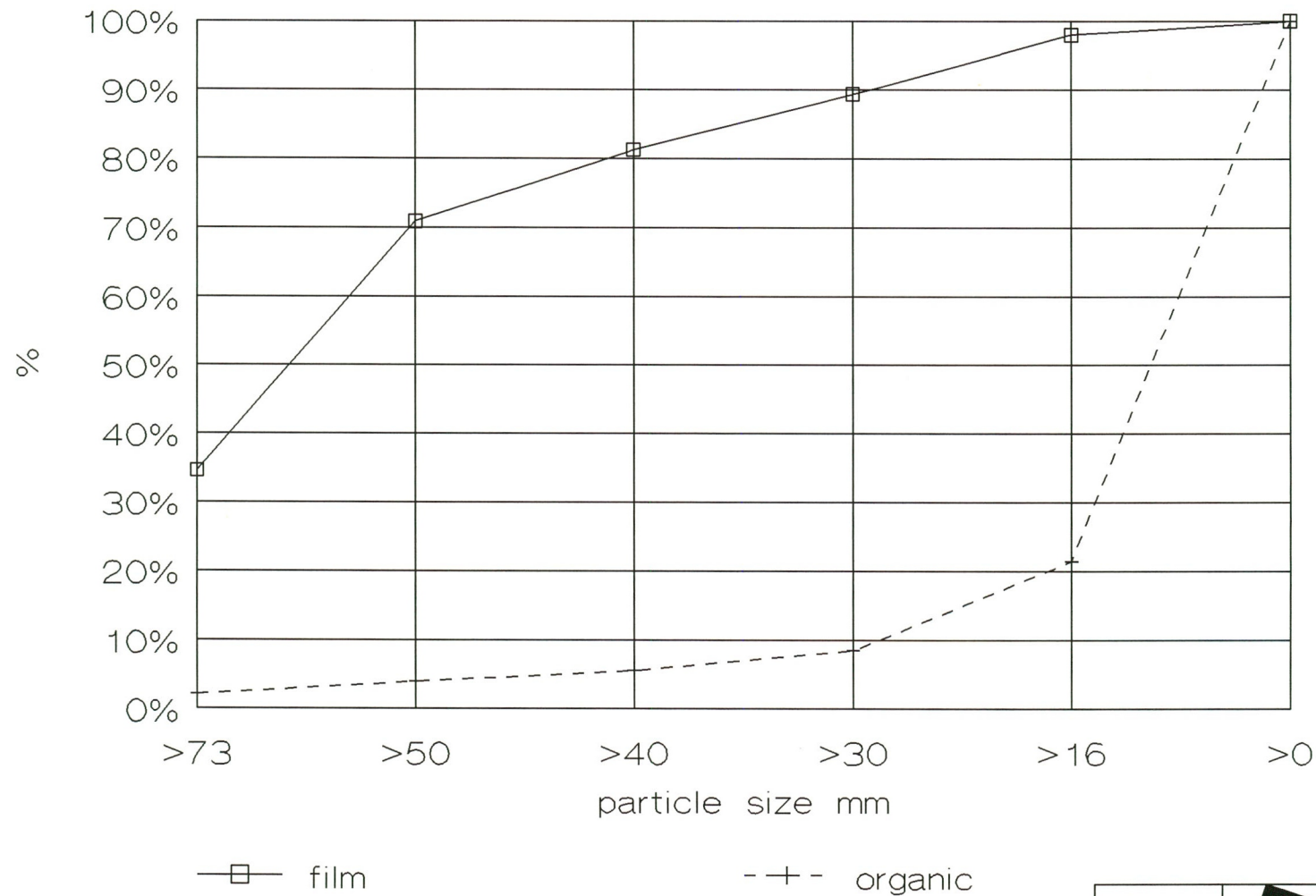


figure
2f



Composting of a mixture of VFG waste and used paper diapers

Table 2g WILLIBALD 3500 minium size reduction

Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt. %	wt. %	wt. %	wt. %	wt. %
> 73	100.0	1.5	51.9	28.4	18.2
50 - 73	100.0	1.7	28.5	60.3	9.5
40 - 50	100.0	5.1	10.6	78.8	5.5
30 - 40	100.0	2.3	6.3	85.7	5.8
16 - 30	100.0	1.0	2.5	94.7	1.8
0 - 16	100.0	0.0	0.2	99.7	0.2
> 73 - > 0	100.0	0.5	5.7	91.4	2.3

