Odour Emissions from Compost Plants

Dimensioning Values for Enclosed and Open Plants

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Published by
Prof. Dr.-Ing. habil. Werner Bidlingmaier
Bauhaus-Universität Weimar

The content of this book is based on the sub-project 1/1 of the
joint research project "New Technologies for Composting"

Sponsored by the
Federal Ministry of Education, Science,
Research and Technology (BMBF)

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CIP-short title
Odour Emissions of Composting Plants
Keywords:
Waste composting, odour, emissions, immissions

ISBN: 3-930894-11-4

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Chapter 1 Introduction

Odour emissions are the main problem for the planning of a compost plant. A compost process without the release of odorous substances is not possible. Hereby are responsible: the raw material biowaste or green waste, but also the metabolic products which arise during the aerobic and partly also during the anaerobic degradation. A further reason for the odour formation is the way in which a compost plant is operated.

The knowledge of odour emissions to be expected with each composting process, independent from the raw material, together with the possible avoidance of this emission, is a fundamental precondition for a successful and environmentally friendly composting.

It is always a problem to prepare a prognosis about the arising odour emissions when a new compost plant is designed.

For the time being there are no generally accepted instruments available which allow the designer of a compost plant to calculate expected arising emissions in a simple, quick and save manner when planning the site and measures for a reduction of emissions considering all legal demands.

The assessment of odour emissions is based mainly on experimental values which have been gathered on comparable composting plants. However, the transfer of the determined quantity of emissions from one plant to another is partly connected with great difficulties as in very rare cases frame conditions are the same. These frame conditions like input quantities, waste composition, the processing of different composting units, the dwell time and the temperature of the decomposition material and many others, should be especially considered in order to avoid a drastic misinterpretation of the quantities of the emissions.

Uniform approaches and basic data for emission values of composting plants shall be created within the study. These should be used as the basis for the calculation sheets "Odour Emissions". The calculation sheets are meant as a help for authorities, engineering consultants and designers of composting plants.

The preparation of the odour data which was collected since years proved to be very difficult as the orderer of an expertise, usually plant operators and plant manufacturers, did not wish to publish the data material - even not in an annonymised version - and thus were not willing to place their data at one's disposal. Resulting from this behaviour are data gaps which could not always be closed. In order to accomplish and to improve new data it is more than necessary to update the available calculation sheets continuously.

Chapter 2 Odour Definition, Odour Measuring and Odour Generation

Odour is the property of a chemical substance or substance mixtures, dependent on the concentration, to activate the sense of smell and thus being able to start an odour sensation [WINNEKE, 1994].

1 Odour perception and odour sensation

Odour is a parameter which cannot be measured physically or chemically. It only reflects the property of a certain substance or substance mixture. Odour perception is a sensoric reaction of the olfactory cells which are settled in the dome of the nasal cavity as olfactory epithelium, the human being having about 10 to 25 million.

Odour perception like the perception of tastes arise through a direct reciprocal effect between chemical compounds and the corresponding peripheral receptor system. Flavouring substances in an aqueous solution stimulate the sensory cells on the tongue. Odour substances which are exclusively transported in volatile compounds are conducted by breathing to the osmoceptors situated in the upper nose.
Hereby the odour perception is generated over the sense of smell. The sense of smell consists of three main components [OHLOFF, 1990]:

- *the nose with its stimulus receptors, osmoceptors.*
- *a nerve conductivity system for the transfer of the electrical pulses generated through the odour perception*
- *part of the brain (odour brain, rhinous cephalon) where the arriving pulses are worked up and transferred into an odour sensation.*

Compared with the sense of taste which is limited to the four sensory perceptions: sweet, sour, salty and bitter, and which can even be realized in a relatively high concentration, the sense of smell can perceive a relatively unlimited number of chemical compounds at very low concentrations.

This is probably the reason for the fact that the sense of smell is not totally researched until now. All theories about odour perception refer only to a strictly limited selection of odour substances and their exact description of the reactions. Considering the multitude of odour substances which are known to chemistry this group represents just a small part.

Men are perceiving the odours very differently. Known or rarely arising odours are felt as being pleasant contrary to strange and often arising odours which are felt to be annoying.
Figure 2.1 shows the causal chain for the description of a spreading of odorous substances.

Emission		Transmission		Immission		Exposition
odorant mass flow emission rhythm wind dependence	↔	meteorology topography	→	frequency of the perception of odours	→	reaction to odours

Figure 2.1: Causality chain for the description of a spreading of odour substances [KRAUSE & LUNG, 1993]

The chain starts at the point where odorous substances leave a plant, with the collection of odour emissions. These are diluted through the atmospheric transport (transmission) and lead to a situation of immission, which is responsible for the human reaction to odours.
A perceived odour sensation can be mentioned not before a psychological interpretation of the odour stimulus has been realized. Between individuals this odour sensitivity varies very much. The odour interpretation is dependent upon a multitude of personal and cultural influences. Influences like education, the general attitude towards life or personal experiences and knowledge can be listed as forming sensations at the creation of reaction patterns to odours.

Another influence follows here which can be defined as an attitude of expectation. This means that stimuli which have been perceived with other senses are compared with already stored stimuli combinations. E.g. the term "waste water" is often connected with the visual impression of putridity and rotten material which on the other hand may influence the odour perception. WELLER (1978) reports that observers of a new, not yet operated sewage plant mentioned a (negative) impression of the odours.

Certain preconditions must be fulfilled before a substance can create an odour impression [JAGER & KUCHTA, 1993]:

- **Volatility**

Under normal conditions sufficient odour molecules must be in the air before they get into the nose and release there a stimulus.

- **Water solubility**

The olfactory mucous membrane of the nose has a water layer which can only be penetrated if the odour substance is water-soluble.

- **Fat solubility**

The fat layer of the nerve cells can only be penetrated by fat-soluble odorous substances. Organic residues at the odour active group lead to the fat-solubility.

- **Polarity**

Decisive for the perception of the odours is the intensity of the polarity. It must be moderately accentuated, as high polar compounds (ionic bonds) are water-soluble but not fat-soluble and therefore inodorous.

Important for the sensation of odour perception are [ANEMÜLLER, 1993]:

- the frequency and duration of an odour impact
- the intensity of the odour impact and
- the quality of the affecting odour

A certain concentration of molecules leads to a sensation dependent on the odorant substance and the perceiving human. However, this alone does not lead to an identification of the odour. The term for this perception threshold is sensation or odour threshold.

As far as odour substances have no toxic effect are they not directly harmful for the health. As, however, they are perceived over the sense of smell they leave an impression in the range of being very comfortable and very uncomfortable. This odour property is determined as hedonic tone.

Odour thresholds may vary from one human being to the other. The perception may change through diseases (e.g. cold), toxic damages of the olfactory cells (e.g. drugs) or forced impacts on the skull (head), usually it deteriorates. Permanent impacts of odour substances on the olfactory cells lead to a deterioration of the sensitivity on account of adaptation. These processes are described as adaptation or habituation. Evidence for the influence of age on the perception is furnished. The odour sensation threshold increases with increasing age, i.e. the odour sensitivity declines [ANONYM, 1986/a]. The sensitivity of odour substances does not increase in the same way like the odorant concentrations (i.e. the number of odour molecules in the inspiration air). The olfactory strength of sensitivity I (intensity) is approximately proportional to the logarithmic odorant concentration. According to WEBER-FECHNER [ANONYM, 1992]:

$$\boxed{I = k_w * \log \frac{c_{G,P}}{c_{G,S}}}$$

with $c_{G,P} > c_{G,S}$
$c_{G,S}$ *threshold concentration*
$c_{G,P}$ *odorant concentration*
k_W *Weber-Fechner-coefficient*

The Weber-Fechner-coefficient depends on the odour substance or the odorant material mixture. If an odour substance A is felt to be more intensive than an odour substance B with the same odorant concentration, the substance A will be allocated a correspondingly higher Weber-Fechner-coefficient. On the other hand two samples of odour material with a different Weber-Fechner-coefficient have dissimilar high odorant concentrations if their intensity is felt to be the same.

2 Fundamentals of odour measuring

2.1 Applied methods of odour measuring

Fundamentally two different methods of odour measuring can be mentioned:

- sensory and
- chemical-physical measuring methods

The measuring methods are shown in figure 2.2.

One distinguishes between wet-chemical methods within the chemical-physical methods and the capillary gas-chromatography. The wet-chemical method purposefully determines the search for single substances. This method, however, is of little importance for the odour measuring in biological waste treatment plants, as being a matter of very complex substance mixtures.

With the detection of material groups respectively individual substances, the capillary gas-chromatography offers the possibility of a separation of complex substance mixtures. The mostly used detector for this test is the flame ionisation detector (FID). This measuring allows a continuous determination of the organic compound carbon. But even this method does not replace men as odour detector. Following EITNER (1986) it is not possible to deduce in general a correlation between odour perception or carbon content. So, strongly smelling sulphur or nitrogen compounds are not collected during total carbon measuring, whereas the measuring instrument registers odourless methane.

Both observations show that for the time being the sensory measuring method of olfactometry, i.e. the odour perception by men, is still the better method in order to evaluate odours from biological waste treatment plants.

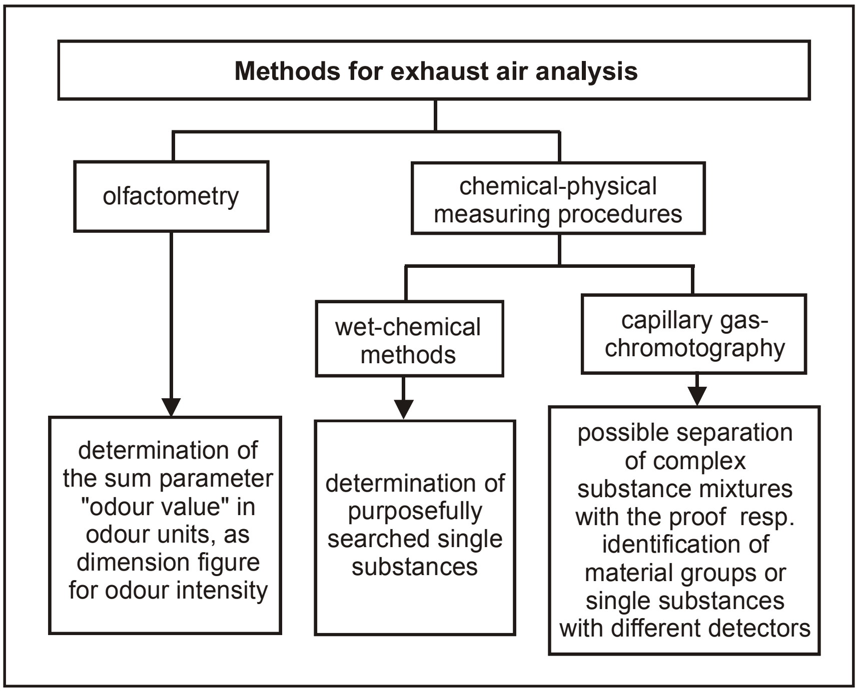

Figure 2.2: Survey of the methods for exhaust air analysis [EITNER, 1986]

The analysis of the total carbon content of the sample air by means of an ionization flame detector (FID), simultaneously carried out with most of the measures for odorant concentrations, are listed in the tables as additional information. An evaluation respectively a correlation with the odorant concentrations, however, was not carried out.

The reasons are as follows:

- Gases, like e.g. methane are also acquired with the ionization flame detector (FID). They are furnishing a contribution to the sum parameter TOC in [mg C/m³], but are inodorous.
- On the other hand, odour intensive substances, like ammonia, have no FID value.
- A correlation between FID value and odorant concentrations may be valid for particular plant units (e.g. the biofilter) or even for total plants after the calibration of the measuring system for the individual plant type or plant location, but it is not the case for most of the here used measuring results.

Considering a correct evaluation and classification of the measuring values, contained in this report, it must be said, that the statement of different concentrations of odorants does not allow an evidence about the hedonic odour intensity, i.e. about the quality of the measured odours (pleasant/annoying). Furthermore it has to be pointed out that a tenfold increase of the odorant concentrations corresponds only to a duplication of the perceivable odour intensity, as the human nose perceives the sensation "smell" only in a logarithmic scale according to its intensity. Therefore the measured concentration in figure 3 to 5 is shown in a logarithmic scale.

$$\boxed{[\text{dB OD} = 10 \times \log^{10} [\text{OU/m}^3]}$$

Some values arranged in couples are shown here as an example:

Odorant concentration [OU/m³]	**Odour intensity [dB OD]**
10	10
100	20
1.000	30
10.000	40
100.00	50

The intensity of the odour emission dependent on the temperature is mentioned here as a last factor relevant for the evaluation of odour data. As the substances arising odour impressions are volatile the temperature of the odour source (e.g. windrows) is significant. Odour intensive intermediate degradation substances in their utmost concentration are present during the "hot" first phase of the composting process.

2.2 Olfactometry

According to VDI Guidelines 3881 sheet 1 [ANONYM,1986/a] olfactometry is the controlled performance of odour carriers and the collection of sensitive sensations caused in man by this process. That means that this measuring method does not prove the amount of odour carriers, but the effect of these individual particles on the human being.

Olfactometry is the actual method of the determination of odours which is mostly used for the moment and which offers results close to reality. Olfactometry is momentarily the only possible odour determination as odour perceptions can be released even if the corresponding concentrations cannot be proved with chemical-physical methods and the determination of material mixtures with chemical-physical methods being extremely expensive or not at all possible. Even if individual material concentrations are known, no statements can be deduced about the odour properties of the material mixtures. The following characteristics of odour are determined by olfactometry [ANONYM,1986/a]:

- its odorant concentration,
- its odorant intensity,
- its hedonic tone and
- its quality.

The odorant concentration of the gas sample to be measured is determined by dilution with neutral air down to the odour threshold. The numerical value of the odorant concentration in OU/m^3 (odour unit per m^3) results from the volume flows of the gas sample and the neutral air at the moment when the odour threshold is reached. The odorant concentration must be judged differently from the odorant intensity. It is a dimension for the strength of the odour sensation as like with the sound not the absolute but the relative changes are perceived.

Like with nearly any other measuring method sample taking in olfactometry is an essential criteria for the quality assurance of the measuring results. Basically one has to distinguish between two different sampling techniques:
- dynamic sampling and
- static sampling

The dynamic sampling provides that a partial flow of a source is conveyed direct and continuously from the source to the olfactometer. The static sampling provides that an odorous gas is filled into an odourless vessel (usually a foil bag) and is then examined with the olfactometer. In order to avoid errors at sampling the following has to be observed according to VDI Guidelines 3881 [ANONYM, 1986/a]:

- Avoidance of the formation of condensate by predilution with dry and odourless air,
- no particles should enter the olfactometer,
- one has to ensure the absence of odours in the sampling system,
- during transportation from the sampling place to the olfactometer chemical reactions between the components as well as sorption at the walls of the sampling system have to be avoided.

In addition to the method of sampling the selection of panellists (test persons) is of importance for the assessment of the measuring results (see also chapter 4).

The sense of smell of the panellist can be tested with the help of standardised odorous material. One of the most usual standard odorous material is hydrogen sulphide. The odour threshold with H_2S determined in inter-laboratory tests lies in the limits of $0,60\ \mu/m^3 <$ test results $< 15\ \mu/m^3$. If the results of the reference tests of the panellists are lying within these limits and meet all the other requirements, they are satisfactory to the actual requirements of an olfactometric measuring. Further information about the sample taking can be looked up in the VDI Guidelines.

2.2.1 Odorant concentration

The determination of the odorant concentration is based on the idea that the odour intensity of the air to be tested is higher the more this air must be diluted in order to reach the odour threshold. The odorant concentration at the odour threshold is the dilution ratio between odourless air and the air to be tested, whereby 50 % of the penallists realize an odour impression and the other 50 % not. This concentration is defined as odour unit per cubic meter (1 OU/m^3).

Contrary to most of the other measuring methods (e.g. for dust measuring) the knowledge of the sample composition for the odour determination is not necessary, however, the quantity or quality must not change before the measuring.

Valid is:

$$\boxed{c_{G,P} = 1 + \frac{V_N}{V_P}}$$

with:

$c_{G,P}$ odorant concentration in OU/m^3
V_N volume percent odourless air, odourless, in volume per time unit
V_P volume percent sample, in volume per time unit

2.2.2 Odour intensity

As the concentration at the perception of concentrations above the odour threshold is not a sufficient criteria for the assessment of an odour impact, among others the odour intensity is additionally determined. The intensity is theoretically calculable through the relation between odour intensity and odour concentration.

When immissions are tested in the field the odour intensity is determined by means of inspection. The determination by olfactometer is realized under the same conditions like those of the odour threshold determination. The realization is described in the VDI Guidelines 3881 sheet 1-4 and 3882 sheet 1. The determined stages of intensity range from not perceptible (0) until extremely strong (6) as described in table 2.1.

Kommentar [A1]: Gibt das Wort Inspections wirklich wieder, dass man abschreitet. Also nicht nur schaut.?

Kommentar [b2]: Bid fragen, soll VDI Kurzfassung rein?

Table 2.1: Stages of odour intensity

Odour	Intensity stage
not perceptible	0
very faint	1
faint	2
distinct	3
strong	4
very strong	5
extremely strong	6

2.2.3 Odour quality (hedonic tone)

In order to determine an odour annoyance the hedonic tone of an odour is quite of importance. Hereby the odour can be graduated from "very comfortable" over "neutral" to "very uncomfortable" (see figure 2.3). Through the quality of an odour the human perception can be determined more exactly. According to Henning [COOPERATIVE, 1992] the odours are classified in six basic types: flowery, putrid, fruity, spicy, burning and resinous.

- 4	**- 3**	**- 2**	**- 1**	**0**	**+ 1**	**+ 2**	**+ 3**	**+ 4**
extremely annoying				neither annoying nor comfortable				extremely comfortable

Figure 2.3: Scale of the hedonic property [ANONYM, 1994/a]

The hedonic tone is an important odour property for the assessment of annoyances and can be determined at emissions and immissions by means of panellists (test persons). The German Odour Immission Guideline [GIR, 1993] does not provide a determination of a hedonic odour impact.
At least 15 panellists have to be engaged because of the great dependency on the odour properties of the individual panellists [ANONYM, 1994/a].

Before an odour investigation is started a preliminary threshold destination should be carried out in order to assess the range of concentration. The sample presentation must be carried out following the constancy method (dilution stages in random order). The first concentration stage has to be adjusted in medium range, in addition check plots can be mixed in. Hereby the panellists shall indicate if they are smelling something at all and afterwards assess the hedonic property according to the scale shown in figure 2.2 [ANONYM, 1994/a].

3 Reasons for odour in composting processes

At the generation of odours a differentiation between aerobic and anaerobic processes is necessary. As in this work composting is examined only the aerobic biochemical processes are treated.

The composting of biowastes is mainly a microbiological, catalytical degradation and transformation process. Within this process four dissimilarly long lasting phases (temperature development) can be considered (figure 2.4) [KUCHTA, 1994]:

- Mesophile starting phase,
- self-heating phase,
- thermophile phase,
- maturation phase.

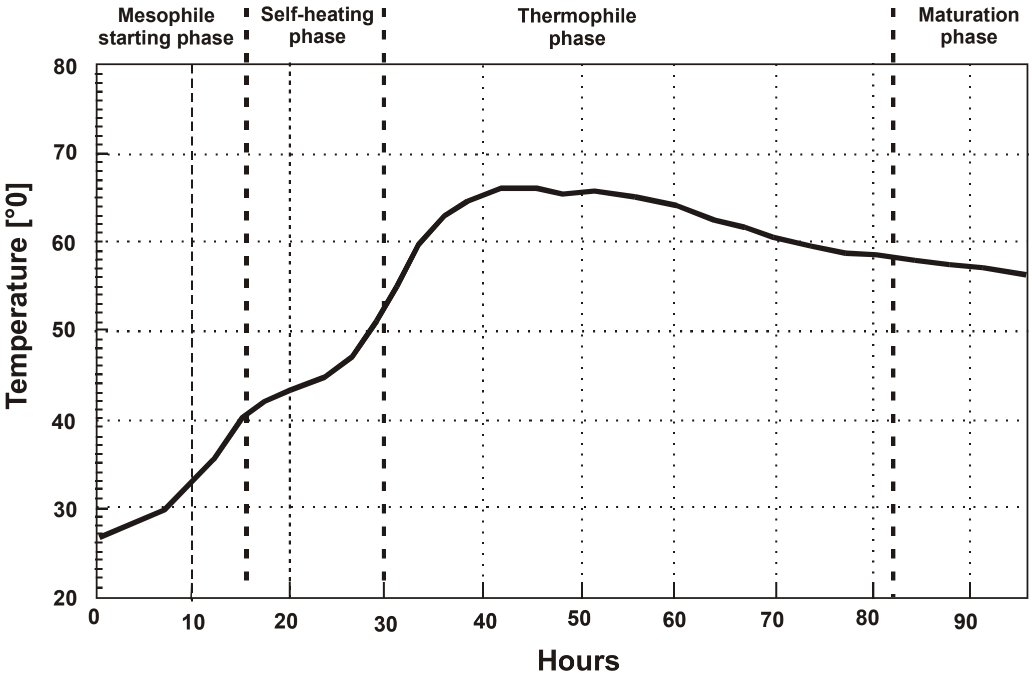

Figure 2.4: Experimentally determined march of temperature at composting (decomposition test in a Dewar vessel) and allocation to the various process phases [KUCHTA, 1994]

According to SCHILDKNECHT & JAGER (1979) the various phases can be classified in three odour ranges of the aerobic biochemical odour formation at composting:

- Waste smell, odour substances of the original products,
- biogenic odours,
- abiogenic odours.

The classification of these three ranges is shown in figure 2.5.

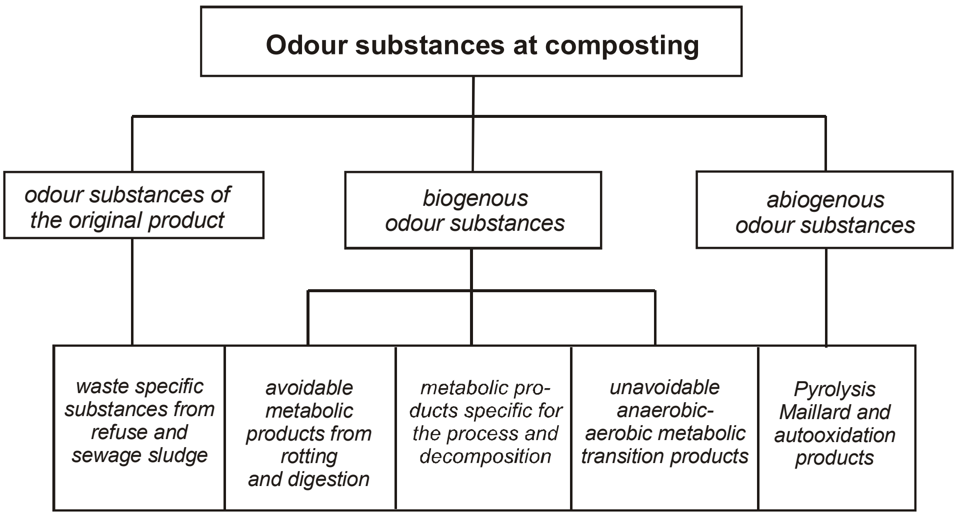

Figure 2.5: Odour substances at composting [JAGER et al., 1995]

Mesophile starting phase

The waste smell of the original substrate is determined by waste specific substances. It is mainly generated in the mesophile starting phase during dumping, at the storage and treatment of biowaste and at the beginning of the composting process. The odours arising from the material are not only dependent on its organic components but also to a high degree on the fact that the biowaste is already in a decomposition process at the time of supply or the treatment of the biowaste is not carried out properly. The odour is caused by such components as limonia and terpene and intermediates of anaerobic degradation processes [KUCHTA, 1994].

During the starting phase of composting the biowaste stands out for a high portion of easily degradable organic substances. These are mainly decomposed by mesophile micro-organisms in fresh biowaste under consumption of oxygen. Thus the available oxygen is prematurely used. The diffusion of oxygen from the ambient atmosphere is not enough to reach deeper areas, so more and more anaerobic degradation processes arise.
The aeration of the material during decomposition improves the oxygen input, what means that the volatile substances are more easily released which leads to a heavy odour load in the ambient air.

Self-heating phase

On account of the increasing biological activity followed by an increasing temperature the mesophile micro-organisms are replaced by a heat-loving thermophile population. Additionally the high temperature level releases less volatile biogenic odour components. A lack of oxygen during this phase preponderantly causes anaerobic processes. Thus the aerobic-anaerobic metabolic transition products together with the metabolic products of rotting and fermentation phases are increasingly responsible for the odour emission. The rotting and fermentation metabolic products, which can be avoided, arise, above all, through too long dwell times in the bunker.
The unavoidable odours are those arising from the anaerobic and aerobic transition products and the process-related metabolic products which are generated during decomposition by turning or aeration of the windrow. The development of the micro-organisms in the decomposition material sometimes cause a fractional lack of oxygen (e.g. in small anaerobic voids). A one-hundred-percent aerobic decomposition is not realizable. The micro-organisms transform their metabolism because of the anaerobic zones and form the odour-intensive, anaerobic-aerobic intermediate products [JAGER et al., 1995]. These odorant substances are released by turning of the windrows.

Thermophile phase

As the easily degradable substances in biowaste decrease during the decomposition period, a decrease of the formation of biogenic odour components follows. However abiogenic odour substances are simultaneously generated which are released via a purely chemical way, through pyrolisis, autooxdation and Maillard products. Their formation grows with increasing temperatures [EITNER, 1986]. A very annoying odour (sweet-spicy) with a very low threshold value can arise at temperatures about

80 °C during the first two weeks of decomposition [NITHAMMER, 1995]. Such substances can be perceived over long distances.

Maturation phase

Increasingly more medium and heavily degradable components of biowaste are degraded during the last phase of composting. This changes the properties of the decomposed material followed by a decreasing microbiological activity and temperature decline. The progressing degradation of the oxygen consumption causes a new aerobic environment and the odour emissions decrease.

According to PÖHLE et al. (1993) the process regarding the released odorant substances can be classified in three phases during the total decomposition period. The three phases and their characteristics are compiled in table 2.2.

Table 2.2: Phases and odour active substances of the decomposition process [accord. to PÖHLE et al., 1993]

Decomposition phase	Characteristic odour active substances	Determinating odour impression	Concentration [OU/m^3]	Period [d]	pH-value
I. Acid starting phase	aldehyde, alcohol, carboxylic acid ester, ketone, sulphide, terpene	alcoholic - fruity	6.000 - 25.000	3 - 14	4,3 - 6,0
II. Thermophile phase	ketone, sulphideorganic compounds, terpene, ammonia	sweet - fungoid, annoying- musty	1.000 - 9.000	4 - 14	limit to the basic range
III. Cooling phase	sulphide, terpene, ammonia	musty - fungoid - pungent	150 - 3.000	to the end of the test period	-

Chapter 3 Determination of the Odour Flow Rates and Odorant Immission

According to the German Federal Immission Control Act for Ambient Air [BImSchG, 1990] and under the fulfilment of appointed criteria are odours subject to the category of considerable annoyances. These have to be avoided by order of law in the frame of new emitting plants, i.e. prophylactic, or by the order of subsequent measures with already existing plants [BOTH et al., 1993].

Despite the fact that the perception of noises and odours are very similar is the assessment of odours by far more difficult than the one for noises. While the noise measuring can be carried out with distinct physical methods, the odour measuring cannot be done without the not always reliable "signalising detector" - the human being.

The question, whether odour annoyances have to be looked upon as being harmful environmental impacts, does not only depend on the immission concentration but also on the type of odour, the distribution of the impacts over the day time and year, the rhythm where the annoyances arise, the use of the relating area and on further criteria [GIR, 1993].

The Odour Immission Guideline (GIR) of the Federal State of North Rhine-Westphalia is the basis for the measuring of odour emissions and their assessment at the moment. It is now recommended for application in all Federal States of Germany.

1 Dispersion mechanisms of odours

Olfactometric measures allow statements about odorant concentrations on the point of the emissions. However, no statements can be made for immissions. Therefore it is of importance to describe the spreading mechanisms of odours in the atmosphere.
Two different odour sources have to be distinguished:

- defined sources and
- diffuse sources.

Defined sources have known emission conditions such as:

- location of the site,
- time of emission,
- height of emission (e.g. height of chimney),
- upper clear width of the source,
- exhaust air velocity and exhaust air quantity,
- exhaust air temperature and exhaust air humidity.

The determination of the exhaust air flow of diffuse sources is not at all possible or can be just roughly estimated, thus many sources on composting plants can be allocated to be diffuse sources. The unrecognizable condition of a multitude of factors makes an assessment of the spreading situation more complicated.

When odour loads are determined one has to differentiate between active and passive odour sources.

<u>Active odour sources</u>, like e.g. the biofilter, are structural components or units of a plant through which a defined volume flow streams for the purpose of aeration, during

its passage through the system the volume stream loads itself with odorants [HOMANS, 1993]. In case the odorant concentration is measured with an olfactometer or a FID together with the air quantity, the odour load can be calculated quite exactly.

Passive odour sources, on the contrary, are mostly large-surface areas (e.g. windrow surfaces) to which no defined volume flow can be allocated during the measuring of the odour outlet. Thus a determination of the air load is very difficult to achieve. In order to determine this air load hoods or tents are usually put on a defined area on the emitting surface and after an appointed time the odorant concentration can be determined.

To obtain a representative result HARKORT, [1989] recommends to partition the areas in four commeasurable sections and to take samples from the focal points of the surfaces. By these means fissures, crude gas offtake, edge fringing and irregularities of the fill can be ascertained. An artificial air mass flow can be caused with this method which influences the thermal conditions in the windrow and which allows the registration of the actual odour loads only with rough approximation. This means for the dispersion calculation that the precision of the prognosis of the immission prognostic deteriorates with an increasing portion of passive sources.

Besides the aforementioned factors is the dispersion behaviour of air admixtures also dependent on the source height as air pollutants fundamentally expands and dilutes in the horizontal and vertical planes of the space. As odour sources from composting plants are mostly coming from sources near to the ground it has to be considered that the vertical dispersion towards the ground is avoided and thus concentrations are generated in the upper half of the space which are twice as large, contrary to a dispersion to all sides of the space (assumption of the Gauß models of a full reflection at the ground) [SCHULTZ, 1986]. The dispersion behaviour of emissions near the ground is shown in figure 3.1.

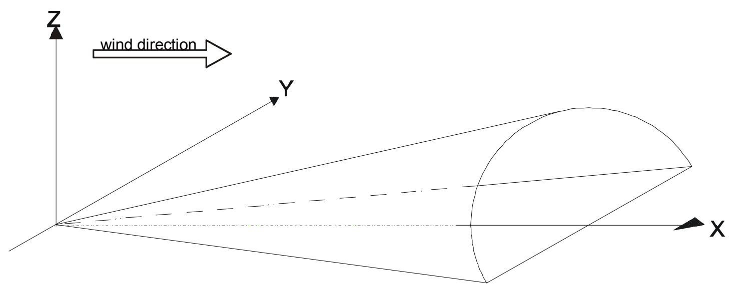

Figure 3.1: Half coniform dispersion near ground [ENGELHARDT, 1982]

As shown in the picture odour dispersion is a tri-dimensional action which takes place within an air layer directly on the ground surface, that is called mixing layer. In the first instance the height of the layer depends on the temperature conditions. A nearly stable air pressure condition is prevailing above this mixing layer, so that its border acts like a lid and no upward air exchange takes place. [KÖSTER, 1996].

The following parameters influence the transportation of gases emitting from an odour source:
- *wind velocity,*
- *wind direction,*
- *temperature,*
- *air pressure,*
- *cloudiness,*
- *insolation,*
- *local conditions like location on slopes, planting, type of buildings and water bodies.*

If the wind velocity is constant the odour distance (odour plume) usually becomes shorter towards the wind direction of a source with rising height of the mixing layer and increasing degrees of turbulences. As both factors are influenced by the intensity of insolation the odour distance is subject to seasonal and daily fluctuations. The dispersion in horizontal direction is mainly determined by the wind velocity. It runs in wind direction, however, also across [KÖSTER, 1996].

In sunny weather and the resulting large temperature drop the odour is perceivable only over short distances depending on the increasing height, the mighty mixing layer and high wind velocities. Towards the evening or at night the temperature profile smoothes down through a lack of insolation what deteriorates the situation considerably. In this situation the odours can also be perceived in great distance [KRÄMER & KRAUSE, 1977]. Proof for this phenomenon is that most of the complaints about odour annoyances are made between 6 p.m. and 12 p.m [FRECHEN, 1988].

Very unfavourable conditions for an odour dispersion exist during periods of atmospheric inversion. Contrary to the normal situation when the ground temperature decreases with increasing height, an inversion of the temperature gradient takes place. The air volume above the cooler ground air layer does not allow a vertical exchange.

During summer this barrier usually dissolves itself in the mornings after a short insolation. In wintertime, however, it can happen that insolation is not intensive enough and the inversion is only removed through a weather change and/or upcoming winds [ENGELHARDT, 1982].

A further factor that has to be considered is the topographic location of the sources. The temperature rise of the air is higher in valleys, whereby emission-relevant valley breezes are generated. Furthermore the formation of the ground has to be considered as the flow course of the ground air conforms itself to the ground. The dispersion situation above lakes, rivers or larger, connected buildings, which serve as heat accumulator, can be changed additionally [ENGELHARDT, 1982]..

Composting plants are considered to be a ground-near source whose emissions have no ascending force (cold sources). From this reason the dilution of the emitted odorant substances is mostly carried out horizontally. Contrary to a high source (chimney) is the vertical substitution at a ground-near source only possible in one direction. This leads to the fact that odours are still perceived over long distances because they can be transported over relatively long ways and within these ways are scarcely diluted.

The situation gets extremely problematic if the weather situation with little wind velocities and little atmospheric vertical substitution deteriorates the situation additionally and the immission concentrations rise extremely (inversion weather condition) [MÜLLER & OBERMEIER, 1989].

2 Determination of odorant immissions

An odorant immission, according to GIR (1993), is to be assessed as such, if its origin is clearly coming from plants, i.e. can be separated from odours resulting from traffic, the domestic coal incineration, vegetation, agricultural fertilizing measures or similar [GIR, 1993].

In fact there are different methods for the assessment of the relevance of an odorant immission (table 3.1). In all cases the odorant immission is characterized through a value, which describes its time dependant perception above a certain intensity (recognition threshold).

Table 3.1: Methods for the determination of odour immissions [GIR, 1993]

Method	existing load	additional load
A	Olfactorous determination of the odour immission through panellists and determination of the frequency distribution	Calculation of the odour immission (OU/m^3) from the emission of the odorant flow (OU/h) and determination of the frequency distribution
B	Chemical-analytical measuring of the immission concentration of an odorant ($\mu g/m^3$) determination of the frequency distribution	Calculation of the immission concentration of an odorant from chemical-analytical determined emission data and determination of the frequency distribution (dispersion calculation)

For each plant to be approved the GIR, like the Technical Data Sheet Air (TA Luft), demands a collection of the existing load IV before the plant is set up and the additional load IZ which is expected by the planned plant. Both are added to a total load IG and then compared with the immission values for residential and mixed areas (table 3.2) and tested on exceeding.

Table 3.2: Immission values, quoted as relative limit values for different settlement types [GIR, 1993]

Residential / mixed area	Commercial / industrial area
0,10 (10 %)	0,15 (15 %)

(in parenthesis: data in percentage of the annual hours)

Contrary to the Technical Data Sheet Air (TA Luft) the GIR compulsorily prescribes the determination of the existing load (IV). Usually it is determined with the help of field measurements with panels. [ANONYM, 1993/a].

2.1 Field measurements carried out by panellists

Size and shape of the area to be tested must be determined before the panellists start. According to use and type of the odour source, they are different depending on the use of the area and type of the odour source. Following GIR the test area must be designed in such a range that the minimum distance from the border of the area source will be 600 m. Thereafter the area is divided in a square assessment grid with distances of 1000, 500, 250 or 125 m, the guideline provides a distance of 250 m. Unfavourably situated measuring points can be moved by a maximum of 25% of the grid width. Measuring points in areas where people are very rarely present (e.g. agricultural areas) can be omitted.

According to VDI Guideline 3940 the period of assessment is one year and only in exceptional cases half a year. The Guideline for the Protection against Immissions GIR sees a representative period of half a year as being sufficient. Within the period of assessment 13 respectively 26 independent individual measurements must be carried out, according to the requirements per measuring point and year. These are in total 52 respectively 104 measuring days per test area and year. In order to make the measuring representative, times of the year, the weeks and the days must be considered (week-end, public holidays, night [NITHAMMER, 1995].

The inspection of the assessment squares has to be arranged in such a sequence that neighbouring measuring squares must be inspected on different days. This method assures that in each case the assessment for each assessment square and each measuring period carried out on 4 different measuring days enters the determination of the characteristic quantity [GIR, 1993].

The panellists determine on the site perceivable site-specific odours, if necessary differentiated for different odour qualities. The odour impression is made by a yes/no questioning ("yes, there is a smell" / "no, there is no smell"). The intensity of the odour and the hedonic tone cannot be determined.

The specific individual odour sensitivity of the panellists must be tested before they are in action. Panellists whose olfactometrically determined odour threshold for hydrogen sulphide is lying above 6 or below 1.5 $\mu g/m^3$ must be excluded from the measurement [GIR,1993].

In order to describe the frequency and time of odour occurrence the panellist must stay at a measuring point for 10 minutes. Within this period he examines the site on perceivable odours.

Two methods for the measuring of the perceived odours within the time interval can be used [BOTH et al., 1993]:

1. The time from the beginning until the end of the odour is recorded by means of an electronic recording device. When 10% of the time of the measuring interval with odour are reached is the criteria of an odour hour fulfilled.

2. The odour inquiry is carried out by clock frequency (10 second-clock frequency), i.e. six times per minute or 60 times at a gate time of 10 minutes. When 6 clock frequencies with odour are reached is the criteria of the odour hour fulfilled.

The ten minute stay at the measuring point is looked upon as being representative for a hypothetical stay of one hour, the term "odour hour" is deduced from this fact.

The field measuring method by means of panels records the odour immission situation in a certain area in form of a frequency of odour hours. The existing load can be calculated with the following formula:

$$\boxed{IV = k * n/N}$$

N = scope of sampling
n = sum of odour hours
k = correction value (table 3.3)

Table 3.3: Correction value k in dependence on scope of sampling N and the settlement type [GIR, 1993]

Scope N	Residential area-/ mixed area	Commercial-/ industrial areas
52	1.7	1.6
104	1.5	1.3

The expected additonal load (IZ) is determined by means of a dispersion calculation. This calculation has to be carried out according to the Guideline VDI 3782 sheet 4 on the basis of 1 OU/m^3.

The formula for the calculation of IZ runs as follows:

$$\boxed{IZ = n / (9 * 8760)}$$

n = sum of the odour hours at the 9 measuring points of the assessment area
8760 = number of hours per year

The expected total odour load is determined by the arithmetic addition of IV and IZ:

$$\boxed{IG = IV + IZ}$$

Despite an existing or expected exceeding of the immission values plants can be approved if the additional load (IZ) is not more than 20 % of the permitted immission value for residential and mixed areas (irrelevance criteria) [BOTH et al., 1993].

2.2 Plume inspection

The most usual method for the determination of a site-specific odour in the neighbourhood of an emission source is the plume inspection. The odour plume of an emission source is the area where the odour frequency is 5 % or higher. The plume limit is reached per definition if the odour frequency or the odour time rate is 10 %. The plume axis is the line in direction of the distribution where near ground level the maximum of the odour frequency or the odour time rate is defected. As a rule it coincides with the wind direction. The wind direction is measured 2 m above ground level (potential immission area) [ANONYM, 1993/a].

The total measurement consists of three intersectional measurements vertical to the spreading axis with 5 measuring points each or/and 5 panellists (figure 3.2). The measuring time should be 10 minutes and be realised across to the actual wind direction. The distances are subject to the expected spreading of the odour plume, however, they must not be equally large.

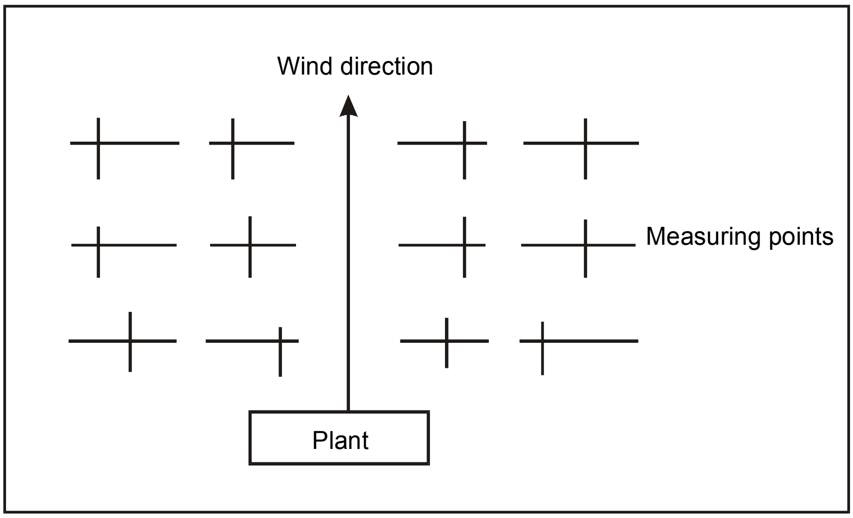

Figure 3.2: Arrangement of the measuring points of the plume measuring on the leeward side of the source [ANONYM, 1993/a]

The dispersion of the odour plume is determined by:

- the size of the emission source,
- the odorant flow rate,
- the spreading parameter,
- building area and
- topography.

The plume measuring is suitable for the calibration of the dispersion model, where calculated concentration values which were determined by plume measuring are compared. This method is particularly used if the measurements of the odorant flow rate must be hedged because of difficulties arising from measuring techniques (diffuse sources, sources spread from areas).

2.3 Dispersion calculation

The odorant flow rate of a plant is determined by olfactometric plume inspection. This odorant flow and the statistics of the dispersion class intervals (meteorological data), representative for the location, form the basis for the calculation of the dispersion. The statistics of this data material is usually determined by the German Weather Service over a period of 10 years. According to TA Luft (Technical Data Sheet Air) the transferability to the individual location of a plant must be examined. [TA-LUFT, 1996]. This is especially valid for the distribution of the wind direction, as described in chapter 3.1, which is of special importance. Wind direction measurements on site should be carried out for control purposes in order to modify the statistics of the dispersion class intervals.

Being the basis for the dispersion calculation, it is of special importance that the previously determined emission data are exact. The dispersion calculation itself is not free from errors. According to BOTH (1992) this is due to the introduction of the factor 10 in the TA-Luft-Model. Besides the TA-Luft-Model the model according to the VDI Guideline 3782, sheet 4 is used for the odour dispersion. A new model (DASIM-ODEUR) has been developed at the Technical University of Darmstadt, it is, however, not yet used. This model shall remove the weak points of the TA-Luft-model. The decisive mistake of the TA-Luft-model is according to MANIER (1994), that a windfield is assumed to be spatially constant and this assumption does not coincide with the reality. Wind direction and wind velocity changes with the altitude: Individual ground roughness also influences a change in the horizontal level of the wind field. According to MANIER (1994) the TA-Luft does not correspond anymore to the state of the art.

As this model is not generally used at the moment, the following is based on the two aforementioned models.

Both the immission concentrations from which on the odour frequencies shall be calculated and the immission time assessment must be given for the calculation of the odour dispersion. These determined values must be compared with the limit values. At present the given values are differing between 1 and 10 OU/m^3 respectively 3 and 6 minutes. A calculation threshold of 1 OU/m^3 and an immission time assessment of 6 minutes will be implemented in the planned Immission Guidelines.

Further parameters are:

- the source height in m,
- the exhaust gas plume superelevation in m,
- the emission time in h/a,
- the co-ordinates of the source and
- the odorant flow rate (odour freight) in OU/h.

The odorant flow rate q_G to be determined is the product from the concentrations c_G determined by olfactometric means and the volume stream V. In case of composting plants, where many source areas exist, which are difficult to be determined, the odour loads can also be ascertained by a combination of the dispersion calculation and with panellists [KETTERN & KÖSTER, 1992].

The following is assumed:

$$\boxed{q_{Gi} = c_{Gi} * F_i * f}$$

q_{Gi} (OU/h)	= odorant flow rate of the ith area source
c_{Gi} (OU/m^3)	= measured odour concentrations ith area source of odours
f (m/h)	= proportionality factor
F_i (m^2)	= area of the ith area source

The odour frequencies of the odour relevant emitters on the leeward side are determined by panellists. The proportionality factor f in the dispersion calculation is varied so often until the square deviation between the calculated frequencies of perceptions and those made through field measurings reach minimum. The mean factor of f = 10 could be determined through quite a number of field inspections on several composting plants [TÜV, 1992].

2.4 Questioning of residents

Today it is still very hard to determine the relation between material emissions, perceptions and odour annoyances when new plants are planned. The determination of already existing annoyances is safer and "easier". Hereby three methods are available [NITHAMMER, 1995]:

1. The acquisition of complaints (statistic complaints),
2. the systematic single questioning in defined assessment areas with questionnaires and
3. the systematic multiple questioning of panellists living in the area regarding determination of frequency and temporary occurence of the odour impacts. [ANONYM, 1994/a].

Frequency and degree of annoyances can be determined in an assessment area by means of questionnaires. The systematic single questioning is carried out in one area over a longer period.

Hereby a representative opinion in the population can be ascertained. A systematic multiple questioning is preferably used when individual odour occurrences are perceived. The questionnaire contains the following information:

- Frequency and duration of odour impacts,
- the subjective classification of the perceived annoyances and possible acceptance of annoyances,
- reaction and changes of behaviour,
- sources and time of odour immission,
- contentment of the inhabitants with the residential environment.

Chapter 4 Assessment and Comparison of Odour Data

The determination of odour data by means of an olfactometer is available since many years. The technique of the implements, the requirements and the measuring together with the legal standards of odour measurements have remarkably changed during these years.
This and the fact that each measuring is carried out under different conditions (different panellists, different seasons for the measuring of samples, e.g. summer/winter etc.) are leading to the fact that the individual measuring data can hardly be compared with each other.

The difficulty of comparability is influenced by the following factors:
- Measurements taken by different institutes,
- measurements taken during different weather conditions (e.g. winter, summer),
- measurements taken by panellists of different age,
- Measurements taken with different olfactometers and different panellists.

Measurements taken by different institutes
MANNEBECK & PADUCH (1992) carried out an interlaboratory test with four test institutes (IPT 1158, TO6, Ströhlein, MEO 5 [ESSERS, 1992]) with different olfactometers. Hereby two odorants have been used, n-butanol and dibutylamin. Each test institute received both odorants in three concentrations and in three replications in a 50 liter nalophan bag. The order of the individual concentrations was not known to the panellist. The only demand was the number of panellists limited to four.

Table 4.1: Odour thresholds [µg/m³] of the test persons (A, B, C, D) per bag sample (= single measurement) [BOTH, 1993]

		Odorant flow rate concentrations [mg/m³]								
n-Butanol		**970**	**970**	**970**	**1940**	**1940**	**1940**	**3880**	**3880**	**3880**
A	**µg/m³**	216	137	115	218	162	121	259	228	194
B		237	651	439	362	710	585	230	338	273
C		334	571	539	539	451	669	456	579	539
D		545	405	428	212	84	128	342	440	179
		Odorant flow rate concentration [mg/m³]								
Dibutylamin		**455**	**455**	**455**	**910**	**910**	**910**	**1820**	**1820**	**1820**
A	**µg/m³**	331	1138	687	535	827	506	520	289	700
B		1813	1813	1850	3840	1358	3043	2510	4313	1209
C		1422	1422	1468	1685	1282	1444	1517	1400	1400
D		870	636	1207	1058	1020	1162	1844	2642	1584

Table 4.1 shows the dilution numbers of the calculated odour thresholds in µg/m³ taken by four different test persons (panellists) for two odorant substances and different concentrations [BOTH, 1993]. The results determined by one test institute show a maximum deviation of the odour thresholds for n-butanol by the factor 6 (test person D) and for dibutylamin by the factor 4 (test person A and D).