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re-mainder	Re-mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	6.5	6.5	55.6	55.6	2.0	2.0	50.6	50.6
50 - 73	5.1	11.6	24.8	80.4	3.4	5.4	20.8	71.4
40 - 50	2.4	14.0	6.0	86.4	2.1	7.4	5.6	77.0
30 - 40	3.5	17.5	4.7	91.1	3.2	10.6	8.6	85.6
16 - 30	12.4	29.9	7.0	98.1	12.9	23.5	9.7	95.3
0 - 16	70.1	100.0	1.9	100.0	76.5	100.0	4.8	100.0
> 73 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS

WILLIBALD 3500 minimum size reduction

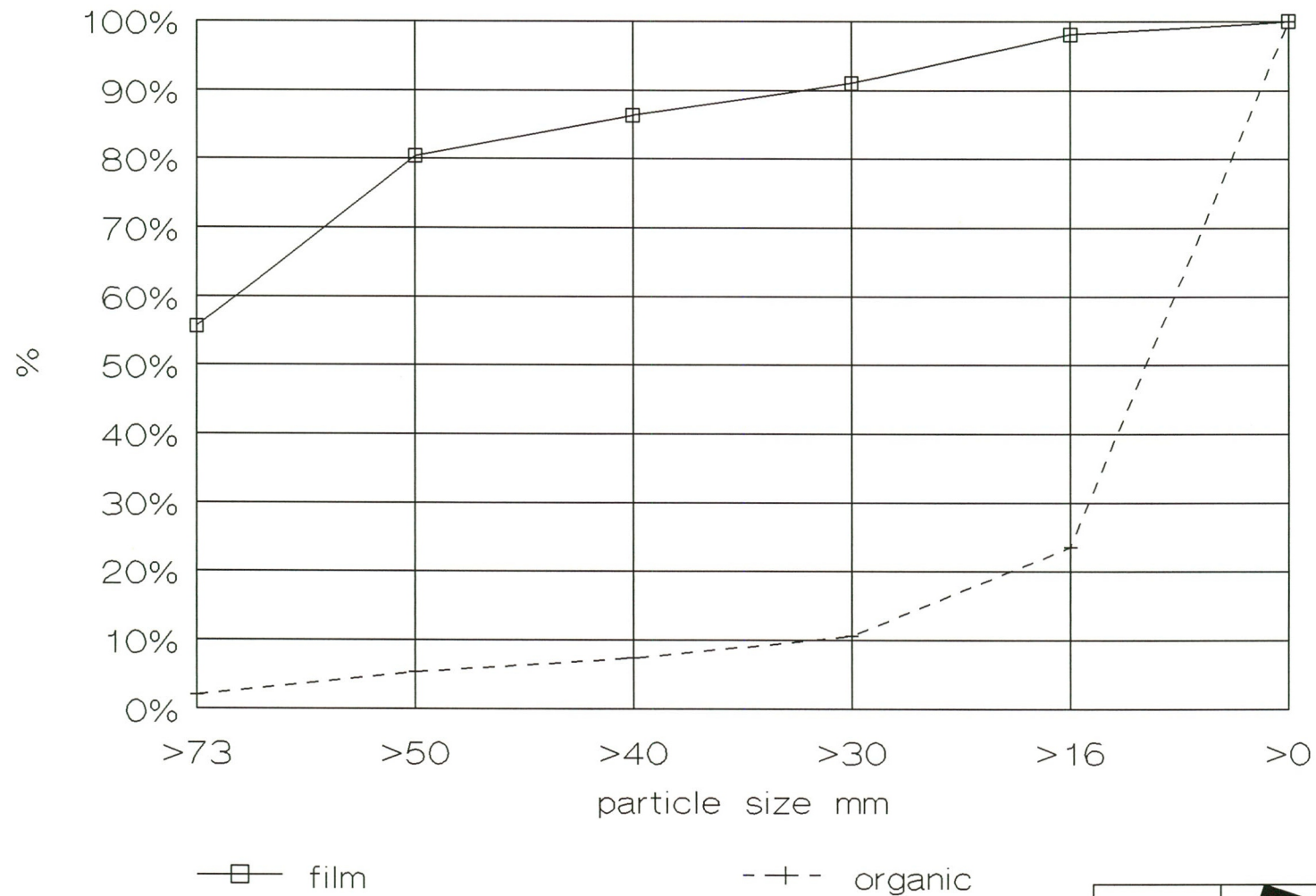


figure
2g



Annex 3a Mass balances after screening of compost obtained from VFG waste with paper diapers

Mass balances and dry matter contents of compost obtained from VFG waste with diapers												
	Total			Organic			Plastic diaper film			Remainder		
Fraction	wet kg	DM %	dry kg	wet kg	DM %	dry kg	wet kg	DM %	dry kg	wet kg	DM %	dry kg
< 15	15887	67.0	10645	15850	67	10620	7	70	5	30	70	20
15 - 25	4024	64.1	2580	3970	64	2540	14	70	10	40	70	30
25 - 35	3620	62.6	2265	3470	62	2150	50	70	35	100	80	80
> 35	1670	62.9	1050	670	60	400	810	62	500	190	80	150
> 35 - > 0	25200	65.6	16540	23960	65.6	15710	880	62.5	550	360	77.8	280

Distribution within the fractions (horizontal distribution wet)				
Fraction mm	Total wt. %	Organic wt. %	Plastic diaper film wt. %	Remainder wt. %
< 15	100	99.77	0.04	0.19
15 - 25	100	98.66	0.35	0.99
25 - 35	100	95.86	1.38	2.76
> 35	100	40.12	48.5	11.38
> 35 - > 0	100	95.08	3.49	1.43

Distribution over the fractions (vertical distribution wet)								
	Total		Organic		Plastic diaper film		Remainder	
Fraction	% ¹⁾	cumul. %	%	cumul. %	%	cumul. %	%	cumul. %
< 15	63.0	63.0	66.1	66.1	0.8	0.8	8.3	8.3
15 - 25	16.0	79.0	16.6	82.7	1.5	2.3	11.1	19.4
25 - 35	14.4	93.4	14.5	97.2	5.7	8.0	27.8	47.2
> 35	6.6	100.0	2.8	100.0	92.0	100.0	52.8	100.0
> 35 - > 0	100.0		100.0		100.0		100.0	

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is present per screen fraction.

Annex 3b Mass balances after screening of reference VFG compost

Mass balances and dry matter contents of reference VFG compost									
	Total			Organic			Remainder		
Fraction	wet kg	DM %	dry kg	wet kg	DM %	dry kg	wet kg	DM %	dry kg
< 15	14380	60.9	8757	14343	60.9	8731	37	70	26
15 - 25	5043	57.2	2884	5010	57.1	2861	33	70	23
> 25	8157	48.8	3989	8002	48.3	3865	155	80	124
> 25 - > 0	27580	56.7	15630	27355	56.5	15457	225	76.9	173

Distribution within the fractions (horizontal distribution wet)			
Fraction mm	Total wt.%	Organic wt.%	Remainder wt.%
< 15	100	99.74	0.26
15 - 25	100	99.37	0.63
> 25	100	98.09	1.91
> 25 - > 0	100	99.18	0.82

Distribution over the fractions (vertical distribution wet)						
	Total		Organic		Remainder	
Fraction mm	% ¹⁾	cumul. %	%	cumul. %	%	cumul. %
< 15	52.1	52.1	52.4	52.4	16.4	16.4
15 - 25	18.3	70.4	18.3	70.7	14.7	31.1
> 25	29.6	100.0	29.3	100.0	68.9	100.0
> 25 - > 0	100.0		100.0		100.0	

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is present per screen fraction.