Comparing the test institutes one with another there is a maximum deviation factor of 8 for n-butanol and 15 for dibutylamin.

Furthermore table 4.1 proves that no correlation exists between the determined odour thresholds and the offered odorant flow rate concentrations. As a result the nine measuring values can be considered like the results from repeated measurements.

Results from field inspection taken by different test institutes may also be subject to deviations. The Institute on the Protection against Immissions in Essen carried out an interlaboratory test in 1994 with field measurements by panels [BOTH, 1993]. During June until October 1989 52 field measurements have been carried out at 45 appointed assessment squares with a total of 60 assessment points with a grid spacing of 500 m. Each test institute used its own panellist team.

It could be determined that the method of field measurements for the measuring of odour immissions is fundamentally suitable as all the participants found a decreasing odour immission load with increasing distance to the source. However, the comparability of these results must be questioned [BOTH, 1993].

The following figure 4.1 shows the result of the interlaboratory test, where the determined odour frequencies (in % of the annual hours) have been booked by three different institutes in dependence of the distance to the emitter.

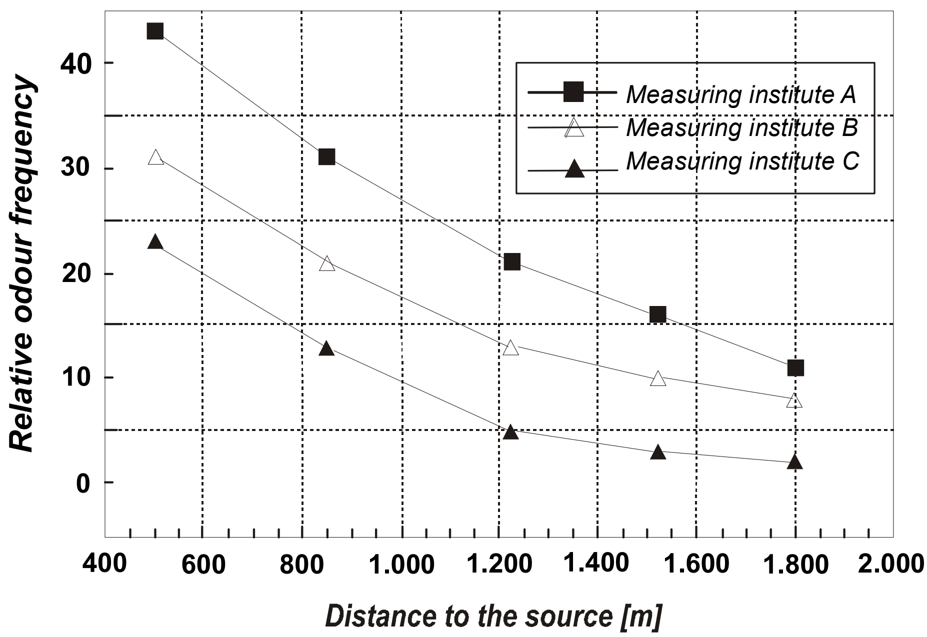

Figure 4.1: Determined odour frequencies measured by different institutes - [BOTH, 1993]

From the previous figure can be seen that there is a considerable difference between the results of the measuring institutes A, B and C which is in the mean a ratio of 1 : 2 : 3.

The following quality criteria for field inspection can be appointed through the results

- Standardisation of the measuring method, e.g. by appointment of criteriae for the selection of panellists and a directive for the training of panellists,
- to carry out further field measurements

Measurements at various weather conditions
It is important for an assessment of the odour data at which temperatures the odour measurements have been carried out. As the substances which induce the odour perceptions are easily volatile substances which are dependant on temperature it is not only the temperature at the odour source that is important but also the temperature of the day. During the summer months by far more odorant concentrations are released from the plant than during the winter season. With most of the present measurements it can not definitely be determined at which time of the year they were taken.

Measurements with different ages
The problem of measurements with different ages is also to be seen under the aspect that various olfactometers are applied. Like any other technology, the olfactometers, too, steadily improve their properties.

Measuring with different olfactometers and panellists
The olfactometric measuring, even if two identical olfactometers are compared, is dependent on many different frame conditions, which can not yet be qualified and quantified. These factors can be defined as follows [JAGER et al., 1995]:

- Ambient temperature (sample taking/laboratory/sniffing sample),
- air humidity (sample taking/sniffing sample),
- air pressure,
- age of the panellists,
- physiology (affect of the sense of smell, partial anosmia from influenza),
- habituation and lifestyle habit (e.g.: smoking).

According to HABENICHT (1992) odour threshold concentrations of hydrogen sulphide (H_2S) between 0.08 und 8 $\mu g/m^3$ can be determined by the team of panellists, used for this purpose, or their daily condition. Values of 0.3 to 15 $\mu g/m^3$ are named by the VDI guideline 3881, other literature sources quote values between 0.06 and 63 $\mu g/m^3$ with a sample distribution with a maximum at 3 - 4 $\mu g/m^3$. Table 4.2 shows the variation of odour thresholds within one panellist team.

As shown in the table the values vary mainly through the varying high odorant concentrations. It is surprising that the odour threshold reaches the highest level when the concentration is lowest.

Table 4.2: Odour threshold variation of a panellist team, dependent on concentration [HABENICHT, 1992]

H_2S [mg/m^3]	Odorant concentration [OU/m^3]	Odour threshold H_2S [µg/m^3]
28.40	12.200	2.32
14.20	5.800	2.45
2.84	920	3.08

Figure 4.2 shows comparative tests of odorant concentrations with two olfactometers TO 6 and IPT 1158 in relation to each other (trend) [HABENICHT, 1992].

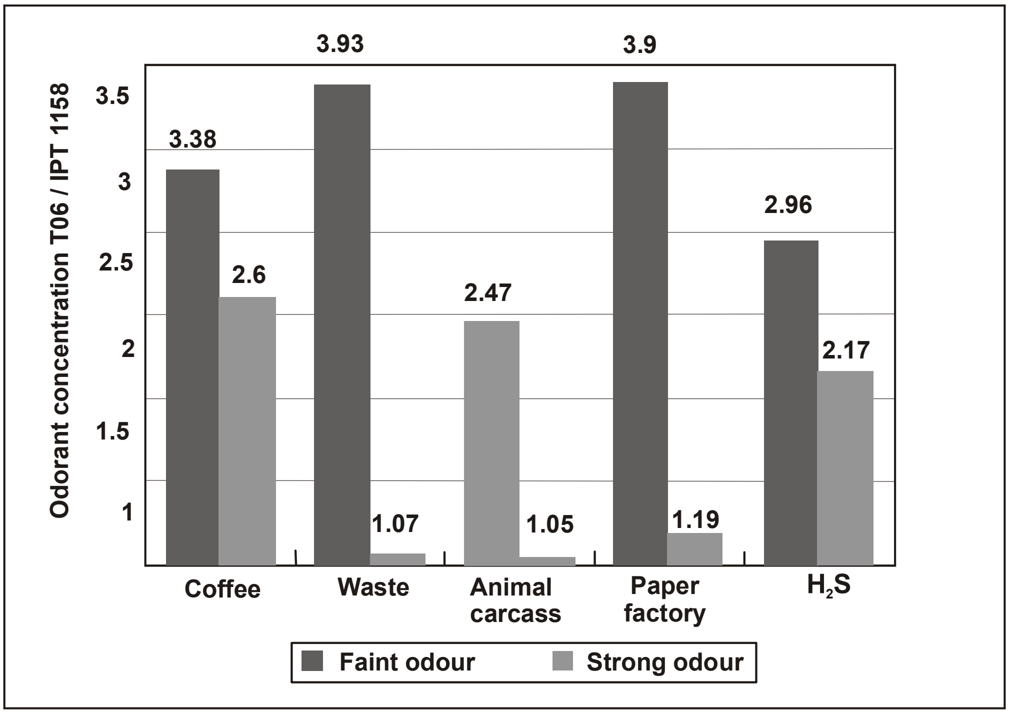

Figure 4.2: Ratio of odorant concentrations by olfactometers TO6 and IPT 1158, faint and strong odours [similar to HABENICHT, 1992]

This view distinctly shows an increasingly higher difference (ratio T06 to IPT 1158) between the concentrations when the odours were perceived more faintly. Differences between both olfactometers could be determined (less than 1.000 OU/m^3), varying up to fourfold (3.93), whereby the concentrations measured with TO6 were always higher than those with IPT 1158. Strong odour perceptions (greater than 10.000 OU/m^3) measured with T06 resulted in a 3-fold (2.96) higher odorant concentration than those measured with IPT1158.

Even the same team of panellists determines different odorant concentrations during one day (table 4.3). These differences result from the aforementioned factors.

Table 4.3: Comparative tests of odorant concentrations taken on two different days and at different times per day [similar to HABENICHT, 1992]

Sample	**1st day**		**2nd day**	
	morning	**afternoon**	**morning**	**afternoon**
Sample 1	4.800	5.200	6.300	5.800
Parallel sample	4.598	4.096	7.298	6.889
Sample 2	13.777	12.274	11.585	14.596
Parallel sample	13.274	13.004	14.596	19.48

The amount of possible influences on the olfactometric measurement makes it clear that in future quality assurance of odour measurement must rank higher than before. This results from the fact that the assessment criteria deduced from different measurements are used for a decision about the approval of a plant.

Chapter 5 Modular Types of Composting Systems and the Belonging Odour Emissions

1 Composting systems and their modular type classification

Approximately 380 composting plants exist in the Federal Republic of Germany, with a total of 4.1 million tons of material processing [WIEMER & KERN, 1996]. The numerous treatment methods within this large number of plants includes at present 26 different composting systems [WIEMER & KERN, 1996]. Those are subject to a permanent change of technology and manufacturers.

In order to simplify the handling with the different systems and to make them easier for the user, similar systems were collected in one group or one modular type.

The composting systems currently available on the market have been classified in 6 types of modules as follows:

Table 5.1: Modular types for composting systems

Modular types	Composting system
Modular type I	Box- and container composting
Modular type II	Tunnel and channel composting
Modular type III	Drum composting
Modular type IV	Windrow composting, aerated
Modular type V	Windrow composting, unaerated
Modular type VI	Special systems (composting in bricks, towers and reactors)

Simplifications within the various composting systems must have been carried out at their classification in modular types, which, however, did not change the flow-chart of the individual system. So, e.g., all processing steps which are necessary for the preparation of the biological material (e.g. metallic separator, homogenization, screening etc.) have been collected in one block (module) "pre-treatment". The same is valid for the block "fine preparation". Which blocks have been united is described more closely in chapter V.2. In the following, those aforementioned plant modules are described as general processing steps.

Box and container composting (modular type I)

Both composting systems are based on a very similar treatment system. The intensive decomposition of both systems is realised in a closed room with forced aeration and complete collection of exhaust air. The capacity of a reactor differs between 20 and 60 m^3.

In general the aeration of the reactors is carried out with perforated floors. The intensive decomposition takes between 7 and 14 days with the objective to maximize the decomposition of the material at a simultaneous hygienization. The advantage of this method is the complete monitoring of the decomposition parameters like temperature, CO_2 content and O_2 content and the control of the aeration intensity and thus degradation. Another great advantage is the easy collection of emissions of any kind. Thus the odour emissions especially at the beginning of the decomposition process can be minimized.

After the intensive decomposition period is finished a decomposition degree I to II can be assumed. In the case that the decomposition material shall reach a higher decomposition degree, a subsequent windrow decomposition must be achieved or the decomposition material must pass the reactor once more.

Both systems are available with or without re-stacker. The essential difference between both systems is the transport of the material from the intensive decomposition phase to the subsequent decomposition phase. Concerning box composting the material is filled in the box by means of a wheel loader or conveyor belt and transported with these means to the subsequent decomposition. Container composting is carried out in such a way that after the filling with biowaste the whole container is transported to the decomposition place by means of a crane or a truck and emptied again after the intensive decomposition process has terminated. The enterprises which are currently offering closed box or container systems are e.g. Herhof, ML, Strabag, Thöni and Kirow. Figure 5.1 shows the module I as flow-chart.

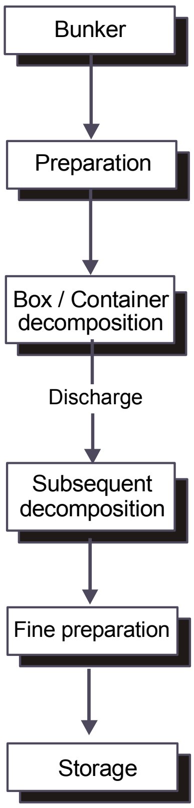

Figure 5.1: Flow chart of modular type I (box- and container composting)

Tunnel and channel composting (modular type II)

Rows separated by parting fix walls and with an open top are filled with biowaste for decomposition. Each row is separately aerated and re-stacked by a special re-stacker. The system of channel composting is offered by Messrs. Sutco. The open decomposition modules of Messrs. BRV and Compag are also belonging to this group.

Tunnel composting is carried out in rows the top of which are closed. Thus keeping the exhaust air volume very low what minimizes the odour emissions during the first phase of decomposition, similar to box or container composting. Tunnels are offered with or without re-stacker. Some enterprises (with and without re-stacker) are AE&E, Deutsche Babcock, Passavant, Gicom, Geotec, Horstmann, Umweltschutz Nord und VAR. A special feature offers Messrs. Passavant, where each tunnel is not closed singularly, but always group-wise.

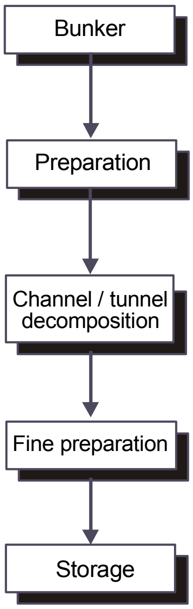

Figure 5.2: Flow chart of modular type II (channel and tunnel composting)

Today, both methods are used for preliminary or main decomposition after which in any case a subsequent decomposition must be carried out in case a mature compost is produced. Some manufacturers are offering a tunnel system with which the total decomposition can be achieved in a decomposition time of 7 to 11 weeks. Figure 5.2 shows Module II as flow-chart.

Decomposition drum (modular type III)

Decomposition drums are mainly used for the mixed waste composting process. The rotary motion of the drum mixes the material and homogenization and comminution at simultaneous aeration takes place. The drum can only be used for preliminary or intensive composting. The time for pre-treatment lasts 1 to 7 days according to the plant type. Drum systems with short dwell times are meant for an optimal preparation of the material. Hereby hygienization will take place during subsequent decomposition.

Manufacturers of decomposition drums are: Altvater, Envital, Horstmann and Lescha. Figure 5.3 shows the flow chart of the drum decomposition system. The two lines before and after decomposition are alternative lines as the individual manufacturers offer both systems.

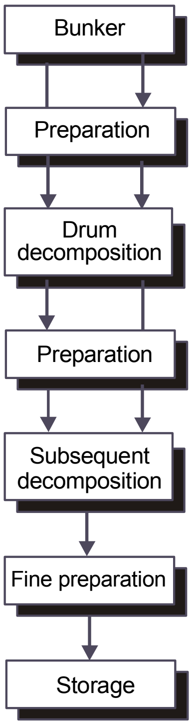

Figure 5.3: Flow chart of modular type III (decomposition drums)

Aerated windrow composting (modular type IV)

Regarding odour problems through forced aeration and the reduction of decomposition areas at large input quantities - encapsulated decomposition systems are usually used, mostly in form of table windrows. The windrows are usually re-stacked with a special automatic re-stacking device and force-aerated (pressure, suction aeration or a combination of both systems) and also watered (mostly during the re-stacking process). The aeration is usually controlled over the O_2-and CO_2 content. The windrow height is about 3 m. According to the manufacturers mature compost is ready within 8 to 12 weeks. The following manufacturers are offering closed, aerated systems for windrow composting: Bühler, Thyssen, Koch-AE&E, Horstmann, Mabeg, Noell, Rethmann, B.Ö.L.

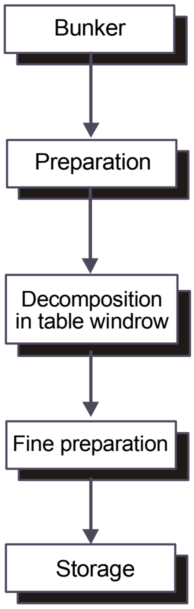

Figure 5.4: Flow chart of modular type IV (windrow composting, aerated)

Unaerated windrow composting (modular type V)

The oldest and most simple form of composting is the unareated windrow composting. Usually a heap, that is not enclosed (open land windrows), is piled up with biowaste and structure material. For this purpose a specific minimum volume is necessary so that the windrow does not cool down too rapidly. The windrows are naturally aerated. This natural aeration uses in most cases triangular windrows with a maximum height of 1.5 m, so that the oxygen supply of the micro-organisms is assured. The re-stacking of the windrows is carried out by means of a wheel loader or re-stacking machine. The re-stacking loosens the heap and during this process it will be aerated. Here a maximum height of 1.5 m makes sense, too. In cases the windrows are higher (up to 3.0 m) aeration through a ground plate should be made. On account of the open construction and the arising odours a suction aeration is recommended. The sucked off air must be conducted to a biofilter. The decomposition time lasts 3 to 6 months according to the re-stacking frequency. This method is mainly used with smaller input quantities under 6.500 Mg/a.

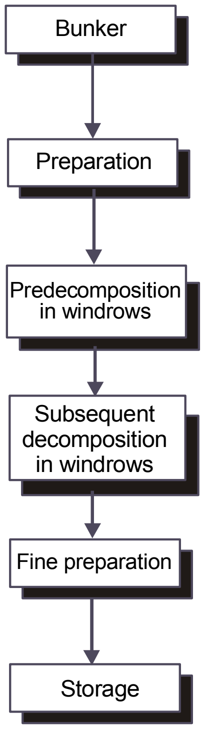

Figure 5.5: Flow chart of modular type V (windrow composting, unaerated)

Special systems (modular type VI)

Two special methods are introduced within this work: "composting in stacked bricks" and "tower composting". The "stacked brick" method is a special way of composting being completely deviating from usual composting methods. Here the material is compressed into bricks with a weight of up to 30 kg per piece which are then stacked on pallets in the decomposition hall. The bricks have a water content of approx. 55 weight-%. Resulting from the capillary effect the bricks are steadily drying out and aerobic decomposition processes are accelerating because of the simultaneous increase of temperature. Degradation is maintained over 4 weeks by watering measures. After this period degradation has come to a stop and the material is preserved [JÄGER & EMBERGER, 1995]. For further treatment the bricks must be crushed. This method results in fresh compost. After a new moistening of the material subsequent decomposition can be effectuated. According to producer's statements the decomposition period lasts from 5 to 6 weeks and reaches a decomposition degree of III to IV [RETHMANN, 1994]. Messrs. Rethmann are currently the only manufacturer on the market.
Tower composting, too, can be listed as a special method in the area of biowaste composting. However, up to now it has not been successful. As a rule decomposition takes place in a main reactor and a reactor for subsequent decomposition (tower). The material is filled in over a distributing device under the roof of the towers and is withdrawn from the tower by a discharging screw. Re-stacking of the material takes place only during reloading of the material into the subsequent decomposition tower. Thereafter it can be moved in the reactor. The main decomposition time is 14 days and further 28 days for subsequent decomposition.

The aeration of the material is generated by the blowing in of air through the ground plate. For the moment there are only few manufacturers of decomposition towers on the market, e.g. Steinmüller, Weiss Bio Anlagen.

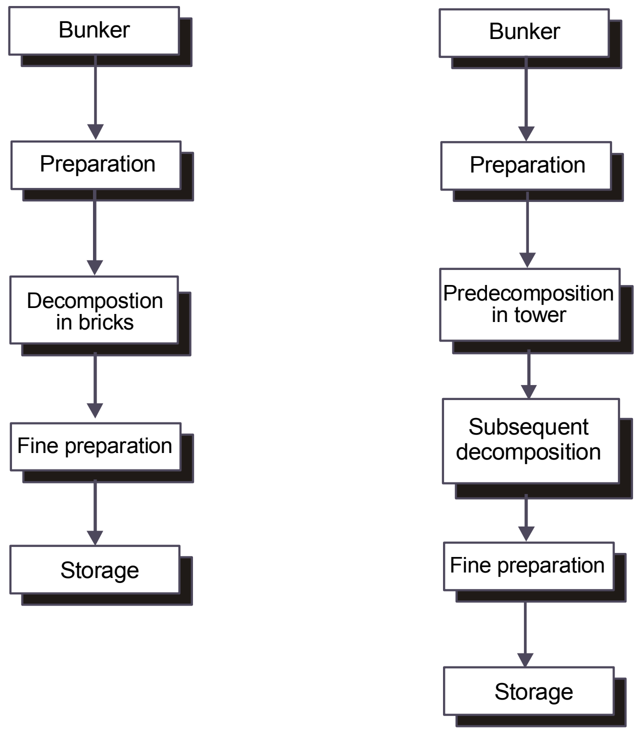

Figure 5.6: Flow chart of modular type VI (brick [left] and tower composting [right]

2 Odour sources in different composting systems

Nearly all steps of the composting process have to be considered as a source for emissions. However, with increasing maturation of the material the emissions diminish heavily. The partial steps of the process and thus the emission sources are divided in two levels within the dimensioning sheets. One level is the level of the generally valid process steps and the other level includes the specific process step. The main level is the modular type itself. The following plant modules are included in the generally valid process steps:

- Delivery and bunker,
- preparation of fresh material,
- fine preparation
- storage
- biofilter and
- diffuse sources

The specific process steps are a compound of re-stacking, watering and aeration through the decomposition process which is divided in preliminary or intensive and subsequent decomposition.

Figure 5.7 shows once more the distribution of the levels.

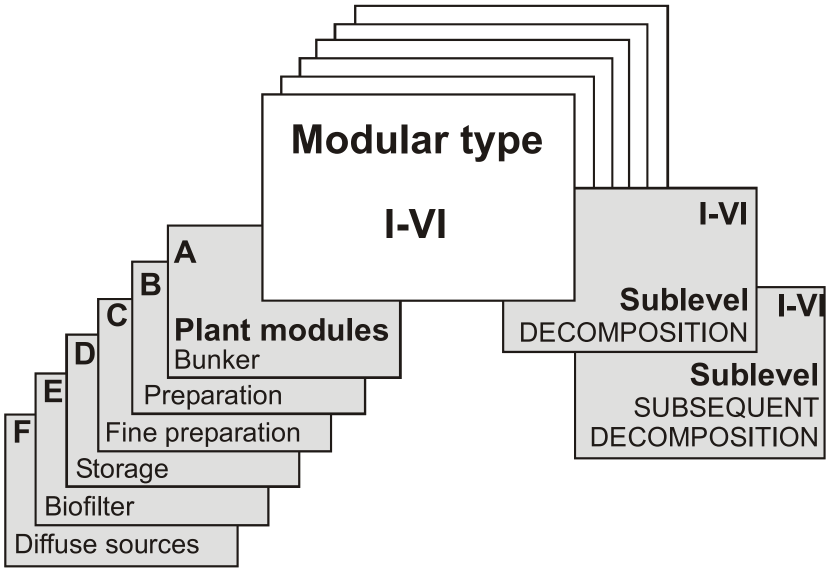

Figure 5.7: Design of the different levels within the dimensioning sheets

Figure 5.8 shows typical process steps of biowaste composting and the generated emissions related to air and water.

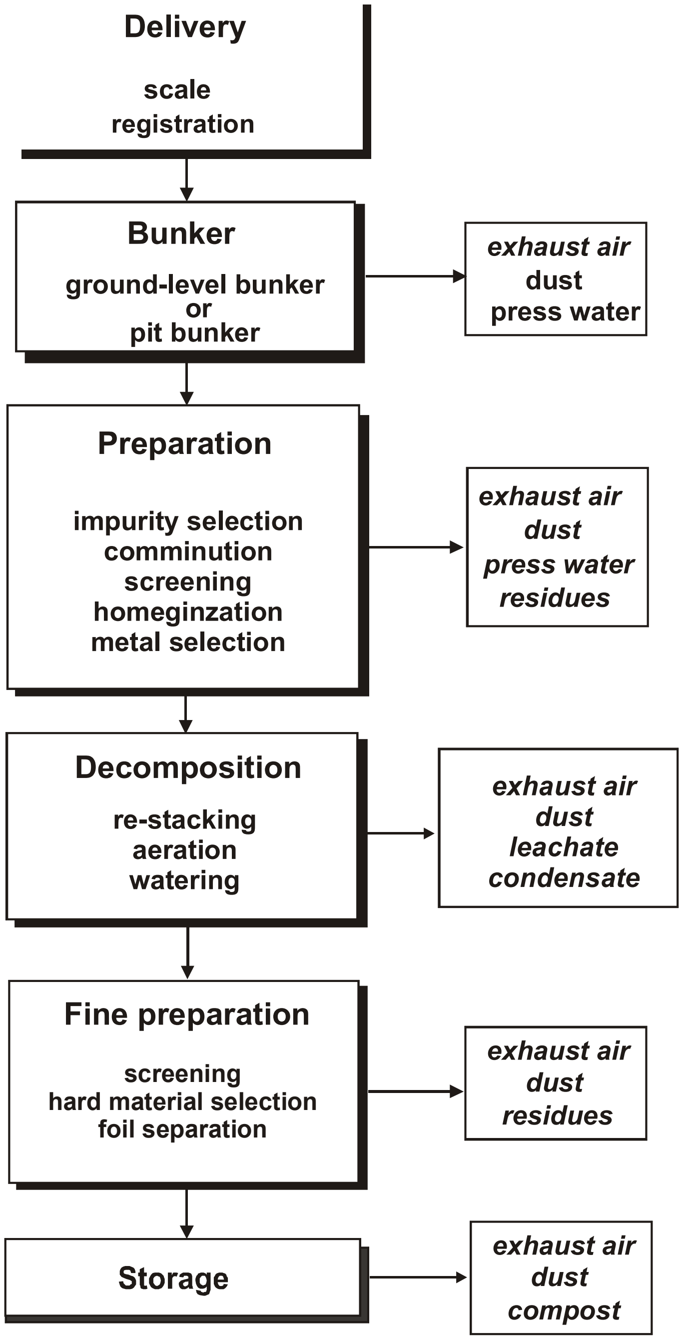

Figure 5.8: Process of biowaste composting and odour related emissions [BIDLINGMAIER & MÜSKEN , 1992]

2.1 Generally valid process steps

The term "generally valid process steps" means all the processing steps which normally exist in every composting plant. These are:
- Delivery and bunker,
- treatment of fresh material,
- fine treatment
- storage
- biofilter and
- diffuse sources

This classification corresponds to the grouping in the conception of the modular types which has been described in chapter V.2.

The odour emissions which are generated within these process steps are described later. The odorant concentrations listed in the tables show the variations and the dimensions of the various measurements.

Delivery and bunker
The in-vessel plant parts, like delivery and bunker area, are today deaerated by force (change of air numbers > 1). The exhaust air is then guided into a treatment plant for exhaust air (e.g. biofilter or biowasher) or blown into the decomposition systems to reduce the volume flow.

According to MÜSKEN & BIDLINGMAIER (1993) the specific air load (related to 1 m^3 compost) of delivered fresh biowastes can be determined with 8.5 - 17 OU/(m^3*s) with small plants (6.500 Mg/a) and with 3.4 - 9.8 OU/(m^3*s) with large plants (25.000 Mg/a). According to JAGER et al. (1993) the specific emission rates in the delivery area with 3 - 4 OU/s*m^3 are approximately in the same dimension like those measured in big plants. KÖSTER (1996) indicates the emission rates related to the windrow surface with 2.9 OU/(m^2 *s), a value similar to those given by MÜSKEN & BIDLINGMAIER (1993) with 3.31 - 6.97 OU/(m^2 *s).

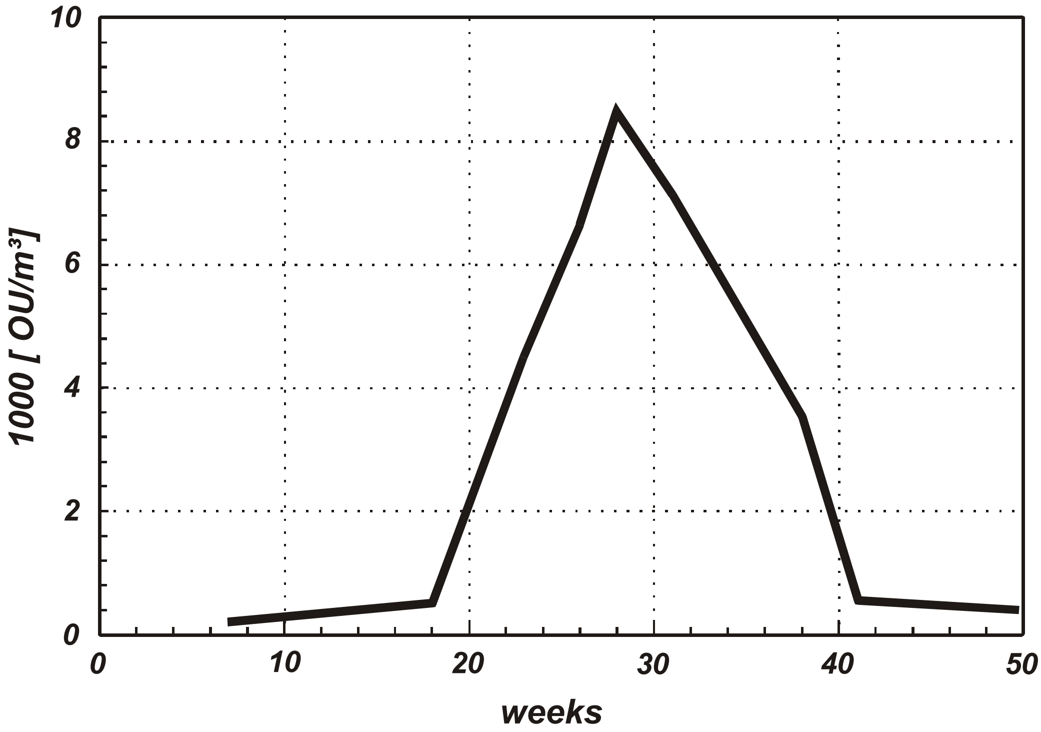

Figure 5.9: Odour radiation from fresh delivered biowaste over the year [BIDLINGMAIER & MÜSKEN, 1992]

Figure 5.9 shows the odour radiation of fresh delivered biowaste over the year. This indicates that there is not only a relation between the composition of the wastes and the generated odorant concentrations but also a relation to the annual seasons and temperatures. Thus the maximum odorant concentrations (>1.000 to max. 8.500 OU/m^3) are generally measured within the months May to September and the lower values below 1.000 OU/m^3 from October to April [BIDLINGMAIER & MÜSKEN, 1992].

Odorant concentrations from different measurements are listed in table 5.2.

Table 5.2: Odorant concentrations in the delivery and bunker area of a composting plant

Source	Odorant concentration [OU/m^3] Z50	Explanation
LEIBINGER & MÜSKEN, 1990 **BIDLINGMAIER & MÜSKEN, 1992**	3.360 - 5.470 3.070 - 8.450 260 - 720 630	SP (measured on the SU surface of the fresh AU delivered biowaste) WI
EITNER, 1986	250	Reception of household waste with exhaust air
SCHADE, 1993	200 - 400 300 - 600 500	8.000 Mg/a throughput 25.000 Mg/a throughput 50.000 Mg/a throughput
JAGER & KUCHTA, 1992	200 - 800 500 - 800	Bunker and treatment 50.000 Mg/a throughput
FISCHER, 1992	100 - 300	-
HENSLER & SCHWARZ, 1995	1.900 - 2.200 1.000 - 4.000	Bunker reception box
MÜSKEN, 1989	256 - 8.450	Delivery biowaste
MÜSKEN, 1994	100 - 300 150 - 500 500 - 1.000 1.000 - 8.500	Intake hall, 1-fold air exchange rate pit bunker, green cuttings bush cuttings, comminuted pit bunker biowaste, 2-fold air exchange rate
BIDLINGMAIER & MÜSKEN, 1991	100 - 200 100 - 1.000	Delivery bush cuttings Delivery biowaste
BIDLINGMAIER & MÜSKEN, 1992	46 - 350 7 - 73 150 - 8.450	Pit bunker mixed waste Pit bunker bio waste Flat bunker biowaste
MÜSKEN & BIDLINGMAIER, 1993	46 - 350 ø 350; max. 710 ø 180; max. 510	Mixed waste Biowaste, input 6.500 Mg/a Biowaste, input 25.000 Mg/a
KÖSTER, 1996	80 - 400 300 - 12.300 290	Mixed waste Delivery biowaste Delivery of green waste

Preparation

The following individual steps can belong to the process of waste "preparation" in a compost plant:

- Comminution,
- mix and homogenization drum,
- screening,
- magnetic separator,
- manual separation.

On account of odour reasons the preparation department in a plant is often planned in a hall together with the bunker area (see also table 5.2). One can proceed in new plants that the individual preparation units (mills, sieves, conveyor belts) are installed encapsulated and can be sucked off separately. Only by this means low numbers of air exchange rates can be achieved and the staff can work unmolested in the hall. If all the parts of the preparation process are encapsulated one can assume that at a low air exchange rate number of > 0.5 an odorant concentration of less than 200 OU/m^3 can be expected.

The material will be moved one to three times together with the air, e.g. when it is shredded, screened or re-stacked. In the measurements by the authors samples have been taken right after the windrows have been piled. In smaller plants (6.500 Mg/a) a mean value of 10 OU/m^3*s (maximum 19 OU/m^3*s) specific odorant loads could be determined, whereas larger plants (25.000 Mg/a) showed 3.8 OU/m^3*s (maximum 7.2 OU/m^3*s). When the windrows are covered decreasing specific odorant loads with mean values of 2.6 OU/m^3*s (max. 5.0 OU/m^3*s) could be determined in small plants and in large plants 0.95 OU/m^3*s (max. 1,9 OU/m^3*s).
In the following table 5.3 odorant concentrations from different preparation ranges are collected from varying literature sources.

Table 5.3: Odorant concentrations in the preparation of a composting plant

Source	Odorant concentration [OU/m^3] Z50	Explanation
BIDLINGMAIER & MÜSKEN, 1991	200 - 1.500	Enclosed chopper, feeding funnel and material feeding open
MÜSKEN & BIDLING-MAIER, 1992	165 17 - 48 185 470 2.740 - 7.100 2.810 - 9.480	Machine hall mixed waste, Air exchange =1.5 Treatment hall, high air exchange rate Drum hall Grinding room Mixing drum, 14 d pre-degradation Discharge mixing drum, fresh material
MÜSKEN & BIDLING-MAIER, 1993	5.000 (max. 9.500) 1.250 (max. 2.500)	Fresh treated material: not covered covered
MÜSKEN, 1994	300 - 500 1.200 - 3.000 250 - 1.200	Exhaust air treatment hall Pre-comminution Discharge screen
EITNER, 1986	185 - 600	Exhaust air of the hall
LEIBINGER & MÜSKEN, 1990	 2.810 - 9.480 2.740 - 7.100	Mix and homogenization drum (Discharge after 1 d) (Discharge after 12 - 14 d)
FISCHER, 1992	50 - 500	Sorting and separation area
SCHADE, 1993	200 - 500	Delivery and preparation
ANONYM, 1994/d	407 - 1.468	Indoor air, aerated
HENSLER & SCHWARZ, 1995	2.900 370 - 840	Screen drum Sorting room

Refining

Very little odour measurings are available for the refining, i.e. the preparation of the decomposed material (screening and bagging). Mean values of about 500 OU/m^3 can be assumed. In case the screening station is encapsulated the values are distinctly below 100 OU/m^3. These values can be assumed if preliminary decomposition took place under optimal conditions thus offering a mature compost.

Table 5.4: Odorant concentrations in fine preparation/refining of a composting plant

Source	Odorant concentration [OU/m^3] Z50	Explanation
BIDLINGMAIER & MÜSKEN, 1991	200 - 600	Screening
BIDLINGMAIER & MÜSKEN, 1992	21 - 57 395 395 60	Input screen, 70 d Output comminution, 73 d Output screen biowastes Output screen, green wastes
MÜSKEN & BIDLINGMAIER, 1993	< 500	-
MÜSKEN, 1994	1.200 300 600	Screening Bagging, WC < 35% Exhaust air screen + bagging
EITNER, 1986	85 - 300	-
ANONYM, 1994/d	871	Hall air, wheel loader operation
HENSLER & SCHWARZ, 1995	323 - 1.773 1.367 - 2.580	Hall air Wheel loader operation

Storage area
Normally only a small amount of annoying odours is generated from the compost storage, when it can be assumed that the material is mature. Odorant concentrations of less than 100 OU/m^3 arise on the material surface of compost that is at least 10 weeks old. Maximum values of windrows which were cut up may rise to 1.100 OU/m^3 but usually arise only where anaerobic parts occur or not fully degraded material is stored.

Table 5.5: Odorant concentrations in the storage area of a composting plant

Source	Odorant concentrations [OU/m³] Z50	Explanation
ANONYM, 1986/b	136 - 160	Enclosed, freshly cut up
BIDLINGMAIER & MÜSKEN, 1991	50 - 300	Storage windrow
BIDLINGMAIER & MÜSKEN, 1992	16 - 93 85 - 310 85 - 1.085	Storage windrow, undisturbed, 70 d Storage windrow, 112 d Storage windrow cut up, 70 - 150 d
MÜSKEN & BIDLINGMAIER, 1993	80 (max. 200) 250 (max. 1.100)	Storage windrow, static Storage windrow, cut up
EITNER, 1986	10 - 30	Open-air store
LEIBINGER & MÜSKEN, 1990	16 - 93 85 - 939	static cut up
FISCHER, 1992	20 - 200	-
MÜSKEN, 1991	20 - 90	Storage windrow, cut up
MÜSKEN, 1994	250 1.200	Table windrow, static Table windrow, cut up
ANONYM, 1994/d	203	Windrow static
SCHADE, 1993	150 - 300	-

Biofilter

The odour emissions of a biofilter consist of its own typical smell and the efficiency of the passed in and odour-loaded air.

The efficiency of the different filters is according to own measurements of KUCHTA (1994) between 30 and 85 %. The low values of these measurements could be explained by a not professional installation of the filter and/or a not proper maintenance, which could be proved. An adequate measuring technology and maintenance provides an efficiency of up to 95% [KUCHTA, 1994].

According to the state of the art a maximum odorant concentration of 100 – 150 OU/m^3 can be assumed on the output-side at a proper maintenance of the filter. Output-concentrations of different plants are listed in table 5.6.

Table 5.6: Odorant concentrations at the biofilter of composting plants

Source	Odorant concentrations [OU/m³] Z50	Explanation
ANONYM, 1992/b	336 - 977 93 - 163	Input biofilter Output biofilter
ANONYM, 1993/b	2.000 100 1.300 84	Crude gas, at turning Clean gas, at turning Crude gas, static Clean gas, static
ANONYM, 1994/b	10 - 88	Output biofilter
ANONYM, 1994/c	772 - 1.396 60 - 106	Crude gas Clean gas
FISCHER, 1989	100 - 287	-
FISCHER, 1991	373 39 129 - 313 16 - 44	Crude gas filter, at night Clean gas filter, at night Crude gas filter, at the day Clean gas filter, at the day
FISCHER, 1992	50 - 250	-

The diffuse sources in a composting plant are:
- Emissions from open hall gates,
- dirt on traffic areas,
- delivery traffic, odours from refuse vehicles,
- shipping of compost,
- open containers of impurities.

To cover an emission prognosis KUCHTA (1994) proposes an additional charge of 10% of the pre-calculated emissions. Odorant concentrations of 20 to 200 OU/m^3 can be expected according to the following table which must be explained mostly by the dirty traffic areas.
Only little examinations are available about diffuse sources. Table 5.7 shows some results.

Table 5.7: Odorant concentrations of diffuse sources in a composting plant

Source	Odorant concentrations [OU/m³] Z50	Explanation
BIDLINGMAIER & MÜSKEN, 1991	50 - 200	Traffic areas
FISCHER, 1992	20 - 200	Traffic areas
MÜSKEN, 1994	50 - 200	Traffic areas

2.2 Specific process steps in different modular types

The decomposition system of modular types belongs to the specific process steps. The results of odour measurements in different plants are presented and explained in the following:

Modular type I - boxes and containers

Table 5.8 shows the results of odour measurements in bio-reactors.
It is obvious that the water content of the decomposition material and thus its biological activity/temperature has a decisive influence on the odour emissions when they escape from the reactor. The special advantage of this system, odour minimization through the closed reactors, will be realised only if for a further degradation process the material must not be humidified once more after a maximum of 14 days. This would lead to a renewed activity and renewed odour generation.

A mean value of approx. 0.6 OU/s*m^2 can be determined for a dry (WC = 30-40%) and freshly discharged compost, for humid material, up to 11 OU/s*m^2 can be assumed. This corresponds to the odour radiation of fresh re-stacked biowaste after one week's degradation on a triangular windrow.

Table 5.8: Odorant concentrations at boxes and containers

Source	Odorant concentration [OU/m^3] Z50	Explanation
LEIBINGER & MÜSKEN, 1990		Subsequent decomposition in open land windrows after
	11.300	1 week in the reactor
	85 - 240	Piling the windrow before
	970 - 3.820	turning, 2 - 8 weeks
	350 - 460	after turning, 2 - 5 weeks
		after turning, 7 - 8 weeks
MÜSKEN, 1991		Cut up material
	360 - 1.220	7 d, dry
	11.300 - 15.900	7 d, humid
	2.740	14 d, dry-humid
	15.940 - 17.400	Crude gas exhaust air, 7 d, humid
BARTSCH & WIEGEL, 1988		1 d old
	10.109	before cooler
	4.230 - 5.295	Biofilter input
	337	indoor air
		2 d old
	8.932	before cooler
	4.266 - 4.861	biofilter input
	337	indoor air
		6 d old
	289	before cooler
	171 - 193	Biofilter input
	254	indoor air

		7 d old
	176	before cooler
	110 - 156	biofilter input
	81	indoor air
WIEGEL, 1989		subsequent decomposition, surface, 1 - 6 weeks after reactor
	178 - 270	static
	270 - 348	cut up
ITU, 1992	49 - 221	measured at the filter outlet of the box
SCHADE, 1993	25.000 - 30.000	7 d old, 5 m^3/m^3,h
	10.000 - 13.000	5 d old, 10 m^3/m^3,h
	10.000	1 d old, 20 m^3/m^3,h
	200	7 d old, 20 m^3/m^3,h
BIDLINGMAIER & MÜSKEN, 1992		Output
	120 - 1.220	7 d, dry (WC = 30 - 40%)
	11.300 - 15.900	7 d, humid (WC = 50 - 60%)
	2.740	14 d, dry-humid (WC = 40 - 50%)
		Exhaust air before heat exchanger
	10.110	1 d
	8.930	2 d
	290	6 d
	180	7 d
	15.940 - 17.400	7 d, humid
		Subsequent decomposition, WC < 40%, unaerated piled windrow, 1 week in box
	11 - 340	static
	140 - 350	cut up
MÜSKEN & BIDLING-MAIER, 1993	30.000	5 m^3/m^3 ,h fresh air, 7 d, humid
	200 - 10.000	20 m^3/m^3 h fresh air, 7 - 1 d
	13.300	Output, 7 d, humid

The odorant concentrations in the exhaust air of a bioreactor must be assumed with 17.000 OU/m^3 whereby the air, which is blown in, is significant. High air amounts cause a heavy decrease of the concentrations onto 200 OU /m^3 mainly towards the end of the preliminary decomposition phase at a simultaneous low water content (35%).

Own measuring values of pre-degraded biowastes from boxes and containers are available for the subsequent decomposition (table 5.8). The measurements come from a dry stabilized material (water content < 40%). The pre-degraded material was piled up to an unaerated windrow, which was neither re-stacked nor watered. Odorant con-centrations between 50 and 270 OU/m^3 could be measured on the surface of static windrows with an age of up to 8 weeks. This means an odour radiation of maximal 1.2 OU/s*m^2 related to the surface. If the windrows are cut up measuring values are achieved between 140 and 340 OU/m^3, that is a maximal surface radiation of 1.6 OU/s*m^2. The mean values of the concentrations for cut up windrows are about 80 OU/m^3 higher than those of static windrows.

Modular type II - tunnel and channel composting

At present no odour data are available for tunnel and channel composting. Therefore the odour data of modular type I (box and container composting) are used on account of the many parallel features of the procedures.

The parallel features are mainly those: the decomposition in the reactors is used as preliminary decomposition thus the dwell time of both modular types being nearly equal. As a rule a dwell time of one to two weeks can be considered.

The difference to tunnel composting lies predominately in the way of transporting the material in the reactor. In most of the tunnel and channel systems the material is continuously transported from the input side to the output side. Considering the box or container composting there the material rests at the same place within the reactor and is in some cases moved by means of a mechanism at the bottom of the reactors. During the first two weeks of decomposition the following presumptions are not valid for the systems of module II, which remain the whole time in the tunnel respectively in the channel.

The odorant concentrations taken from the box and container composting are listed in table 5.9. Special data referring to modular type I has not been considered.

Table 5.9: Odorant concentrations at tunnel and channel composting, following the data of box and container composting

Source	Odorant concentration [OU/m³] Z50	Explanation
LEIBINGER & MÜSKEN, 1990		Subsequent decomposition for the system in open land windrows after 1 week in the reactor
	11.300	Piling of the windrow
	85 - 240	Before re-stacking, 2 - 8 weeks
	970 - 3.820	After re-stacking, 2 - 5 weeks
	350 - 460	After re-stacking, 7 - 8 weeks
MÜSKEN, 1991		Cut up material
	360 - 1.220	7 d, dry
	11.300 - 15.900	7 d, humid
	2.740	14 d, dry-humid
	15.940 - 17.400	Crude gas exhaust air, 7 d, humid
WIEGEL, 1989		Subsequent decomposition, surface, 1 - 6 weeks after reactor
	178 - 270	Static
	270 - 348	Cut up
ITU, 1992	49 - 221	Measured at the filter outlet of the box
BIDLINGMAIER & MÜSKEN, 1992		Discharge
	120 - 1.220	7 d, dry (WC=30 - 40%)
	11.300 - 15.900	7 d, humid (WC= 50 - 60%)
	2.740	14 d, dry-humid (WC= 40 - 50%)
		Subsequent decomposition, WC <40%, unaerated Piled windrow, 1 week in box
	11 - 340	Static
	140 - 350	Cut up

Modular type III – decomposition drum
Table 5.10 shows the odorant concentrations of some measurements of odorant emissions in decomposition drums and the subsequent decomposition.
As a rule the dwell time in the decomposition drum is between 1 and 3 days. Very little systems provide a dwell time of up to 7 days. The decomposition drum as preliminary decomposition device is deposited in a closed hall, so the exhaust air can be sucked off under control and lead into an air purifying system.

Table 5.10: Odorant concentration at decomposition drums

Source	Odorant concentration [OU/m^3] Z50	Explanation
EITNER, 1986	600	-
FISCHER, 1991	362	Drum static, Compost surface
	102 - 645	5 min. revolve
	479 - 575	10 min. revolve
	313 - 627	15 min. revolve
	249 - 406	Fresh discharge
	271 - 497	Subsequent decomp., 7 d
	222 - 296	Subsequent decomp., 14 d, re-stacked once
LEIBINGER & MÜSKEN, 1990 BIDLINGMAIER & MÜSKEN, 1992	2.800 - 9.500	Output, 1 d, humid
	11.600	Output, 7 d, humid
	7.100	Output, 12 d, humid
	2.750 - 6.900	Output, 14 d, humid-dry
	14.600	Crude gas exhaust air, 1 d, humid
	15.500	Crude gas exhaust air, 4 d, humid
	23.900	Crude gas exhaust air, 5 d, humid
	27.600	Crude gas exhaust air, 6 d, humid
		Subsequent decomposition in open land windrows after 1 week revolving drum
	11.590	Piling of the windrow
	220 - 500	Static, 7 - 14 d
	210 - 790	Before re-stacking, 2 - 3 weeks
	30 - 90	Before re-stacking, 5 - 8 weeks
	230 - 4.320	After re-stacking, 2 - 8 weeks
FISCHER, 1992	20.000 - 80.000	-
SCHADE, 1993	18.000	8.000 Mg/a, exhaust air amount 600 m^3/h
	30.000	60.000 Mg/a
MÜSKEN & BIDLINGMAIER, 1993	15.000	6.500 Mg/a, 2,5 d, fresh air 5 m^3 /m^3 , h
	30.000	25.000 Mg/a, 1,5 d, fresh air 5 m^3 /m^3 , h

If the odorant concentrations in the inner part of a drum are considered, very different values are achieved depending on the kind of measurement (see table 5.10).