Annex 4 Hand picking analyses of the ground VFG waste/diaper mixture with Willibald 3500

Distribution within the fractions (horizontal distribution)					
Fraction	Total	Film	Film + pulp	Organic	Remainder
mm	wt.%	wt.%	wt.%	wt.%	wt.%
> 73	100.0	2.5	53.3	27.1	17.2
50 - 73	100.0	1.1	20.6	68.4	9.9
40 - 50	100.0	1.1	12.2	78.4	8.3
30 - 40	100.0	1.2	6.4	89.1	3.3
16 - 30	100.0	0.7	0.9	98.0	0.4
0 - 16	100.0	0.0	0.1	99.8	0.1
> 73 - > 0	100.0	0.3	3.7	94.5	1.5

Distribution over the fractions (vertical distribution)								
Fraction	Total	Total cumul.	Film + pulp	Film + pulp cumul.	Organ.	Organ. cumul.	Re- mainder	Re- mainder cumul.
mm	% ¹⁾	%	%	%	%	%	%	%
> 73	3.8	3.8	52.9	52.9	1.1	1.1	42.1	42.1
50 - 73	4.1	7.9	22.3	75.3	3.0	4.0	26.3	68.4
40 - 50	3.1	11.0	10.4	85.6	2.6	6.6	16.6	85.0
30 - 40	3.3	14.3	6.3	91.9	3.1	9.7	7.0	92.0
16 - 30	16.8	31.0	6.8	98.6	17.4	27.1	4.1	96.1
0 - 16	69.0	100.0	1.4	100.0	72.9	100.0	3.9	100.0
> 73 - > 0			1.0		1.0		100.0	

¹⁾ Percentages of the total quantity by weight of a particular material in the ground product which is present per screen fraction.

MATERIAL DISTRIBUTION OVER FRACTIONS

WILLIBALD 3500 date 7-7-93

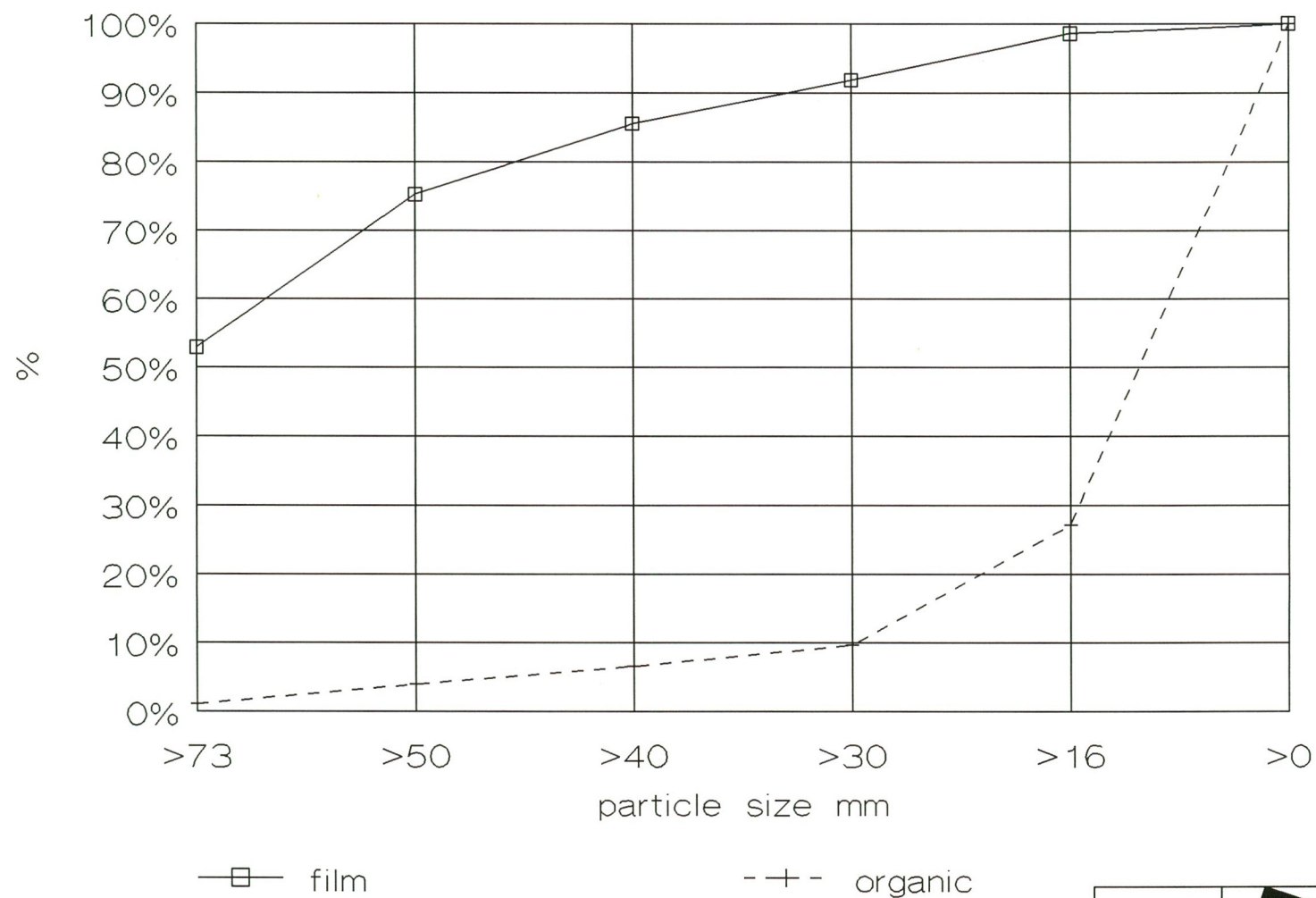


figure
4a



Annex 5 Composition of the compost final product (< 15 mm) obtained from VFG waste without and with paper diapers

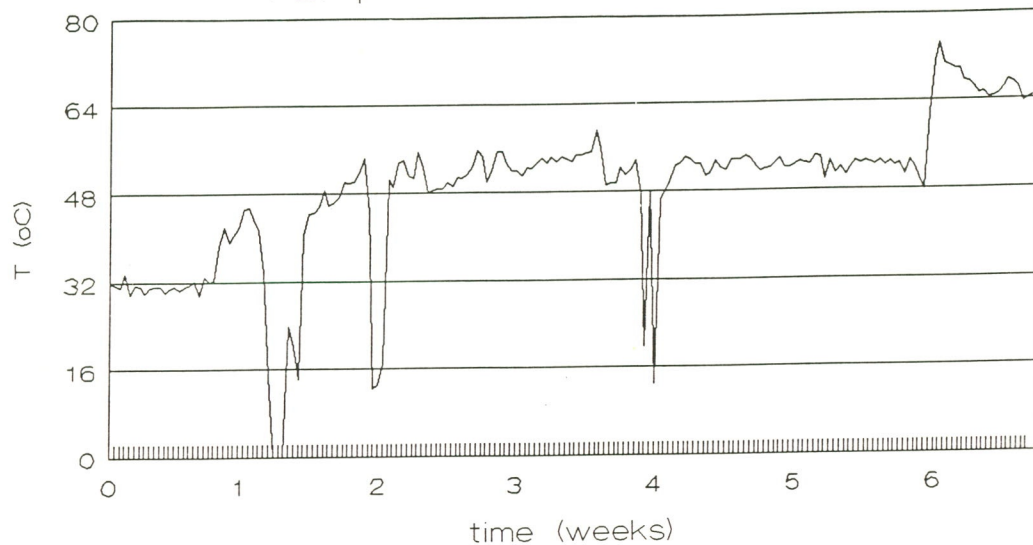
		Reference VFG compost	Compost from VFG waste with paper diapers	Standard BRL ¹⁾ BOOM '95 ²⁾
Dry matter	%	56.7	65.6	
Organic matter	%	33.8	41.1	> 20
pH		7.0	7.5	
Conductivity	mS/cm	4.8	3.6	< 5.5
N-total	g/kg	15	13	
P ₂ O ₅	g/kg	6.1	6.1	
K ₂ O	g/kg	9.8	9.8	
MgO	g/kg	3.2	3.1	
CaO	g/kg	15	18	
Cd	mg/kg	0.51	0.56	< 1.0
Cu	mg/kg	24	23	< 60
Ni	mg/kg	7.8	9.8	< 20
Zn	mg/kg	119	127	< 200
Pb	mg/kg	55	61	< 100
Cr	mg/kg	14	20	< 50
Stability		2 (53 °C)	3 (47 °C)	
Germ. test	% ³⁾	79	75	> 90
Stone	%	1.8	0.87	< 3.0
Impurities	%	0.3	0.3	< 0.5

¹⁾ BRL = Assessment Guidelines VFG compost (Beoordelingsrichtlijn GFT-compost).