Despite of the different aeration rates (2.4 – 20 m^3 air per m^3 compost material) concentrations in the tight variation range of 10.000 to 35.000 OU/m^3 could be measured. At these measurements, samples were taken from drums with a dwell time of 1.5 days.

Odour loads of 40.000 – 50.000 OU/s were measured in the drum exhaust air at high air volumes of mostly over 15 to 20 m^3 air per m^3 compost material and hour and at a calculated drum content of approx. 330 m^3 compost. Values of 120 – 150 OU/s,m^3 are calculated from the processed compost volume.

If the drum is used as a „real decomposition drum“ with dwell times of 7 days a distinct increase of the odorant concentrations is shown in the exhaust air over the time base. After seven days of decomposition the discharge material shows values of about 10 OU/s.m^2. Humid raw material from decomposition boxes and unaerated triangular windrows which have been newly re-stacked have the same values after one week of decomposition.

According to SCHADE (1993) similar odorant concentrations could be determined. They are in the range of 18.000 and 30.000 OU/m^3.

The results from EITNER (1986) proved to be too old (see chapter III) and thus classified as being too low. In order to illustrate the difference, however, they have been included in all tables. It could not be explained why the values of FISCHER (1991) are so low. As all the other results in the table show by far higher values, these higher concentrations are the basis in the following.

Modular type IV – windrow composting, aerated

Table 5.11 shows odorant concentrations of different plants with aerated windrow composting.

The aerated windrow composting is classified in windrows aerated by pressure and suction. According to the state of the art the forced aerated windrow composting is mainly carried out with a completely enclosed table windrow. However, even today there are still open land windrows or windrows under roofs which are aerated. On account of the odour generation suction aeration is preferable.

Table 5.11: Odorant concentrations at aerated windrow composting

Source	Odorant concentration [OU/m^3] Z50	Explanation
FISCHER, 1989	1.500 - 4.100 1.370 - 14.600	Hall suction Decomposition hall, decreasing with decomposition age
ANONYM, 1993/b	 1.900 - 2.100 73 - 150 1.200 - 1.500 69 - 275 660 - 2.300 110	Table windrow Crude gas, at re-stacking Clean gas, at re-stacking Crude gas, static Clean gas, static Decomposition hall Subsequent decomposition
ANONYM, 1993/c	 5.793 362 3.469 342 10.321	Table windrow Crude gas, at re-stacking Clean gas, at re-stacking Crude gas, static Clean gas, static Crude gas, direct on windrow
ANONYM, 1994/b	 811 - 2.423 70 - 224 772 - 1.396 60 - 106	Table windrow Crude gas, at re-stacking Clean gas, at re-stacking Crude gas, static Clean gas, static
JAGER & KUCHTA, 1992	1.000 - 12.000 1.400 - 1.600 280 - 320	Windrow exhaust air, suction-aerated Subsequent decomposition, pressure-aerated Subsequent decomposition, pressure-aerated, after 4 - 5 fold dilution
SCHADE, 1993	1.000 - 10.000 300 - 400	Windrow exhaust air, suction-aerated Hall exhaust air after 7th week decomp., pressure-aerated, h = 2 m, after 4 - 5 fold dilution
MÜSKEN, 1991	 7.810 50 - 420 160 - 10.030	Triangular windrow, pressure-aerated, not prepared, 0 - 6 weeks At piling Before re-stacking After re-stacking
BIDLINGMAIER & MÜSKEN, 1991	 100 - 300 500 - 2.000 100 - 150	Table windrow with green waste Pre-decomp., suction- or pressure-aerated Pre-decomp., at re-stacking Subsequent decomp. (> 3 mon.), suction- or pressure-aerated

	200 - 500	Subsequent decomp. (> 3 mon.), at re-stacking
BIDLINGMAIER & MÜSKEN, 1992	 2.460 - 14.600 18.300 25.900 1.240 345	Table windrow, surface, pressure-aerated, max. 7 d max. 10 d max. 31 d max. 70 d max. 77 d
	 47.730 - 56.070 100 - 15.440 10.650 - 76.930	Pile, surface, pressure-aerated 1 d, fresh piled static t, 5 - 42 d, decreasing 1 d after re-stacking, decreasing
	  1.150 - 5.020 22.600 - 31.200 2.470 - 4.610	Table windrow, hall exhaust air, pressure-aerated, 0 - 70 d at re-stacking after re-stacking
	  30 - 1.900 363 - 20.200 9 - 4.300	Mixed waste, table windrow, surface, suction-aerated Hall exhaust air Windrow exhaust air Windrow surface
MÜSKEN & BIDLINGMAIER, 1993	 350 - 4.300 11.500 - 20.000 < 2.000	Table windrow, suction-aerated, h = 2,30m, 0 - 70 d Surface, Windrow exhaust air, 19.800 m^3/h Hall exhaust air, full capacity
	  8.000 30.000 5.000/30.000	Table windrow, pressure-aerated 0 - 70 d Static (fresh air 19.800 m^3/h) 20 % fresh re-stacked Hall exhaust air, with/without re-stacking
MÜSKEN, 1994	 300 - 800 1.500 - 4.500 500 - 3.000 1.200 - 5.000 580 - 2.240	Table windrow Suction-aerated, surface Suction-aerated, surface, at re-stacking Pressure-aerated, surface Pressure-aerated, surface, at re-stacking Hall exhaust air
	  250 800 1.200	Table windrow as filter, after 16 weeks Active filter element Adapted filter element Piling/Cut up

Pressure-aerated windrows demonstrate a decreasing odour emission with an increasing compost age. Figure 5.10 shows this dependency. This statement can be transferred to other decomposition procedures.

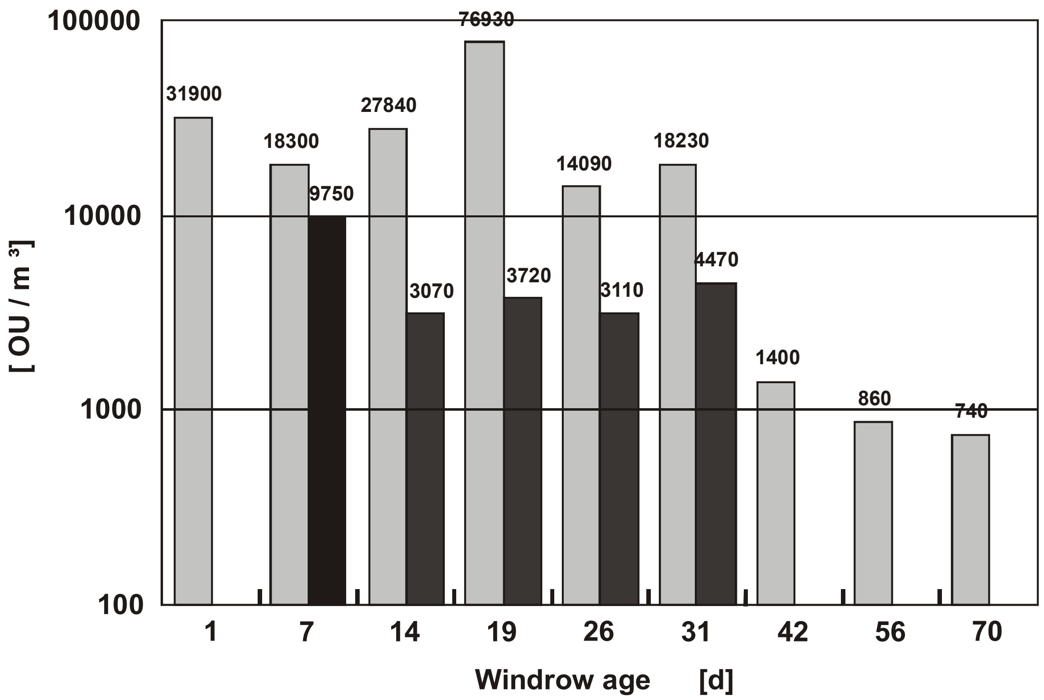

Figure 5.10: Odorant concentrations on the surface of pressure-aerated windrows (mean values from up to 4 single measurements) [BIDLINGMAIER & MÜSKEN, 1992]

With their tests BIDLINGMAIER & MÜSKEN (1992) could determine that concentrations on the windrow surface have decreased by the factor 10 from the 1st to the 10th decomposition week. However, this could not be determined in all composting plants, but the tendency could be ascertained in all plants.

The tests resulted in the fact that on the surface of pressure-aerated static windrows in the first decomposition week 10.000 OU/m^3 with peaks of up to 15.000 OU/m ^{3} can be expected. And until the 5th week with odorant concentrations of about 5.000 OU/m^3, the values are decreasing distinctly under 2.000 OU/m^3 after this time. Values of up to 30.000 OU/m^3 are measured after re-stacking with distinctly higher peaks in the 4th and 5th decomposition week. A decreasing tendency can be recognized after this period. Related to the processed compost volume specific loads of 12 - 45 OU/ m^3*s can be calculated for the first five decomposition weeks after re-stacking processes.

After the assessment of all measurements mean values of 8.000 OU/m^3 for static windrows and 30.000 OU/m^3 for newly re-stacked windrows could be ascertained at a model plant with an annual throughput of 25.000 Mg/a.

A similar dimension show the odorant concentrations measured by JAGER & KUCHTA (1992). They state values between 1.000 and 12.000 OU/m^3 according to the decomposition age of the aerated windrows.

Compared with the unaerated triangular windrows and with the pressure-aerated windrows essentially lower odorant concentrations are measured at suction-aerated windrows. Suction-aerated windrows are often used in the open land and the arising air volume is pressed through the subsequent decomposition windrows, which are effective as a filter and are simultaneously humidified.
There is also an influence between the compost age and the odorant concentration with suction-aerated windrows. The measuring was carried out at composting plants with mixed waste, which, regarding odour emissions, behave in a similar way like biowaste plants. A mean concentration of 1.000 OU/m^3 is measured with material that is 10 days old and up to 88 OU/m^3 with material that is approx. 65 days old. The difference between static windrows and newly re-stacked windrows is not so distinct like with unaerated and pressure-aerated windrows.

Referring to a model plant with 25.000 Mg/a throughput BIDLINGMAIER & MÜSKEN (1992) assume at the surface of suction-aerated windrows a mean value of 350 OU/m^3 and peak values of up to 4.300 OU/m^3. Mean values of 11.500 OU/m^3 were determined for the windrow exhaust air, and maximum values up to 20.000 OU/m^3.

Similar values like BIDLINGMAIER & MÜSKEN (1992) were measured by KÖSTER (1996). Considering the odorant flow on top of the windrows related to one m^2 he detects with 760 OU/(m^2*h), however, lower by approx. 300 OU/(m^2*h). He explains this with the barrier effect of the fleece with which the windrows in the researched plants were covered.

Modular type V – windrow composting, unaerated

Unaerated windrows are mostly used in small, decentralised plants and are not enclosed. The odour emissions are directly discharged into the atmosphere.
The odorant concentrations on unaerated windrows can also be considered as decreasing with an increasing progress of degradation. Furthermore extreme differences between static windrows and newly re-stacked windrows can be recognized with unaerated windrows. The differences are by far more significant than with aerated windrows. Figure 5.11 shows the relations.

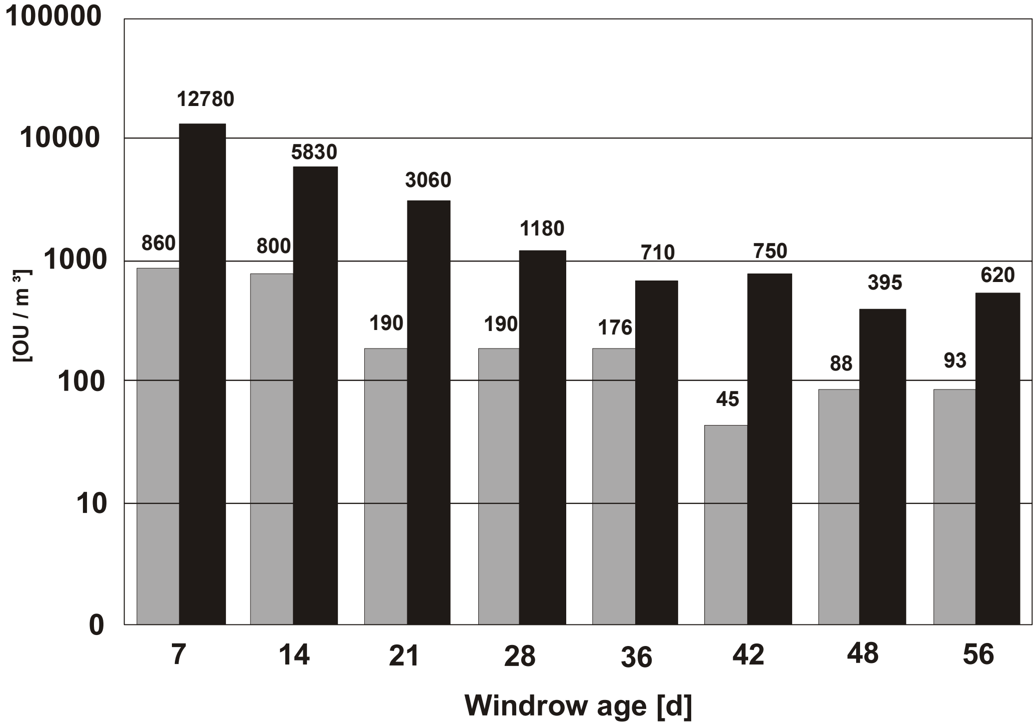

Figure 5.11: Odour radiation from unaerated triangular windrows of biowaste (example) [BIDLINGMAIER & MÜSKEN, 1992]

Some measuring results of different forms of windrows and material ages are listed in table 5.12.

Table 5.12: Odorant concentrations at unaerated windrow composting

Source	Odorant concentration [OU/m^3] Z50	Explanation
FRICKE et al., 1989		Pre-decomp., max. 3 weeks old
	3.494 - 6.419	Freshly piled
	57 - 2.308	Freshly piled, covered
	5.565 - 6.297	Static, 1 d
	1.154 - 4.321	Static, 1 - 2 weeks
	76 - 393	Static, 3 weeks
	3.255	Static, covered, 1 week
	63 - 348	Static, covered, 2 - 3 weeks
	34 - 134	Subsequent decomposition
KÖSTER, 1996		Triangular windrows, static
	800 - 7.600	Up to 2 weeks
	140 - 680	2 - 8 weeks
	40 - 205	8 - 13 weeks

		Triangular windrows, after re-stacking
	10.000 - 20.000	Up to 2 weeks
	1.000 - 6.300	2 - 8 weeks
	40 - 205	8 - 13 weeks
MÜSKEN, 1991		Triangular windrow, 1 week pre-decomp. in reactor
	11.300	At piling
	85 - 190	Before re-stacking
	350 - 3.820	After re-stacking
		Triangular windrow, 1 week Pre-decomp. in decomp. drum
	11.590	At piling
	30 - 790	Before re-stacking
	230 - 4.320	After re-stacking
		Triangular windrow, without pre-decomposition
	4.420 - 5.280	At piling
	860	Freshly piled, covered
	30 - 8.210	Before re-stacking
	345 - 14.820	After re-stacking
MÜSKEN & BIDLING-MAIER, 1992		Triangular windrows, surface
	5.570 - 6.300	after piling, 1 d
		6 - 21 d, static
	76 - 5.590	22 - 112 d, static
	34 - 130	7 d, before re-stacking, cov-ered
	710 - 1.150	7 d, before re-stacking, not
	8.210	covered
	17 - 2.040	14 - 56 d, before re-stacking
	420 - 16.870	6 - 21 d, after re-stacking
	160 - 2.590	22 - 56 d, after re-stacking
		Table windrow, surface
	1.900 - 48.400	7 - 21 d
	160 - 9.170	28 - 98 d

The odorant flows, related to the surface, are at the beginning of the decomposition in the range of 10.5 OU/s*m^2. This corresponds to radiations from equally aged, humid discharge material of decomposition drums and decomposition boxes. After 14 days the value lowers to one half (4.8 OU/s*m^2), after 3 weeks to one third (2.5 OU/s*m^2) and after 4 weeks a mean value of about 10 % of the initial value is measured.

KÖSTER (1996) measures area-related values of 21.600 OU/h*m^2 (related to one hour), what corresponds to a converted value of 6.0 OU/s*m^2 in a static windrow, 2 weeks old at maximum. He quotes values of 43.200 OU/h*m^2 (12 OU/s*m^2) measured in freshly re-stacked windrows. Thus he achieves similar results like BIDLINGMAIER & MÜSKEN (1992). After one week of decomposition, related to the compost volume of triangular windrows, a value of 27 OU/s*m^3 can be considered after re-stacking at odorant concentrations of 13.300 OU/m^3.

Already after 3 weeks the value decreases to 6.3 OU/s*m^3, if decomposition has reached degree III the specific freight is only 1.2 OU/s*m^3. The values of static windrows are very low. A specific load of 2.0 OU/s*m^3 can be considered until the second decomposition week and older windrows have values of approx. 0.4 OU/s*m^3. The rather rare unaerated table windrows have essentially higher odorant concentrations than the triangular windrows. The values can be compared with those of pressure-aerated table windrows. The resulting odour load, however, are definitely lower, as the air volume flow is caused exclusively by the thermal current of the windrows.

Modular type VI – special methods

Composting in bricks with heavy odour emissions only at the beginning of decomposition, as the material is progressively drying out up to a water content of 30 to 35%. The compressed material, stacked on pallets for 5 to 6 weeks in form of bricks, is stored on the same place in a decomposition hall. It is not re-stacked and not force-aerated. With other methods high odour emissions would arise, but this system can be looked upon as being advantageous. A humidification of the material for a subsequent decomposition would result in considerable odour emissions. With a not optimal decomposition process odour emissions arise after decomposition by the loosening in the mill and the following screening.

Table 5.13: Odorant concentrations at the special process with bricks

Source	Odorant concentration [OU/m^3] Z50	Explanation
BARDTKE, 1986	14.700 101	Fresh bricks Old bricks
BIDLINGMAIER & MÜSKEN, 1992	60 - 165 14.700 100	Hall air, 0 -30 d Mixed waste, 7 d, surface Mixed waste, max 30 d, surface

At the completion of the report no data was available for the system of tower composting. This special method cannot be compared with any other system. It is necessary to supplement the dimensioning sheets with this data in the next years.

Within the Modular type "special systems" is just the main level described in the annex for both composting methods because the data basis was only available in fragments or not at all.

Chapter 6 Air Conduct in Composting Plants

The possible features of air conduct in the internal plant, described in this chapter, are mainly based on the specifications in chapters II/3 and V/2. The target of an optimized air management in a composting plant is to minimize at any rate the emitted odorant mass flow (air freight or source concentration measured in [OU/h] or in [OU/s]. For this purpose different instruments are available according to the plant technology and plant size.

The intelligent distribution of the arising air volumes in partly enclosed or totally enclosed plants is of highest importance, but measurements for a reduction of odour emissions can also be realised in open composting plants.

In order to take correct individual steps the knowledge of the following parameters is unavoidable:

- **The quality of the exhaust air** of the individual plant parts respectively plant units. Besides the odour load also the air humidity, the dust content, other ingredients of the air (e.g. ammonia, organic acids etc.) and in case of working places, the germinal load are of importance. The actual conditions of the plant and the season can play a part, too.
- **Exhaust air volume** from the individual plant parts respectively plant units. The volume of exhaust air can vary strongly depending on the plant conditions or plant parts (e.g. day and night operation, maintenance etc.).
- **Fresh air demand** and necessary **fresh air quality** in those plant parts or plant units which are designed for a multiple utilization of air streams. So, e.g. the fresh air for windrows at pressure-aerated windrows can be of a very bad quality, however, the necessary air volume is strongly depending on the decomposition process and is of little importance. Fresh air of minor quality can be blown in enclosed decomposition halls without working places after an adequate dust extraction. Machine halls (coarse and fine treatment) are only partially suitable for the intake of already used air flows.

Concerning the multiple utilization of air flow quality graduations have to be considered in general, i.e. the lower loaded exhaust air flow can be used as a new air supply only in a higher loaded environment. At a reverse order additional cleaning measurements would be necessary what is contradictory to an economic plant management. The planning of an air management that is suitable for the individual plant configuration implies:

- a correct assessment of the concentration measurements for the odorants which is the basis for the load calculation,
- an assessment of the external effects of the chosen composting method by means of an emission/immission prognosis,
- best attention has to be given to the exhaust air purification and plant operation,
- the set-up of an internal plant conception to avoid odour emissions over the admissible size.

Assessment of Odour Measurements
The values for odorant concentrations which can be calculated for the different process parts of waste composting can be classified in two main groups which must then be assessed in different ways. (see III/1).

These are those values which can be directly allocated to an air volume flow, like e.g. exhaust gases from preliminary decomposition units or from decomposition halls (active odour sources). A direct calculation of odour loads can be carried out. Furthermore these exhaust gases can be easily collected and supplied to a purification plant for deodorization.

The other main group of measuring values are e.g. the odour radiation from windrow surfaces or during delivery (passive odour sources). They cannot be allocated to a direct exhaust air volume flow, a load consideration is therefore not easily possible. For the determination of the odour load of these passive odour sources only approximate values are available in form of conversion factors which have been developed by the sample taking equipment. Considering this aspect the achieved load quotations in [OU/s, m^2] for passive odour sources on areas can only be applied to compare dimensions, an exact calculation of, e.g., the source intensity or volume is not possible.

A last fact, relevant to the assessment of odour data, is the intensity of odour emissions which are to a great extent dependent on the temperature. As the substances, which cause an odour impression are volatile, the temperature of the odour source (e.g. windrow) is of importance. Additionally odour intensive inter-degradation products exist in the first degradation phase of the composting process in their highest concentration.

Emission and Immission prognosis

The assessment of the external effects of composting plants regarding their odour emissions (immission prognosis) makes a differentiation necessary in two cases:

- Systems working partly or totally without enclosure need calculations of the intensity of the odour emissions for each plant part that is emitting odours.
- Completely enclosed composting plants need only a calculation of the exhausted air volume for the determination of the source intensity, an exhaust air cleaning according to the state of the art provided, as one can assume that in the cleaned exhaust air constant odorant concentrations exist which, regarding their amount, are only dependent on the purification process.

In the first case, which is relevant for smaller plants with an input amount of approximately 6.000 Mg/a and a total decomposition time of 10 weeks, the odour loads shown in table 6.1 can be taken as an example for a calculation.

The rough comparison shows that a composting plant with a throughput of approx. 6.000 Mg/a (related to the input) is emitting about 4.200 OU/s at pure windrow decomposition on unaerated triangular windrows (h = 1.60 m), in case of a weekly restacking until the 3rd decomposition week and every 2 weeks until the 10th decomposition week. Measures reducing emissions, like covering of the windrows with chopped material or semipermeable membranes (air-permeable canvas) have not been considered here.

The use of decomposition boxes in the first decomposition week reduces the total load by approximately 10%, if the dwell time in the box is prolonged by 2 weeks a reduction of 40% of the total load is achieved, however, under the condition that an optimal water content for the decomposition progress is adjusted. In this case the purification of the exhaust air from the box is realised over a correspondingly dimensioned biofilter, to which possibly an intermediate cleaning device must be added in order to keep the determined clean gas concentration of 150 OU/m^3.

Table 6.1: Example for odour emissions of a composting plant with an input of approximately 6.000 Mg/a

Location / units	Material quantity [m^3]	Composting on un-aerated triangular windrows [OU/s] (h = 1.60 m	Pre-installation of decomposition boxes (dwell time 7/14 d) [OU/s]
Bunker	46	390	390
Input - Fresh prepared - Covered	 23)[1] 23)[1]	 235 40	 235 -
Decomposition boxes - Exhaust air after biofilter (5m^3/m^3*h) Discharge (humid)	230/460 41/39	- -	48/96 1.120/640
Triangular windrows (static) - Max. 14 d old - Over 14 d old	Approx. 340)[3] 160)[3] 1.300)[3]	 680 - 520	 - 320/- 520
Triangular windrows (re-stacking) - 7 d old - 14 d old - 21 d old Decomposition degree >III)[2]	 41 39 37 Approx.60)[3]	 1.120 640 240 72	 - 640/- 240 72
Fine treatment)[4]	23	28	28
Storage (12 weeks) - Daily quantity, cut up - Storage windrow static	 23 1.380	 12 235	 12 235
Sum	-	4.212	3.860/2.468

)[1] half of daily quantity
)[2] re-stacking rhythm 14 d (2 windrows per day)
)[3] mean value
)[4] like re-stacking at decomposition degree > III

Completely enclosed composting plants (2nd case) are actually emitting odours over the purified exhaust air, therefore, the total exhaust air volume determines the source intensity of the plant; this results in the fact that a minimised exhaust air volume is decisive for a favourable immission prognosis.

In the following a rough comparison of the total exhaust air volumes of composting halls with suction and pressure aerated table windrows is carried out by means of an example. A plant input of 20.000 Mg/a has been chosen for the example. Hereby an aeration rate with an average of 3 m^3 air/m^3*h was applied for the compost.

The total area of the decomposition part of about 3.800 m^3 and the hall height of 8.00 m amounts to a hall volume of 30.400 m^3. A hall volume to be deaerated of 23.800 m^3 remains if the compost volume of 6.600 m^3 (ten weeks' decomposition) is deducted. Based on a simple air ventilation in the hall (no permanent working place) 23.800 m^3/h must be discharged from the hall.

When **suction aeration** is concerned and the exhaust air from the windrow (19.800 m^3/h) is totally calculated to the ventilation number of the air, remain 4.000 m^3/h, which have to be supplied for purification as hall exhaust air.

In case of **pressure aeration** and a single air exchange in the hall, 23.800 m^3/h must be sucked off, too. Contrary to the suction aerated windrows the utilization of pressure aeration makes a partial circular supply of the hall exhaust air possible, what reduces the amount of the total exhaust air. If the portion of the circulating air is given with 30% of the hall exhaust air, so in this arithmetic example 7.140 m^3/h must not to be supplied to the exhaust air purification. The remaining air volume to be treated, simultaneously the emitted air volume, is only 16.660 m^3/h.

The exhaust air flows (hall inlet air) from the bunker area, from the input preparation and fine treatment can be used for the aeration of the windrows. Even at a simultaneous minimization of the air volumes there (e.g. by encapsulation of individual units) is this amount, at least with 50%, still high enough for the aeration of the windrows during the daily normal operation.

The comparison of the aeration systems regarding a highest possible reduction of the total exhaust air volumes of a composting plant proves that in a plant with approximately 20.000 Mg/a throughput up to 30 % of the exhaust air volume from the decomposition part can be saved with pressure aerated table windrows, in comparison of the suction aerated windrows. An optimized exhaust air purification with odorant concentrations of < 250 OU/m^3 after the filter, provided in both cases, means that the odour load emitted from the exhaust air flow from the decomposition hall with pressure aerated windrows is also reduced by 30 %.

The special case of the partly suction and partly pressure-aerated windrows, which use windrow exhaust air as additional air from the suction-aerated part for the pressure-aerated part, can be compared in an air volume calculation with an all suction-aerated windrow operated by circulating air.

That means in a plant of 20.000 Mg/a input, using suction aerated table windrows and operating with an optimal air conduct (multiple utilization, circulating air), odorant loads arise at the biofilter of about 1.700 OU/s and with pressure aeration of about 1.200 OU/s from the exhaust air of the decomposition hall. The additional air volumes furnished to the exhaust air purification unit from other plant parts increase this emission mass flow correspondingly.

Rough estimations of a small plant (about. 6.000 Mg/a throughput) without encapsulation and without special measures for a reduction of odours compared with a “large-scale plant” (about 20.000 Mg/a throughput) with suction aerated windrows show that the large plant is emitting from the decomposition part just about 40 % of the total odour load of the small plant. When pressure aeration is used this emitted load decreases even to 30 %. The completely encapsulated “large-scale composting plant”, with an optimized air conduct of the exhaust air volume and an emitted odour load from the decomposition hall after the exhaust air was purified, with a throughput of about 20.000 Mg/a and a measured value of at least 50 % of the total load is still more favourable regarding the total emissions than the exemplary “small plant” with an annual throughput of 6.000 Mg/a.

It must be derived from these calculations that before a composting plant is designed the immission values to be stipulated for the environment must be calculated according to the admissible odour sources of this plant. Then an adequate planning can be carried out with the objective of an optimal process when it comes to odours.

Exhaust air purification

Biofilter with layers of compost, crushed bark, mixtures with swelling clay, broken root timber, fibrous peat and heather are presently used in order to deodorize odour-loaded exhaust air flows. Heavily loaded exhaust air flows (e.g. from decomposition drums, exhaust air from suction aerated windrows) have additional preceding bio-scrubbers as the crude gas concentration is too high in order to achieve satisfying results of clean gas at a filter efficiency of > 95 %. A humidifier for the exhaust air flow installed before the biofilter also reduces the concentrations by means of the washing out of the odorants.

A tendency to multiple stage exhaust air procedures is inevitable for the future requirements of odour emissions which must be expected in a more tightened way for biological waste treatment plants. This can lead to combinations of bioscrubbers and several series connected biofilters. A collection of the exhaust air flows after their purification and the conductive discharge via chimneys must be taken into consideration in future on account of the positive influence of the increased source height on the immission values. (see III/1).

If all conditions, mentioned above and in chapter IX, are fulfilled it can be assumed that an optimal air management for partly or completely encapsulated composting plants can be found that is accustomed to the individual plant technology, which reduces the external effects of the plant operation arising from the emission of odorant concentrations to a minimum.

Table 6.2 shows a summary of odour relevant data for an encapsulated composting plant with an annual throughput of 12.500 Mg/a. This example is taken in figures 6.1 to 6.3 to demonstrate which effects the air conduct within the plant has on the source intensity of the biofilter. The plant example largely corresponds to Modular type IV (windrow composting aerated, see V)

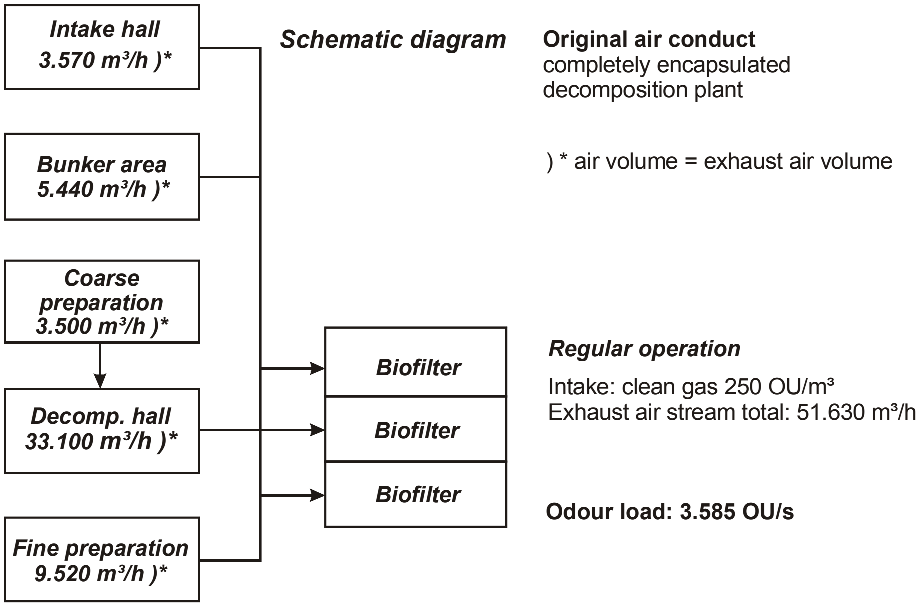

Figure 6.1: Example for a not optimized air conduct (data from table 6.2)

In this case the emitted odour load from the biofilter can be reduced by approximately 30 % contrary to the original planning by a consequent multiple utilization of the air flows (figure 6.1). Of course hereby must be considered:

- In case exhaust air flows from single plant parts are conducted in other operational plant parts the portion of the used additional air must only be 60 to 80 % from the air amount discharged from the same section. The rest should be sucked in over fresh air ventilators. By this way a steady light low pressure can be kept thus avoiding the discharge of odorants.
- During special operational conditions (e.g. maintenance work) it may become necessary to by-pass or to switch off used additional air flows in order to improve the atmosphere in the concerning plant part (figure 6.3).

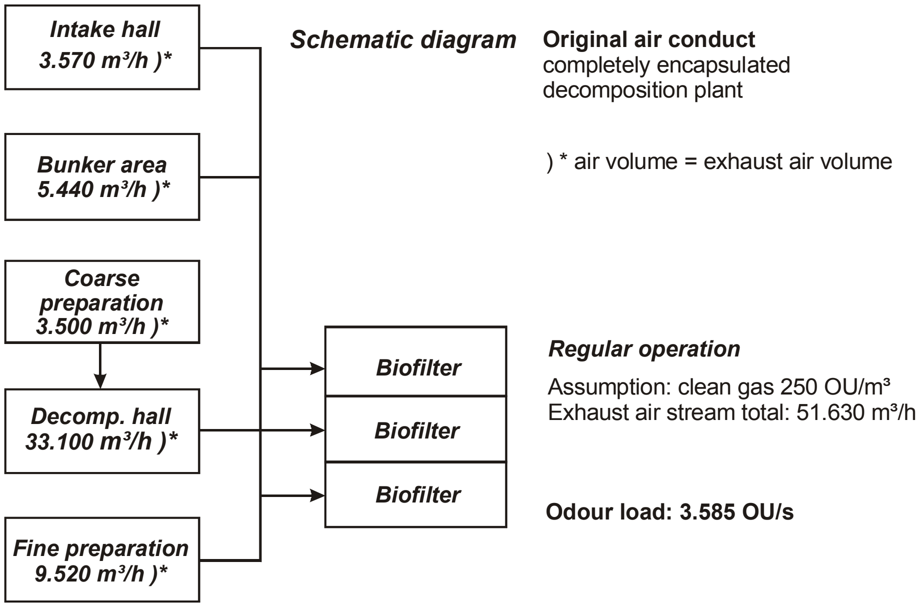

Figure 6.2: Example of an optimized air conduct (data from table 6.2)

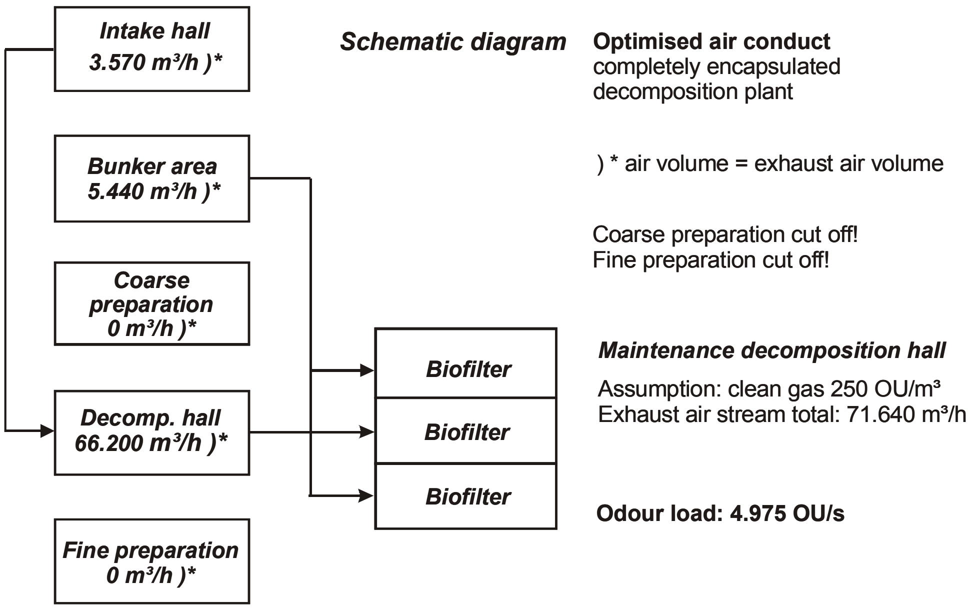

Figure 6.3: Example of an optimized air conduct during maintenance in the decomposition hall (data from table 6.2)

Table 6.2: Values of Odour Emissions of a composting plant with a throughput of 12.500 Mg/a (example)

Pos. 1	Source	Area [m²]	Volume [m³]	Surface [m²]	Air stream [m³/h]	Odorant concentration [OU/m³]	Odour radiation [OU/m²,s]	Odour load [OU/s]
1.1 1.2	Material box, shredder material, Intake hall	25 525	50 3.570	70 -	- 3.570	500-1.500 100-300	0.41-1.24	29-87 100-300
-	**Exhaust air intake hall**	525	3.570	**-**	**3.570**	150-400	**-**	**150-400**
2.1 2.2 2.3	Pit bunker biowaste Pit bunker green waste Pre-comminution	50 166 -	60 500	80 300 30	- - -	1.000-8.500 150-500 1.200-3.000	0.83-7.04 0.12-0.41 0.99-2.49	66-560 36-120 30-75
-	**Exhaust air bunker area**	270	2.720	-	**5.440**	200-800	-	**300-1.210**
3.1	Preparation hall	216	1.750	-	3.500	300-500	-	290-490
3.2	Encapsulated units	-	-	-	500	2.160	-	300
-	**Exhaust air coarse preparation**	216	1.750	-	3.500	610-810	-	590-790
5.1 5.2	Table windrow storage pile./cut up	340 -	1.000 -	400 120	- -	250 1.200	0.21 0.99	84 120
5.3 5.4	Screening unit (passive) Bagging unit (passive)	- -	- -	150 50	- -	1.200 300	0.99 0.25	150 13
5.5	Exhaust air screening and bagging	-	-	-	500	600	-	83
-	**Exhaust air fine preparation and storage**	867	4.760	-	**9.520**	170	-	**450**
4.1	Additional air, decomposition hall)[1]	-	-	-	18.460	260-480	-	1.340-2.450
4.2 4.3	Windrow suction-aerated Windrow pressure-aerated	1.750 1.750	2.800 2.800	1.780 1.780	- 5.040	300-800 500-3.000	0.25-0.66 -	445-1.170 700-4.200
4.4 4.5	Re-stacking suction-aerated windrow, re-stacking pressure-aerated windrow	- -	- -	450 450	- 1.275	1.500-4.500 1.200-5.000	1.24-3.73	560-1.680 425-1.770
-	**Exhaust air decomposition hall**	4.320	33.100	-	**33.100)[2]** **66.200)[3]**	1.170-2.090 580-1.040	- -	10.760 bis 19.220 10.670 bis 19.120
7.1 7.2	Container for residues discharge screening unit	- -	- -	20 80	- -	500-2.500 250-1.200	0.41-2.07 0.21-0.99	8-41 17-79
7.3	Traffic areas, outside	1.000	-	-	-	50-200	0.04-0.17	40-170
7.4	Other diffuse sources	-	-	-	-	-	-	200
-	**Maximum total emission active**	-	-	-	**33.100** **66.200**	250 250	- -	**2.300** **4.600**
-	**Maximum total emission passive**	-	-	-	-	-	-	**490**

)[1] optimized air conduct, exhaust air streams from the bunker are incl. intake hall, coarse preparation and fine preparation)[2] normal operation with simple air change per hour in the decomposition hall
)[3] maintenance work with two-fold air change per hour in the decomposition hall

Chapter 7 Preparation of Dimensioning Sheets for the "Odour Formation in Composting Plants"

The dimensioning sheets described in the following shall standardize and simplify the assessment and calculation of odour emissions and immission. This objective is achieved when all composting methods, actually available on the market, are allocated to the 6 modular types.
The basis for the dimensioning, i.e. the odour data, were taken from the data of the literary study in chapter 5.
The precondition for a correct assessment of the emissions is a permanent characterization of the planned plant. A continuous actualisation of the data basis is inevitable.

1 Structure of the dimensioning sheets

The dimensioning sheets are divided in two parallel levels. One describes the emissions and their influence quantity of the specific process steps and the other level describes the generally valid process steps which can be found in every method. Figure 7.1 illustrates the structure of the dimensioning sheets with the two parallel levels. Listed are the 6 individual modular types as main levels and the specific and general process steps with the belonging influence quantities as the two sublevels. The dimensioning sheets for the individual modular types are documented in the annex.

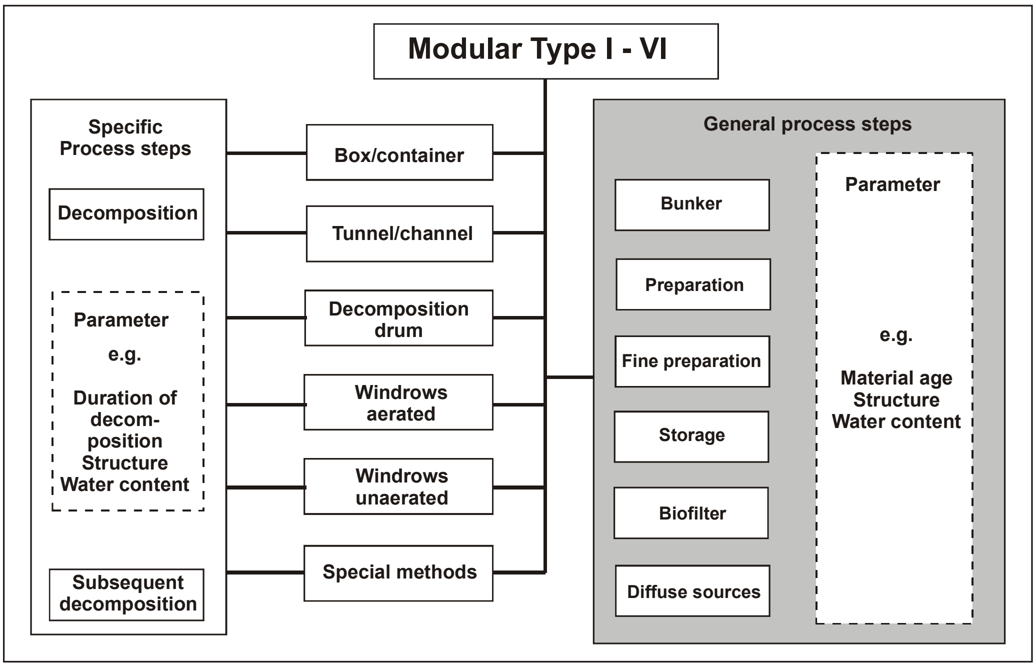

Figure 7.1: Structure of the two parallel arranged levels of the dimensioning sheets

The individual levels are described in detail in the following and documented with exemplary figures.

Main level I to VI

The main level is shown in figure 7.2 as an example of box/container composting. This level describes the process type by means of a flow chart. Within this flow chart are the individual procedure steps displayed with two different colours. The steps with a light-coloured background describe the level of the generally valid process steps and the dark-coloured background describes the level with the specific parts of the procedure. Furthermore all manufacturers which are actually present on the market are listed here.

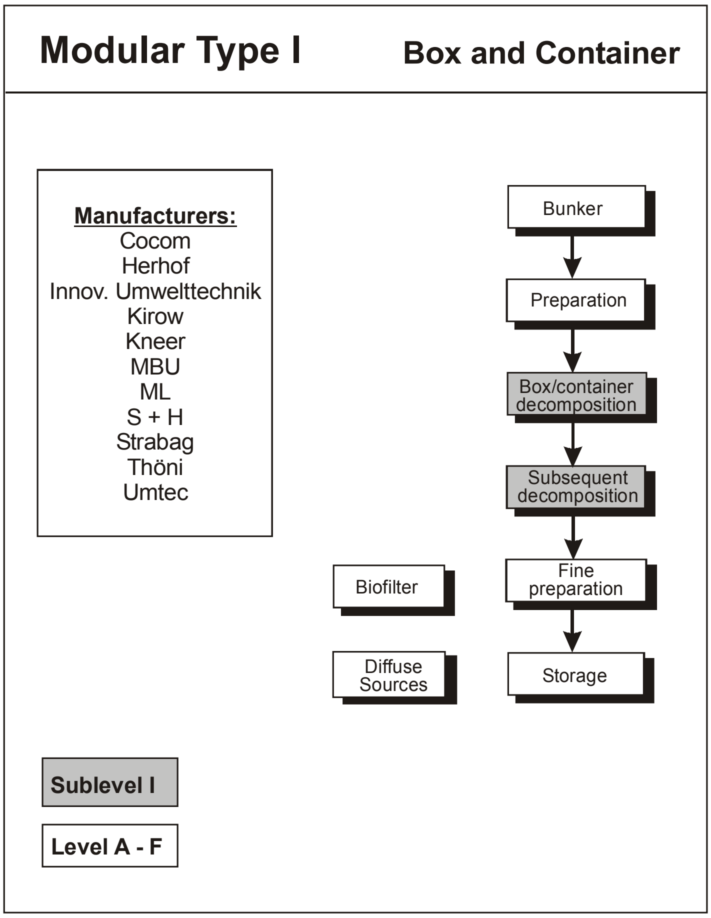

Figure 7.2: Main level of modular type I

Sublevel I to VI (specific process steps)

The process-specific partial modular components like decomposition and subsequent decomposition and their emissions are listed in this sublevel. Hereby all the emitting working steps within the process-specific steps and the possibilities for exhaust air together with the corresponding odorant concentrations are dealt with. Additionally named to all possible emissions are the corresponding influencing parameters. These are necessary, as often very large ranges of deviations occur within the concentration (see chapter 4). These influencing parameters could be e.g. the water content or also the decomposition time of the material. In figure 7.3 is shown the sublevel I, of the box and container composting as an example.