²⁾ BOOM = Other Organic Fertilizers Order (standard '95)
(Besluit Overige Organische Meststoffen (norm '95).

³⁾ See comments on page 19.

Reference VFG waste
Temperature variation



VFG waste with paper diapers
Temperature variation

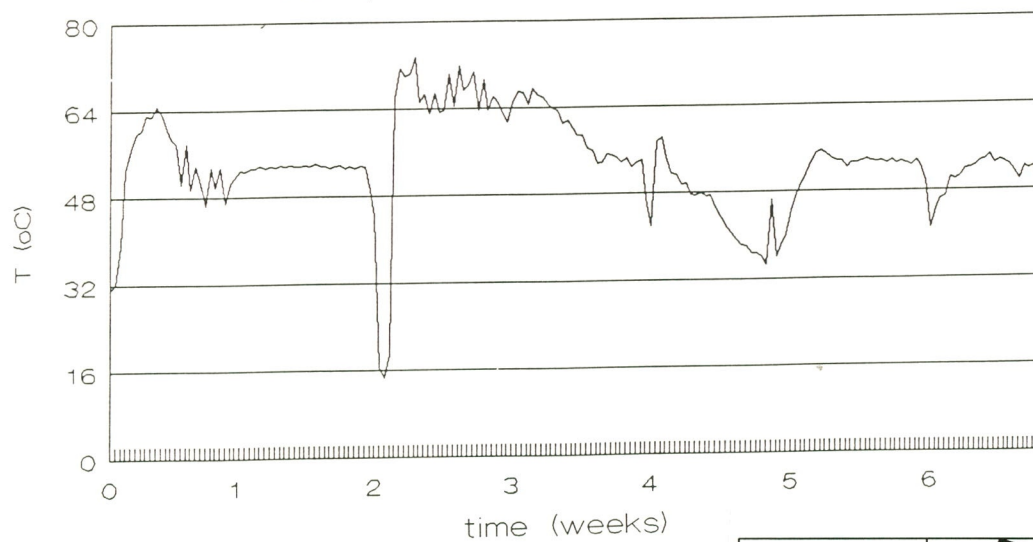


figure
5a



Annex 6 Technical specifications of the air classifiers

Zig-zag air classifier	
Number of stages above feed	3
number of stages below feed	6
Air classifying channel cross-section	80 x 20 cm
Air classifying channel sloping length	60 cm
Feed	metering gate
Air velocity	0 - 15 m/s
Capacity	approx. 2000 kg/hour

Vertical air classifier	
Channel diameter	35 cm
Channel length	420 cm
Feed	conveyor belt
Air velocity	0 - 15 m/s
Capacity	approx. 1000 kg/hour

Drum air classifier	
Type	Scandinavian Recycling TRV 10
Drum diameter	100 cm
Drum length	350 cm
Angle of repose	5 - 10°
Drum speed	16 rpm
Feed	conveyor belt
Air velocity	0 - 11 m/s
Capacity	approx. 3000 kg/hour

Annex 7 Air classifier trials for the removal of plastic diaper film from compost screen fractions

Trial 1

Material	25 - 25 mm
Total	2265 kg dry
Organic	2150 kg dry
Diaper film	35 kg dry
Remainder	80 kg dry
Air classifier type	zigzag air classifier
Air velocity	8 m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	1775	100.0	78	490	100.0	22
Organic	1677	94.5	78	473	96.5	22
Diaper film	20	1.1	58	15	3.0	42
Remainder	78	4.4	97	2	0.5	3

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction 25 - 35 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	490	62.3	787	3.1
Organic	473	62	763	3.2
Diaper film	15	70	21	2.4
Remainder	2	80	3	0.8

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

Composting of a mixture of VFG waste and used paper diapers

Trial 2

Material	> 35	mm
Total	1050	kg dry
Organic	400	kg dry
Diaper film	500	kg dry
Remainder	150	kg dry
Air classifier type	zigzag	air classifier
Air velocity	8	m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	658	100.0	63	393	100.0	37
Organic	380	57.8	95	20	5.1	5
Diaper film	135	20.5	27	365	93.0	73
Remainder	143	21.7	95	8	1.9	5

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction > 35 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	393	62.2	631	2.5
Organic	20	60	33	0.1
Diaper film	365	62	589	66.9
Remainder	8	80	9	2.6

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

Trial 2a (calculated from trials 1 and 2)

Material	> 25	mm
Total	3315	kg dry
Organic	2550	kg dry
Diaper film	535	kg dry
Remainder	230	kg dru
Air classifier type	zigzag air classifier	
Air velocity	8	m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	2441	100.0	74	874	100.0	26
Organic	2066	84.6	81	485	55.5	19
Diaper film	155	6.4	29	380	43.5	71
Remainder	221	9.0	96	9	1.1	4

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction > 25 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	874	62.1	1406	5.6
Organic	485	62	781	3.3
Diaper film	380	62	613	69.6
Remainder	9	80	12	3.2

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

*Composting of a mixture of VFG waste and used paper diapers***Trial 3**

Material	25 - 35	mm
Total	2265	kg dry
Organic	2150	kg dry
Diaper film	35	kg dry
Remainder	80	kg dru
Air classifier type	vertical air classifier	
Air velocity	8	m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	1550	100.0	68	716	100.0	32
Organic	1462	94.4	68	688	96.2	32
Diaper film	15	0.9	42	20	2.8	58
Remainder	73	4.7	91	7	1.0	9

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction 25 - 35 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	716	62.3	1148	4.6
Organic	688	62	1110	4.6
Diaper film	20	70	29	3.3
Remainder	7	80	9	2.5

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

Composting of a mixture of VFG waste and used paper diapers

Trial 4

Material	> 35	mm
Total	1050	kg dry
Organic	400	kg dry
Diaper film	500	kg dry
Remainder	150	kg dry
Air classifier type	vertical air classifier	
Air velocity	8	m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	498	100.0	47	553	100.0	53
Organic	332	66.7	83	68	12.3	17
Diaper film	35	7.0	7	465	84.2	93
Remainder	131	26.2	87	20	3.5	13

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction > 35 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	553	62.2	888	3.5
Organic	68	60	113	0.5
Diaper film	465	62	750	85.2
Remainder	20	80	24	6.8

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

Composting of a mixture of VFG waste and used paper diapers

Trial 4a (calculated from trials 3 and 4)

Material	> 25	mm
Total	3315	kg dry
Organic	2550	kg dry
Diaper film	535	kg dry
Remainder	230	kg dry
Air classifier type	vertical air classifier	
Air velocity	8	m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	2036	100.0	61	1279	100.0	39
Organic	1785	87.7	70	765	59.8	30
Diaper film	48	2.4	9	487	38.1	91
Remainder	202	9.9	88	28	2.2	12

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction > 25 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	1279	62.3	2054	8.1
Organic	765	62	1234	5.1
Diaper film	487	62	785	89.2
Remainder	28	80	35	9.6

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

Composting of a mixture of VFG waste and used paper diapers

Trial 5

Material	> 35 mm
Total	1050 kg dry
Organic	400 kg dry
Diaper film	500 kg dry
Remainder	150 kg dry
Air classifier type	drum air classifier
Air velocity	8 m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	262	100.0	25	788	100.0	75
Organic	144	55.0	36	256	32.5	64
Diaper film	25	9.5	5	475	60.3	95
Remainder	93	35.5	62	57	7.2	38

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction > 35 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	788	62.3	1264	5.0
Organic	256	60	427	1.8
Diaper film	475	62	766	87.1
Remainder	57	80	71	19.8

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

Composting of a mixture of VFG waste and used paper diapers

Trial 6

Material	> 25 mm
Total	3315 kg dry
Organic	2550 kg dry
Diaper film	535 kg dry
Remainder	230 kg dry
Air classifier type	drum air classifier
Air velocity	8 m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	1156	100.0	35	2159	100.0	65
Organic	893	77.2	35	1658	76.8	65
Diaper film	59	5.1	11	476	22.1	89
Remainder	205	17.7	89	25	1.2	11

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction > 25 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	2159	62.2	3473	13.8
Organic	1658	62	2673	11.2
Diaper film	476	62	768	87.3
Remainder	25	80	32	8.8

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (top stream fraction).