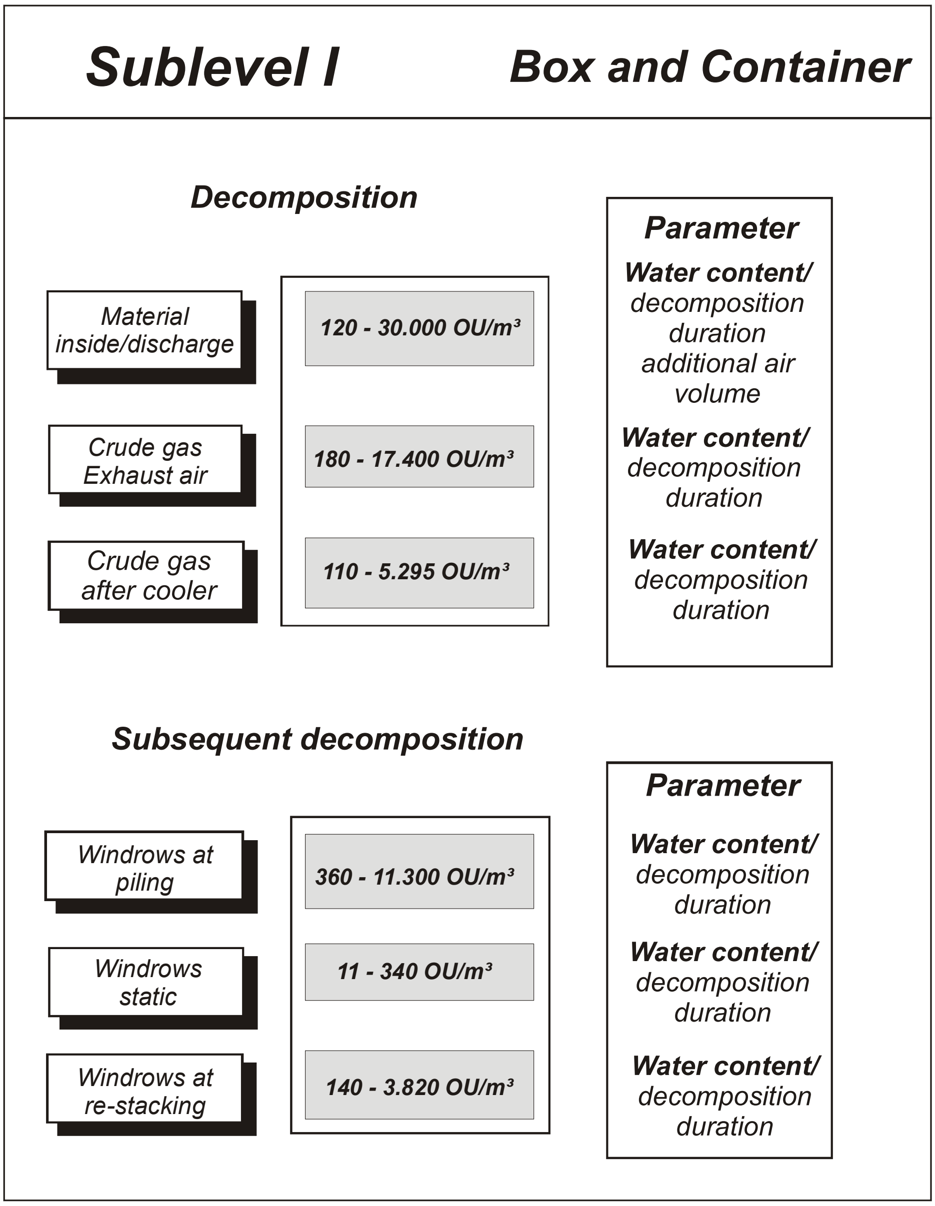

Figure 7.3: Sublevel I of modular type I

Influencing parameters of sublevels I to VI

More closely described in this level are the previously named parameters which influence the individual emitting sources. This level is meant as help for an assessment of odorant concentrations which are lying between larger deviations. As far as this is possible the concentrations are more intensely allocated and made transparent. In figure 7.4 are shown the exemplary influencing parameters of the sublevel I of the box and container composting.

Sublevel I Parameter	**Box and Container** Decomposition
Water content	The higher the water content the higher the odorant concentrations; **Material surface:** WC 30 - 40 %: 120 - 1.220 OU/m^3, WC 40 - 50 %: 2.740 OU/m^3, WC 50 - 60 %: 11.300 -> 15.900 OU/m^3. **Crude gas:** after 7 d humid, minimum delivery air: 15.940 - 30.000 OU/m^3, 1 - 7 d, dry: 10.100 - 176 OU/m^3
Decomposition duration	Decomposition duration in the reactor; at optimal WC decrease the concentrations; 10.100 OU/m^3 on the 1st day, 180 on the 7th day with dry material; with humid material up to 30.000 OU/m^3 on the 7th day
Delivery air volume	Odorant concentrations in the crude gas decrease at higher additional air volume, humid material: 50 m^3/m^3*h: 30.000 OU/m^3; 20 m^3/m^3*h: 200 - 10.000 OU/m^3 (7-1 d)

Basis of calculation related on 1 m^3 material:
at a small plant with 6.500 Mg/a:
delivery air 5 m^3/m^3*h: 41 OU/(m^3*s);
delivery air 20 m^3/m^3*h: 30 OU/(m^3*s);
discharge, humid (daily quantity approx. 41 m^3): 27 OU/(m^3*s);
delivery air 25 m^3/m^3*h, 7 d, WC < 40 %: 1,4 OU/(m^3*s);

Figure 7.4: Influencing parameters for sublevel I of the modular type

Level A to F (a generally valid process steps)

A parallel level to the sublevel I to VI are the general process steps like the treatment or the delivery of biowaste signed with the letters A to F (see also chapter V). They are equally designed and have a level which describes the influencing parameters, as described above. The design of the two levels is shown in figure 7.5 and 7.6 as example of the process step preparation (level B).

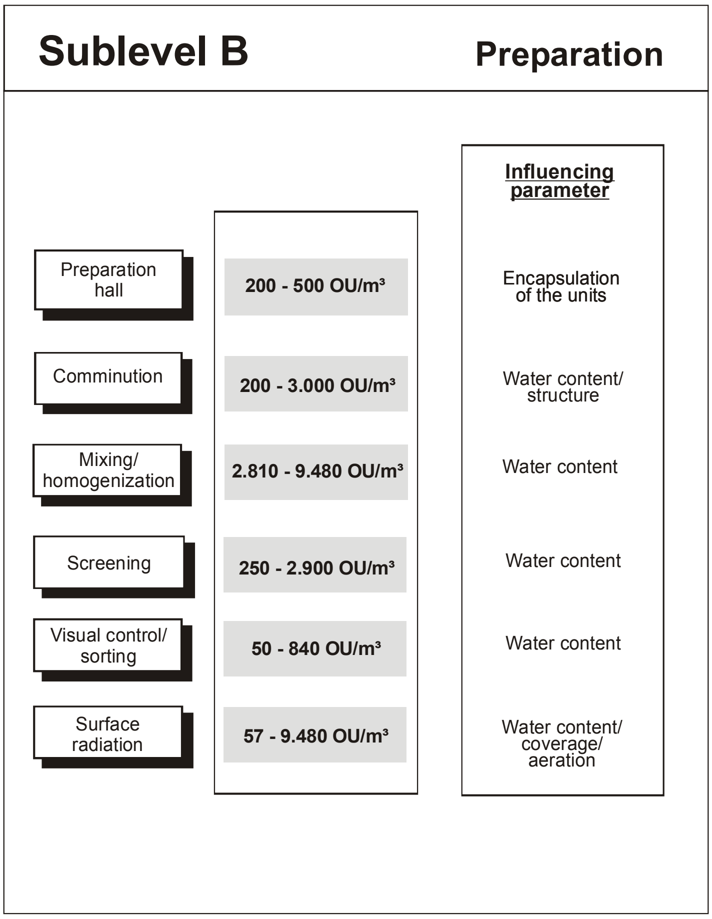

Figure 7.5: Level B - Preparation

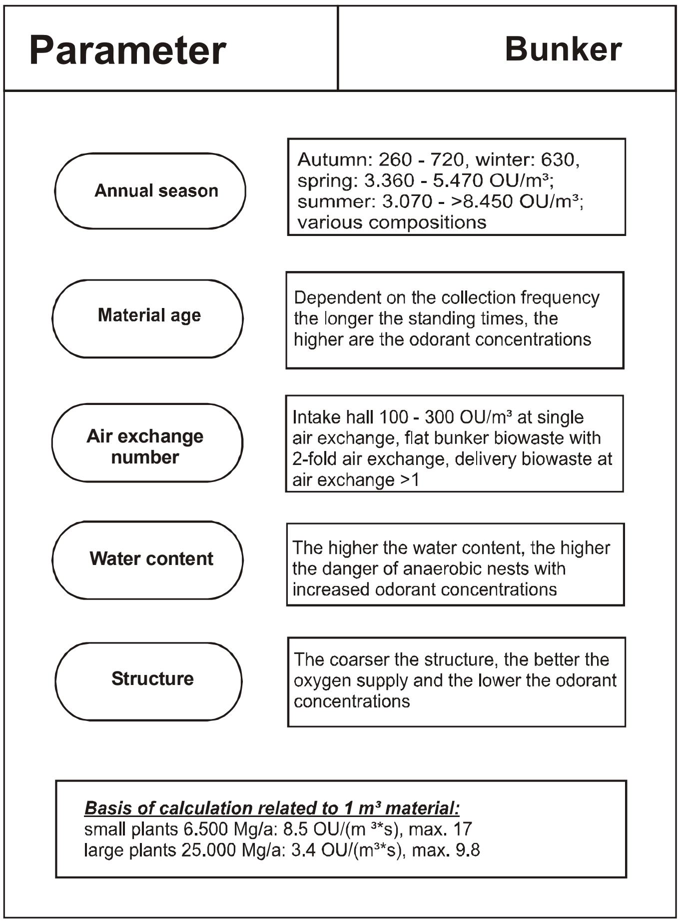

Figure 7.6: Parameters for sublevel B

2 Handling of the dimensioning sheets

In order to simplify the use of the dimensioning sheets the procedure is shown by means of an example in figure 7.7.

If the planner of a composting plant made the decision for a composting system, the first question is, which modular type has to be applied. If he decided himself for a modular type, in this case modular type I, he must choose the level (general or specific process steps), which has to be covered. In the example it is sublevel I, i.e. the process specific sublevel. Within this sublevel he can choose between two different possibilities (see also figure 7.1), here decomposition and subsequent decomposition.

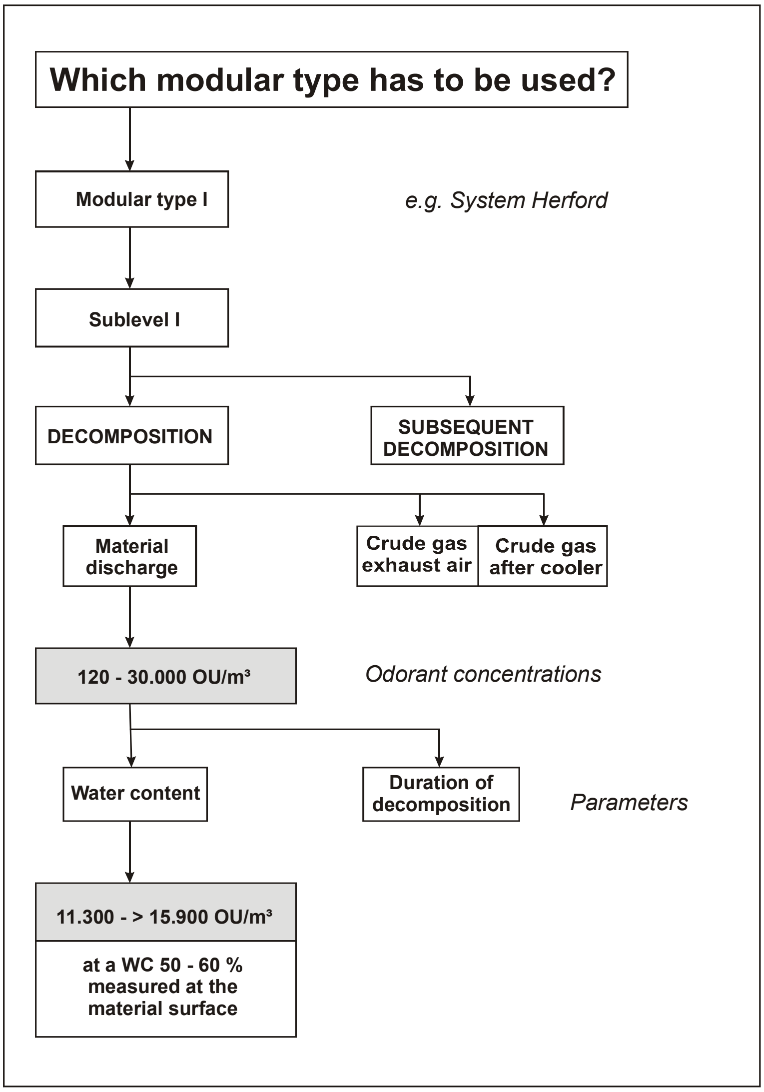

Figure 7.7: Method for the use of the dimensioning sheets by means of an exemplary modular type

In this case that decomposition was chosen which is subdivided in areas relevant to the emissions, like e.g. material input and discharge, material surface, re-stacking procedures etc. In this sequence the material discharge was chosen as an example, which is quoted with an odorant concentration of 120 to 30.000 OU/m^3. In order to simplify the selection of the height of the odorant concentrations for each emission relevant area, as far as this was possible, influencing parameters have been determined together with the belonging odorant concentrations.
These influencing parameters are e.g. the water content of the material, the time of decomposition etc. (see also figure 7.4).
As an example of a parameter the water content of the material was chosen. In this case the concentrations rise with the increasing water content. With a water content of 50 and 60 % the odorant concentrations are between 12.000 and 16.000 OU/m^3.

Chapter 8 Example of a Load Calculation and Assessment of Immission in a Composting Plant with Emission Reducing Measures

This load calculation shall demonstrate the present state of how the cycle of an emission or immission works and how costly this process is. Furthermore it is made clear that the odour data is selected accidentally from the literature. This proves that uniform approaches for the assessment of the emissions and immission are urgently needed.

1 Description of an exemplary plant

1.1 Origin, type, quantity and quality of the biowaste

Approximately 160.000 inhabitants are connected to the biowaste composting of the example county. The collection of biowaste is usually carried out in aerated biobins, which are emptied in a cycle of a 2 weeks collection. On planning the plant it was assumed that on account of the rural character of the disposal area with 30 to 40 % a high portion of structure material would be in the biowaste. However, these expectations could not be fulfilled up to now. The portion of impurities, consisting of plastic foils, broken glass and stones, contained in the delivered biowaste, is with about 5 weight % in the usual framework. A volume of about 50 - 60 kg/(inhabitant*a) arise for the time being, that is a biowaste amount of approximately 8.000 - 9.600 Mg/a.

2 Process sequence of composting

Together with the composting plant there is a recycling station, taking off hazardous wastes from households, delivery of bulk waste and a transfer station with a waste press on the site.

The process sequence of the exemplary composting plant is shown in figure 8.1 as flow chart.

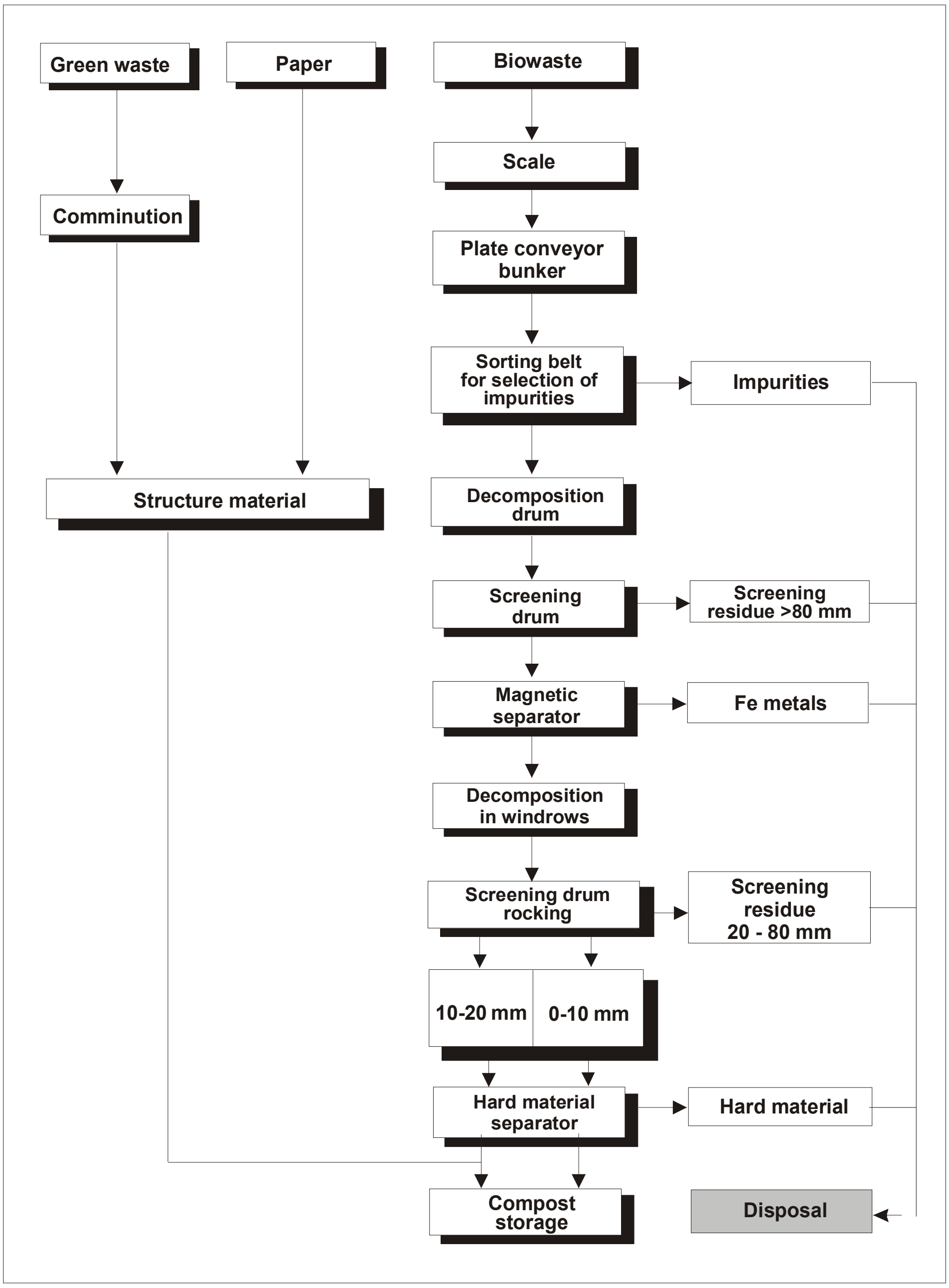

Figure 8.1: Flow chart of the process of the composting plant

2.1 The delivery area

On 5 days per week during 8 hours/day biowaste is delivered. After weighing and registration the vehicles are driving into a closed bunker hall with roller shutters and dump the biowaste on a plate conveyor.

The plate conveyor bunker is made of an enlarged funnel tube (50 m^3) which works as storage and a subjacent plate conveyor. Immediately after the filling process is realized, the biowaste is discharged through the horizontally attached plate conveyor from below and conveyed into the treatment hall. The ambient air of the closed intake hall with a volume of approximately 1800 m^3 is permanently sucked off (10.000 m^3/h) during delivery and furnished to the biofilter.

2.2 The preparation and pre-decomposition area

The plate conveyor transports the biowaste to the pre-treatment plant and is taken over by a mobile sorting belt. In case charges with impurities should be sorted out the belt can be stopped, moved out of the transporting position and the impurity charge is loaded into a container. After the belt is moved back into its original position the biowaste is furnished into the decomposition drum.

The decomposition drum with a diameter of 3.75 m and a length of 20 m is running in continuous operation. The biowaste is filled in together with the structure material and comminuted and homogenized over a period of 24 hours. The structure material, that is partly stored in the pre-treatment hall and furnished to the decomposition drum via conveyor belts, is a compound of two different materials. One part is green waste with a high amount of green cuttings which is added with a 20 weight per cent. The green waste is predominantly meant for an improvement of the structure of the compost material.

Paper, from newspapers and cardboard, is added with about 10 weight per cent. The paper has the function of a water binding material adjusting the high water content of the biowaste of 70 % onto 50 - 55 % in the original material of the decomposition drum. Following the information of the plant operator the added paper has no decisive influence on the increase of heavy metal contents in the mature compost.

Despite the assumption that with a dwell time of just one day the decomposition drum serves primarily for homogenization, temperatures of up to 50 centigrade are measured in the material. As the decomposition drum is continuously in operation, the delivery of the material, takes place only on 5 days per week, an increasing degradation of the organic substances at the weekends can be expected. A suction unit with a capacity of 6000 m^3/h provides for the discharge of the odour loaded exhaust air and the supply to the biofilter. The decomposition material is not continuously discharged through a period of about 3 hours and is supplied with a conveyor belt to the screening drum.

From the discharge of the decomposition drum pieces > 80 mm are selected in the screening drum (diameter 2.5 m, length 6 m) and supplied to the transfer station via an encapsulated conveyor belt. Besides other wastes the impurities and the fractions > 80 mm and 20 - 80 mm are compacted in a waste press and then driven to the landfill with vehicles. Iron metals are extracted from the material in the next treatment unit by means of a magnetic separator which is installed over the belt and thrown in a container. The metallic fraction is furnished to the transfer station while the compost raw material leaves the pre-treatment hall over encapsulated conveyor belts and is then furnished to the windrow composting.

2.3 The subsequent decomposition area

The compost prepared for the unaerated subsequent decomposition has a water content of about 50 - 55 % and a bulk density of about 0.65 - 0.70 Mg/m^3.
The open and unaerated windrow composting takes place on two different decomposition areas under the cover of a roof, which are separated from each other. The coverage was necessary because of the high mean values of about 1.000 mm precipitation per annum, in order to protect the windrows from wetting and to control the humidity content actively.

The decomposition material is transported by means of an encapsulated conveyor belt to the first decomposition area, there it is tipped and piled up to 2.5 m high rectangular windrows with a wheel loader. The area comprising about 2.000 m^2, is equipped with mounting grids. Thus enabling an aeration from below and avoiding a wetting of the windrow bottom. The decomposition area 1, situated in the north-western direction, has been equipped with a wall on a total length of 45 m, in order to protect the neighbours from the dust swath and the emitting odour packages. The windrows are bored in an interval of 1 m and to a depth of 1.5 m to improve the aeration. Through the borings with a diameter of 20 cm a chimney effect is caused which shall avoid anaerobic zones in the interior of the windrow.

Contrary to the decomposition area 2 there is no technical objection against a complete housing of the decomposition area 1 as the supporting framework and the roof coverage are already prepared for such a housing.

The arising loss of liquid reached at mean temperatures of 60 - 70 centigrade in the inner part of the windrow must be compensated by watering after a one month's dwell time, so that the decomposition process does not come to a stop. The re-stacking of the windrows by means of a wheel loader should be realized in a 2 weeks' rhythm according to the opinion of the operating manager. On account of operational reasons it is, however, not possible for the moment, so after a mean dwell time of about one month the material is transported to the second decomposition area without re-stacking.

The decomposition material is picked up by wheel loaders, delivered into a funnel and tipped with an open conveyor belt onto the decomposition area 2 with a size of approximately 3.500 m^2. Here the decomposition material is piled with wheel loaders to windrows of a height of 2.5 m, which are bored and re-stacked in an approximate rhythm of 2 months (planned were 2 weeks).

After an approximate decomposition of 3 months on the second decomposition area, the compost is transported via an encapsulated conveyor belt in the subsequent treatment hall for refining.

2.4 The refining area

At first the material is furnished into a rocking screening drum and sorted according to grain sizes in the fractions 0 - 10mm, 10 - 20 mm and 20 - 80 mm. The screening > 20 mm is transported to the transfer station by means of conveyor belts, whilst the fine screening 10 - 20 mm and 0 - 10 mm is transported to the densimetric separator. The remaining impurities like stones and broken glass are removed here in order to receive an optically acceptable and saleable product.

The separated solid materials are also disposed of via the transfer station. The high portion of screening residues 20 - 80 mm with a weight percent of 12 % charged with foils, broken glass and stones on account of a missing air separator was surprising and thus not suitable as structure material.

In order to reduce the expenditures for costs and the acquisition of the structure material the fraction 10 - 20 mm is re-transported to the decomposition drum and reused there as structure building material. Following the operating manager a 50 % mass reduction can be calculated after decomposition, removal of impurities and screening. The operator calculates a 30 weight per cent on behalf of decomposition and further 20 weight per cent on behalf of screening losses and impurities. The extremely high portion of screening residues of about 20 weight per cent is according to JAGER (1991) quite usual for the process combination decomposition drum - screen. Comparable plants had a volume of screening residues of 20 - 40 weight per cent with a correspondingly high organic portion. These high screening residues are usually caused by an insufficient comminution efficiency of the decomposition drum which does not guarantee a sufficient cutting of tough and coarse organic components like branches and of the paper components. After refining the compost leaves the subsequent treatment hall over encapsulated conveyor belts and is transported to the compost storage in fractioned grain sizes.

2.5 The compost storage area

The compost is tipped with the conveyor belt and piled with a wheel loader on rectangular windrows to a height of 3.5 m, in fractions of 0 - 10 mm and 10 - 20 mm grain size. The compost is stored on a roofed area of about 2.300 m^2 the north-west and west sides of which are walled. As both the volume of biowaste and the compost sale are subject to seasonal deviations, the storage area was dimensioned in such a way that a compost production of 4 months can be stored temporarily. In order to cope with the high amount of sales in spring the storage area is mounting to a high capacity in winter, contrary to the summer months where short storage periods can be expected.

2.6 The biofilter

The biofilter installed on the composting plant is a surface filter with a filter area of 200 m^2 and a filter surface load of 100 m^3/(m^2*h) which is designed for the purification of 20.000 m^3/h exhaust air. The odour loaded exhaust air volumes of the bunker hall (10.000 m^3/h), of the decomposition drum (6.000 m^3/h), of the screening drum and the hall for pre- and subsequent treatment (4.000 m^3/h) are deodorized here. The filter height is 1.5 m and consists of three filter layers. The bottom layer has a 30 cm thick drainage layer which is meant for a quick let off of the leakage water coming out of the filter. The two layers on top are responsible for the deodorizing itself. They consist of a 100 cm thick shreddered greenwaste layer and a 20 cm thick layer of mature compost (screening 25 mm). The biowasher installed before the biofilter has to minimize odour peaks and leads to a more steady burden of the biofilter.

3 Emission prognosis of the composting plant

The emission prognosis for the individual plant parts is made for three different input cases. Case 1 has today's input volume of 12.500 Mg/a as basis for the calculation. The second case refers to the emission prognosis for the allowed plant quantity of

20.000 Mg/a. The last case shall examine the arising emissions at full work load of 25.000 Mg/a. Furthermore it is assumed in the following that the composition of the biowaste and thus the water content does not change even at a higher input quantity. That means a reduction of the water content in the biowaste by adding a paper amount of 10 %.

- case 1: input quantity 12.500 Mg/a (70% biowaste, 20% green waste, 10% paper)
- case 2: input quantity 20.000 Mg/a see above
- case 3: input quantity 25.000 Mg/a see above

3.1 Determination of the decomposition specific initial data

The precondition of each emission prognosis is the determination of the chemical-physical initial data which can indicate important data about the decomposition process and possible improvements of the procedure. The main points are the bulk density, the mass or material balance, water contents, air pore volume, the pH value, the C/N ratio and the process of the organic dry matter.

Bulk density
The weight of the bulk density is mainly determined by the water content, the grain size distribution and the type and form of the individual grain groups and is subject to heavy seasonal deviations. The following bulk densities are assumed:

- decomposition area 1: 0.65 Mg/m³
- decomposition area 2: 0.60 Mg/m³
- compost storage: 0.65 Mg/m³

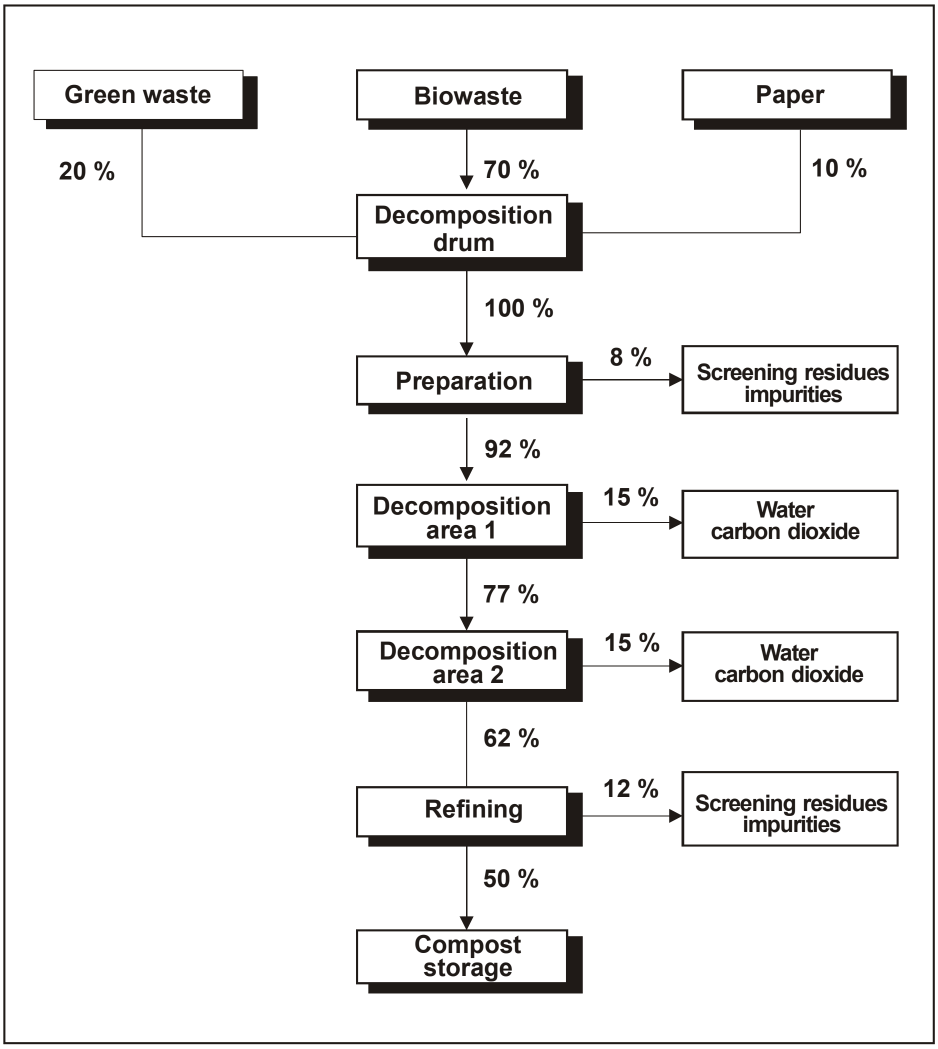

Figure 8.2 Assumed mass balance of the composting plant

Mass balance:
According to the statements of the operator a compost yield of 50 % is calculated, whereby losses from screening residues and impurities of 20 % and 30 % from decomposition are assumed. The basis of the following calculation is the mass balance shown in figure 8.2

3.2 Emission assessment of the individual plant parts / areas

3.2.1 Emission assessment of the intake area

The plate conveyor bunker consists of an enlarged funnel tube (50 m^3) and the subjacent plate conveyor. Contrary to other bunker types like flat and pit bunker it has many advantages regarding the expected odour emissions. Advantageous is the quick and continuous transport by the plate conveyor which reduces the dwell time of the biowaste to a minimum. Leachate and press waters are very seldom as the material discharge is carried out very quickly and in cases where they are arising a channel running below the plate conveyor can take them up and remove them. The decisive advantage of the plate conveyor bunker, however, is the fact that the surface where emissions arise can be reduced by the funnel tube. While other types of bunkers have a sidewise odour emission, the odour emitting area of plate conveyor bunkers reduces itself on the horizontal dimensions of the tube (assumed is a full-capacity utilization of the plate conveyor surface). Independent from the biowaste input the emission relevant surface has a constant size of 32 m^2 (about 8 m x 4 m) which enables a prognosis for a steady odour freight.

Initial data:

- biowaste intake:	250 d/a
- exhaust air volume :	10.000 m^3/h
- hall volume :	1783 m^3
- air exchange:	5.6 h^{-1}

In order to assess the odour load, the determined odour emissions of biowaste of flat bunkers were available. Following from this specific emissions of 3.31 - 6.97 OU/(m^2*s) can be expected [MÜSKEN & BIDLINGMAIER, 1993].
Based on the high water content and the collection interval of 14 days, that is also maintained during the summer months, a strongly digested and also decomposed biowaste must be taken into account. A high odour emission of 6.0 OU/(m^2*s) seems to be justified.

Table 8.1: Odour loads of the intake area

Input quantity [Mg/a]	**Biowaste input [Mg/a]**	**Odour emission [OU/(m^2*s)]**	**Odour load [OU/s]**	**Odour concentration [OU/m^3]**	**Odour intensity [dB OD]**
12.500	8.750	6.0	195	70	18
20.000	14.000	6.0	195	70	18
25.000	17.500	6.0	195	70	18

It can be determined by the expected odour concentrations of 70 OU/m^3 (air exchange figure 5.6) that the exhaust air volume stream of 10.000 m^3/h was chosen very high regarding the reduction of the emission. According to MÜSKEN & BIDLINGMAIER (1993) a mean concentration of 156 OU/m^3 (range of deviation 46 - 350 OU/m^3) in the aerial region of plants processing mixed waste have been determined at a triple air exchange. SCHADE (1993) even determined a mean value of 300 - 400 OU/m^3 in plants with a twofold - triple air exchange and an input quantity of up to 25.000 Mg/a. Although this very low odorant concentration can be allocated positively on account of the reduction of the germ number, and the high air exchange rate probably excludes an escape of the odorant material through the open hall gates, the arising odour loads will be increased at the biofilter.

3.2.2 Emission assessment of the decomposition drum

Initial data:
- dwell time : 24 hours
- exhaust air volume : 6.000 m³/h
- run time/a : 8760 h
- drum load: 250 d/a
- drum volume: 221 m³
- air exchange: 27.1 h^{-1}

Strikingly high are the aeration rates with which the decomposition drum is operated. The calculation showed that with a material input during 5 days per week (intake of a constant daily delivery) and the resulting biowaste amount, the decomposition drum is operated with an aeration rate of 78 m^3 (12.500 Mg/a) air per m^3 compost and hour. With higher input quantities the aeration rate is reduced to 48.8 m^3/m^3*h) at 20.000 Mg/a and 39 $m^3/(m^3$*h) at 25.000 Mg/a.

If these values are compared with the data determined by MÜSKEN & BIDLING-MAIER (1993) and SCHADE (1993) (2.4 - 20 m³/(m³*h) and 3 - 15 m³/(m³*h)) and the data of similar plants it must be assumed that the high exhaust air volume at a throughput of 12.500 Mg/a is not justified on account of the oxygen supply. The operator stated that the aeration is not adjustable, this underlines the assumption that the aeration implement is exclusively designed for a maximum processing capacity of 25.000 Mg/a.

A further possible aspect is that the high air exchange rate of the decomposition drum was chosen by the plant designer in order to keep up the air climate in the pre-treatment and subsequent treatment hall. The decomposition drum which is installed together with other units for the input preparation and refining in the pre-treatment and subsequent treatment hall, takes the odour loaded hall air in, avoiding by this method a higher odorant concentration in the pre-treatment and subsequent treatment hall. However, it cannot be expected that this high air exchange leads to a reduction of the odorant concentrations in the exhaust air of the decomposition drum. Therefore are the dimensioning values, determined by MÜSKEN & BIDLINGMAIER (1993) and SCHADE (1993) of 10.000 - 35.000 OU/m^3 and 18.000 - 30.000 OU/m^3, directly used for the calculation of the odour load in the crude gas.

Table 8.2: Odour loads of the decomposition drum

Input quantity [Mg/a]	Assessed concentration [OU/m^3]	Odour intensity [dB OD]	Odour loads [OU/s]
12.500	18.000	43	30.000
20.000	22.000	44	36.670
25.000	25.000	44	41.670

3.2.3 Emission assessment of the input preparation and refining

Pretreatment and refining are processed in a hall of about 15.000 m^3 with forced aeration. Odour emissions arise in the hall through the treatment of the material which can be traced back to:

- the conveyor belts charged with the compost material,
- the screening drum,
- the rocking screening drum,
- the magnetic separator,
- the densimetric separator
- the container for extraneous matter and
- the green waste, which is partially stored in the pre-treatment hall.

In order to protect the operating staff from high odorant concentrations in the hall and to avoid the emission of odorant material from the open hall gates the hall air is changed with 10.000 m^3/h and furnished to the biofilter. From this amount are 6.000 m^3/h treated by the ventilator of the decomposition drum (air from the hall is supplied to the decomposition drum) and 4.000 m^3/h by means of a ventilation unit which manages both a selective suction of the screening drum and an air exchange in the hall. The allocation of the exhaust flows (hall or screening drum) is regulated by the ventilator with an efficiency of 4.000 m^3/h over a shutter which makes an exact assessment difficult. The following uses a joint determination of the odour load of screening drum and hall air.

According to MÜSKEN & BIDLINGMAIER (1993) odorant concentrations of below 200 OU/m^3 are also achieved in the hall with a lower air exchange rate (< 0.5). The air exchange in the pre-treatment and subsequent treatment hall of the example plant is calculated with 0,67 h^{-1}, so in the hall an assessed odorant concentration of 150 OU/m^3 is possible. On account of the selective suction of the screening drum a slightly higher concentration will be measured in the exhaust air flow (4.000 m^3/h) than in the hall. When the input quantity rises and the air exchange remains constant, an increase of the odorant concentration must be taken into account as the capacity of the conveyor belts increases together with the quantity of the structure material stored in the hall.

Therefore a value of 200 - 300 OU/m^3 is calculated for the odorant concentrations dependent on the input quantity. Odour loads are listed in table 8.3 which have to be calculated for the input preparation for all 3 plant sizes.

Table 8.3: Odour loads of the input preparation and refining

Input Quantity [Mg/a]	Assessed concentration [Mg/a]	Odour intensity [dB OD]	Odour loads [OU/s]
12.500	200	23	220
20.000	250	24	280
25.000	300	25	330

3.2.4 Emission assessment of the decomposition area 1

The main sources of odour emissions in composting plants are usually the windrows. An exact prognosis of odour emissions from windrows is especially important in order to react against a wrong assessment. It proves, however, that loads with passive area sources which are partially (suction aerated windrows) or totally (unaerated windrows) emitting over the surface can be assessed very badly on account of missing volume flows.

Initial data:

- Bulk density:	0.65 Mg/m^3
- Dwell time :	about 30 days
- Re-stacking :	monthly (planned every 2 weeks)
- Loss of decomposition :	23 weight per cent
- Type of windrow:	table windrow (h = 2.5 m)

A definition of the odour loads requires a determination of the emitting surface of the table windrow. Besides the number and dimension of the windrows the surface is especially dependent from the bulk density and the input quantity. It makes no sense to measure the windrows and the exact surface as the measurements and the number of the windrows change permanently. To simplify the matter a roughly calculated ratio of surface to volume of 0.8 is determined.

In order to increase the oxygen supply of the micro-organisms by the chimney effect borings with a diameter of 0.2 m are drilled in the upper windrow surface with an interval of one meter. According to the operating manager are the borings stable to a depth of one meter. This method of passive aeration was already successful in other composting plants and is urgently necessary for a sufficient oxygen supply depending on the windrow height and the actual re-stacking interval of 4 weeks.

The borings change the thermal conditions in the windrow decisively. While one part of the windrow is still supplied with air oxygen through the diffusion, the chimney effect in the other part, caused through the borings, can be compared with a forced aeration with an essentially higher air volume flow. In order to determine the odour load via the emitting surface without a simultaneous neglecting of the influence of the borings the following strongly reduced assumption is made at a windrow height of 2.5 m:

- Following from the assumption that per week an average quantity to be processed is piled to a table windrow and the 4 table windrows lead to a decomposition volume of 1.970 m^3 with an emitting surface of 1.576 m^2. The above mentioned number of table windrows has a portion of upper windrow surfaces including the borings of about 35 % of the total windrow surface (sides surfaces included).
- The windrow is completely supplied with oxygen from the air.
- Oxygen from air can penetrate the windrow until a depth of 70 cm through diffusion processes (i.e. 1 m^2 of upper windrow service supply 0.7 m^3 material with oxygen from air).
- The rest of the windrow body is aerated over the borings (i.e. 2.57 m^2 fictitious windrow surface supply 1.8 m^3 material with oxygen).

Table 8.4: Emitting surfaces of the windrows from decomposition area 1

In put quantity [Mg/a]	**Material volume at the start of decomposition** [m³]	**Material volume at the end of decomposition** [m³]	**Medium material volume** [m³]	**Medium windrow surface without borings 1)** [m²]	**Fictitious windrow surface with borings 2)** [m²]
12.500	1.420	1.180	1.300	1.040	1.980
20.000	2.260	1.900	2.080	1.660	3.150
25.000	2.830	2.370	2.600	2.080	3.950

1) Medium windrow surface without borings = 0,8*medium compost volume
2) Fictitious medium windrow surface with borings = 0,35*3,57m5/m5 * medium windrow surface without borings + 0,65*1.0 m5/m5 * medium windrow surface without borings

When the windrows are re-stacked a medium odour radiation of 2.0 OU(/m²*s) can be expected with table windrows 2 m high (30 - 0 d) after the decomposition drum (t = 2.5 d), (1,0 - 1.5 OU/(m²*s) are to be calculated for older windrows and 3.0 - 4.0 OU/(m²*s) for younger windrows [SCHADE, 1993]).

As an exception HOMANS (1993) found for young windrows values of up to 22.2 OU/(m²*s). MÜSKEN & BIDLINGMAIER (1993), however, measured odour emissions of 11 OU/(m²*s) with unaerated triangle windrows (pure windrow composting) when they were re-stacked after the first decomposition week and 2.56 OU/(m²*s) after the third week. The same authors determined mean values of 4.12 OU/(m²*s) for fresh piled table windrows after input preparation. A quantifying of the odour radiation for fresh piled table windrows after the decomposition drum could not be realized, however, it was assumed that the expected values are lying distinctly above the aforementioned.

A differentiation between the piling of windrows and re-stacking of windrows has not been made. A simplified linear decrease of the odour radiation (8.0 OU/(m²*s) after the windrow is piled onto the decomposition area 1 is the basis for the calculation of the odour load of windrows and 2.0 OU/(m²*s) after 30 days. The relatively high determined mean value of 5.0 OU/(m²*s) seemed to be sensible, as the operation of the decomposition was not quite optimal.

The windrows on decomposition area 1 are turned only twice during the monthly re-stacking. At first after the decomposition drum and second on transferring to the decomposition area 2. Hereby approximately one daily production is piled to a table windrow and another is transported to the decomposition area 2. Thus 10 % of the mean material volume and the belonging surface are moved per working day.

Table 8.5: Odour loads at the re-stacking of unaerated windrows of the decomposition area 1

Input quantity [Mg/a]	Agitated windrow surface [m^2]	Mean specific odour emission [$OU/(m^2*s)$]	Odour loads [OU/s]
12.500	104	5.0	520
20.000	166	5.0	830
25.000	208	5.0	1.040

SCHADE (1993) quotes values of 0.3 to 1.5 $OU/(m^2*s)$ with a mean value of 0.9 $OU/(m^2*s)$, while HOMANS (1993) determined odour emissions of 0.3 - 1 $OU/(m^2*s)$ (30 - 0 d).
The mean value of 1.0 $OU/(m^2*s)$, determined here, has been chosen on account of the following reasons:

- Odour intensive material from anaerobic degradation cannot arise in such a high volume on account of the increased air supply caused by the borings.
- The increased air volume flow is taken into account over the fictitious windrow surface.
- The low re-stacking interval retards the decomposition process.

Table 8.6: Odour loads from static and unaerated windrows of decomposition area 1

Input quantity [Mg/a]	Fictitious static windrow surface [m^2]	Specific odour radiation [$OU/(m^2*s)$]	Odour loads [OU/s]
12.500	1.980	1.0	1.980
20.000	3.150	1.0	3.150
25.000	3.950	1.0	3.950

The total odour load follows from the sum of the odour loads for agitated and static windrows and is shown in table 8.7.

Table 8.7: Total odour loads of the decomposition area 1

Input quantity [Mg/a]	Odour loads from agitated windrows [OU/s]	Odour loads from static windrows [OU/s]	Odour loads total [OU/s]
12.500	520	1.980	2.500
20.000	830	3.150	3.980
25.000	1.040	3.950	4.990

3.2.5 Emission assessment of the decomposition area 2

Initial data:
- Bulk density: 0.60 Mg/m³
- Dwell time: approximately 90 days
- Re-stacking: monthly (planned every two weeks)
- Loss during decomposition: 38 weight per cent of the material
- Type of windrow: table windrow (h = 2.5 m)

The determination of the emission relevant surface is carried out according to the calculation in 3.2.4

Twelve table windrows with a mean decomposition volume of 5.020 m^3 amount to an emission relevant surface of 4.016m^2. The windrow surfaces of the decomposition area 2 are also bored so that here, too, an increase of the emission relevant surface has to be calculated. The portion of the upper windrow surface with borings is only 25 % of the total windrow surface (including side surfaces) with the higher number of windrows and smaller dimensions. The emission relevant surfaces are shown in table 8.8.

Table 8.8: Emission relevant surfaces of the windrows of decomposition area 2

Input [Mg/a]	Compost volume start of decompo-sition [m³]	Compost volume decom-position finish [m³]	Mean compost volume [m³]	Mean windrow surface without borings [m²] [3])	Fictitious mean wind-row surface with borings [m²] [4])
12.500	3.850	3.100	3.480	2.780	4.570
20.000	6.160	4.960	5.560	4.450	7.310
25.000	7.700	6.200	6.950	5.560	9.130

[3]) Mean windrow surface without borings = 0.8*mean compost volume
[4]) Fictitious mean windrow surface with borings = 0,25*3.57m²/m² * Mean windrow surface without borings + 0.75*1.0 m²/m² * Mean windrow surface without borings.

The odour emission from 2 m high agitated table windrows (after decomposition drum and main decomposition on table windrows) is according to SCHADE (1993) about 0.5 - 1.0 OU/(m²*s). However, MÜSKEN & BIDLINGMAIER (1993) still determined values of 0.8 OU/(m²*s) with unaerated triangular windrows (pure windrow composting) after decomposition degree III was reached.

To simplify matters a linear decrease of the odour radiation with a mean value of 1.4 OU/(m²*s) is assumed here, too. An odour radiation of 2.0 OU/(m²*s) is calculated at the beginning, with a reduction on 0.8 OU/(m²*s) after a dwell time of another 90 days.

A monthly re-stacking frequency and 12 weeks of dwell time lead to one piling operation (already considered in decomposition area 1) with a maximum of two re-stacking processes and the transport to the refining area. An agitated material volume of 5 % has to be considered if per work day an average of three daily processing quantities are re-stacked. The odour loads arising during re-stacking are shown in table 8.9.

Table 8.9: Odour loads at re-stacking of unaerated windrows of decomposition area 2

Input quantity **[Mg/a]**	**Agitated windrow surface** **[m²]**	**Specific odour emissions** **[OU/m² *s]**	**Odour loads** **[OU/s]**
12.500	139	1.4	190
20.000	223	1.4	310
25.000	278	1.4	390

Specific odour radiations of 0.02 - 0.1 OU/(m²*s) are to be expected for static windrows [SCHADE, 1993]. HOMANS (1993), however, determined values of 0.081 OU/(m²*s) with windrows 60 days old and 0.3 OU/(m²*s) with windrows up to 30 days old, independent from windrow type and pre-decomposition unit. A specific odour radiation of 0.15 OU/(m²*s) was chosen in the example (see table 8.10).

Table 8.10: Odour loads from static and unaerated windrows of decomposition area 2

Input quantity **[Mg/a]**	**Fictitious static windrow surface** **[m²]**	**Specific odour radiation** **[OU/m² *s]**	**Odour loads** **[OU/s]**
12.500	4.570	0.15	690
20.000	7.310	0.15	1.100
25.000	9.130	0.15	1.370

The total odour load is the result of the sum of the odour loads for agitated and static windrows and is shown in table 8.11.

Table 8.11: Total odour loads of the decomposition area 2

Input quantity [Mg/a]	Odour load of static windrows [OU/s]	Odour load of agitated windrows [OU/s]	Odour loads total [OU/s]
12.500	690	190	880
20.000	1.100	310	1.410
25.000	1.370	390	1.760

3.2.6 Assessment of the emission from compost storage

Initial data:
- Bulk density : 0.65 Mg/m^3
- Dwell time : 16 weeks
- Loss during decomposition : 50 weight per cent of the material
- Type of storage: table windrows (h = 3.5 m)

In order to cope with the seasonal variations of the compost sales the produced compost can be stored in an interim storage. A utilization rate of the storage capacity is reached, above all during the winter months, whereas in the summer months essentially shorter storage periods can be expected.
Average specific loads of 0.07 $OU/(m^3*s)$ at 10 weeks old static windrows were determined, whereas agitated storage windrows show values from 0.23 $OU/(m^3*s)$ to maximum of 1.0 $OU/(m^3*s)$ [MÜSKEN & BIDLINGMAIER, 1993].

KUCHTA et al. (1994) calculates a value of 0.01 OU/s per Mg input material for the determination of odour loads of the matured compost.

Measurements in the composting plant proved that temperatures of up to 60 centigrade are possible in fresh stored windrows, which demonstrates a not sufficiently decomposed material. A forced stabilization of the compost can be considered, however, at a storage time of 16 weeks, which can be explained by the water evaporation of the windrows. This results in a decrease of odour loads with an increasing storage time and it seems to be correct to assume an average specific freight of 0.07 $OU/(m^3*s)$ for static storage windrows with a value of 0.4 $OU/(m^3*s)$ for agitated windrows (daily output). (Table 8.12 and 8.13).

Table 8.12: Odour loads from agitated storage windrows at a daily output

Input quantity [Mg/a]	Agitated storage volume [OU/m^3]	Specific odour loads [$OU/m^2 * s$]	Odour loads [OU/s]
12.500	38	0.4	15
20.000	62	0.4	25
25.000	77	0.4	31

Table 8.13: Odour loads at static windrows

Input quantity [Mg/a]	Static storage volume [OU/m³]	Specific odour loads [OU/m² * s]	Odour loads [OU/s]
12.500	3.080	0.07	215
20.000	4.920	0.07	350
25.000	6.150	0.07	430

The total odour load is the result of the sum of the odour loads for agitated and static windrows and is shown in table 8.14.

Table 8.14: Total odour loads of the compost storage

Input quantity [Mg/a]	Odour loads of agitated windrows [OU/s]	Odour loads of static windrows [OU/s]	Odour loads total [OU/s]
12.500	15	215	230
20.000	25	350	380
25.000	31	430	460

3.2.7 Assessments of emissions from the biofilter

The purification efficiency of a biofilter depends on several conditions. Besides the construction (single and multiple-stage filter systems, with or without bioscrubber), the filter maintenance (humidity content, pore volume, volatile solids), the filter material, the material mix to be purified, the contact time and the specific filter load must be named as the most important factors for the efficiency of a biofilter. Figure 8.3 shows the determination of the efficiency rate for a two-step, closed filter system for the intensive decomposition stage of a biowaste composting plant [KUCHTA & RYSER, 1993].

Evident hereby is, that even at a nearly identical filter input (2 and 3), related on the odorant concentration, a constant efficiency rate cannot be proceeded. While the first and second measuring runs up to filter efficiency rates of about 87 %, the third measurement drops to round 79 %.

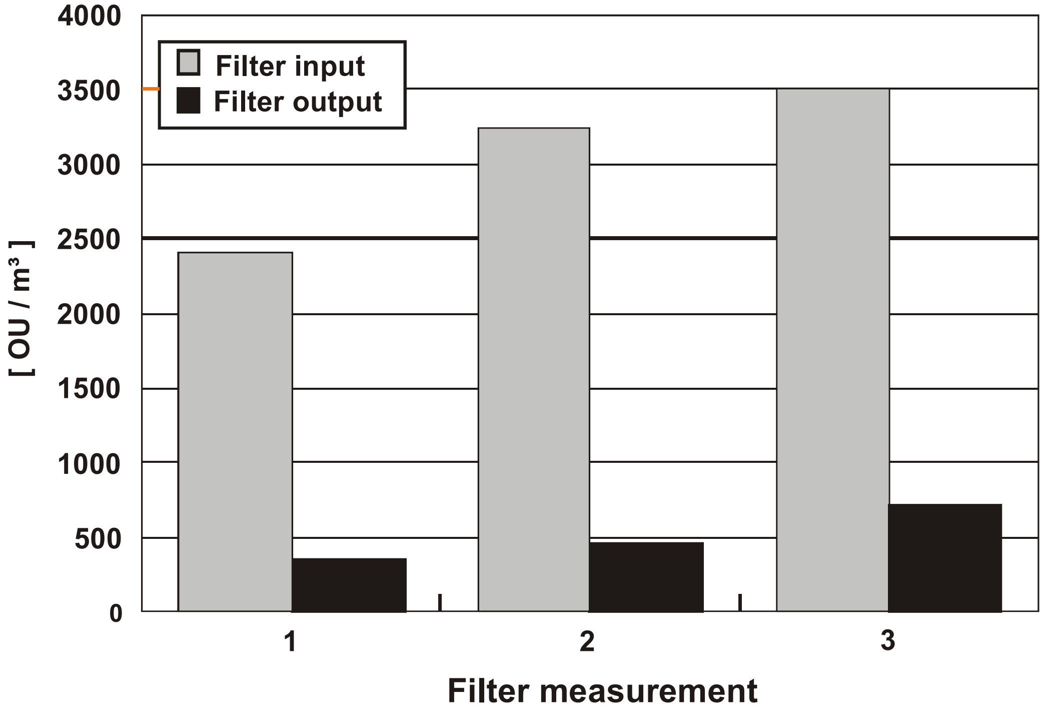

Figure 8.3: Determination of the filter efficiency rate through olfactometric measurements [KUCHTA & RYSER, 1993], changed

Yet two marginal conditions can be formulated enabling a limitation of the expected odour loads.

1. The result of the purification of a biofilter, related to odour, is limited by the inherent odour of the filter material. On the whole, the inherent odour is depending on the used filter dumping material and on the filter condition and is in the range of 100 OU/m^3 [KUCHTA & RYSER, 1993].

2. As a rule a filter efficiency rate of more than 80 % can be expected. [KUCHTA & RYSER, 1993].

Various possibilities for a determination of odour loads for the biofilter are recommended in the literature applied:

- The filter efficiency rate of the biofilter is determined or assessed by means of olfactometric measurements and summoned for the determination of odour loads. The initial value for the calculation is the odorant concentration of the exhaust air mixture before the biofilter. SCHADE (1993) assumes a filter efficiency rate of 95 %.

- When planning a composting plant, JAGER & KUCHTA (1992) assume that the odour emissions of the biofilter or compost filter are composed of its inherent odour (0.2 OU/(m^2*s)) and an efficiency rate of 95 % which is nominated as being realistic.

- MÜSKEN & BIDLINGMAIER (1993) on the contrary, expect exhaust air concentrations of 150 OU/m³ and 250 OU/m³ [BIDLINGMAIER & MÜSKEN, 1994] with biofilters (biofilter according to the state of the art, probably with pre-connected bioscrubbers) as being realistic.

For the calculation of the odour load a minimum odorant concentration of 100 OU/m³ and a maximum efficiency rate of 98 % is the basis. Hereby the minimum odorant concentration should be relevant as long as the maximum efficiency rate is not surpassed (table 8.15).

Table 8.15: Determination of the relevant clean gas concentration after the biofilter

Input quantity [Mg/a]	**Mixed concentration in the crude gas [OU/m³]**	**Mixed concentration in the clean gas 98 % efficiency rate [OU/m³]**	**Minimum odorant concentration in clean gas [OU/m³]**	**Decisive odorant concentration in the clean gas [OU/m³]**
12.500	5.475	110	100	110
20.000	6.685	134	100	134
25.000	7.595	152	100	152

Based on the relevant odorant concentrations in the clean gas and the exhaust air flows of the individual locations/units the odour loads of the biofilter in table 8.16 are as follows:

Table 8.16: Odour loads of the biofilter

Input quantity [Mg/a]	**Intake area /bunker (10.000 m³/h) [OU/s]**	**Decomposition drum (6.000 m³/h) [OU/s]**	**Input preparation/refining/ screening drum [OU/s]**	**Odour loads after biofilter [OU/s]**
12.500	5.475	110	100	110
20.000	6.685	134	100	134
25.000	7.595	152	100	152

3.2.8 Emission assessment of diffuse sources

Odour emitting components of a composting plant are summarized under the name "diffuse sources" which cannot be avoided on the whole or only to a limited extent and cannot be allocated to a special plant part. These are above all soiling of the site by traffic, surface water and delivery traffic, insufficiently maintained biofilter, compost shipping, open residual waste containers and emissions from open hall gates. According to JAGER & KUCHTA (1992) in most cases an additional charge of up to 10 % is assumed on the total load of odorant substances after the biofilter.

The operation with wheel loaders on the plant is restricted to the decomposition area, as the transport of the material, except the structure material, is exclusively realized by means of conveyor belts. The through roads and the entry roads have been very clean which can be attributed to a regular cleaning and a separation between the intake area and the specific composting area, which justifies only a minimum additional load. The emissions from the diffuse sources of the green waste, stored outside the hall, should be considered, too, the quantity of which rises with an increasing input. Instead of the percentage of the additional charge for diffuse sources of the example plant, the odour load was allocated with 50 OU/s at 12.500 Mg/a, 100 OU/s at 20.000 Mg/a and 150 OU/s at 25.000 Mg/a.

3.3 Summary of the odour loads of the actual situation

The windrow surfaces, ascertained as the main emitting sources, can be seen in table 8.17 as the actual emission situation. By far the highest portion of nearly 60 % of the odour loads is emitted from decomposition area 1. Following from this an enormous potential for a lowering of the odour loads is exactly here in order to improve the emission situation. Decomposition area 2 has a portion of about 20 % of the odour loads of the total emissions. The plant parts connected with the biofilter have an emission of about 14 % of the total odour load. The loads from compost storage and diffuse sources with a total of 6.6 % are scarcely relevant on account of the high emissions on decomposition area 1.

Table 8.17: Odour loads of the actual situation

Location/ Unit	Odour loads [OU/s]					
	Input quantity (12.500 Mg/a)	Emis-sions portion [%]	Input quantity (20.000 Mg/a)	Emis-sions portion [%]	Input quantity (25.000 Mg/a)	Emis-sions por-tion [%]
Delivery area / bun-ker	310	7.3	370	5.6	420	5.1
Decompo-sition drum (t = 1d)	180	4.2	220	3.3	250	3.0
Input prepa-ration / Screening drum /refining	120	2.8	150	2.3	170	2.1
Decompo-sition area 1 (t = 4 weeks)	2.500	58.5	3.980	60.2	4.990	60.9
Decompo-sition area 2 (t = 12 weeks)	880	20.6	1.410	21.3	1.760	21.5
Compost storage (t = 16 weeks)	230	5.4	380	5.7	460	5.6
Diffuse sources	50	1.2	100	1.5	150	1.8
Sum	4.270	100	6.610	100	8.200	100

4 Study of the odour imission at the example plant

4.1 Odour pre-load at the location of the composting plant

Figure 8.4 shows once more the distribution of emissions at the different plant units.

It could not be taken from the available data whether during the last four years a field measurement with panels was carried out for the determination of a pre-load on the site. Former measurements are not admissible for an immission prognosis according to GIRL, para 4.4.1 and TA Luft, para 2.6.2.1 and thus cannot be used.

A possible odour pre-load shall be assessed by means of available maps. The following larger emissions could be determined for 3 kilometres round:

- Smaller factories in a distance of about 1.3 kilometre west of the composting plant site.
- A larger industrial area in a valley 1.5 kilometre north of the composting plant site.
- About 2 kilometres south of the site of the composting plant a small sewage plant.
- In the north-east, at a distance of about 2.5 km, a landfill and a big metal work.

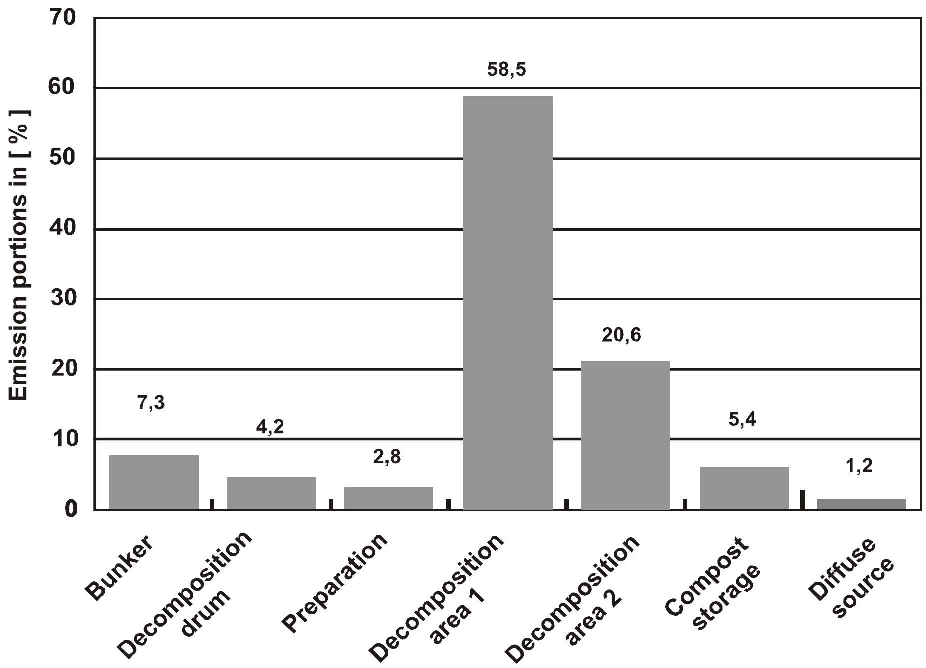

Figure 8.4: Emissions of locations/unit parts at 12.500 Mg/a (actual situation)

The south-western wind directions prevailing in Central Europe and the large distances of the individual emissions to the plant location probably excludes an odour pre-load. Possible smaller odour emissions from stock keeping in cow sheds, open liquid manure containers or others can also be excluded as here an intensive cattle breeding is not carried out.
The conclusion of the above mentioned reasons is that on site and in the nearer surroundings no odour pre-load will be expected. The total load IG results only from the immission of the composting plant (additional load IZ).

4.2 Determination of the additional load of immissions (actual situation)

According to TA Luft, para 2.6.1.1 the additional load to be determined by dispersion calculation is defined as the immission contribution which is initiated by a project for which an application was made. Following the given standards of the Odour Immission Guideline (GIR), analogous to the VDI guidelines 3782, sheet 4, the dispersion calculation has to be made on the basis of a counting threshold of 1 OU/m^3 (see also chapter 3.2.3).
As the total load IG only results from the additional load IZ of the composting plant, the presentation and assessment of the actual immission situation can be proceeded immediately.

4.3 Assessment of the immission situation (actual situation)

The assessment of the immission situation is realized according to the standards of the Odour Immission Guideline and according to those of the circular order for the implementation of the regulations of the Technical Guideline TA Luft (Air). By this measure both, the operating manager and the approval authorities shall have the possibility to assess the odour immission by means of the two legal basis presently valid.

If a technical assessment is required, a deviation from the dimensions of the panneling areas (border length 250 m) can be made according to GIR. On account of the short distance to the next neighbouring residential buildings panneling areas with a border length of 150 m have been chosen for the present case. Thus 9 measuring points were made on each area at an interval of 75 m.

A screen, (mesh size 75 m) congruent with the assessment surface of the GIR, was laid over the assessment area for the corresponding presentation of the ISO line of the circular order for the execution according to TA Luft. Each assessment area of the GIR consists of 4 grid areas of the circular order, also with 9 measuring points. Dependent on the smaller grid all measuring points of the GIR and the circular order are lying directly upon another thus simplifying the comparison.

The estimated centre of gravity of the emissions (R: 259535 , H: 56840) is lying in the centre of the internal assessment area.

As the parameter IZ follows from the averaging of the nine grid intersections, the choice of the dimensions influences directly the amount of the additional load at the GIR. In order to illustrate the effects of the different sizes of the assessment areas on the immission frequency of the actual situation, a prognosis of the odour immission for both of the here selected assessment areas (150*150 m) and 250 m border length was made.

For the moment the presentation and assessment of the immission situation is just made for an annual input quantity of 12.500 Mg (figures 8.5 and 8.6). The prognosis for the input quantities of 20.000 Mg/a and 25.000 Mg/a can be taken from annex B.

Figure 8.5 shows distinctly the exceeding frequency in per cent of the actual situation (12.500 Mg/a) of the annual hours with reference to 3 OU/m^3. The 4 % Iso-line proves that the areas north-north-east and south-south-west from the plant location are increasingly bothered by high odorant concentrations. The presumed wind situation leads to an upper deviation of the immission concentration of 3 OU/m^3 stipulated by the regional administration in approximately 7 - 8 % of the annual hours.

When using the dispersion category statistic exceeding stipulated immission concentrations of about 6 - 7 % of annual hours have to be calculated.

The obligations of the public works planning procedure ("the odour annoyances are not relevant if in less than 4 % of the annual hours 3 odour units (OU/m^3) arise at the next-neighbouring residential houses) cannot be kept in both cases so that the composting plant with the present decomposition technology and the belonging odour loads cannot be approved.

However, limit cases could be observed in the later following prognosis for immission of the scenario, when using the two different dispersion category statistics. The plant would have been approved in these cases by using the modified weather data, whereas the utilization of the unmodified weather data was leading to an exceeding of the immission frequency. Regarding an exact assessment of the local immission effects the operator should undertake own measurements of the meteorological data at the plant location in order to react to inaccuracy at the transfer of dispersion category statistics.

Exceeding frequency in % in relation to 3 OU/m³ - scale 1:7000

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

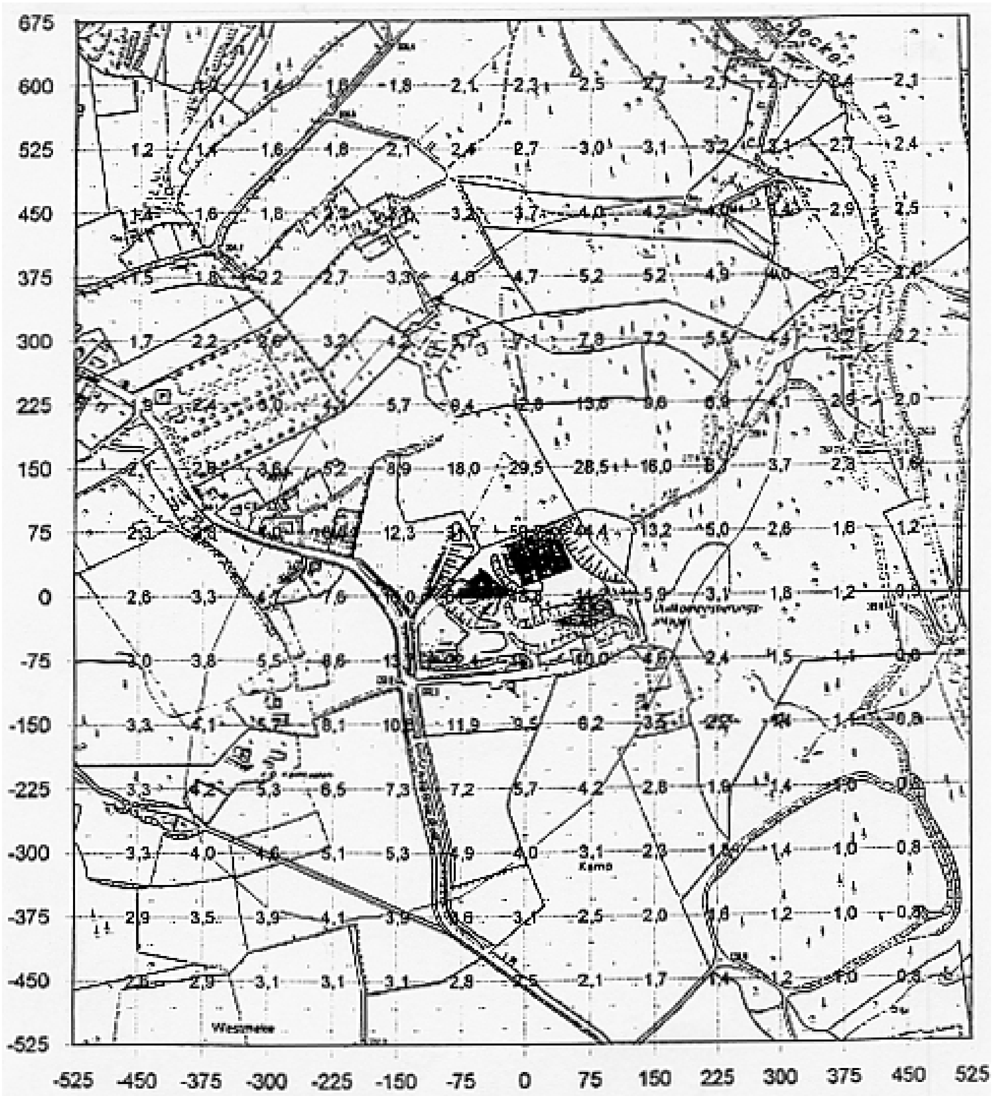

Figure 8.5: Immission prognosis of the actual situation (12.500 Mg/a), dispersion category statistics [SCHLOSSER, 1995]

The following two figures show an immission prognosis of the actual situation (12.500 Mg/a) for the composting plant according to the Odour Immission Guideline. The figures show the exceeding frequency in per cent of the annual hours regarding 1 OU/m^3, dependent on the chosen size of the assessment areas.
Hereby assessment areas with border lengths of 250 m (see GIR = odour immission regulation, para 4.4.3) and 150 m were compared. Odour frequencies between 13.6 and 26.5 % of the annual hours (1191 to 2321 h/a) were ascertained for the next neighbouring residential house.

The reasons for those enormous differences are obviously the result of the various intervals of the grid intersecting points to the emission sources of the composting plant, the location of the residential buildings within an assessment area (at the border, in the centre or in a corner) and a nonuniform distribution of the immission. The selection of smaller assessment areas in areas with a nonuniform distribution of the immission concentration could result in an overestimation of the immission frequency. The immission frequencies of the grid intersecting points of the assessment area with a border length of 150 m situated in the west and north of the composting plant are tested as an example. Figure 8.6 is the basis.

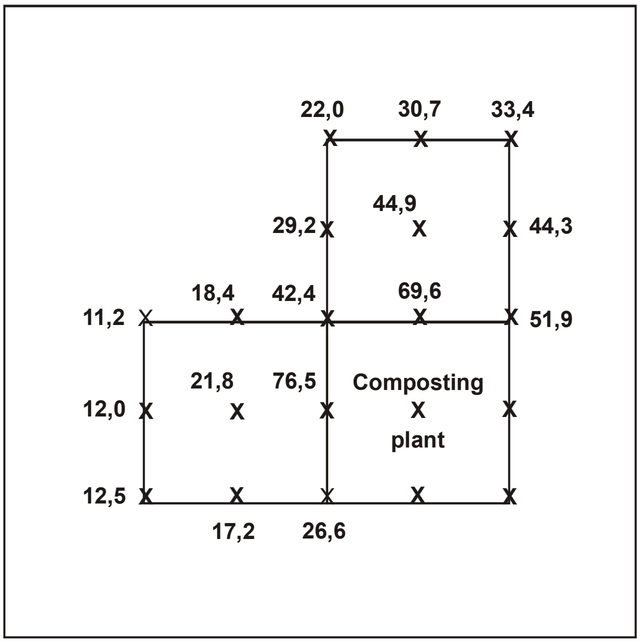

Figure 8.6: Exceeding frequency in % of the annual hours of the nine grid intersecting points of the single assessment area (150 x 150m) [SCHLOSSER, 1995]

Exceeding frequency in % in relation to 1 OU/m³ scale 1:7000

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

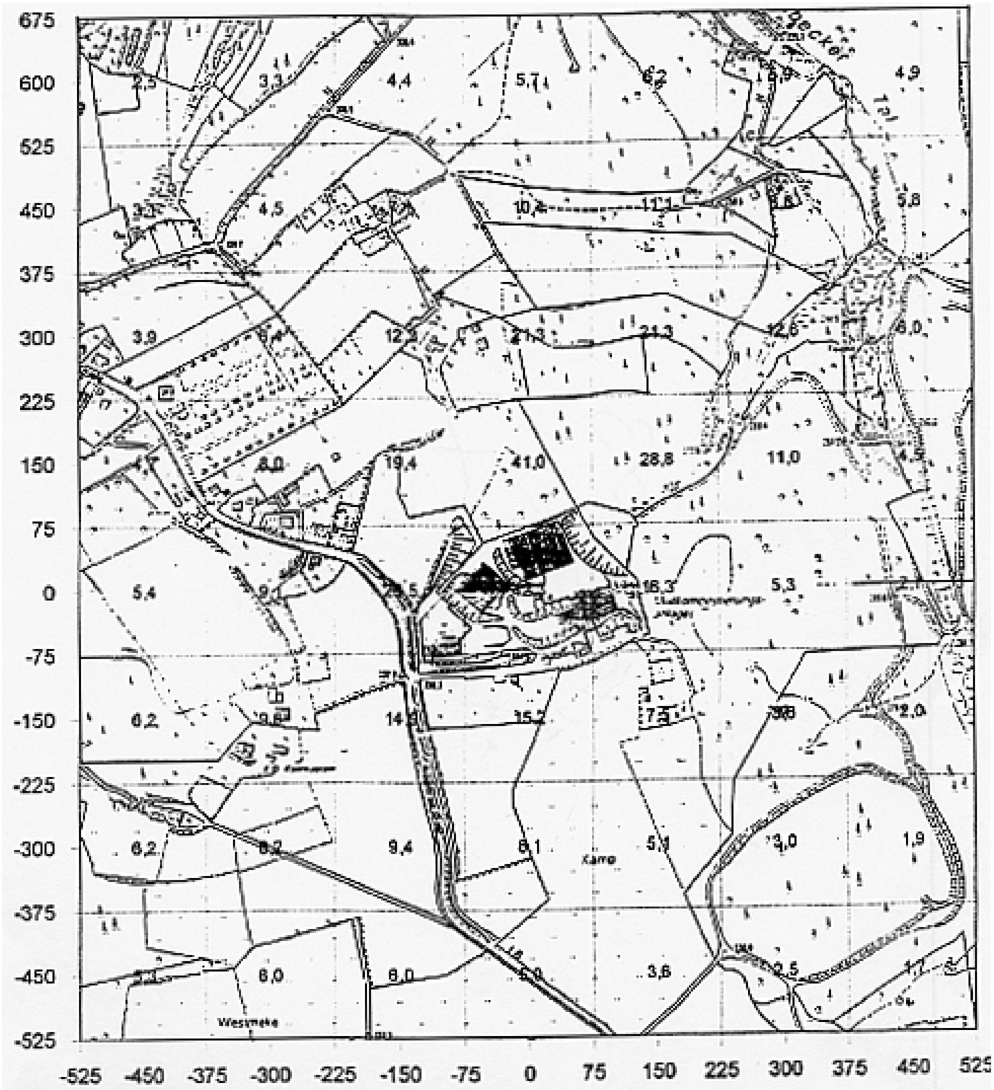

Figure 8.7: Immission prognosis of the actual situation (12.500 Mg/a) with assessment areas 150 x 150 m according to GIR [SCHLOSSER, 1995]

Exceeding frequency in % in relation to 1 OU/m³ scale 1:7000

The numbers in the map describe the area values within the assessment area according to GIR (here 250 m border length).

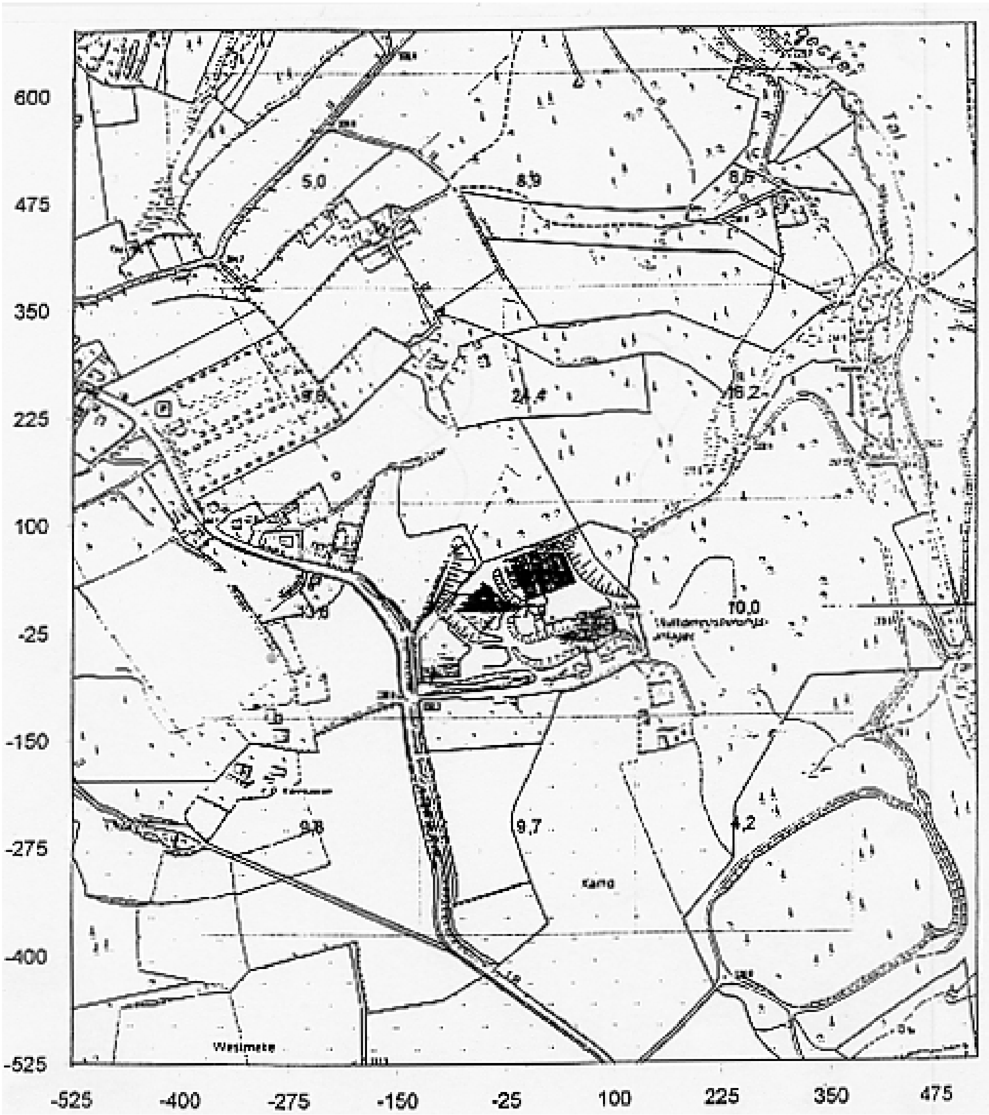

Figure 8.8: Immission prognosis of the actual situation (12.500 Mg/a) with assessment areas 250 x 250 m according to GIR [SCHLOSSER, 1995]

Regarding the corner location of a residential building at the western assessment area, an overestimation of the exceeding frequency (26.5 %) caused by the mean value formation of individual and very different values is the result, whereas this is not to be expected in the northern assessment area because of the more homogenous distribution (41.0 %). Assessment areas with a border length of 250 m, on the other hand, show a distinct excess of small values that may result in an underestimation of the immission frequency.

It is obvious that the choice of a wrong size of the assessment area can lead to a considerable false estimation of the immission prognosis, when the assessment is made according to the Odour Immission Guideline (GIR). Therefore only the approval authorities should select the assessment area.

When the immission situation is assessed on the basis of the GIR the following prognosis uses the total odour load parameter IG of the assessment area situated in the north-west of the composting plant (border length 150 m). Though this assessment area includes only a very small area of the buildings at the north-eastern border of the residential area, it describes the direct vicinity of individual houses and the frequency of the odour perception in approximately 19 % of the annual hours with a sufficient exactness. A comparison with the immission values of the GIR shows that the odour immission in the residential buildings (0.19, 0.21) must be looked upon as being harmful and the composting plant, already at an annual input quantity of 12.500 Mg, following the Odour Immission Guideline, cannot be approved. The operator must undertake further measures to reduce the emissions.

5 Summary of the actual situation

After the acceptors in a selected area of immission impacts around the plant location have been described more closely and the processing method of the composting plant was explained, approximately 60 % of the total load could be determined as main cause for the high odour loads in the following emission prognosis of decomposition area 1.

Responsible is the amount of solid structure material which is too small, the monthly re-stacking interval (only once a month) and a windrow height of 2.5 m. In order to guarantee the oxygen supply for the micro-organisms despite of the unfavourable conditions for decomposition, borings are brought into the windrows which on the other hand rise the odour loads by the multiplying factor 1.9. Furthermore the too short re-stacking intervals avoid a regular progress of degradation of the compost raw material and a further slashing of the compost components, so even in later phases of degradation increased odour loads can be expected. The formation of humid and dry zones in the windrow body is favoured through the long re-stacking intervals and offers no optimal conditions for an optimized microbiological activity.

A surface filter with a size of 200 m^2 purifies the partly over-dimensioned exhaust air flows in the reception hall (air exchange 5.6 h^{-1}), of the decomposition drum (air exchange 27.1 h^{-1}) and in the hall for pre- and subsequent treatment, which leads here also to outstanding high odour emissions. The accumulation of the loads of all individual sources in the actual situation resulted to an amount of 4.300 to 8.200 OU/s (table 8.17 in chapter VIII/3.3) of odour loads dependent on the input quantity.

After the emission assessment the surface sources have been divided up in an appropriate number of point sources and related their location to an evaluated emission gravity centre.

The next step was to evaluate the odour pre-load in the assessment area by describing existing emissions (in this case an odour pre-load does not exist) and to determine the additional immission load by dispersion calculation according to both, the prior demands of the approval authorities (requirement) and those of the new odour immission guidelines. In order to assess possible effects on the immission situation the corresponding prognosises for the immission have been compared with each other. Both cases showed distinct deviations of the immission values which reveal possible falsification of the results and eventual manipulations at the assessment basics. For a final assessment of the immission frequency the dispersion calculation statistic of the assessment areas was used with a border length of 150 m for the assessment following the Odour Immission Guidelines.

When using both assessment basics (approval requirement and GIR) it was detected that the required exceeding frequency of the odour immission concentrations (3 OU/m^3 and 1 OU/m^3) are exceeded by nearly twice as much and following from this the composting plant cannot be approved on account of the arising odour immission.

6 Proposals for a reduction of the emission at the example plant

A reduction of the odour emissions can be achieved with different methods. The potentials of the measures for an odour decrease are just as varying as the necessary investments and do not run proportionate to each other. The fact that the human nose collects the odour in a logarithmic scale according to its strength shall be pointed out here once more. This should mean for the planning person and the legal authorities that not the expensive emission reducing measures should be most important but the distance between residential buildings and emissions.

Whether an immission reduction is possible with other means than encapsulation of the decomposition area 1, which additionally can be realised by a balanced expenditure/yield ratio, shall be investigated in the following two example scenarios. A reduction of the exhaust air flows in the intake area and in the decomposition drum shall be abandoned in the following investigations as this is impossible, according to the plant manager, on account of the not controllable exhaust air units.

6.1 Scenario I

Proposed measures:

- Increase of the structure material
- Re-stacking interval related to odour emission

The most simple possibility of an emission reduction can be realized by the use of a decomposition control corresponding to odours, which is especially related to the portion of structure material and the re-stacking interval, according to the research work of FRICKE et al. (1989).

Re-stacking frequency

Increased re-stacking of the windrows leads to an improved air exchange and a higher air pore volume in the windrow body and thus contributes to an optimization and an acceleration of the decomposition process. A positive effect on the degradation process has the mixing of materials from humid zones of the windrow, like the windrow roof (condensation zone) and the windrow bottom with the dry materials of the core of the windrow and the windrow border.

This assures a steady moistening of the total windrow material with a water content that is optimal for the micro-organisms and new substratum surfaces are continuously available for degradation. The formation of odour intensive compaction areas can be avoided, at least to a certain extent. FRICKE et al. (1989) proposes a 2 weeks' re-stacking interval during the first 6 weeks which can then be prolonged to a 3 weeks' interval. A special concern should be given to the first re-stacking term which should not be realized before the first two weeks of the windrow decomposition. While the self-odour of the material was prevailing at an earlier re-stacking term of decomposition, the typical rotting odours have been perceived after a 3 weeks' re-stacking.

KEHRES & VOGTMANN (1989) found that between the re-stacking frequency and the achievable decomposition degree an interrelationship exists which is often underestimated. Following their researches a satisfactory oxygen offer is not sufficient for a decomposition degree that can be accepted after an appointed time of decomposition. The capability for a self-heating of two composts is shown in figure 8.9. Hereby biowaste compost 1 comes from an unaerated windrow composting where the material was re-stacked four times during a decomposition period of 14 weeks and reached decomposition degree V. Biowaste compost 2 is the compost from a windrow composting with forced aeration which has been re-stacked only once after a decomposition time of 16 weeks and which reached decomposition degree II.
The authors substantiate their results with the re-stacking process which strongly supports the material processing and the mixing of the material and thus a high portion of internal surface is available for the micro-organisms, enabling an increase of the intensity of decomposition.

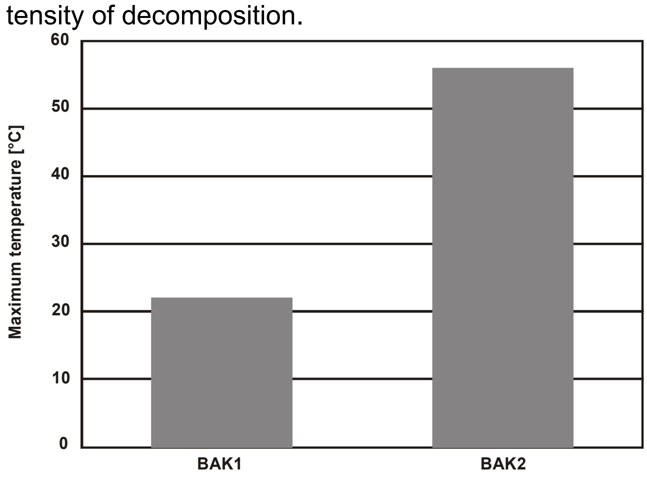

Figure 8.9: Self-heating capability and decomposition degree of composts from different plants [KEHRES & VOGTMANN, 1989]

Volume of structure material

An essential pre-condition for a necessary oxygen supply of the decomposition material is the structure of the raw material of the compost. The portion of solid structure material is directly connected with the amount of the tolerable water content and the airpore volume in the compost resulting from it. If the compostable biowaste does not have sufficient structure material, a lack of oxygen increasingly induces the formation of anaerobic areas in the windrow. This concerns the windrow bottom, as here the material is compressed by the high pressure of the upper compost layers and opposes extremely the air exchange.

As a rule, the portion of the structure material in the biowaste together with the water content and the bulk density are subject to seasonal fluctuations, especially in the summer and winter time where the values are by far below normal. Therefore the storage of structure material in spring and autumn makes sense or the addition of external structure material or supplementary material.

FRICKE et al. (1989) found in their research work that the odour emissions were distinctly reduced by the additional mixing with wood chippings and thus the decomposition process improved considerably. The lower bulk density and the improved structure lead to an optimization of the airpore volume avoiding the formation of anaerobic areas to a great extent and thus could effectively encounter the danger of odorant concentrations. The efficiency related to the outlet of leachate and odour emissions was considerably improved through the utilization of biogenous pre-decomposed wooden chippings, making windrow heights of 2.2 m acceptable with the added amount of wood chippings of 30 %.

6.1.1 Proposals for the improvement of the emission situation of the plant

The proposals made here are based on the perceptions described in chapter VIII/6.1 and essentially enclose alterations which require an optimization of the compost raw material and an intervention in the decomposition process control.

a) Increase of the re-stacking processes:
A 2 weeks' interval should be realized in the first 6 weeks of the windrow decomposition. After this period a 3 weeks' re-stacking interval is sufficient.

b) Increase of the solid structure material on > 30 weight per cent:
The amount of 20 % of added green wastes as solid structure material and the 10 % added paper as a water-binding additive are presumably too inferior as the high bulk densities show. This measure is especially sensible with regard to the windrow heights of 2.5 m, as here especial high pressures must be considered through the load. Regarding the larger input quantities a reduction of the windrow height is not possible, as the windrow areas have been dimensioned too small for the latest decomposition technology.

If structure material is not sufficiently available over the year, the fraction 20 - 80 mm can offer a relatively high potential of structure material with very favourable properties. These are above all the ideal grain size distribution, the here assumed relatively small water content of about 30 - 40 % and a solid biogenous and partly decomposed material. A negative aspect is the high portion of impurities in this fraction.

Critical is the high portion of plastic foils which is overwhelmingly often found in this fraction and without a separation possibility leads to a lasting deterioration of the product. In order to avoid this disadvantage it is advisable to use an air classifier in the refining step which can separate the existing hard material and foils from the structure material. One can estimate that an amount of 70 % of all impurities are in the fraction 20 - 80 mm of which, approximately 8 weight per cent of structure material could be recovered.

6.1.2 Emission assessment of the individual plant units

The odour loads of the delivery area, the decomposition drum, the input preparation, the refining and the compost storage remain unaltered, as the odour reduction fundamentally relates to the windrow decomposition. Though a reduction of the bulk density has to be taken into account, these cannot be included into the calculation. A possible change of the mass balance cannot be predicted because it is dependent on the used structure material and the changed decomposition behaviour through the frequent re-stacking process.

Decomposition area 1

Initial data:

- bulk density : 0.65 Mg/m³
- dwell time : approximately 30 days
- re-stacking : every 2 weeks
- loss of decomposition : 23 weight per cent
- type of windrow: table windrow (h = 2.5 m)

As the emission prognosis of the decomposition area 1 showed, are first of all the borings responsible for a high odour load. By the increase of the structure material and the more often re-stacking process borings should be carried out only in rare cases and on the whole should be totally omitted. In the present case borings should be made during the first 2 weeks as exactly during this phase the highest oxygen supply is demanded by the micro-organisms and according to FRICKE et al. (1989) a windrow height of 2.5 m being still too high. The determination of the emission relevant surface is realized according to the explanations in chapter VIII/3.2.4

Table 8.18: Emission relevant surface of the windrows of the decomposition area 1 (scenario I)

Input [Mg/a]	Compost volume decomp. start [m³]	Compost volume decomp. end [m³]	Mean compost-volume [m³]	Mean wind-row surface without borings [m²]	Fictitious mean wind-row surface with borings [m²]
12.500	1.420	1.180	1.300	1.040	1.510
20.000	2.260	1.900	2.080	1.660	2.410
25.000	2.830	2.370	2.600	2.080	3.020

The 2 weeks' re-stacking and the higher content of structure material implies a lower odour emission, especially during the re-stacking processes. This effect is partly made up by the larger quantities of compost material to be re-stacked. Additionally to the piling process of the windrows on decomposition area 1 and the transport to decomposition area 2 another re-stacking process becomes necessary after a dwell time of 2 weeks, i.e. 15 % of the windrow surface with an odour emission of approximately 2.5 OU/(m²*s) must be moved at one workday.

Table 8.19: Odour loads at the re-stacking of unaerated windrows of decomposition area 1 (scenario I)

Input [Mg/a]	Agitated windrow surface [m²]	Mean specific odour radiation [OU/(m²*s)]	Odour load [OU/s]
12.500	156	2.5	390
20.000	249	2.5	620
25.000	312	2.5	780

The odour radiation of static windrows is assumed to be slightly lower by the faster decomposition progress than described in the emission prognosis, justifying the calculation of 0.9 OU/(m²*s).

Table 8.20: Odour loads from static and unaerated windrows of decomposition area 1 (scenario I)

Input [Mg/a]	Fictitious static windrow surface [m²]	Specific odour emission [OU/(m²*s)]	Odour loads [OU/s]
12.500	1.510	0.9	1.360
20.000	2.410	0.9	2.170
25.000	3.020	0.9	2.720

The total odour load is calculated from the sum of the odour loads for agitated and static windrows and is shown in table 8.21.

Table 8.21: Total odour loads of the decomposition area 1 (scenario I)

Input [Mg/a]	Odour loads from agitated windrows [OU/s]	Odour loads from static windrows [OU/s]	Odour loads total [OU/s]
12.500	390	1.360	1.750
20.000	620	2.170	2.790
25.000	780	2.720	3.500

Decomposition area 2

Initial data:
- bulk density : 0.60 Mg/m³
- dwell time : approximately 90 days
- re-stacking : after the first 2 weeks once, afterwards every 3rd week each
- decomposition loss : 38 weight percent
- type of windrow: table windrows (h = 2.5 m)

On account of the above mentioned reasons in decomposition area 2 the windrows should not be bored, achieving the following emission relevant surface of the windrows:

Table 8.22: Emission relevant surfaces of the windrows of decomposition area 2 (scenario I)

Input [Mg/a]	Compost volume decomposition start [m³]	Compost volume decomposition end [m³]	Mean compost volume [m³]	Mean windrow surface [m²]
12.500	3.850	3.100	3.480	2.780
20.000	6.160	4.960	5.560	4.450
25.000	7.700	6.200	6.950	5.560

An obvious influence on account of the improved structure can be achieved on the odour loads during the re-stacking processes. Approximately 6.7 % of the total compost volume with the belonging surface and an assumed surface radiation of 1.0 OU/(m²*s) must be turned per workday at the above described re-stacking interval.

Table 8.23: Odour loads at the re-stacking of unaerated windrows of the decomposition area 2 (scenario I)

Input [Mg/a]	Agitated windrow surface [m²]	Mean specific odour emission [OU/(m²*s)]	Odour loads [OU/s]
12.500	186	1.0	190
20.000	298	1.0	300
25.000	373	1.0	780

The odour load of static windrow surfaces will decrease considerably if borings are not carried out, however, a lessening of the odour radiation from the surface will scarcely be achieved, so that the load determination will be carried out once more with a value of 0.15 OU/(m²*s).

Table 8.24: Odour loads from static and unaerated windrows of decomposition area 2 (scenario I)

Input [Mg/a]	Fictitious static windrow surface [m²]	Specific odour radiation [OU/(m²*s)]	Odour loads [OU/s]
12.500	2.780	0.15	420
20.000	4.450	0.15	670
25.000	5.560	0.15	830

The total odour load is calculated from the sum of the odour loads for agitated and static windrows and is shown in table 8.25.

Table 8.25: Total odour loads of decomposition area 2 (scenario I)

Input [Mg/a]	Odour loads from agitated windrows [OU/s]	Odour loads from static windrows [OU/s]	Odour loads total [OU/s]
12.500	190	420	610
20.000	300	670	980
25.000	380	830	1.210

The assembled loads and their individual emission portion are shown in table 8.26 and figure 8.10.

Table 8.26: Odour loads of scenario I

	Odour load [OU/s]					
Location/ unit	Input quantity (12.500 Mg/a)	Emission portion [%]	Input quantity (20.000 Mg/a)	Emission portion [%]	Input-quantity (25.000 Mg/a)	Emission portion [%]
Intake area / Bunker	310	9.5	370	7.4	420	6.8
Decomposition drum (t = 1d)	180	5.5	220	4.4	250	4.1
Input preparation / screening / refining	120	3.7	150	3.0	170	2.8
Decomposition area 1 (t = 4 weeks)	1.750	53.5	2.790	55.9	3.500	56.8
Decomposition area 2 (t = 12 weeks)	610	18.8	980	19.6	1.210	19.6

Compost storage (t = 16 weeks)	230	7.1	380	7.6	460	7.5
Diffuse sour-ces	50	1.5	100	2.0	150	2.4
Sum	3.250	100	4.990	100	6.160	100

Facing the actual situation the odour loads could be lowered by increasing the portion of structure material and an odour related re-stacking interval by approximately 1.000 OU/s (12.500 Mg/a). The load on decomposition area 1 decreased by 30 % (750 OU/s) at an annual input quantity of 12.500 Mg, whereas the odour load on decomposition area 2 decreased by approximately 31 % (270 OU/s).

This emission portions proved that decomposition area 1, with over 50 % of the total load, is still the main cause for emissions.