Composting of a mixture of VFG waste and used paper diapers

Trial 7

Material	> 25 mm
Total	3315 kg dry
Organic	2550 kg dry
Diaper film	535 kg dry
Remainder	230 kg dry
Air classifier type	vertical air classifier
Air velocity	13 m/s

Mass balances, composition and distribution (dry)						
	Bottom stream fraction			Top stream fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	1124	100.0	34	2191	100.0	66
Organic	944	84.0	37	1607	73.3	63
Diaper film	3	0.3	0.6	532	24.3	99.4
Remainder	177	15.8	77	53	2.4	23

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction > 25 mm which ends up in the bottom stream or top stream after air classifying.

Removal of materials via top stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	2191	62.3	3515	13.9
Organic	1607	62	2591	10.8
Diaper film	532	62	858	97.5
Remainder	53	80	66	18.4

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (air classifier top stream).

Composting of a mixture of VFG waste and used paper diapers

Removal of materials via bottom stream fraction				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	1124	64.3	1748	6.9
Organic	944	62	1522	6.4
Diaper film	3	62	5	0.6
Remainder	177	80	221	61.5

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (air classifier bottom stream).

The top stream is then screened over 16 mm square.

Annex 8 Vertical air classifier trials at different air velocities

Distribution of materials % (wet)¹⁾

Material 25 - 35 mm						
Air velocity	Total		Plastic diaper film		Organic/remainder	
	Bottom	Top	Bottom	Top	Bottom	Top
8 m/s	69	31	34	66	70	30
11 m/s	49	51	10	90	50	50
13 m/s	39	61	6	94	37	63

Material > 25 mm						
Air velocity	Total		Plastic diaper film		Organic/remainder	
	Bottom	Top	Bottom	Top	Bottom	Top
7 m/s	77	23	18	82	84	16
9 m/s	57	43	6	94	76	24
11 m/s	43	57	6	94	37	63
13 m/s	36	64	1	99	40	60

¹⁾ Percentage of the total quantity by weight of a particular material present in the fraction concerned which ends up in the bottom stream and top stream after air classifying.

Annex 9 Screening of the top stream fraction of the vertical air classifier for the removal of plastic diaper film

Material	top stream fraction vertical air classifier trial 7
Total	2191 kg dry
Organic	1607 kg dry
Diaper film	532 kg dry
Remainder	53 kg dry
Screen type	mesh width 16 mm square

Mass balances, composition and distribution (dry)						
	Undersize fraction			Oversize fraction		
	Weight kg	Weight %	Distribution % ¹⁾	Weight kg	Weight %	Distribution % ¹⁾
Total	1101	100.0	50	1091	100.0	50
Organic	1093	99.3	68	514	47.1	32
Diaper film	6	0.6	1.2	526	48.2	98.8
Remainder	2	0.1	3	51	4.7	97

¹⁾ Percentage of the total quantity by weight of a particular material present in the vertical air classifier top stream which after screening ends up in undersize or oversize fraction.

Removal of materials via oversize fraction screen 16 mm				
	Weight dry kg	DM %	Weight wet kg	Of total ¹⁾ after composting %
Total	1091	62.7	1741	6.9
Organic	514	62	829	3.5
Diaper film	526	62	848	96.3
Remainder	51	80	64	17.9

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (screen oversize).

Composting of a mixture of VFG waste and used paper diapers

Removal of materials via bottom stream fraction vertical air classifier				
	Weight dry kg	DM %	Weight wet kg	Of total¹⁾ after composting %
Total	1124	64.3	1748	6.9
Organic	944	62	1522	6.4
Diaper film	3	62	5	0.6
Remainder	177	80	221	61.5

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (vertical air classifier bottom stream).

Removal of materials via bottom stream fraction vertical air classifier and oversize fraction screen				
	Weight dry kg	DM %	Weight wet kg	Of total¹⁾ after composting %
Total	2217	63.5	3490	13.8
Organic	1458	62	2352	9.8
Diaper film	529	62	853	97.0
Remainder	228	80	285	79.2

¹⁾ Percentage of the total quantity by weight of a particular material present after composting which is removed as residue (vertical air classifier bottom stream and screen oversize).