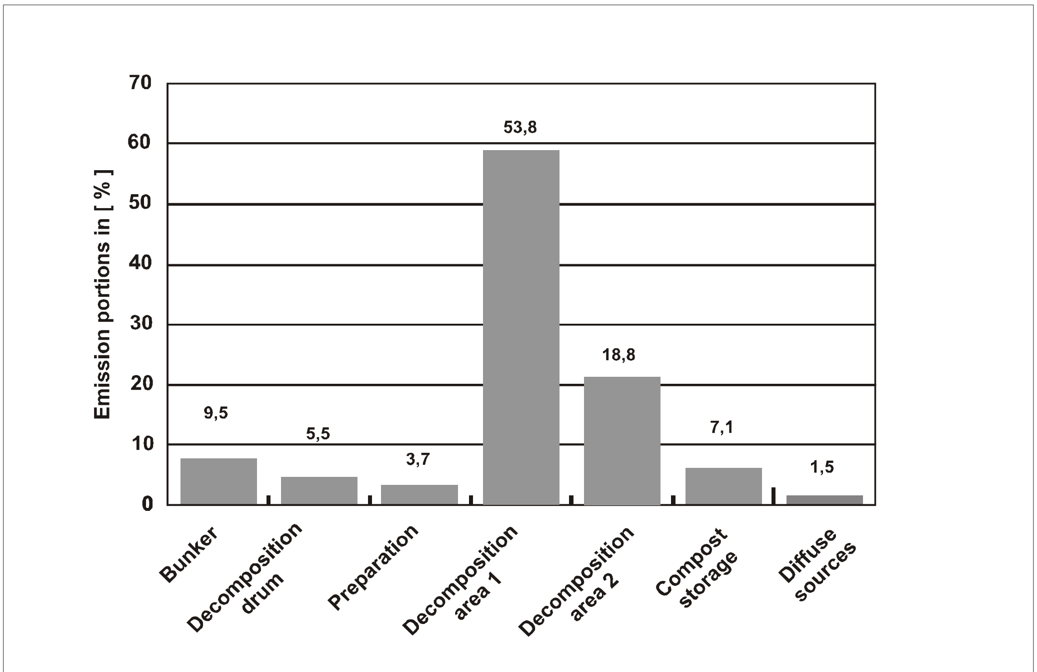

Figure 8.10: Emission portion of the locations/plant units at 12.500 Mg/a (scenario I)

6.1.3 Immission prognosis for scenario I

In the example of figure 8.11 the immission prognosis for scenario I (12.500 Mg/a) is shown by the iso-line graph, according to the requirements of the official planning approval. The direct comparison of the immission prognosis of the actual situation shows that here already a smaller-sized surface of the assessment area is affected by high immission concentrations. Remarkable is that the 4 % iso-line in the assessment area does not conformably draws back to the emission centre of gravity. Whereas the iso-line in the northern part moves by approximately 100 m to the south, and in the western part a dislocation of just 40 m in the direction of the reference point took place.

Possibly responsible are the unfavourable dispersion conditions (frequency ratio of the combination between wind velocity < 3 knots and stable dispersion class I or II) in western directions which are opposing a dilution of the odorant concentrations. Despite a reduction of the odour loads by approximately 1.000 OU/s (12.500 Mg/a), the exceeding of the immission concentration (3 OU/m^3) during approximately 6 - 7 % respectively 4.5 - 5 % of the annual hours affects the residential buildings.

Following the requirements of the Odour Immission Guideline (see figure 8.12) the corresponding immission prognosis shows only in the range of the northern residential buildings a decrease of the required immission frequency of about 10 % of the annual hours. A distinct exceeding (17.5 and 17.7 %) of the immission values could not be avoided in the area of the north-western residential buildings by a higher amount of structure material and the altered re-stacking interval.

The composting plant cannot be approved neither by the emission reducing measurements of scenario I, following the requirements of the governmental authorities nor to those of the Odour Immission Guideline. Thus making further measures necessary for a reduction of the emission load.

Exceeding frequency in % related to 3 OU/m³ - scale 1:7000

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

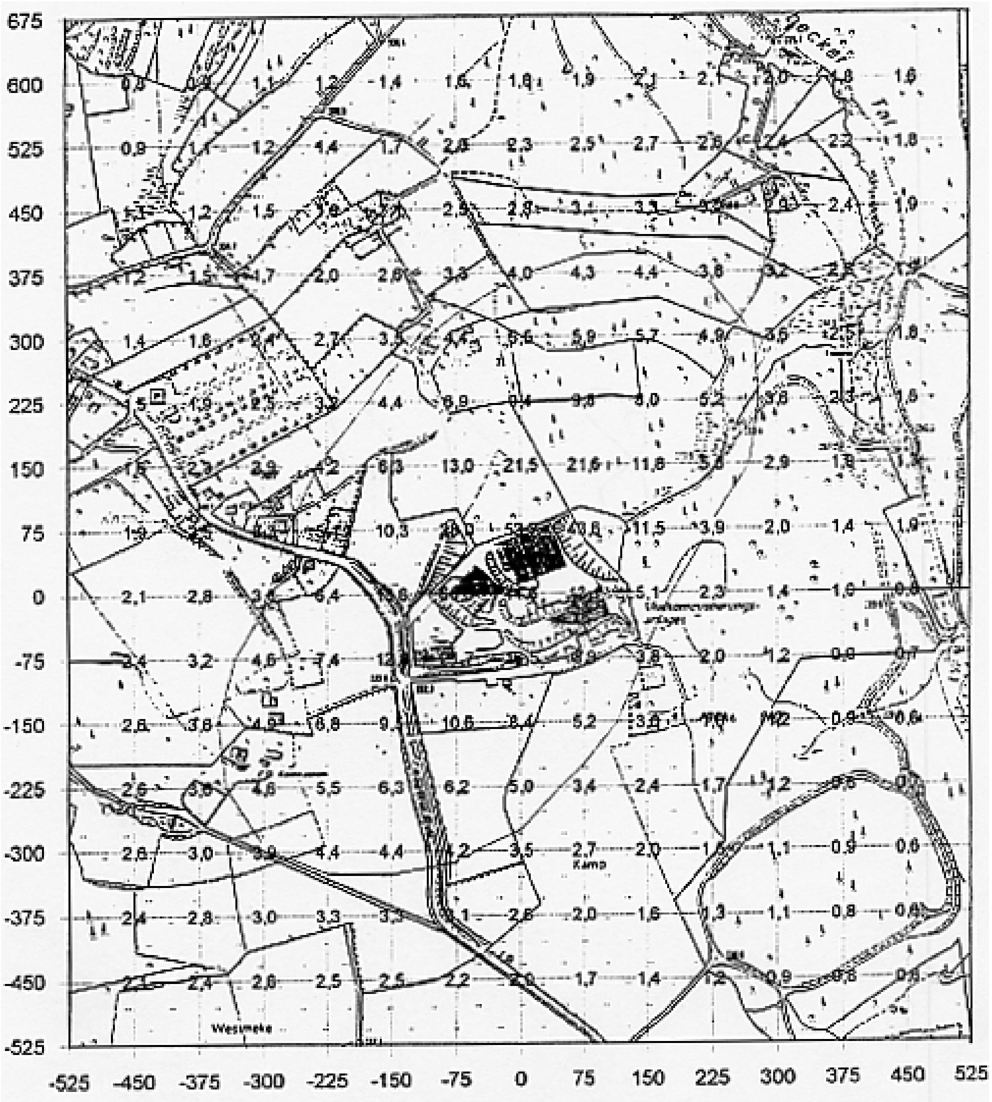

Figure 8.11: Immission prognosis of scenario I (12.500 Mg/a) according to approval requirements [SCHLOSSER, 1995]

Exceeding frequency in % related to 1 OU/m³ - scale 1:7000

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

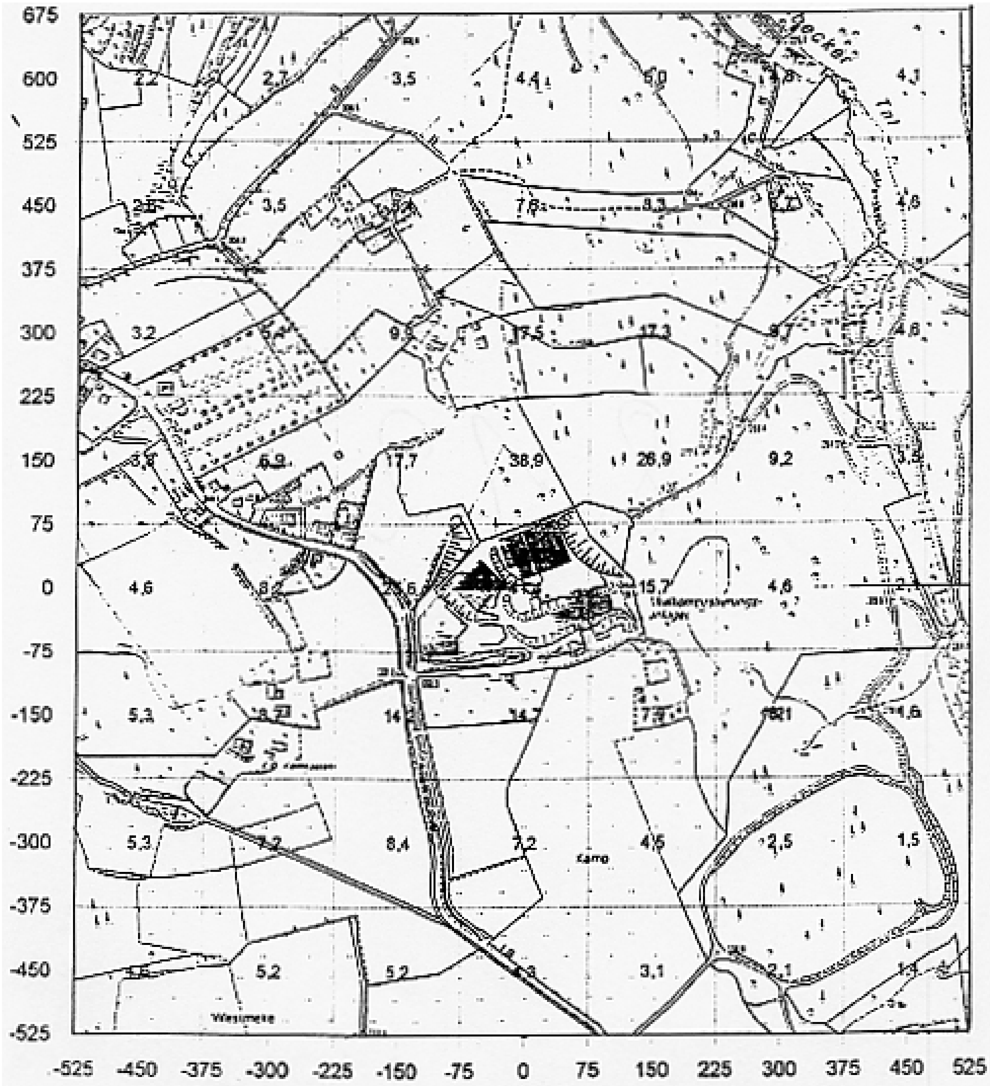

Figure 8.12: Immission prognosis of scenario I (12.500 Mg/a) according to GIR [SCHLOSSER, 1995]

6.2 Scenario II

Proposed measures

- Covering of the windrows on decomposition area 1 with compost
- Increase of the amount of structure material
- Odour related re-stacking interval

A further means for the reduction of emissions, the covering of the windrows with compost, shall be examined. Preconditions are the alterations mentioned in chapter VIII/6.1 regarding the re-stacking frequency and the amount of structure material, as a covering in the actual process seems to be not sensible. The main cause is the covering material, as the functioning of it would be influenced by the borings. Thus a sufficient oxygen supply without the changed structure material content and re-stacking intervals could not be assured. A further problem would be the slightly additional load of the covering material and the higher diffusion resistance of the windrow so that a covering can be recommended only with a higher structure material content and with an altered re-stacking interval.

Suitable as a covering material are those materials which are used in the biofilters, as here an identical functioning principle is prevailing. The degradable odorant concentrations released from the windrows are oxidized by the micro-organisms and / or transformed into biomass. As a rule the layer of the covering material, when compost is used, is between 5 and 10 cm. The small layer can be explained by the long contact period between odour material and substrate surface, resulting from the volume flow which is just based on the thermal current. An important precondition for an optimal odour neutralisation must be the possible self-odour of the covering layer which can arise through the progressing degradation processes of the covering material. If the windrows are covered with compost only mature materials should be used which have a solid substrate surface and are only subject to slight degradation processes.

Two research results have been found in the evaluated literature which enable an assessment of the emission reduction. MÜSKEN & BIDLINGMAIER (1993), considering the coverage of triangular windrows with chopped bushes, found in their research work that during the first 2 weeks of decomposition a tendency for a reduction of the surface emission of 75 % is possible. Figure 8.13 shows the results of this research.

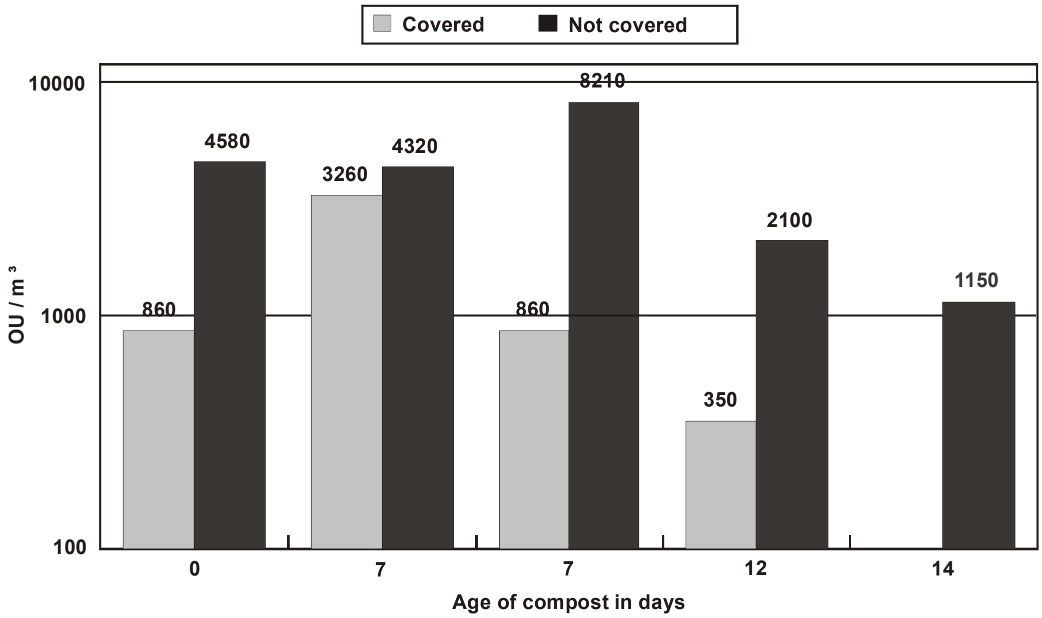

Figure 8.13: Change of the odour radiation of unaerated triangular windrows from biowaste by coverage with green cuttings [MÜSKEN & BIDLINGMAIER, 1993]

When windrows are covered with a 5 cm thick layer of screened mature compost, FRICKE et al. (1989) noticed during their research work, that the emission intensity of the windrows decreased by a 30-fold value after one hour compared with the not covered windrows. Figure 8.14 shows the achieved results.

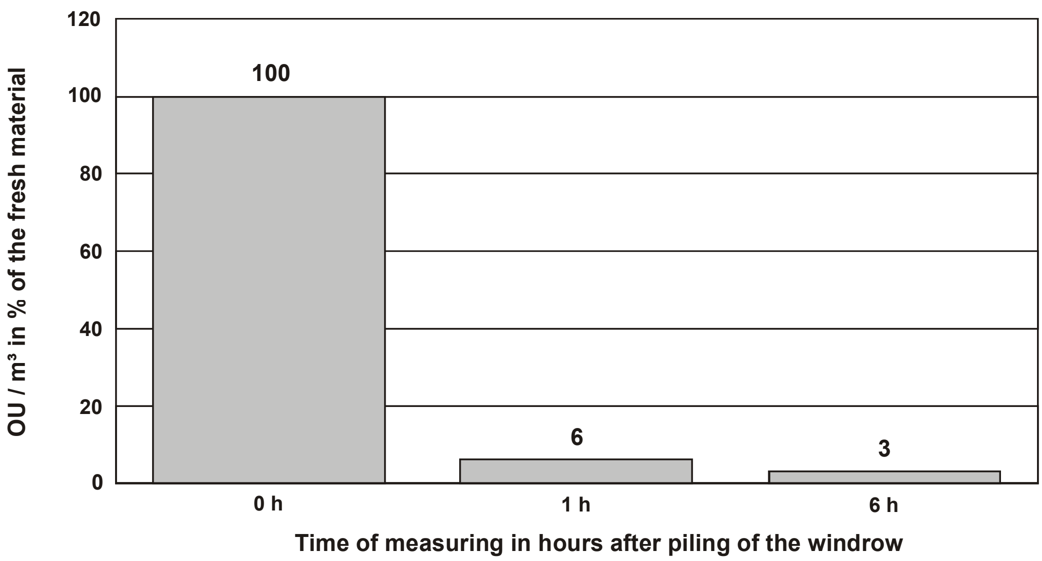

Figure 8.14: Influence of screened (< 20 mm) mature compost as cover material on the odour emission of fresh piled biowaste [FRICKE et al., 1989]

6.2.1 Proposals for an improvement of the emission situation in the plant

A mature compost layer with a thickness of 5 cm, grain size 10 - 20 mm, is suitable as cover material in the example. However, the utilization of mature compost leads to a considerable extra expenditure, therefore it is advisable to restrict this measure on decomposition area 1 on account of cost minimization and practicality. The extra expenditure which arises regarding the piling of the coverage and the transport of the material from the compost storage to decomposition area 1, is only meaningful on these windrows because here arises the highest emission reduction at acceptable costs.

6.2.2 Emission assessment of the individual plant units

Besides decomposition area 1 the odour loads of the rest of the locations and units remain unchanged to those mentioned in Chapter VIII/6.1.2.

Decomposition area 1
Initial data:

- Bulk density : 0.65 Mg/m³
- Dwell time : approximately 30 days
- Re-stacking : 2 weeks
- Decomposition loss : 23 weight per cent of the material
- Type of windrow: table windrow (h = 2.5 m) covered with mature compost.

In order to cover the windrow surface - depending on the input volume - 5.2 m^3 at 12.500 Mg/a, 8.3 m^3 at 20.000 Mg/a and 10.4 m^3 at 25.000 Mg/a mature compost must be transported from the compost storage to decomposition area 1 at one work day, there distributed with a wheel loader on the fresh or re-stacked windrows until they are completely covered. The additionally arising odour emissions, caused through the transport, will not be considered because of their insignificance.

Whether or how the increase and return of the structure material leads to an increase of the decomposition degree of the mature compost and thus to an inferior surface radiation of the cover layer, cannot be predicted.

The expected efficiency of the coverage can be estimated very inaccurate, as the mature compost to be utilized has decomposition degree III and further degradation processes can be expected which increase the self radiation of the coverage. Furthermore it cannot be predicted definitely to what extent the efficiency is subject to the seasonal deviations and which effect on the deodorization of the layer are having the influences caused by the alterations of the water content.

Following the prevailing experiences and the above mentioned restrictions a reduction of the surface emission of 30 % seems to be realistic, also under bad conditions, so that a value of 0.63 OU/(m^2*s) can be determined for the specific odour radiation of static windrows.

Table 8.27: Odour loads from static, uncovered and unaerated windrows on decomposition area 1

Input [Mg/a]	Static windrow surface [m²]	Specific odour radiation [OU/(m²*s)]	Odour loads [OU/s]
12.500	1.040	0.63	660
20.000	1.660	0.63	1.050
25.000	2.080	0.63	1.310

It is assumed that the odour loads during the re-stacking process of the windrows on decomposition area 1, decrease only slightly on account of the insignificant worse oxygen supply, so the values from chapter VIII/6.1.2 are adopted.

Table 8.28: Odour loads at the re-stacking of covered and unaerated windrows of decomposition area 1

Input [Mg/a]	Agitated windrow surface [m²]	Mean specific odour radiation [OU/(m²*s)]	Odour loads [OU/s]
12.500	156	2.5	390
20.000	249	2.5	620
25.000	312	2.5	780

The total odour load results from the sum of the odour loads for agitated and static windrows and is shown in table 8.29.

Table 8.29: Total odour loads of decomposition area 1 (scenario II)

Input quantity [Mg/a]	Odour loads from agitated windrows [OU/s]	Odour loads from static windrows [OU/s]	Odour loads total [OU/s]
12.500	390	660	1.050
20.000	620	1.050	1.670
25.000	780	1.310	2.090

The arising odour loads are completely shown in table 8.30 and documented by figure 8.15.

Table 8.30: Odour loads of scenario II

Location /unit	Odour loads [OU/s]					
	Input quantity (12.500 Mg/a)	Emission portion [%]	Input quantity (20.000 Mg/a)	Emission portion [%]	Input quantity (25.000 Mg/a)	Emission portion [%]
Intake area / bunker	310	12.2	370	9.6	420	8.8
Decomposition drum (t = 1d)	180	7.1	220	5.7	250	5.3
Input preparation / screen drum / refining	120	4.7	150	3.9	170	3.6
Decomposition area 1 (t = 4 weeks)	1.050	41.2	1.670	43.2	2.090	44.0
Decomposition area 2 (t = 12 weeks)	610	23.9	980	25.3	1.210	25.5
Compost storage (t = 16 weeks)	230	9.0	380	9.8	460	9.7
Diffuse sources	50	2.0	100	2.6	150	3.2
Sum	2.550	100	3.870	100	4.750	100

Contrary to scenario I the odour loads could be reduced by further 700 OU/s (12.500 Mg/a) by covering of the windrows on decomposition area 1 with mature compost.

At an annual input quantity of 12.500 Mg and with a total load of 41 % the decomposition area 1 is still the main source for odour emissions, but compared with the biofilter (approximately 24 %) and the decomposition area 2 (approximately 24 %) it looses more and more of importance.

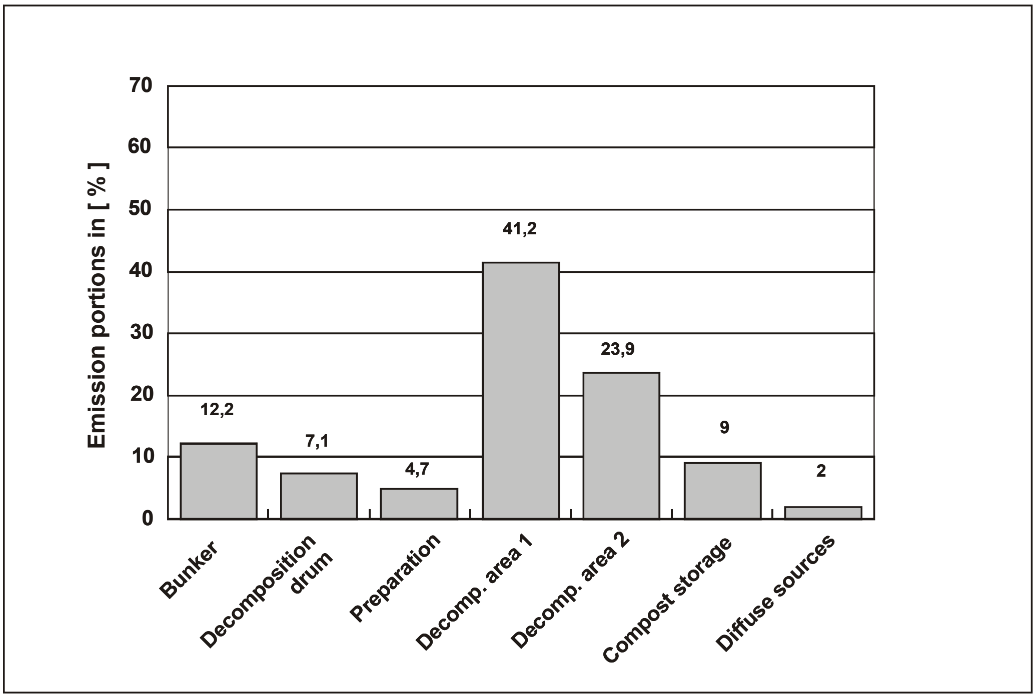

Figure 8.15: Emission output of locations / plant units at 12.500 Mg/a (scenario II)

6.2.3 Immission prognosis for scenario II

By means of the iso-line performance, shown in figure 8.16, can be recognized that through a further reduction of the odour loads of scenario II with about 700 OU/s great parts of the residential buildings in the north-west and south-west of the plant already show exceeding frequencies < 4 % of the annual hours referring to 3 OU/m^3. Only the buildings of the residential buildings located in the east, in the north-west, which are lying in direct neighbourhood to the composting plant are having immission frequencies of up to 5 % of the annual hours, contrary to the houses in the north which have, without exception, nearly no odour annoyances.

For the total load of immission odours of the corresponding assessment area in the immission prognosis following the Odour Immission Guideline (figure 8.17) the odour annoyances are still considerable. The nearby residential buildings have to cope with an odour immission concentration during approximately 16 % of the annual hours of 1 OU/m^3, whereas in the north during 1226 hours/a (14 %) considerable odour annoyances arise.

The assessment of the odour immission according to the Odour Immission Guidelines shows in this special case (utilization of assessment areas with a border length of 150 m) a distinct tendency for higher requirements regarding a reduction of the odour loads than this is realized through the standards of the official planning approval. The requirements for both legal assessment basics are not fulfilled by the additional coverage of the windrows regarding an input quantity of 12.500 Mg/a, so that the emission reducing measurements of scenario II alone are not leading to an approval of the composting plant.

Exceeding frequency in % referring to 3 OU/m^3 - scale 1 : 7000

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

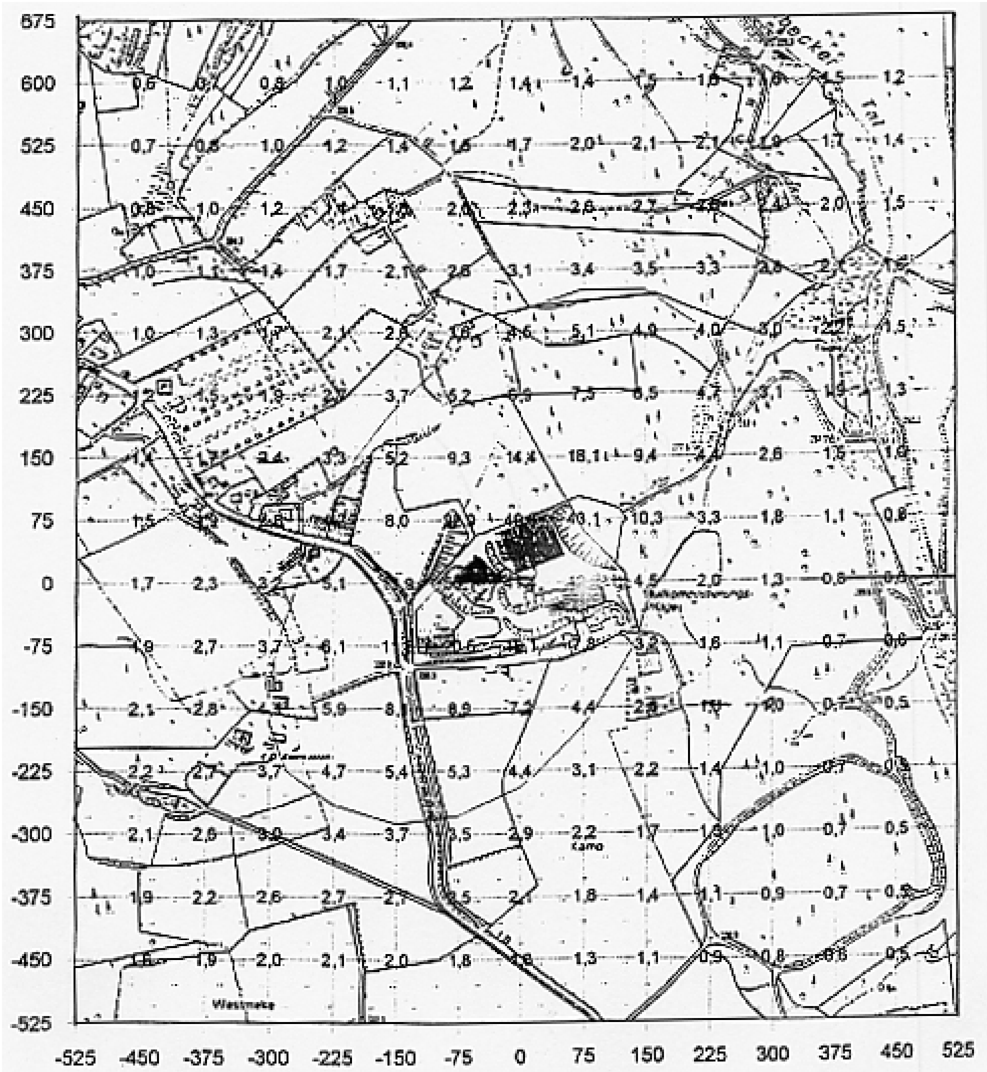

Figure 8.16: Immission prognosis of scenario II (12.500 Mg/a) according to approval requirements [SCHLOSSER, 1995]

Exceeding frequency in % referring to 1 OU/m^{3} - scale 1 : 7000

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

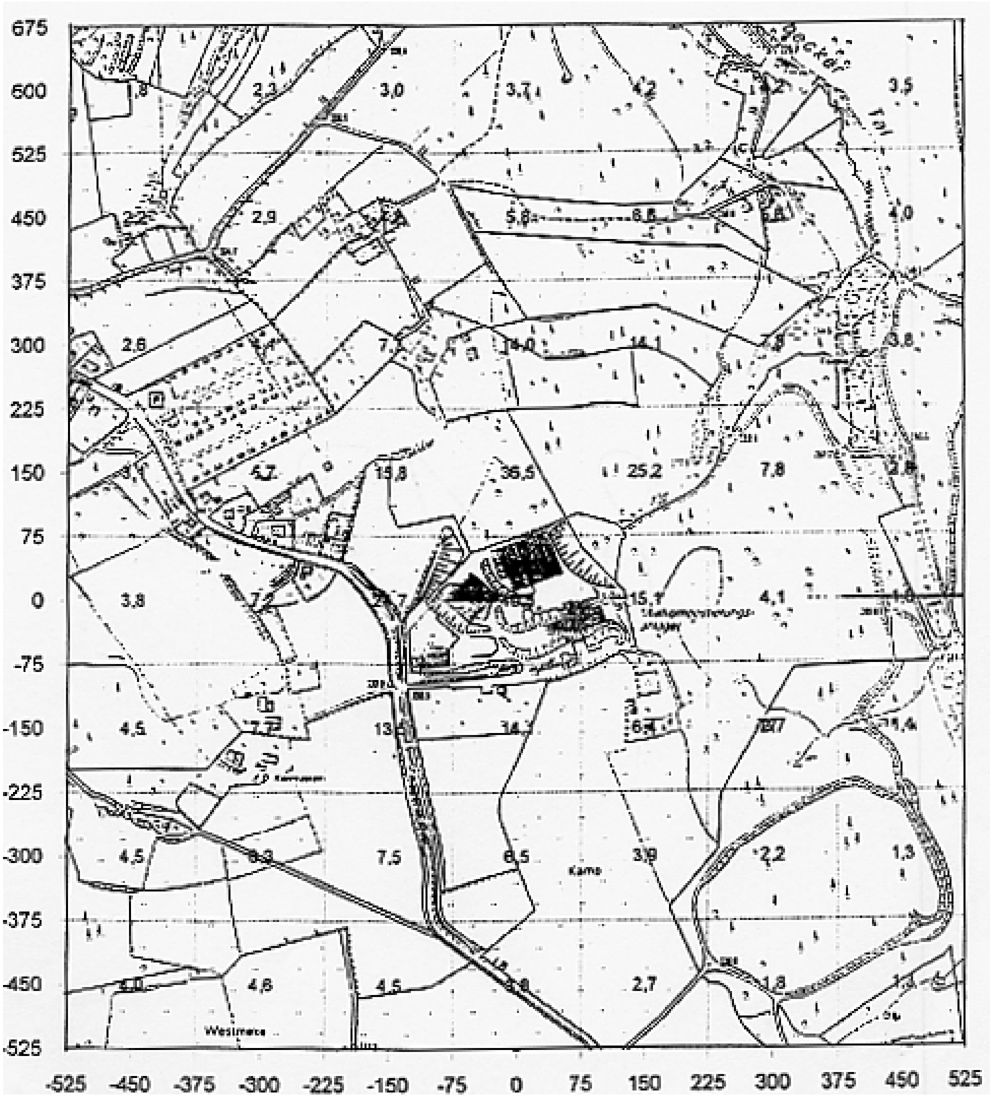

Figure 8.17: Immission prognosis of scenario II (12.500 Mg/a) according to GIR (Odour Immission Guideline [SCHLOSSER, 1995]

Chapter 9 Odour Immission Cases in Composting Plants

1 Collection and evaluation of concrete cases

The operational experiences collected from eight composting plants with a throughput of 7.000 to 35.000 Mg/a and with heavy odour problems have been evaluated together with the experiences of a couple of other works in the range of emissions from odorants. Most of the plant managers made the belonging data available only under the maintenance of secrecy for the individual plant site and its special problems. Therefore the following was considered anonymously and only general statements were made.

Apart from the assessment of the available data like approval decisions, reports of emission assessment, expert opinion for the immission situation and for the decomposition management etc. additional background discussions have been carried on with several plant managers, with experts from approval and other regional authorities in order to obtain a clear picture of the individual local situation.

In the past the inevitable odour emissions arising from the operation of composting units lead to considerable annoyances in the neighbourhood of some composting plants. As a plant site can only exist in the long run if the neighbours are not extremely annoyed, the avoidance of damages caused by odours finds a considerable importance. To operate a composting plant free of odours is nearly impossible on account of the mechanical and biological processes of the composting of waste material. An acceptable situation for the environment can be created only by a perfect planning, equipment and operational management.

The essential influences on the outer effects of odours of a composting plant are besides the choice of a plant location that is not critical and a planning which considers the given local conditions:

- Plant throughput and the kind of the processed wastes,
- the selected decomposition process,
- the extent of the enclosure of the odour emitting plant units,
- the achieved purification efficiency in exhaust air flows from enclosed plant units and
- the operational management.

The analysing of the considered damages shows that the following problems are regularly arising:

- Underestimation of the odorant concentration of the selected composting technology already in the planning stage and correspondingly insufficient measures regarding a protection from emissions.
- Technical problems at the operation of composting plants resulting in not planned operational conditions with higher emissions.

- Wrong dimensioning of the decomposition unit with the result of a too low decomposition degree in the mature product (e.g. decomposition degree II instead of IV), with heavy odour emissions at the compost refining and in the storage area.

- Careless operational management which do not correspond to the demands of the emission protection (keywords: open gates, other diffuse sources).

- Underestimation of the effectiveness of "small" odour sources like e.g. open containers for residual waste or open transport of fresh compost.

- Technically insufficient or wrong dimensioned purification units for exhaust air and bad air management (keywords: filter material, crude gas conditioning).

- Insufficient control and maintenance of the purification units for exhaust air (keyword: filter maintenance).

- Minimization of complaints from neighbours through the plant operator with entailing escalation of the quarrel over tolerable conditions in the surroundings of the plant. Also exploitation of the situation by neighbours which think to make a profit if they are emphasizing the problem of a principally tolerable immission.

- Hesitating problem solving, based on costs or image loss.

- Approach of residential buildings or industry to the borders of the composting plant after the initial operation.

Several of the listed problems are usually coming together, so some plants discussed already the closing down of the plant at the present location.

At this point none of the known poor qualities of the dispersion calculation and an immission prognosis for odorant concentrations according to Technical Guideline Air should be discussed, but the mistakes which are made at the combination of the input parameters (i.e. the source power of individual process units rich in emissions) should be considered. Very often ideal basic conditions are assumed as basis for a calculation, though since the beginning of the nineties (last century) sufficient odour measurements are available which document the total range width of possible heavy odour emissions from individual odour sources.

Prognosis for emissions and immission of odorant concentrations are usually made together with the planning for approval, i.e. that exact data about the later carried out aeration technology and the realized air management are in most cases not yet available. The often uncomfortable expert's job for immission and emission is the demand from the plant planning office and the plant owner for the observation of the admissible emission values in the neighbourhood of the site which probably increase the costs for the project considerably and even exclude certain plant configurations like e.g. the operation of open windrows or similar.

The consequences of an emission/immission prognosis which has been realized in the planning or on the basis of not clearly settled operational specifications could be either the determination of limit values for emissions by the approval authorities, which cannot be kept with the available technology during continuous operation or the emission of essentially higher odour loads than given in the prognosis. In both cases very costly retrofitting or an alteration of the operational functions following from exceeding limit values or from odour annoyances from the neighbourhood are inevitable (see chapter IX para 3).

A conscientious investigation of the meteorological conditions at the planned plant location is necessary, e.g. consideration of the cold air flow or frequency of atmospheric inversional conditions. The costs for a detailed data of the mesoclimate at the location will be essentially inferior than following measures for an emission protection in the existing plant.

It must be pointed out that an investigation of the status quo prior to the initial operation of new composting plants, must be accompanied by the assessment of all existing odour sources.

This can be realized either through field measurements carried out by panels in the sense of the Odour Immission Guideline (GIR) or by measurements, i.e. conscientious assessment of the source intensity of these emissions and insertion in the immission prognosis. The data collection of the pre-load of the site environment according to GIR protects the manager of the composting plant from later unjustified complaints.

Plant operation in general

Of course, an optimal plant operation cannot compensate planning mistakes, or just to some extent. The analysis of the investigated damages shows, however, that independent from the equipment of a plant, certain failures arise over and over again.

In the following can be named:

- Delivery of already odour intensive wastes, e.g. because of longer collection intervals of biowaste in the summertime (alternating, usually 2 weeks collection interval).
- Longer intermediate storage of wastes prior to the processing in the bunker or delivery area, e.g. on account of a plant down-time.
- Processing of wet materials (e.g. from catering, restaurants or markets) at a simultaneous lack of structure material.
- Plant units which are normally closed are left open, above all in the treatment and decomposition area, this behaviour causes heavily increased diffuse odour emissions.
- A regular cleaning of all traffic areas to avoid diffuse odour emissions is not carried out.
- Transportation of odour intensive material at unfavourable wind directions (e.g. towards the neighbour) or during corresponding meteorological conditions (e.g. inversion) with open windrows, but also in the storage area.

- Overloading of the plant by a waste throughput that is too high. In this case doubling effects regarding the emission intensity are the result, as e.g. windrows piled up too high (open plants), decreasing decomposition degree of the mature product (result: higher emissions at subsequent decomposition, at refining and in the storage area). Overload of the composting storage (result: windrows too high or windrows in the storage which are not treated). A renewed self-heating of the compost and thus increased odour emissions. Overload of the purification unit of the exhaust air on account of the increased odour loads from all plant units which are used more intensively. A generally incorrect working method on account of lack of time (result: due cleaning, controlling and maintenance work are carried out too late and/or imperfect.

- Neglecting the regular control and maintenance of the purification unit for exhaust air (see "exhaust air purification" in this chapter) and other emission reducing measures (e.g. covering of open windrows with choppings or special canvas for this purpose).

- Insufficient reactions to accidents like breakdown of ventilators or individual units (example: input in decomposition hall is stagnant, therefore overloading of the bunker area with untreated wastes or prolonged storage time).

- Disregard of the standards for the air management (e.g. multiple utilization of air flows) thus higher exhaust air volumes in the clean gas flow with a corresponding increase of the emitting odour loads (only with plants which are partly or totally closed).

- Material transfer and discharge points between the individual units with a faulty construction and maladjusted, therefore e.g. continuous soiling of the ground (coarse and fine treatment) (result: diffuse odour sources).

Exhaust air purification

The operation of an exhaust air purification plant, which in (partly) enclosed composting plants nearly always is composed of a biofilter, possibly in combination with a bioscrubber, presupposes a good training and experience of the operating staff. Like all biological systems, biological exhaust air purification units also need a continuous monitoring and maintenance, if they are run with an optimal effectiveness (see also chapter VI and IX.3).

If in the neighbourhood of a composting plant odour annoyances arise which are caused by malfunctioning of the exhaust air purification, often the following reasons are responsible:

- The biofilter material is worn out, the purification efficiency decreases continuously.

- The used filter material does not meet the requirements and tends to compaction, does not decompose properly or has a high maintenance expenditure (keywords: high pressure loss, ruptures, frequent loosening).

- The water management in the biofilter is not balanced, dry zones are developing which lead to filter ruptures.

- The crude gas does not flow against the biofilter in a constant manner (e.g. clogging in the slatted floor), preference channels are built respectively zones with an increased area load. Increased emission values or even filter ruptures are the consequences.

- The filter control and maintenance is neglected, therefore arising problems like inconstant flow behaviour, dry zones etc. will not be noticed in time.

- The design of the exhaust gas purification is defective. This causes problems especially with the suction aeration of the exhaust gas filter on account of high exhaust gas concentrations and temperatures, which can only be repaired by a previously connected exhaust gas conditioning respectively bioscrubber.

- The air management of the composting plant is defective, the previously connected bioscrubber or the exhaust air conditioning do not work in a perfect manner, so that the biofilter is loaded with too high concentrations of crude gas and/or temperatures, that, as a rule, leads to an increase of the purification efficiency (efficiency degree in [%]) with a filter that is in good order, however causes a distinct increase of the clean gas concentration and thus an increase of the delivered odour load.

- The construction of the filter is defective (keywords: uniform crude gas distribution, simple cleaning of the delivery air management, easy access to the underground filter units).

Longer lasting, not planned odour emissions at smaller plants which reduce their emissions from open windrows by covering (layers of choppings or canvas) arise only when after the re-stacking process the piled fresh windrows are not immediately covered or the coverage or canvas is not fixed properly.

Social intercourse with complainants

The staff of decomposition plants for biowastes is usually not trained for a gentle dealing with people which feel themselves threatened in their rights or their physical integrity. This is especially necessary if in the neighbourhood of composting plants a distinct emission of odours arise and the complainants should be encountered with a little psychological cleverness and sympathetic understanding for their concerns. On the contrary those opportunities should be used instantly to recognize and if possible to remove weak points in the own plant.

In all cases where complaints on account of odour annoyances came and were encountered only with tactics and appeasement the conflict with the neighbours increased steadily. Bad newspaper articles, political discrepancies and the foundation of citizens' action committees finally seek refuge in attacks with a high amount of costs for staff and expenditure. The reason for the quarrel, the odour annoyances, had to be removed in any case.

Of course there are unacceptable complaints according to the regulations for the protection from immission where special interests or even monetary reasons play a rôle. A possible settling of the conflict in these cases is the change of the residence of the complainant, what is certainly a very costly undertaking, or an agreement on the basis of a financial compensation. In both cases the authorities concerned with the approval for the composting plant in question should be included in the decision-making.

2 Proposals for restoration and their assessment

The problems described in chapter VII/1 and the sources for avoidable odour emissions shown in table 8.1 shall be the basis for restoration and general precautionary measures discussed in the following. Fundamentally it can be assumed that emitting odour loads can be reduced with an advancing enclosure of the plant units (see chapter VI, table 6.). This, however, shall not mean that open working composting equipment has to be refused or cannot be operated, as long as legal regulations are not relevant (see Technical Guideline of Urban Waste (TASI), GIR). In fact it must be considered that on account of cost reasons an enclosure degree will be chosen which is adjusted to the special plant location.

Prognosis of the odour emissions

Deduced from the procedure in the planning process shown in chapter VIII/3.1 article "prognosis of odour emission", the prognosis for the emission/immission of the odorants created for the performance planning has to be updated for the approval planning even until the initial operation stage of the intended plant. Only this can guarantee that all the alterations or improved definitions of the emission situation are included in the prognosis of the odour immission in the plant environment, enabling a permanent feed-back between plant planning and expected effect on the outside world of the finished plant. Unpleasant surprises after initial operation of the composting plant which could have been predicted can be avoided by these measures.

Internal conception

As a consequence of the plant planner's susceptibility to the necessities of the protection from emissions the future operator of the composting plant must be given corresponding instructions for activities. These directions should comprise:

- All necessary information for the minimization of the odour emissions in the running operation, like e.g. the handling of the air management, the effects of the decomposition management, the originating of diffuse odour sources etc.

- Exact information for controlling and maintenance of the units for exhaust air purification.

- A detailed description of the emergency management, which also includes the procedure for necessary maintenance work.

An internal conception for the avoidance of odour emissions which are exceeding the admissible measures should proceed from the following aspects:

- By corresponding experience and training, the operational staff is capable of properly operating all the plant units. A precondition is the presence of at least one competent person to take decisions during operational periods and the instalment of an emergency service out of the normal operating times. Within short term a responsible staff member should arrive at the plant in case of emergency who is capable of repairing failures.

- The maintenance of the plant units which are responsible for the emission situation (deducting equipment, additional air units/exhaust air units, biofilter etc.) is made in regular intervals by means of a maintenance plan which considers the individual operation respectively down times of the units and the requirements given by the manufacturers. A spare part stockroom to store the corresponding parts is self-evident.

- The following meteorological data should be continuously measured for a documentation of the climatic conditions at the plant site:

- Air temperature

- Wind direction and intensity

- Precipitation quantity

- Relative humidity of air

- An intake control for the wastes to be treated with the individual plant units takes place.

- The valid regulations of the TA Urban Waste (compare also para 6, demands on the organisation and the operational staff of waste disposal plants and on the documentation and information) are kept.

The prevention of avoidable odour emissions presupposes that when an enclosed composting plant is operated it must be cared for:

- a regular cleaning of the traffic ways (daily on working days) of the outer areas (traffic areas, delivery of special wastes like e.g. green wastes or wastes with a heavy water content, direct shipping of compost etc.), of the shipping station of compost and the intake area is carried out to avoid diffuse sources,

- hall gates will be opened only if this is necessary and closed immediately after application (e.g. installation of electrical signals which are enabling a recognition of open gates from the control room),

- automatic opening and closing of the hall gates (e.g. remote control from the wheel loader),

- no interim storage of wastes or compost in the outer area,

- plant units into which odour loaded exhaust air flows are conducted (multiple usage of air flows) will be sucked off in a proper way and and these air flows will be passed on to other enclosed and de-aerated plant units or in a direct way to the biofilter.

- a control programme exists for the aeration and de-aeration equipment with which the operational conditions of the total plant and individual plant units are monitored (e.g. day and night operation, maintenance in plant units which are not operated by men, emergency, new equipment of filter parts, minimum air change rate numbers etc.) ensuring the observation of the standard frame conditions for a minimization of odour emissions,

- A steady light low pressure is produced in the sucked off plant units in order to avoid diffuse generation of odorant concentrations,

- the requirements for filter maintenance and filter operation must be given priority (see chapter Exhaust Air Purification).

Exhaust Air Purification

Table 8.1 summarises the often arising malfunctions in plants with exhaust air purification (biofilter), their effects on the emission situation and possible ways for a problem solution. When operating a biofilter the following must be observed:

- when using the provided filter material the maximal admissible room load of the biofilter in the regular operation must not be surpassed,

- a segmental change of the filter material at the remaining filter segments does not cause a too strong decrease of the purification efficiency (redundancy),

- that the approved exhaust air value is guaranteed at the provided maximum room load,

- that the filter material is kept on a water content of > 40 % by suitable measures (additional air humidity, possible watering),

- the requirements of VDI guidelines 3477 are to be observed regarding the dimensioning and the operation of the filter,

- the efficiency of the exhaust air ventilators is dimensioned in such a way that the filter performance is not influenced by a compaction of the filter material and an increasing counterpressure,

- the relative humidity of the additional filter air is kept as far as possible in the range of the water steam saturation (possibly assembly of a humidifier equipment,

- the delivery air temperature in the biofilter lies in the range of +10° C and +40° C,

- the filter body is constructed in such a way that no ruptures arise, above all in the border area,

- the delivery air to the filter is de-dusted as far as possible in order to avoid a clogging of the air distribution equipment and the lower filter layers,
- the pH value in the biofilter material is kept in a neutral range,
- a change of the filter material is carried out before the depletion of the purification efficiency is reached.

Furthermore the following filter maintenance and control measures are recommended:

- a visual control, if possible every day, of the filter surface (determination of ruptures and compaction in the filter material), the best time is the early morning (formation of water vapour),
- measurement of the additional air temperature and the air volume flow at least every work day,
- a permanent monitoring of the additional air humidity is recommended, in order to cope with a drying out of the filter as fast as possible,
- regular measuring of the filter counterpressure (air supply to the filter) in order to ascertain compactions in the filter material,
- Numerous determination of the water content of the filter material during dry periods, at other times on eye contact or in longer regular intervals.
- loosening of the filter surface at uneven off flow behaviour or fouling,
- regular sample taking from the filter material and determination of pH value and volatile solids,
- regular control of the functioning of the irrigation equipment for the material irrigation and the additional air humidifier (if available),
- examination of the filter material on the nutrient content (C, N, P) in regular intervals,
- cleaning of the ventilator, the delivery air channels and the air distribution in the filter fields in regular intervals and the equipment of the delivery air humidifier (in case available).

Table 9.1: Possible sources for avoidable odour emissions

Plant unit	Problems	Consequences	Possible remedies
Traffic areas	impurities	diffuse odour emissions	strict observation of the cleaning programme (at least once per workday
Bunker	odour intensive delivery and/or wet input material	increased odour emission (also in subsequent plant units)	shortening of the collection interval (biowastes), preferred and rapid treatment (e.g. wastes from markets and restaurants)
	longer interim storage of wastes (e.g. plant down time)	increased odour emission (also in subsequent plant units)	joint agreements with other works in case of breakdown, in any case collection on workdays
	press water from collection vehicles	increased odour emission in the bunker area and on traffic areas	separate collection equipment for vehicles with press water tank, regular cleaning interval
	open gates	diffuse odour emissions	automatic gates (e.g. remote controlling from the wheel loader), separation of the reception area and the bunker (sluices, mainly practicable with deep bunkers)
Coarse preparation	wet input material	clogging, press water etc. increased odour emissions	sufficient stock of structure material
	defective points for material supply	material outlet from the material flow, impurities on the ground and on the units, therefore increased odour emissions	retrofitting of the faulty plant units
	odour intensive residues	increased odour emissions from the residual waste containers	covering in the open area or general placement in the sucked off enclosed area
Decomposition	material movement at unfavourable weather conditions/wind direction (open decomposition)	increased odour emission in the direction of the next neighbours	re-adjustment to the operating procedure
	unsatisfying decomposition progress (e.g. decomp. degree IV is not achieved)	increased odour emissions at material discharge, in fine preparation and in the storage	optimization of the decomposition operation, probably decrease of the throughput or enlargement of the decomposition capacity
	careless handling of the emission reducing measures (e.g. coverage of open windrows after restacking)	heavily increased odour emissions	optimization of the operating process
Refinery	defective points for material transfer	material outlet from the material flow, impurities on the ground and on the units, therefore increased odour emissions	retrofitting of the faulty plant units

	odour intensive residual material (fresh compost)	increased odour emissions from the residual waste containers	covering in the open area or general placement in the sucked off enclosed area
	not decomposed compost material	increased odour emissions	optimization of the decomposition operation, possibly a decrease of the throughput or enlargement of the decomposition capacity
Storage	loading in open air	increased odour emissions (fresh compost)	enclosure of the plant unit or utilization of discharge hoses
	not managed stock windrows	renewed self-heating of the compost, increased odour emission when material is agitated	conversion of the operation procedure (e.g. regular restacking, limitation of the windrow height, aeration of the stock windrows etc.)
	lacking capacity	increased odour emissions	dislocation of surplus quantities, enlargement of the stock
All	throughput that is too high	decreasing decomposition degree, overload of all plant units, increased odour emissions	strict limitation of the processed daily quantity, probably joint agreements with other works in case of breakdown
	lacking cleanliness	arising of diffuse odour sources	strict adherence to the cleaning programme (at least every workday)
	lack of time and personnel	inexact working method, lacking control and maintenance, thus increased odour emissions	throughput limitation, more personnel
	poor air management	exhaust air volumes too large, thus increasing of emitting odour loads	strict adherence to the standards, probably retrofitting/optimization of the aeration unit
	lacking emergency management	breakdowns of plant units longer lasting than necessary	definite instructions for operation of breakdowns and a corresponding instruction of the personnel
	open doors and gates in in-vessel plants	generation of diffuse odour sources	strict adherence to the corresponding demands, probably retrofitting of the gates for automatic operation by means of remote control, centralized monitoring of all gates and doors (closing detector)

A bioscrubber that is mounted before a filter must be subject to a regular service and control for perfect functioning. Ruptured root timber and screen residues (40 - 120 mm grain size) from the green waste composting on surface biofilters were most successful with high exhaust air volumes (several ten thousand cubic meters per hour). The coverage for this filter type is spruce bark or similar with a grain size of 80 mm. Dwell times of approximately three years (material from green waste composting) and five years (material from ruptured root timber) can be achieved.

Today exhaust air humidifiers are mostly used for the refining of crude gas that is guided into the biofilter, which, however, show a limited efficiency for the control of alternating exhaust gas temperatures. For the latter case only a heat exchanger can create an effective remedy.

Table 9.2: Effects and maintenance of malfunctions of the exhaust air purification

Problems	Consequences	**Possible remedies**
High odour concentrations in the crude gas flow (e.g. from suction aerated windrows)	high room load of the filter, despite high purification efficiency increased clean gas concentration	crude gas refining respectively pre-connecting of a scrubber
strongly changing odorant concentrations and / or high temperatures in the crude gas	permanent change in the offer of nutrients and the environment for the micro-organisms active in the filter	mixture of different exhaust air flows, probably refining of fractional flows
rapid and/or nonuniform degradation of the filter material	increase of the pressure resistance in the filter, nonuniform purification efficiency, probably filter ruptures	regular preparation and change of the filter material, use of filter material with a long dwell time
drying out of the filter material	decrease of the purification efficiency up to filter ruptures	crude gas humidifying, irrigation equipment for the filter surface
nonuniform flow against the filter	decrease of the purification efficiency up o filter ruptures	regular control and if necessary cleaning of the delivery air conduct
nonuniform flow off behaviour	decrease of the purification efficiency up to filter ruptures	regular control, preparation of the filter material, removal of drying out zones
lack of nutrients in the filter material	decrease of the purification efficiency up to filter ruptures	regular control, maybe refurnishment of the filter material
worn out filter material	decrease of the purification efficiency up to filter ruptures	regular control, refurnishment or replacement of the filter material

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Chapter 10 Summary and Outlook

The emissions from biological plants are momentarily playing an important rôle at the planning of a composting plant. The official project approval procedure determines the success of a plant today with the emissions to be expected and the willingness of the waste producers for a separate collection of the biowaste.

An important component for the editing and assessment of the emissions to be expected within the planning work for a plant was to create uniform standards. An initial basis was prepared with the present dimensioning sheets.

Depending on the difficult data acquisition the dimensioning sheets are not complete in all points. The basis of the data was collected from both a literature search in the framework of the DBU, sub-project 1 "connections between decomposition management and odour emissions at the composting of urban wastes" and own literature researches of publications that is accessible to the public, but also from unpublished measurement reports (anonymous).

A difficult task was to include unpublished measurement reports, as odour data and hygiene data are looked upon as being very sensitive. Some of the composting procedures having too little detailed measurements for a recording in the dimensioning sheets. To be mentioned here are the tunnel and windrow composting and the composting in reactors and with bricks. Various data from the box and container composting could be used for some time on account of the apparent likeness of individual procedures. The data gaps and the borrowing of measuring data should be permanently actualised with new measurements. Only by these means the latest status of the measuring methods of odours can be represented.

After the assessment of all the available measuring data a system appeared that includes the following main points:

- Classification of all procedures available on the market in 6 modular types to simplify the system.
- Classification of the individual modular types in two types of process steps (generally valid and specific).
- Allocation of the researched odour data to individual process steps.
- Influence of the parameters on the volume of the odorant concentrations within the individual process steps.

The simplification of the system was absolutely necessary as for the time being too many different manufacturers are busy on the market. The dividing of the modular type system in two parts becomes meaningful if one considers the many process steps within the composting methods which are running parallel in nearly all types of procedures - here defined as generally valid process steps. This also concerns the classification in specific process steps included, above all, in the different decomposition systems.

The odour data are available in a great range of variation, the cause of which is on the one hand the differential measuring methods in the laboratories (see chapter IV) and on the other hand the different preconditions during which the individual measurements were taken and which often were not known. In order to make the selection of the odour data easier for the person who uses the dimensioning sheets, known parameters have been included in the dimensioning sheets in order to minimize the variation limits. The know-how of the odorant concentrations at definite plant units is important for open or partly open plants, as here the odour emissions can be opposed with corresponding measures.

The air management in completely enclosed plants can be improved by the know-how of the odorant concentrations within the individual process steps. An exhaust air purification provided according to the state of the art, influences only the emitted air volume, the source intensity of the plant and thus the immission prognosis.

On the basis of the researched odour data a computer programme should be developed for an improved and quicker dealing with the data assembled in the dimensioning sheets. An advantage of such a programme would be to calculate the odour loads under certain frame conditions with the previously selected odorant concentrations and the individual air volumes of the planned plant. The air management of the plant could be optimized in such a way and additionally a worst-case-view could be carried out.

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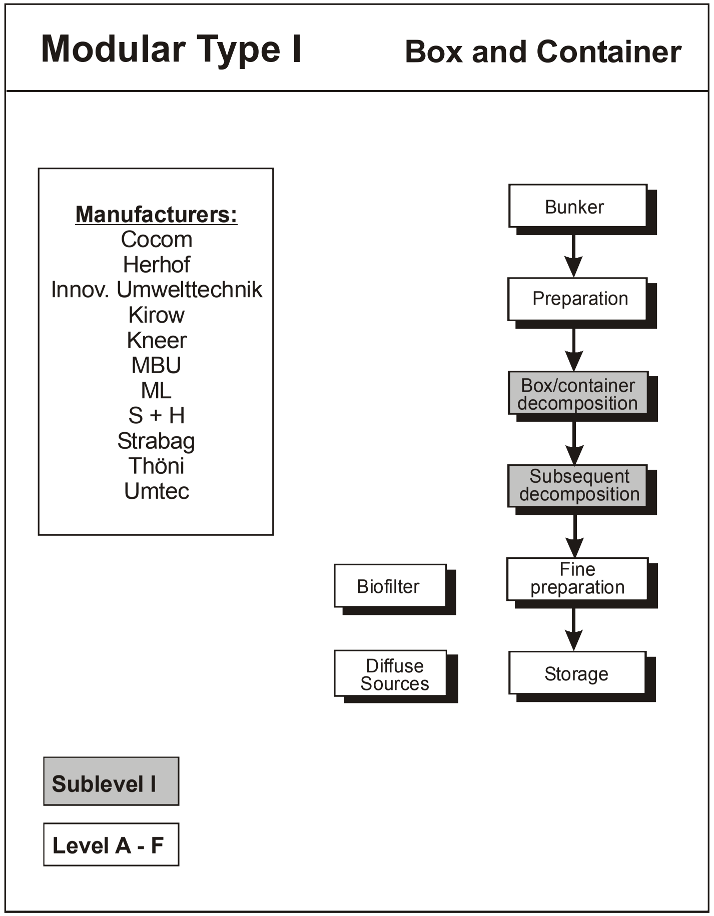
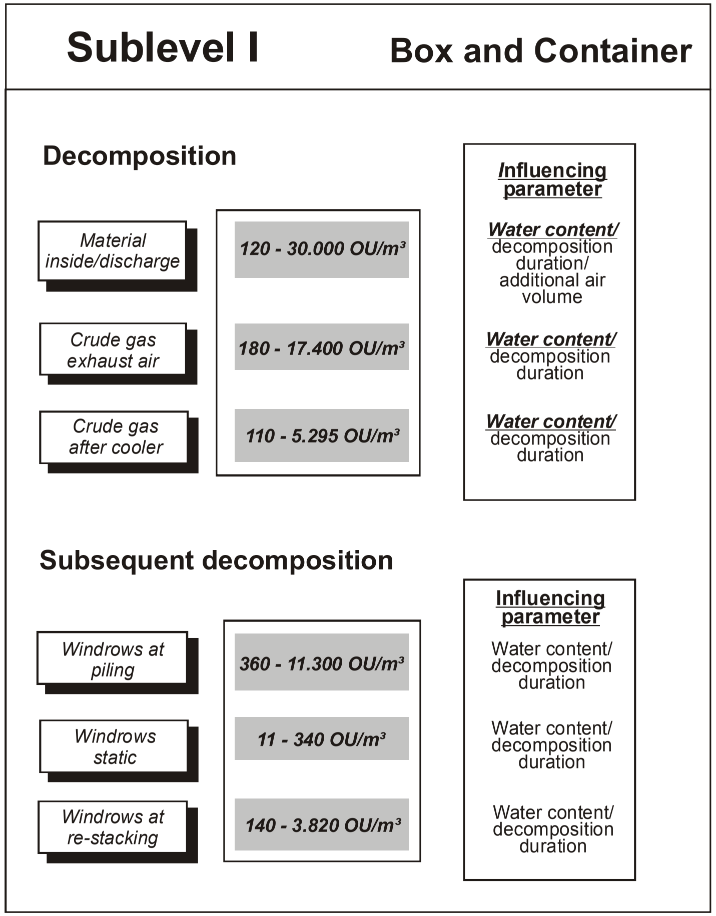
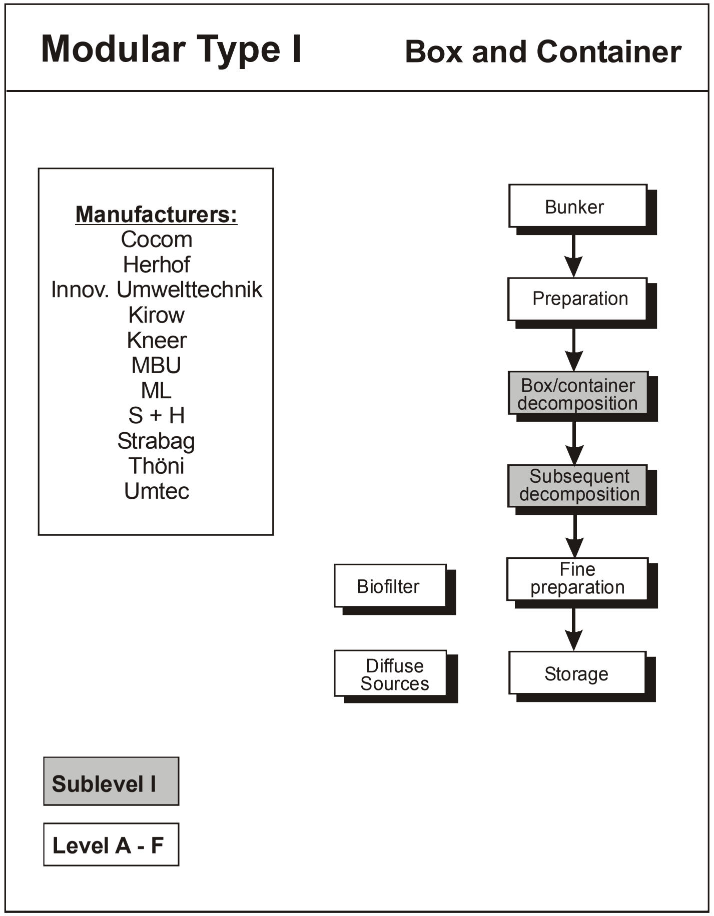
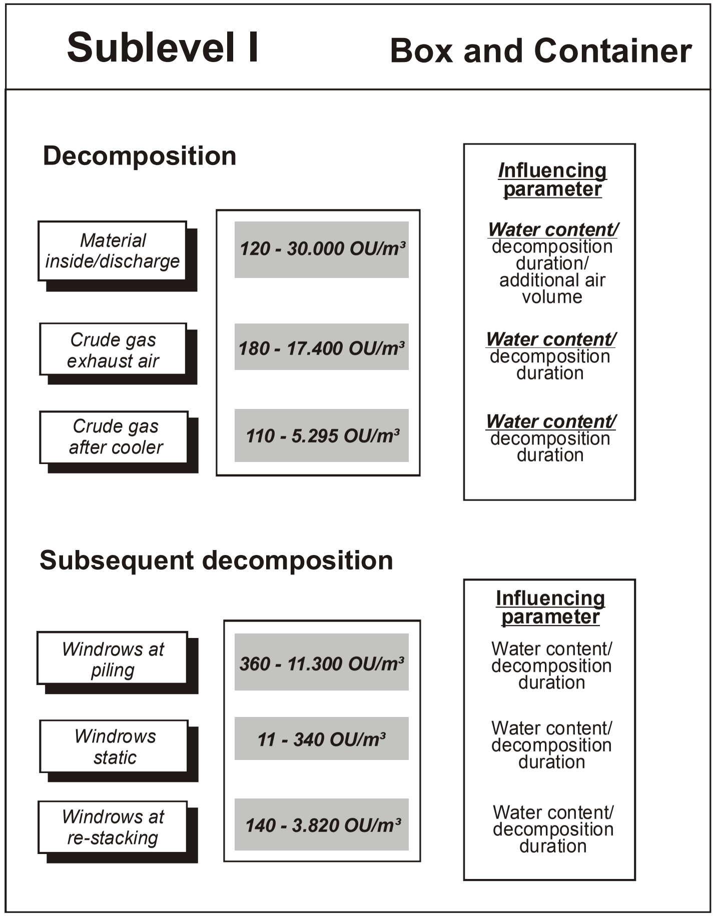
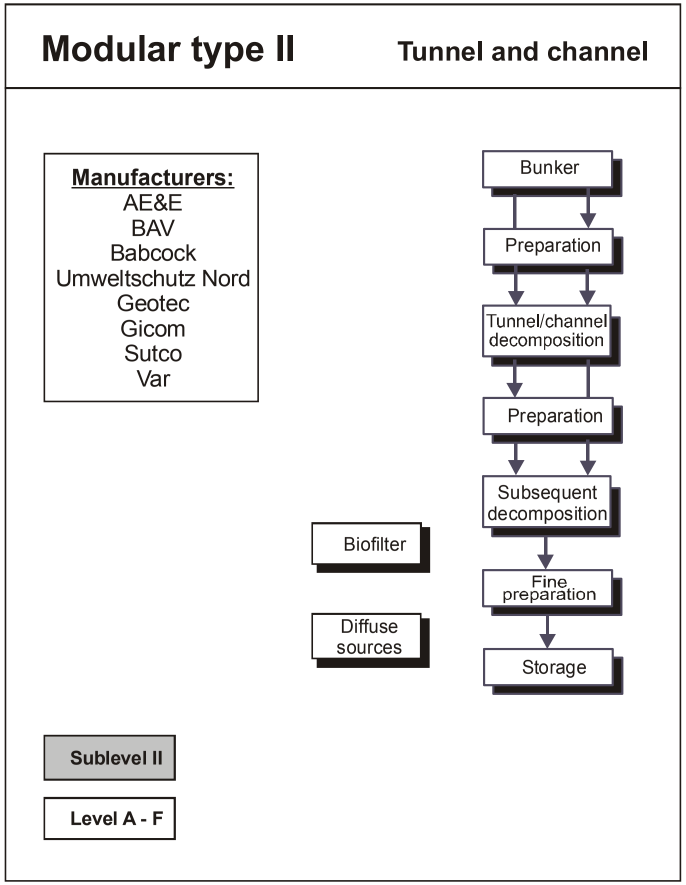
Annex A Modular Types: Dimensioning Sheets

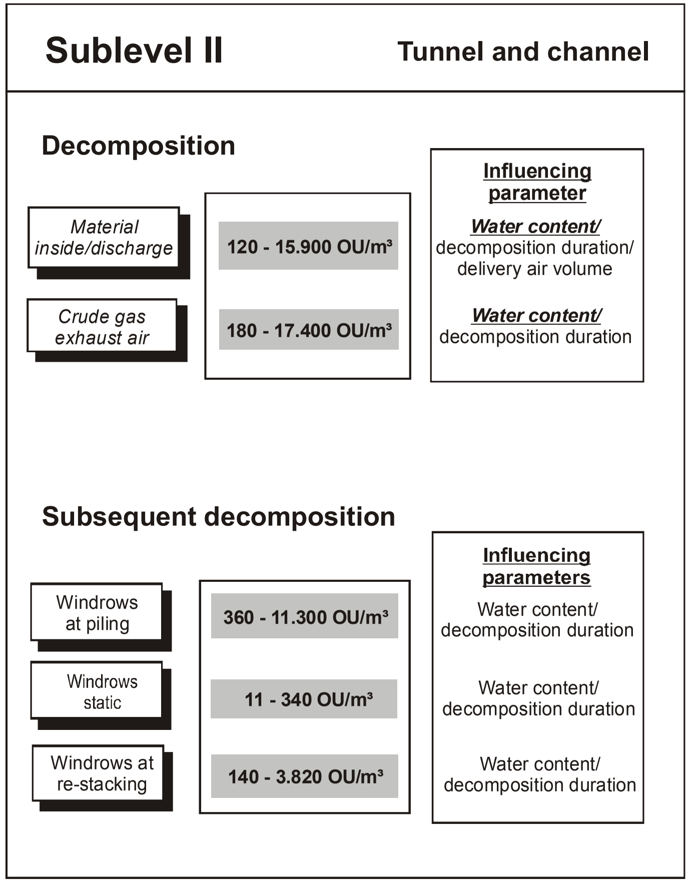

Modular Type I
Box and Container
Manufacturers:
Cocom
Herhof
Innov. Umwelttechnik
Kirow
Kneer
MBU
ML
S + H
Strabag
Thöni
Umtec
Bunker
Preparation
Box/container decomposition
Subsequent decomposition
Fine preparation
Storage
Biofilter
Diffuse Sources
Sublevel I
Level A - F


Sublevel I
Box and Container
Decomposition
Material inside/discharge
120 - 30.000 OU/m³
Crude gas exhaust air
180 - 17.400 OU/m³
Crude gas after cooler
110 - 5.295 OU/m³
Influencing parameter
Water content/ decomposition duration/ additional air volume
Water content/ decomposition duration
Water content/ decomposition duration
Subsequent decomposition
Windrows at piling
360 - 11.300 OU/m³
Windrows static
11 - 340 OU/m³
Windrows at re-stacking
140 - 3.820 OU/m³
Influencing parameter
Water content/ decomposition duration
Water content/ decomposition duration
Water content/ decomposition duration


Modular Type I
Box and Container
Manufacturers:
Cocom
Herhof
Innov. Umwelttechnik
Kirow
Kneer
MBU
ML
S + H
Strabag
Thöni
Umtec
Bunker
Preparation
Box/container decomposition
Subsequent decomposition
Fine preparation
Storage
Biofilter
Diffuse Sources
Sublevel I
Level A - F


Sublevel I
Box and Container
Decomposition
Material inside/discharge
Crude gas exhaust air
Crude gas after cooler
120 - 30.000 OU/m³
180 - 17.400 OU/m³
110 - 5.295 OU/m³
Influencing parameter
Water content/ decomposition duration/ additional air volume
Water content/ decomposition duration
Water content/ decomposition duration
Subsequent decomposition
Windrows at piling
Windrows static
Windrows at re-stacking
360 - 11.300 OU/m³
11 - 340 OU/m³
140 - 3.820 OU/m³
Influencing parameter
Water content/ decomposition duration
Water content/ decomposition duration
Water content/ decomposition duration


Modular type II
Tunnel and channel
Manufacturers:
AE&E
BAV
Babcock
Umweltschutz Nord
Geotec
Gicom
Sutco
Var
Bunker
Preparation
Tunnel/channel decomposition
Preparation
Subsequent decomposition
Fine preparation
Storage
Biofilter
Diffuse sources
Sublevel II
Level A - F


Sublevel II
Tunnel and channel
Decomposition
Material inside/discharge
Crude gas exhaust air
120 - 15.900 OU/m³
180 - 17.400 OU/m³
Influencing parameter
Water content/ decomposition duration/ delivery air volume
Water content/ decomposition duration
Subsequent decomposition
Windrows at piling
Windrows static
Windrows at re-stacking
360 - 11.300 OU/m³
11 - 340 OU/m³
140 - 3.820 OU/m³
Influencing parameters
Water content/ decomposition duration
Water content/ decomposition duration
Water content/ decomposition duration

Sublevel II — Parameter | Tunnel and Channel — Decomposition

Water content

The higher the water content the higher the odorant concentrations;
Material surface:
WC 30 - 40 %: 120 - 1.220 OU/m³,
WC 40 - 50 %: 2.740 OU/m³,
WC 50 - 60 %: 11.300 - 15.900 OU/m³.
Crude gas: after 7 d humid, minimum delivery air: 15.940 - 30.000 OU/m³,
1 - 7 d, dry: 10.100 - 176 OU/m³

Decomposition duration

Decomposition duration in the reactor;
at optimal WC decrease the concentrations;
10.100 OU/m³ on the 1st day,
180 on the 7th day with dry material;
with humid material up to 30.000 OU/m³ on the 7th day

Additional air volume

Odorant concentrations in the crude gas decrease at higher delivery air volume, humid material:
5 m³/m³*h: 30.000 OU/m³;
20 m³/m³*h: 200 - 10.000 OU/m³ (7 - 1 d)

<u>Basis of calculation related to 1 m³ material:</u>
at a small plant with 6.500 Mg/a:
delivery air 5 m³/m³*h: 41 OU/(m³*s);
delivery air 20 m³/m³*h: 30 OU/(m³*s);
discharge, humid (daily quantity approx. 41 m³):
27 OU/(m³*s);
delivery air 25 m³/m³*h, 7 d, WC < 40 %: 1,4 OU/(m³*s);

Sublevel II — Parameter | Tunnel and Channel — Subsequent decomposition

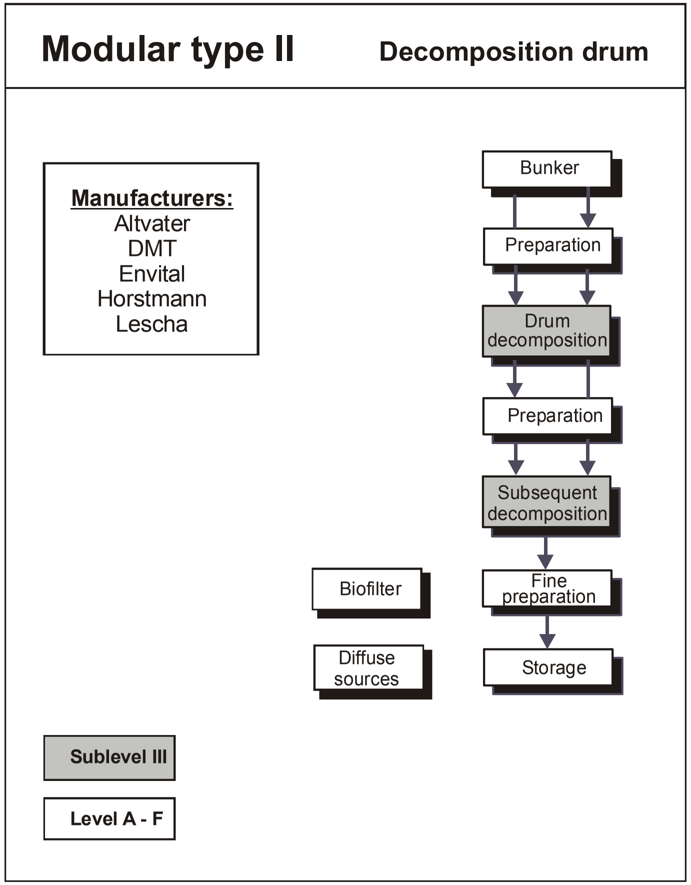
Water content

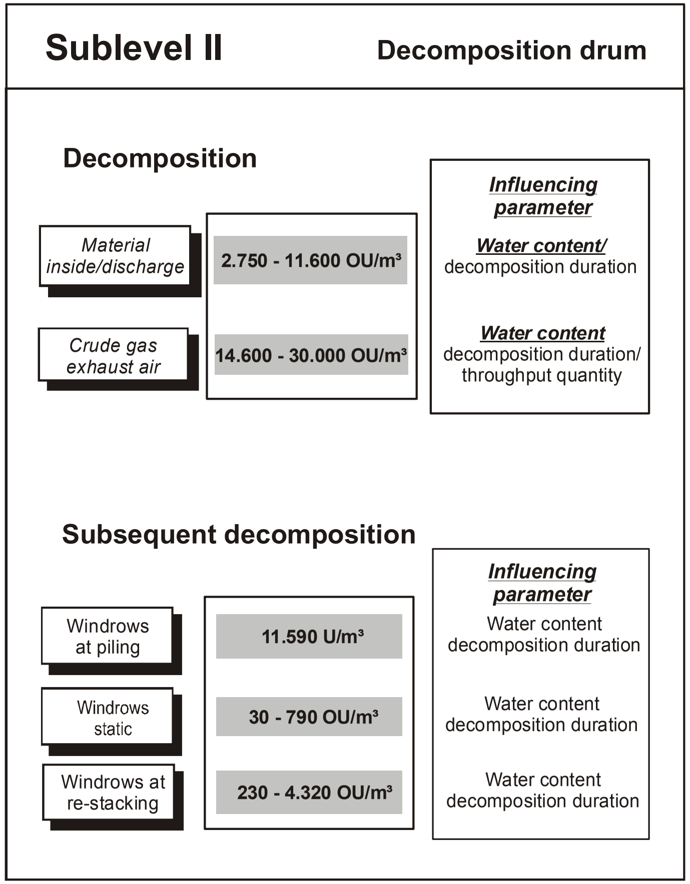
The higher the water content the higher the odorant concentrations;
<u>dry material (WC 30 - 40 %):</u>
static: 11 - 340 OU/m³
cut up: 140 - 340 OU/m³
after re-stacking: 350 - 3.820 OU/m³
at piling: 360 OU/m³
<u>humid material (WC 50 - 60 %):</u>
at piling: up to 11.300 OU/m³

Decomposition duration

<u>After 7 d in the reactor:</u>
at piling: 11.300 OU/m³;
static: 1 - 4 weeks 340 - 83 OU/m³;
5 - 9 weeks 70 - 11 OU/m³
cut up: 1 - 8 weeks 350 - 270 OU/m³;
after re-stacking:
2 - 5 weeks 3.820 - 970 OU/m³;
7 - 8 weeks 460 - 350 OU/m³

<u>Basis of calculation related to 1 m² windrow surface:</u>
fresh piled compost after 7 d reactor,
WC < 40 %: 0.6 OU/(m²*s);
WC > 40 %: 11 OU/(m²*s)
*cut up, dry windrows, unaerated, not re-stacked: max.1.6 OU/s*m²*


Modular type II
Decomposition drum
Manufacturers:
Altvater
DMT
Envital
Horstmann
Lescha
Bunker
Preparation
Drum decomposition
Preparation
Subsequent decomposition
Fine preparation
Storage
Biofilter
Diffuse sources
Sublevel III
Level A - F


Sublevel II
Decomposition drum
Decomposition
Material inside/discharge
Crude gas exhaust air
2.750 - 11.600 OU/m³
14.600 - 30.000 OU/m³
Influencing parameter
Water content/ decomposition duration
Water content decomposition duration/ throughput quantity
Subsequent decomposition
Windrows at piling
Windrows static
Windrows at re-stacking
11.590 U/m³
30 - 790 OU/m³
230 - 4.320 OU/m³
Influencing parameter
Water content decomposition duration
Water content decomposition duration
Water content decomposition duration

Sublevel III — Decomposition drum
Parameter — **Decomposition**

Water content

The higher the water content the higher the odorant concentrations;
Discharge, WC 50 - 60 %:
2.800 - 11.600 OU/m³;
Discharge WC 40 - 50 %:
2.750 - 6.900 OU/m³;
Crude gas, WC 50 - 60 %:
14.600 - 27.600 OU/m³

Decomposition duration

Decomposition duration in the drum
Discharge, 1 d: 2.800 - 9.500 OU/m³;
7 d: 11.600; 12 d: 7.100;
14 d: 2.750 - 6.900 OU/m³;
Crude gas, 1 d: 14.600 OU/m³;
4 d: 15.500; 5 d: 23.900;
6 d: 27.600 OU/m³

Throughput

Delivery quantity in the compost plant;
up to 6.500 Mg/a: 15.000 OU/m³;
8.000 Mg/a: 18.000 OU/m³;
> 25.000 Mg/a: 30.000 OU/m³

Basis of calculation related to 1 m³ material:
at a small plant with 6.500 Mg/a, 2.5 d dwell time,
delivery air 5 m³/m³*h: 21 OU/(m³*s);
at a large plant with 25.000 Mg/a, 1.5 d dwell time,
delivery air 5 m³/m³*h: 42 OU/(m³*s);

Sublevel III — Decomposition drum
Parameter — **Subsequent decomposition**

Water content

The higher the water content the higher the odorant concentrations;
dry-humid material (WC 40 - 50 %):
static: 30 - 790 OU/m³;
after re-stacking: 230 - 4.320 OU/m³;
humid material (WC 50 - 60 %):
at piling: up to 11.590 OU/m³

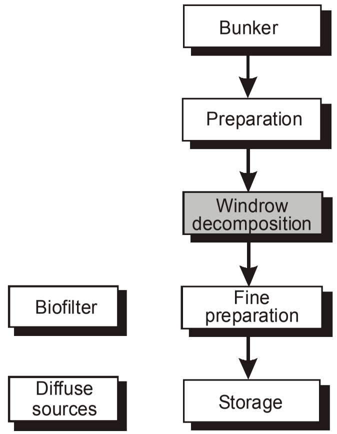
Decomposition duration

After 7 d in the drum:
at piling: 11.590 OU/m³;
static: 1 week 270 OU/m³;
2 - 3 weeks 790 - 211 OU/m³;
5 - 8 weeks 90 - 30 OU/m³;
after re-stacking:
2 - 8 weeks 4.320 - 230 OU/m³;

Basis of calculation related to 1 m² windrow surface:
cut up, dry windrows, unaerated, not re-stacked:
*maximal 1.6 OU/(m²*s);*
*static, 7 d: 0.22 OU/(m²*s); 10 d: 0,41 OU/(m²*s);*
14 d: 0.18 - 0.25 OU/(m²*s)

Modular type IV — Windrows, aerated

Manufacturers:
Backhus
Bühler
Engeler
Hutec
Koch - AE&E
Mabeg
Noell
Thyssen



Sublevel IV

Level A - F

Sublevel IV — Windrows, aerated

Decomposition, suction aerated

		Influencing parameter
Hall exhaust air	**30 - 2.240 OU/m³**	Decomposition duration/ hall occupancy/ air change number
Surface windrow	**9 - 4.300 OU/m³**	Decomposition duration/ hall occupancy
Windrow exhaust air	**363 - 20.200 OU/m³**	Decomposition duration/ hall occupancy

Decomposition, pressure aerated

		Influencing parameter
Windrows at piling	**47.730 - 56.070 OU/m³**	Water content
Windrows static	**100 - 15.440 OU/m³**	Decomposition duration
Windrows after re-stacking	**10.650 - 76.930 OU/m³**	Decomposition duration
Hall exhaust air	**1.150 - 31.200 OU/m³**	Decomposition duration/ windrow moving

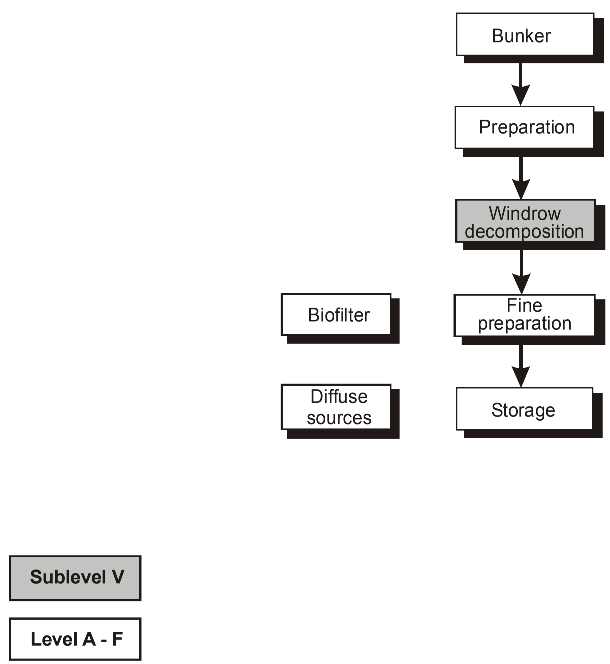
Sublevel IV Parameter	**Windrows, aerated** Decomposition, suction aerated
Decomposition duration	***Windrow surface:*** max. 10 d: 90 - 4.300 OU/m³; max. 20 d: 67 - 2.530 OU/m³; max. 30 d: 88 - 2.080 OU/m³; max. 40 d: 94 - 2.480 OU/m³; max. 50 d: 60 - 560 OU/m³; max. 65 d: 32 - 150 OU/m³
Decomposition duration/ hall occupancy	***Windrow surface:*** 6 - 8 d, 20 % hall occ.: 55 - 400 OU/m³; 9 - 22 d, 40 % hall occ.: 50 - 580 OU/m;³ 6 - 54 d, 60 % hall occ.: 27 - 560 OU/m³; 7 - 65 d, 80 % hall occ.: 110 - 4.300 OU/m³; ***Windrow exhaust air:*** 6 - 8 d, 20 % hall occ.: 3.150 - 5.400 OU/m³; 9 - 22 d: 760 - 5.570 OU/m³; 31 - 54 d: 60 % hall occ.: 363 OU/m³; 7 - 65 d, 80 % hall occ.: 640 - 20.200 OU/m³; ***Hall exhaust air:*** 6 d, 20 % hall occ.: 60 OU/m³; 9 - 22 d, 40 % hall occ.: 30 - 46 OU/m³; 6 - 54 d, 60 % hall occ.: 60 - 260 OU/m³; 7 - 65 d, 80 % hall occ.: 180 - 1.900 OU/m³
Air exchange number	***Hall exhaust air:*** air exchange number (Ae) 0.7: 1.250 - 2.240; Ae 1.0: 1.170 - 2.090 OU/m³; Ae 2.0: 580 - 1.040 OU/m³

Basis of calculation related to 1 m³ material:
hall exhaust air, suction aerated: 3 OU/(m³*s)

Sublevel IV Parameter	**Windrows, aerated** Decomposition, suction aerated
Water content	***Windrow surface, piled:*** 1 d: 47.730 - 56.070 OU/m³; ***Windrow surface, static:*** max. 7 d: 2.420 - 4.830 OU/m³; 8 - 14 d: 4.960 - 3.070 OU/m³; max. 35 d: 7.300 OU/m³; 36 - 77 d: 1.370 - 100 OU/m³; ***Windrow surface, re-stacked:*** max. 7 d: 14.600 OU/m³; max. 14 d: 19.560 - 43.910 OU/m³; max. 20 d: 76.930 OU/m³; max. 28 d: 12.720 - 16.720 OU/m³; max. 35 d: 10.650 - 25.900 OU/m³;
Decomposition duration windrow moving	0 - 70 d, without re-stacking: 1.150 - 5.020 OU/m³; 0 - 70 d, with re-stacking: 22.600 - 31.200 OU/m³; 0 - 70 d, after re-stacking: 2.470 - 4.610 OU/m³;
Water content	The higher the water content, the higher the odorant concentrations;

Basis of calculation related to 1 m³ material and single air exchange rate:
hall exhaust air, pressure aerated, static 10 OU/(m³*s);
hall exhaust air, pressure aerated, re-stacked, 40 OU/(m³*s);

Modular type V — Windrows, unaerated



Sublevel V — Windrows, unaerated

Decomposition

		Influencing parameter
Windrows after piling	**3.494 - 11.590 OU/m³**	Water content
after piling, covered	**57 - 61 OU/m³**	Coverage
Windrows static	**17 - 8.210 OU/m³**	Decomposition duration/ annual season
Windrows static, covered	**63 - 3.250 OU/m³**	Decomposition duration
Windrows after re-stacking	**40 - 20.000 OU/m³**	Decomposition duration
Subsequent decomposition > 21 days	**34 - 9.170 OU/m³**	Decomposition duration
Table windrow	**160 - 48.400 OU/m³**	Decomposition duration

Sublevel IV — Windrows, unaerated

Parameter | **Decomposition**

Decomposition duration

Windrow surface, triangular windrow:
static (before re-stacking):
1 week 4.320 - 8.210 OU/m^3;
2 weeks 52 - 2.040 OU/m^3;
3 weeks 27 - 420 OU/m^3;
4 - 5 weeks 17 - 790 OU/m^3;
6 - 8 weeks 30 - 105 OU/m^3;
static, covered:
1 week 8.530 - 16.870 OU/m^3;
2 weeks 2.810 - 10.340 OU/m^3;
3 - 4 weeks 420 - 9.220 OU/m^3;
5 - 6 weeks 160 - 1.170 OU/m^3;
7 - 8 weeks 350 - 580 OU/m^3;
subsequent decomposition, static:
4 weeks 17 - 790 OU/m^3;
5 - 8 weeks 30 - 240 OU/m^3;
subsequent decomposition, re-stacked:
4 weeks 480 - 2.590 OU/m^3;
5 - 6 weeks 160 - 1.530 OU/m^3;
7 - 8 weeks 350 - 580 OU/m^3;

Windrow surface, table windrow:
1 - 2 weeks 1.900 - 48.400 OU/m^3;
3 - 7 weeks 2.130 - 9.170 OU/m^3;
11 - 14 weeks 160 - 3.740 OU/m^3

Sublevel V — Windrows, unaerated

Parameter | **Decomposition**

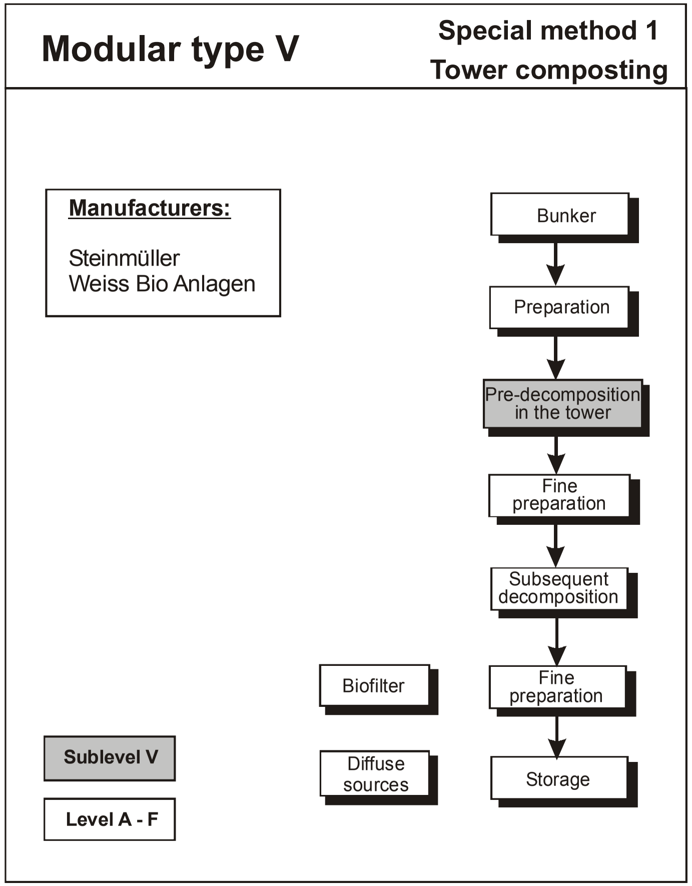
Annual season

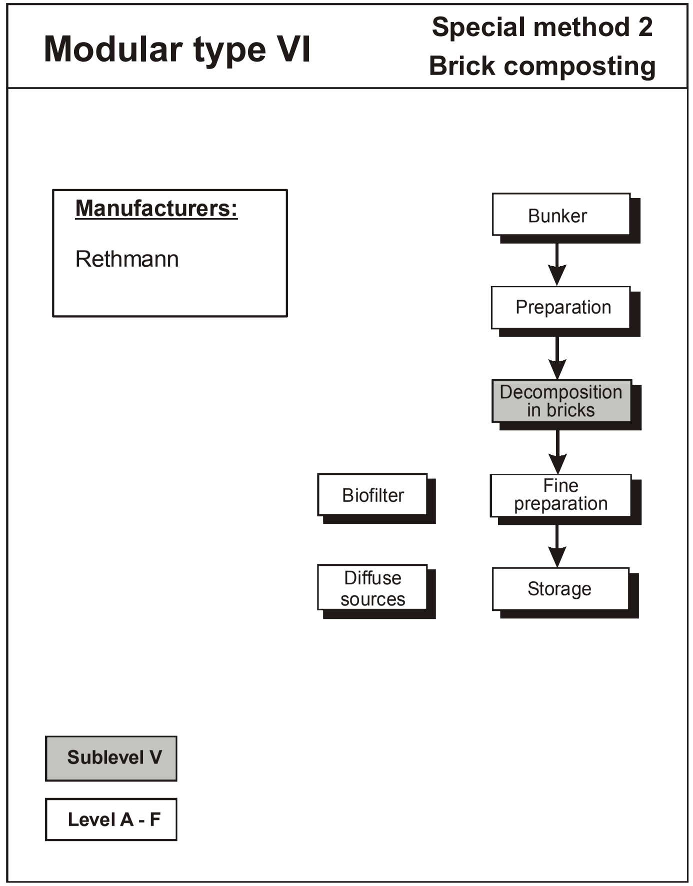
Windrow surface, triangular windrow:
summer, max. 21 d: 94 - 390 OU/m^3;
winter, max. 21 d: 3.520 - 5.590 OU/m^3

Water content

The higher the water content, the higher the odorant concentrations;

Basis of calculatiom related to 1 m^3 material:
windrow surface after re-stacking process:
7 d 10.5 $OU/(m^3*s)$; 14 d 4.8 $OU/(m^3*s)$; 3 weeks 2.5 $OU/(m^3*s)$;
4 weeks an average of just 10 % radiation after one week;
surface windrow static:
7 d 6.77 $OU/(m^3*s)$; 14 d 0.66 $OU/(m^3*s$;
3 weeks 0.16 $OU/(m^3*s)$; 9 weeks 0.06 $OU/(m^3*s)$


Modular type V
Special method 1
Tower composting
Manufacturers:
Steinmüller
Weiss Bio Anlagen
Bunker
Preparation
Pre-decomposition in the tower
Fine preparation
Subsequent decomposition
Fine preparation
Storage
Biofilter
Diffuse sources
Sublevel V
Level A - F


Modular type VI
Special method 2
Brick composting
Manufacturers:
Rethmann
Bunker
Preparation
Decomposition in bricks
Fine preparation
Storage
Biofilter
Diffuse sources
Sublevel V
Level A - F

Sublevel A — Bunker

Source	Odorant concentration	Influencing parameter
Delivery biowaste	260 - 12.300 OU/m³	Annual season/ material age/ air exchange number
Intake hall	100 - 800 OU/m³	Air exchange number
Flat bunker biowaste	1.000 - 8.500 OU/m³	Annual season/ material age/ air exchange number
Flat bunker green waste	150 - 500 OU/m³	Water content/ structure
Delivery green waste	100 - 290 OU/m³	Water content/ material age
Green waste, comminuted	500 - 1.000 OU/m³	Water content/ structure

Parameter — Bunker

Parameter	Bunker
Annual season	Autumn: 260 - 720, winter: 630, spring: 3.360 - 5.470 OU/m³; summer: 3.070 - >8.450 OU/m³; various compositions
Material age	Dependent on the collection frequency the longer the standing times, the higher are the odorant concentrations
Air exchange number	Intake hall 100 - 300 OU/m³ at single air exchange, flat bunker biowaste with 2-fold air exchange, delivery biowaste at air exchange >1
Water content	The higher the water content, the higher the danger of anaerobic nests with increased odorant concentrations
Structure	The coarser the structure, the better the oxygen supply and the lower the odorant concentrations

Basis of calculation related to 1 m³ material:
small plants 6.500 Mg/a: 8.5 OU/(m ³*s), max. 17
large plants 25.000 Mg/a: 3.4 OU/(m³*s), max. 9.8

Sublevel B — Preparation

		Influencing parameter
Preparation hall	**200 - 500 OU/m³**	Encapsulation of the units
Comminution	**200 - 3.000 OU/m³**	Water content/ structure
Mixing/ homogenization	**2.810 - 9.480 OU/m³**	Water content
Screening	**250 - 2.900 OU/m³**	Water content
Visual control/ sorting	**50 - 840 OU/m³**	Water content
Surface radiation	**57 - 9.480 OU/m³**	Water content/ coverage/ aeration

Parameter — Preparation

Encapsulation of the units	When all preparation units are encapsulated plus an air exchange number of at least 0.5 < 200 OU/m³ can be assumed in the hall
Water content	The higher the water content, the higher the danger of anaerobic nests and increased odorant concentrations
Structure	The coarser the structure, the better the oxygen supply and the lower the odorant concentrations
Aeration/ coverage	Fresh prepared material, unaerated, covered: 57 - 2.310 OU/m³; not covered: 1.210 - 6.420 OU/m³; fresh prepared material, aerated, not covered: 6.410 - 9.480 OU/m³;

Basis of calculation related to 1 m³ material:
small plants 6.500 Mg/a: 10 OU/(m ³*s), max. 19
large plants 25.000 Mg/a: 3.8 OU/(m³*s), max. 7.2
(samples taken at the surface of the prepared material, directly after preparation)
related to 1 m² surface: 4.12 OU/(m²*s) mean value

Sublevel C — Fine preparation

		Influencing parameter
Hall air	323 - 1.773 OU/m³	Decomposition process/ water content
Wheel loader operation	1.367-2.580 OU/m³	Decomposition process/ water content
Comminution	395 OU/m³	Water content
Screening	200 - 1.200 OU/m³	Water content/ encaspulation of the units
Bagging	300 OU/m³	Water content

Sublevel D — Storage

		Influencing parameter
Static storage windrow	16 - 310 OU/m³	Water content/ decomposition process/ decomposition duration
Cut up storage windrow	20 - 1.200 OU/m³	Water content/ decomposition process/ decomposition duration

Parameter — Fine preparation

Encapsulation of the units	By encapsulation of the screen unit a hall air load of < 50 OU/m³ of a screening station can be assumed, dependent on the air exchange rate.
Decomposition process	An optimal decomposition process (optimal water content, no anaerobic parts) can realize a surface radiation of the compost of < 500 OU/m³; a not optimal decomposition has hall air values of 1.773 OU/m³ without and up to 2.580 OU/m³ with wheel loader operation.
Water content	A high water content is proof for a not optimal decomposition process; thus the values of the decomposition process are valid.

Parameter	Storage
Decomposition process and duration	At an optimal decomposition process (optimal water content, no anaerobics, decomposition degree **III**) a mean value of 80 OU/m³ is reached in static storage windrows; cut up windrows reach a mean value of 250 OU/m³; a not optimal decomposition reaches up to 1.200 OU/m³.
Water content	A high WC is proof for a not optimal decomposition process; thus the values of the decomposition process are valid.

Basis of calculation related to 1 m³ material:
static storage windrows:
small plants 6.500 Mg/a: 0.17 OU/(m ³*s), max. 0.42;
large plants 25.000 Mg/a: 0.07 OU/(m³*s), max.0.18;
the values rise by the factor 3.1, maximal by 5.5 at cut up windrows

Sublevel E — Biofilter

Crude gas

Clean gas

129 - 2.000 OU/m³

16 - 250 OU/m³

Influencing parameter

Plant operation

Maintenance/ operation

Sublevel F — Diffuse sources

Traffic areas

20 - 200 OU/m³

Influencing parameter

Soiling

Parameter — Biofilter

Operation maintenance

Efficiency of 85 to 95 % can be achieved with a proper operation of the plant and a continuous controlling of the filters

Basis of computation related to 1 m² surface:
inherent_smelling of the biofilter

Parameters — Diffuse sources

Soiling

The degree of soiling on the traffic routes increases the portion of diffuse odorant concentrations outside the buildings.

Additional safety charge of 10 % of the definite emissions for diffuse sources

Annex B Immission Prognosis for 20.000 Mg/a and 25.000 Mg/a

Exceeding frequency in % in relation to 3 OU/m³ - scale 1:8500

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

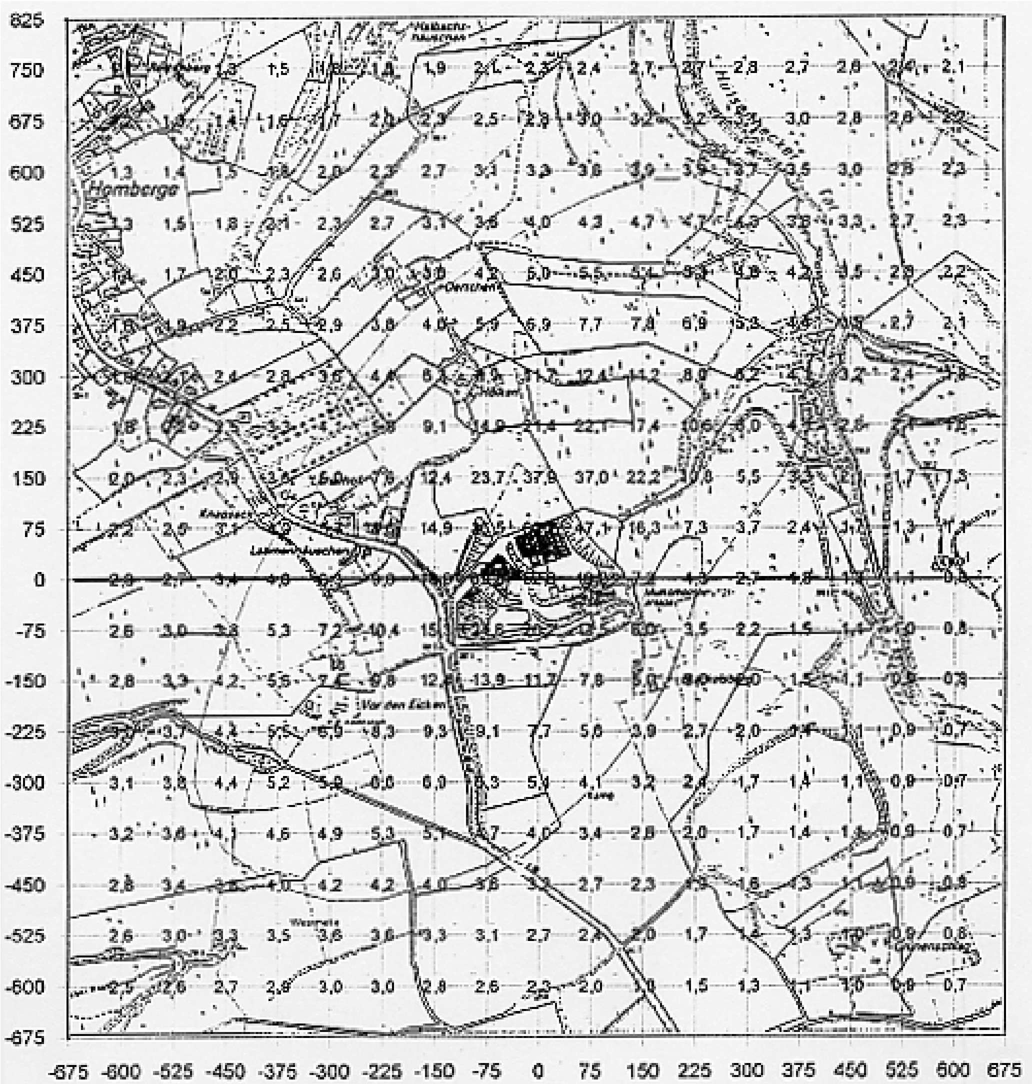


Figure B-1: Immission prognosis of the actual situation (20.000 Mg/a), dispersion category statistic

Exceeding frequency in % in relation to 1 OU/m³ - scale 1:8500

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

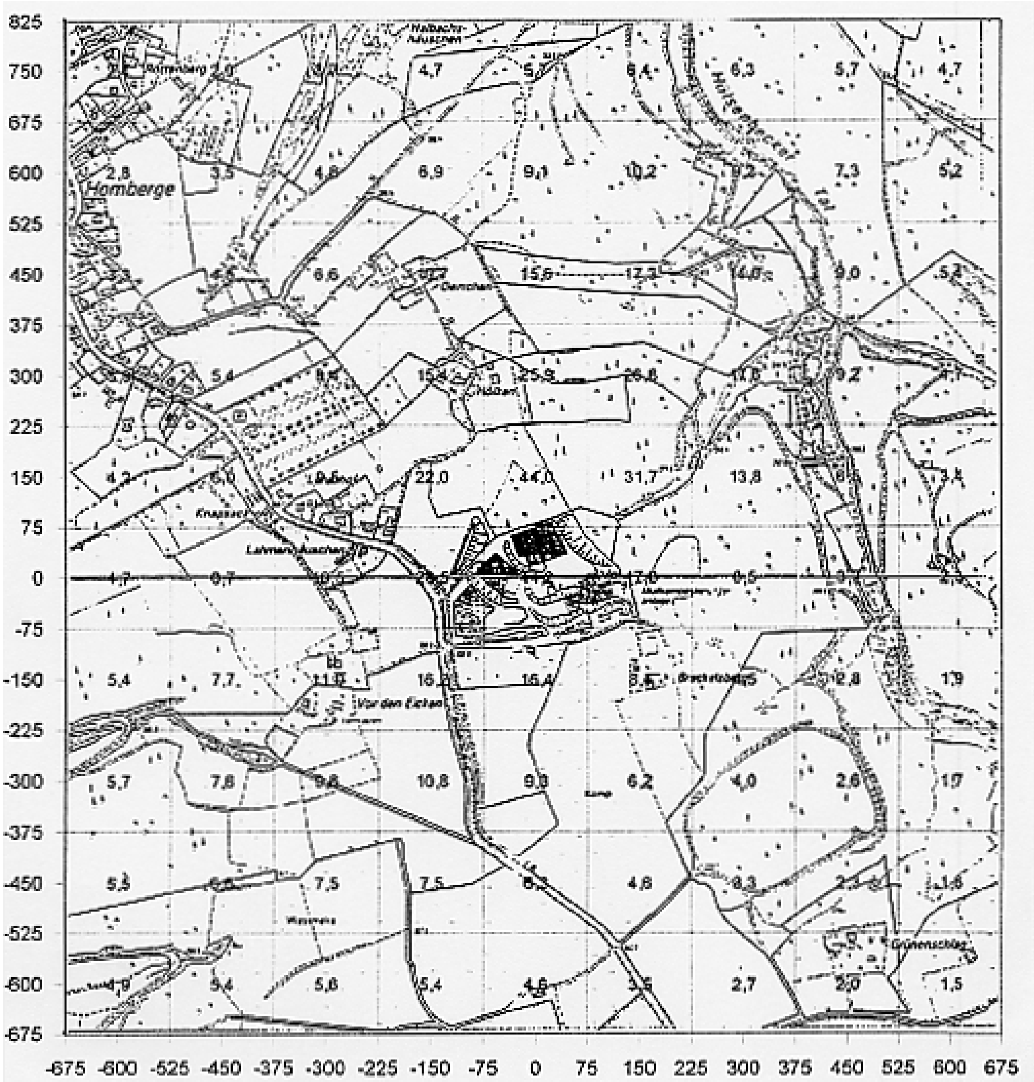


Figure B-2: Immission prognosis of the actual situation (20.000 Mg/a), according to GIR

Exceeding frequency in % in relation to 3 OU/m³ - scale 1:8500

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

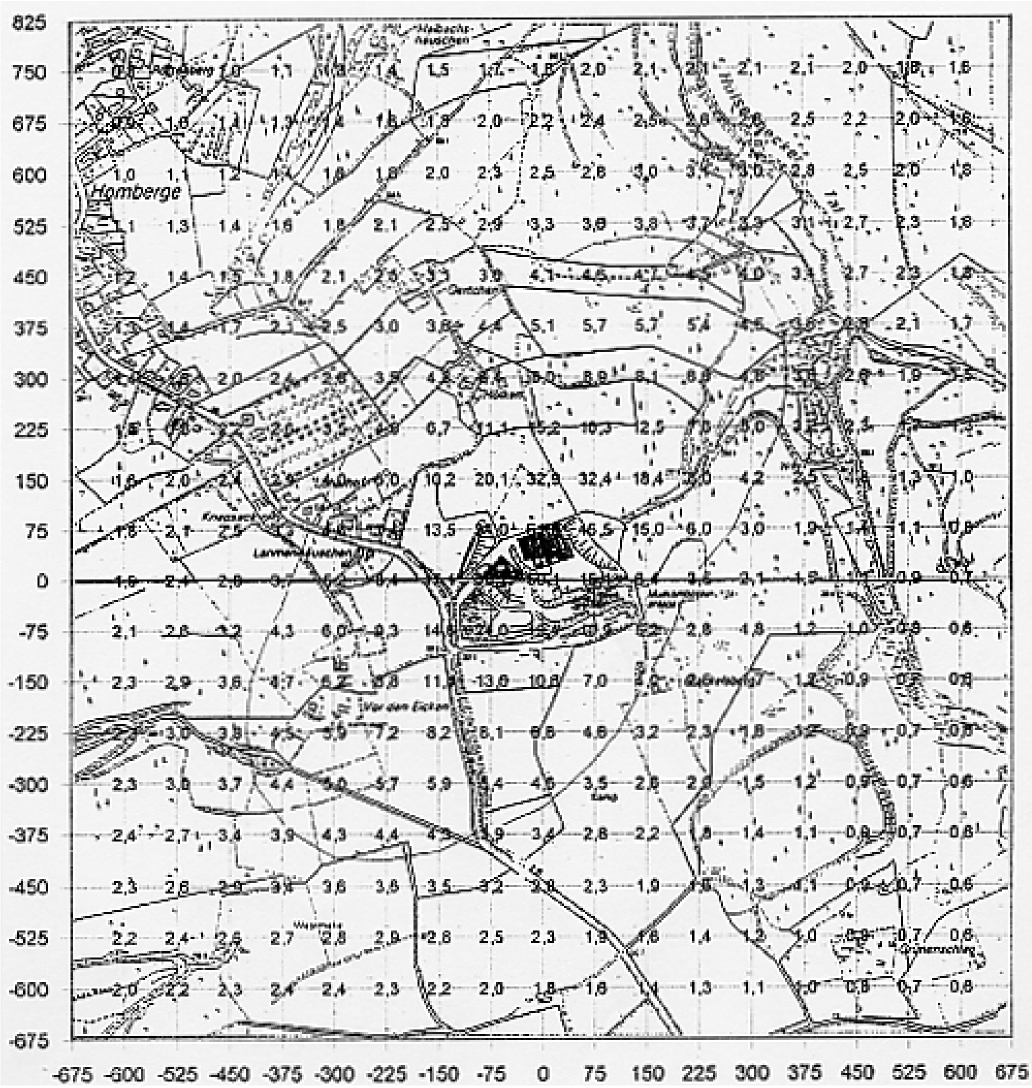


Figure B-3: Immission prognosis of the scenario I (20.000 Mg/a), dispersion category statistic

Exceeding frequency in % in relation to 1 OU/m³ - scale 1:8500

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

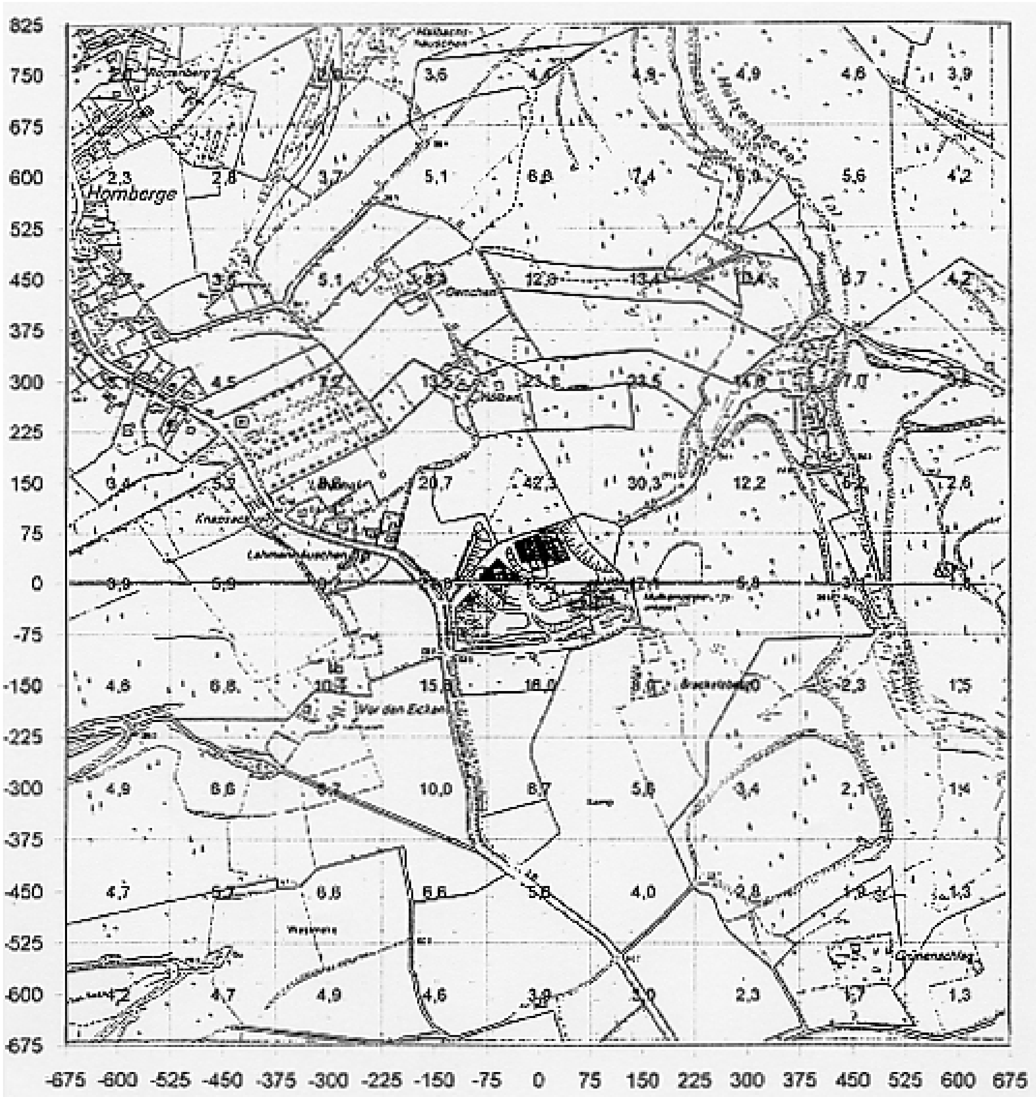


Figure B-4: Immission prognosis of the scenario I (20.000 Mg/a), according to GIR

Exceeding frequency in % in relation to 3 OU/m³ - scale 1:8500

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

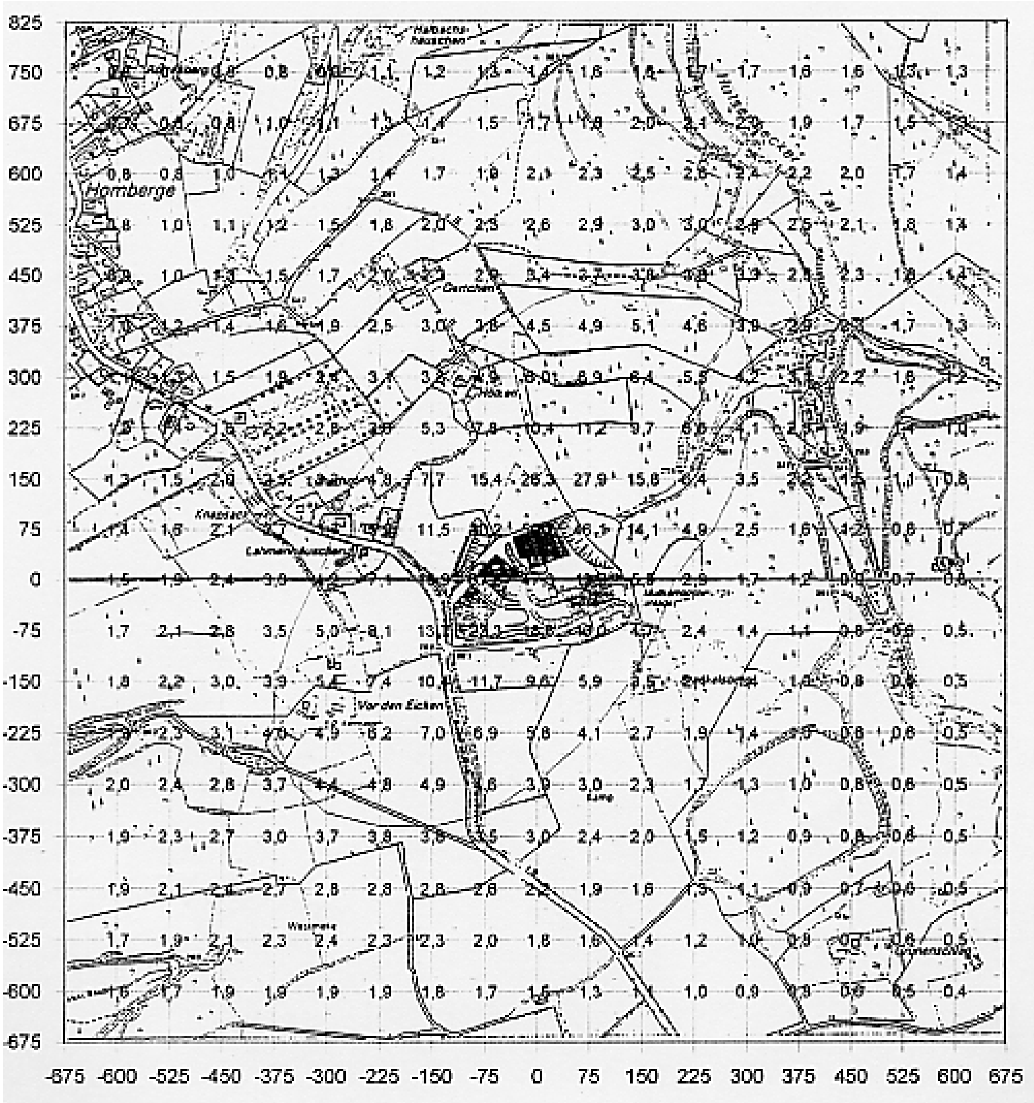


Figure B-5: Immission prognosis of the scenario II (20.000 Mg/a), dispersion category statistic

Exceeding frequency in % in relation to 1 OU/m³ - scale 1:8500

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

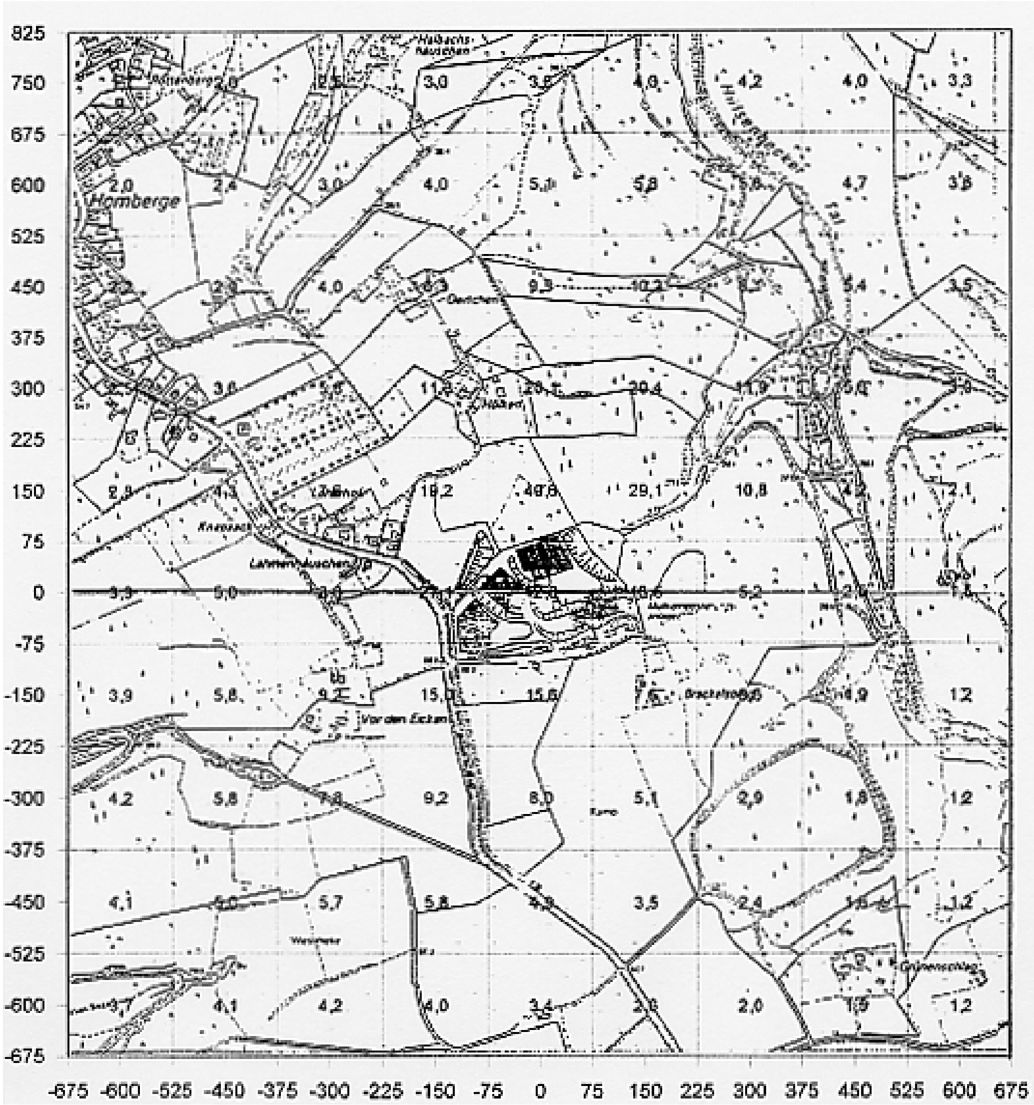


Figure B-6: Immission prognosis of the scenario II (20.000 Mg/a), according to GIR

Exceeding frequency in % in relation to 3 OU/m³ - scale 1:8500

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

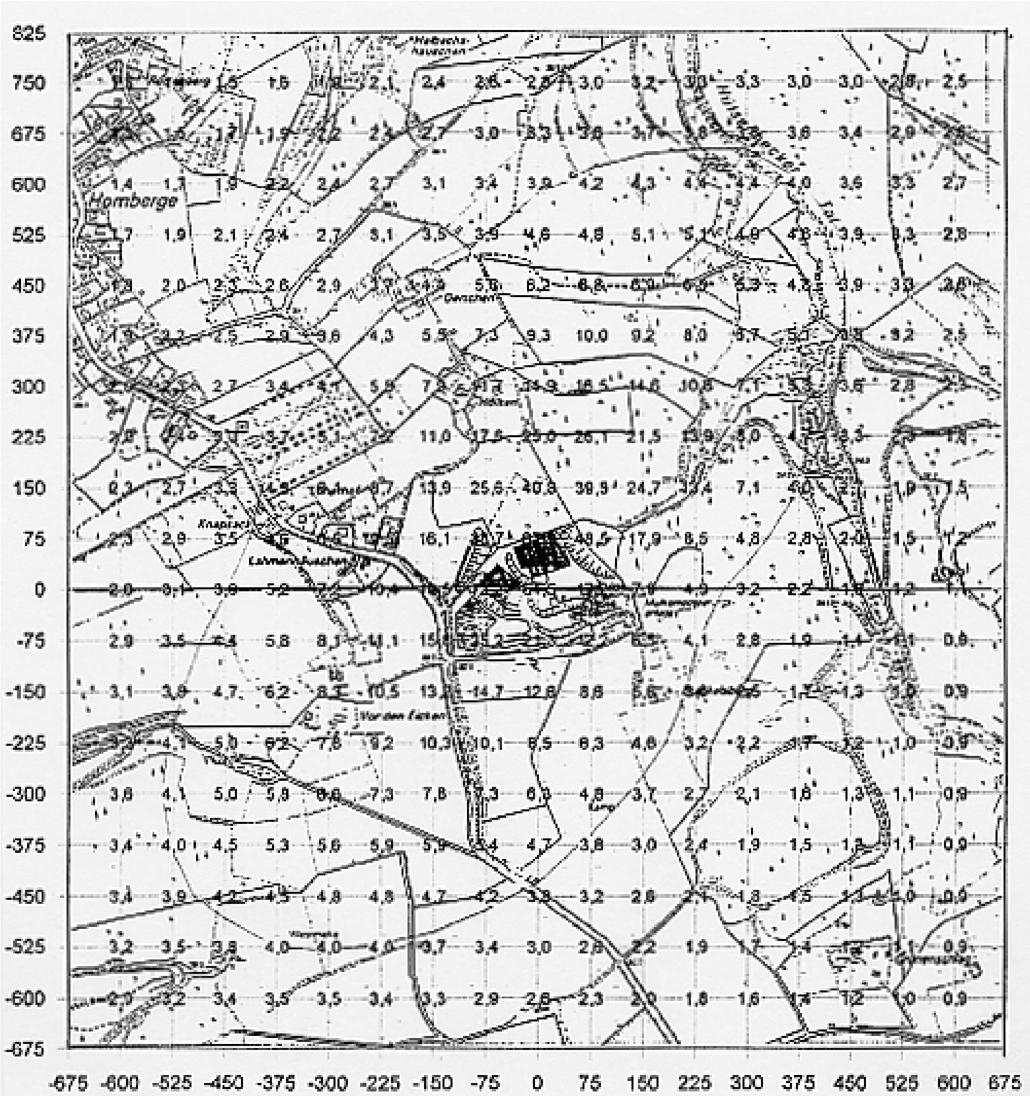


Figure C-1: Immission prognosis of the actual situation (25.000 Mg/a), dispersion category statistic

Exceeding frequency in % in relation to 1 OU/m³ - scale 1:8500

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

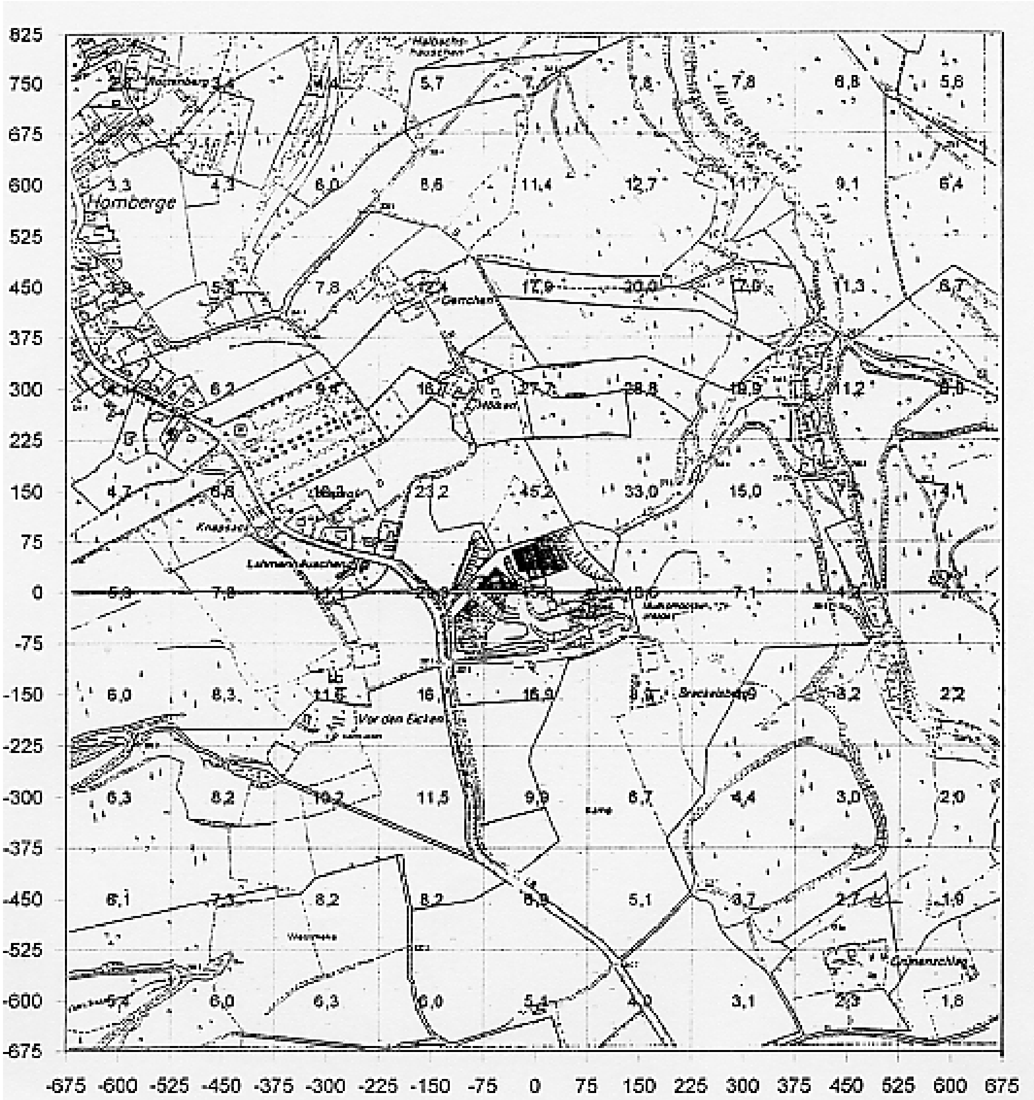


Figure C-2: Immission prognosis of the actual situation (25.000 Mg/a), according to GIR

Exceeding frequency in % in relation to 3 OU/m³ - scale 1:8500

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

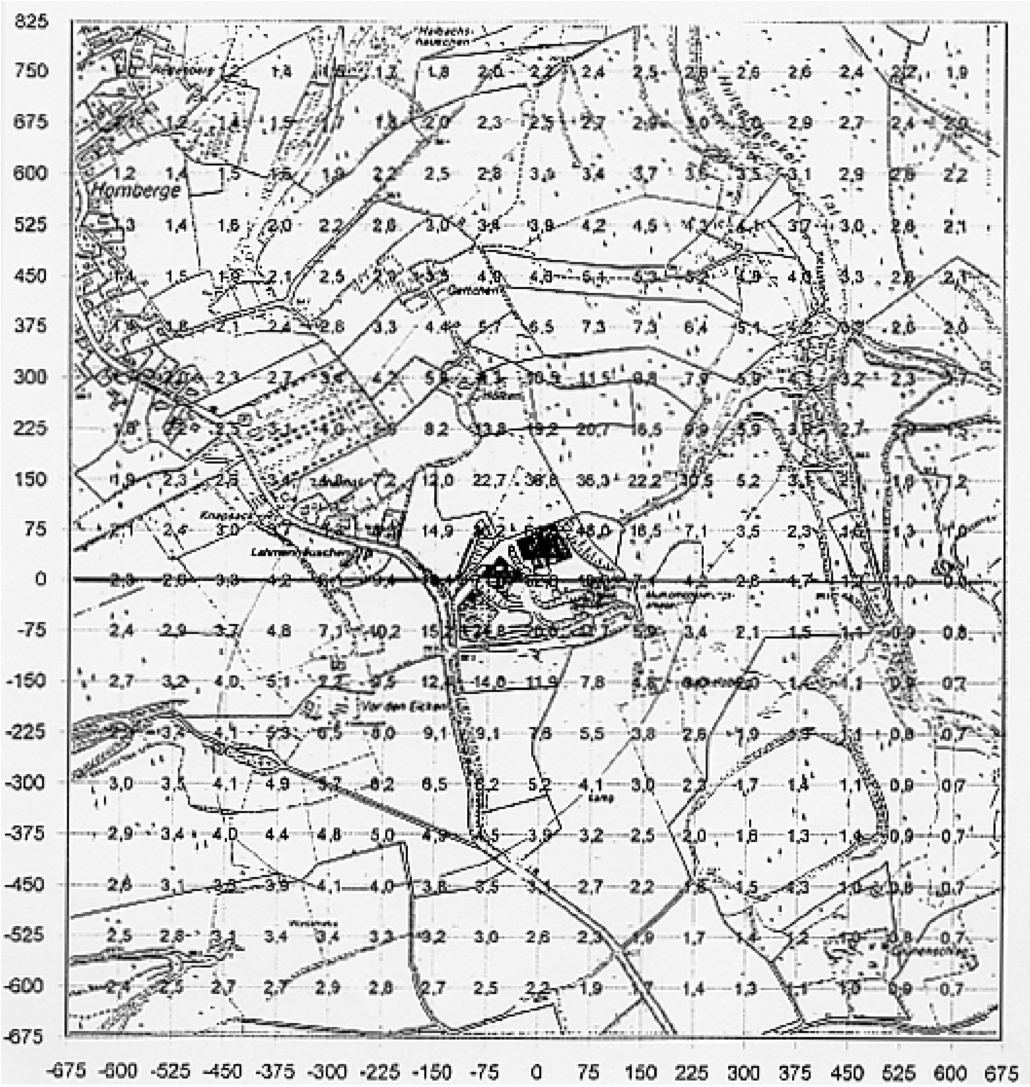


Figure C-3: Immission prognosis of the scenario I (25.000 Mg/a), dispersion category statistic

Exceeding frequency in % in relation to 1 OU/m³ - scale 1:8500

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

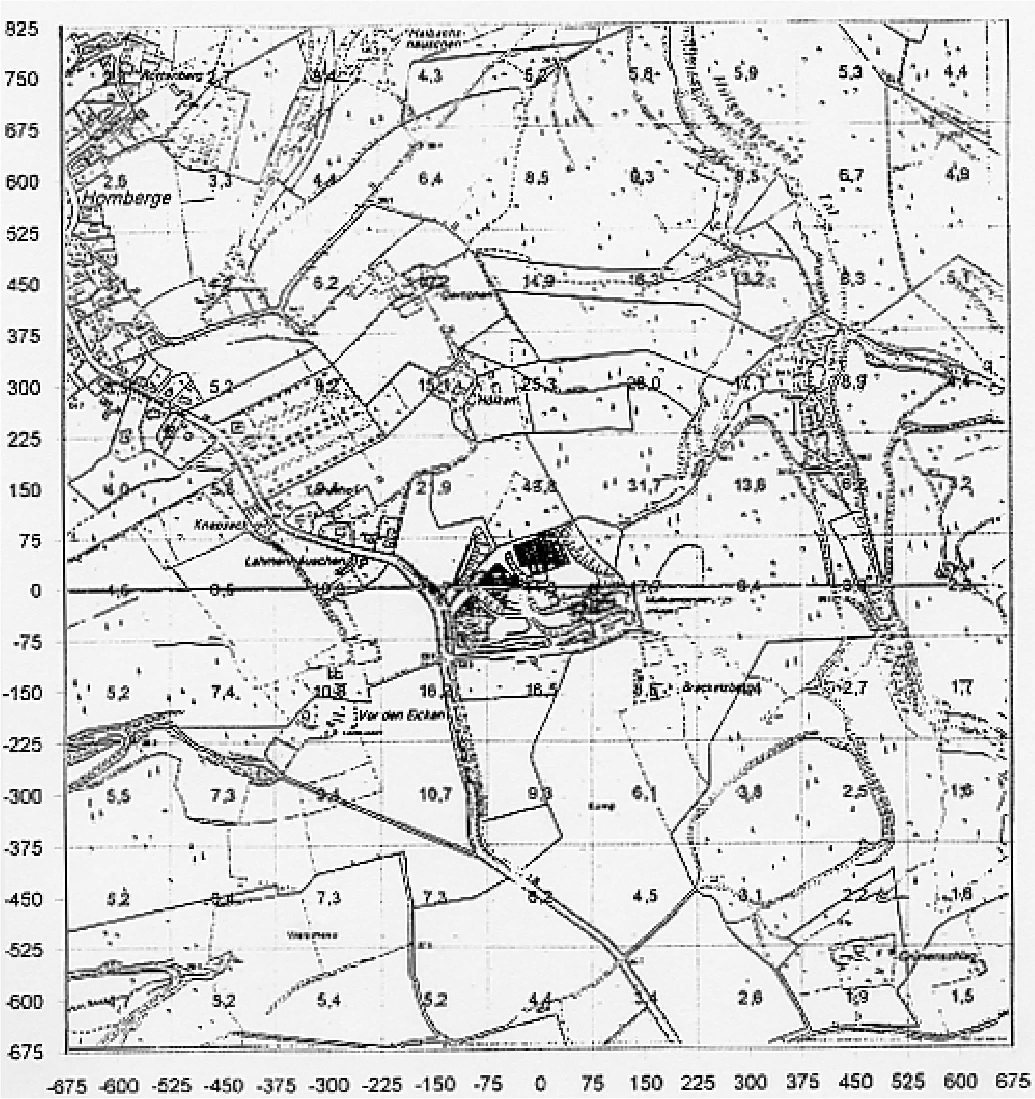


Figure C-4: Immission prognosis of the scenario I (25.000 Mg/a), according to GIR

Exceeding frequency in % in relation to 3 OU/m³ - scale 1:8500

The numbers in the map describe the exceeding frequency in % at the location of emission in the intersecting points of the screen lines with a spacing of 75 m.

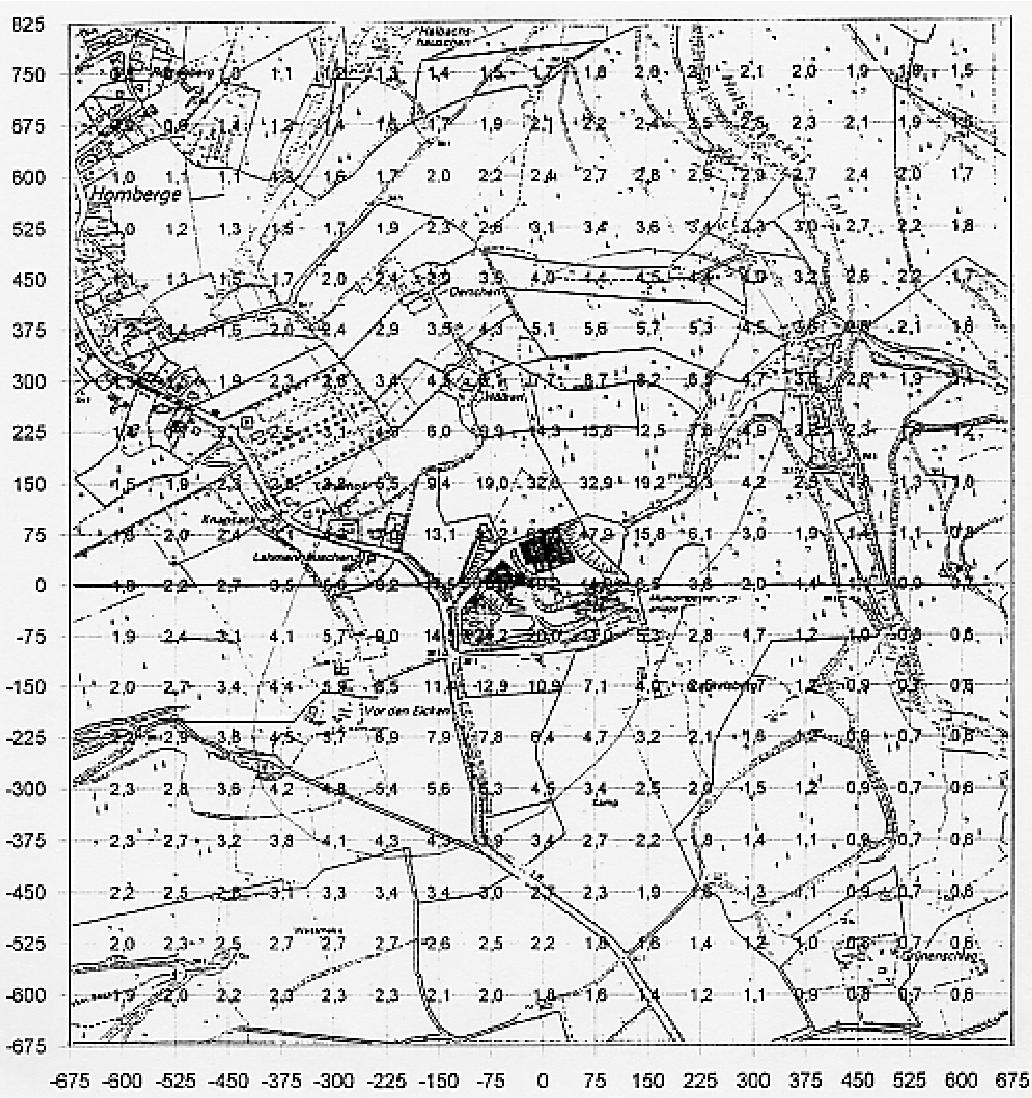


Figure C-5: Immission prognosis of the scenario II (25.000 Mg/a), dispersion category statistic

Exceeding frequency in % in relation to 1 OU/m³ - scale 1:8500

The numbers in the map describe the area values within the assessment area according to GIR (here 150 m border length).

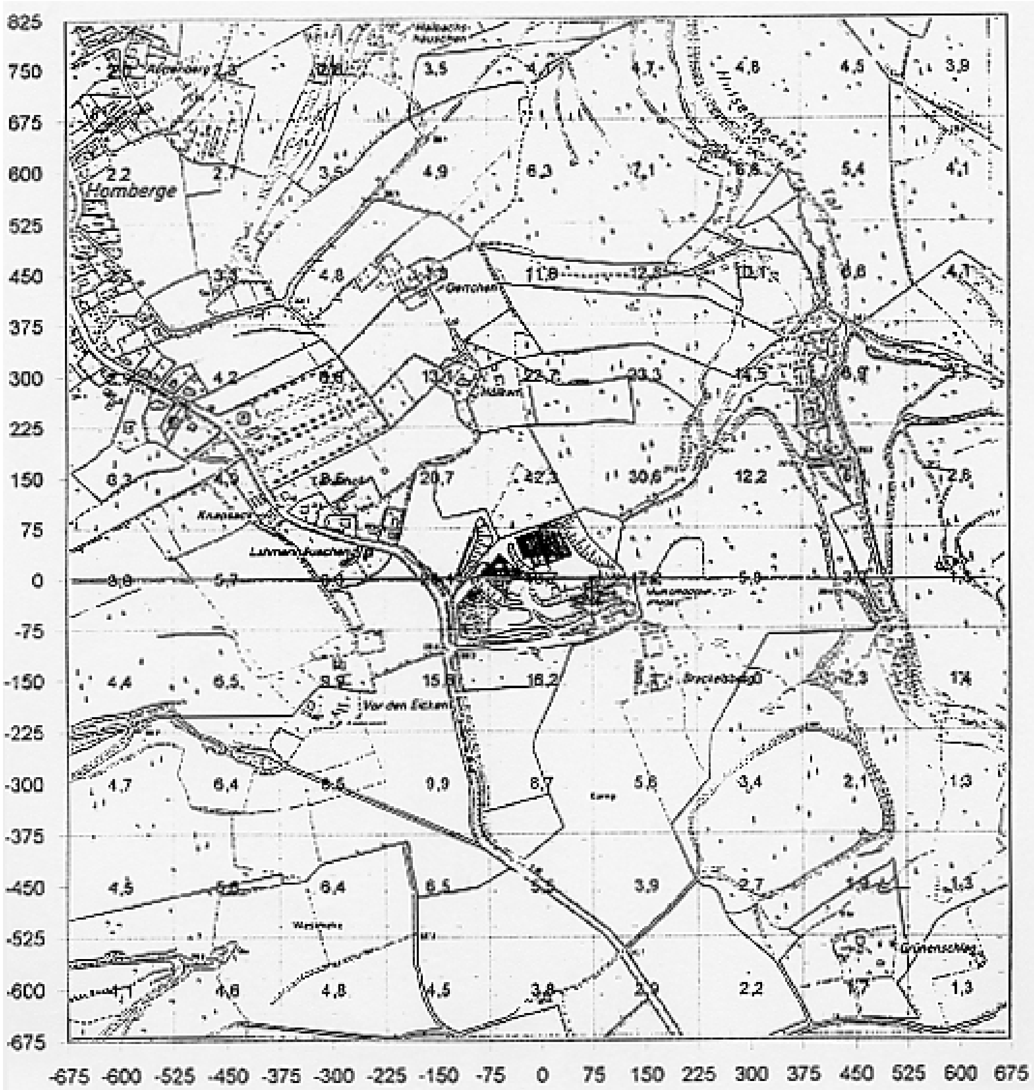


Figure C-6: Immission prognosis of the scenario II (25.000 Mg/a), according to GIR