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EFFLUENT QUALITY AFTER SLUDGE FERMANTATION

Up to now, the anaerobic treatment of biowaste has been of little importance in comparison to composting. In the last few years, however, this technique has won an increasing acclaim, which is apparent from the yearly increase in the number of plants being built. When compared with composting, the advantages, especially in the control of odours and the energy output, can be seen. However, our understanding of the technical procedure and processes, particularly of the problems of process water, is relatively small and leaves much to be desired. In the scope of a project, the Institute for Waste and Wastewater Management, sponsored by the Oswald–Schulze-Foundation, works on basic information about the composition of the process water and the extent of process water purification and what this cost is being estimated. The results obtained so far prove that the composition of wastewater tested is similar to wastewater after leaching. A particularly high chemical oxygen demand (COD) and high nitrogen and phosphorous concentrations dependent on the type of waste added may be observed. Based on the results obtained it may be concluded that the extent of wastewater purification depends on the conditions of water discharge. The required COD-reduction and the elimination of nutrients are important when constructing a wastewater purification plant.

1. INTRODUCTION

In Germany, in the future, about 80–90 kg of biowaste per capita per annum will pass through our biocontainers. We can also expect an extra biowaste (20–40 kg per capita per annum) from the municipal and small industrial plants [1]. With a population of around 80 million, this will mean a biowaste production of ca. 8–10 million Mg.

Under the conditions of the law of economic cycles (Kreislaufwirtschaftsgesetz, KrW-/AbfG, 06.10.94) recycling is given priority over any other form of waste disposal. At the moment, the aerobic treatment (composting) of biological waste is

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of prime importance. However, in the last few years, the anaerobic technique, used especially in sewage purification and in the field of agriculture as liquid manure biogas plant, has won a lot more acclaim. According to [2] there were 19 plants with a yearly capacity of around 350,000 Mg being used in the beginning of 1996 in Germany. These plants ferment industrial and household biowastes, often together with liquid manure.

Fermentation can be seen as a supplementary procedure and, if need be, as an alternative to composting; it is especially suitable for easily degradable, wet and moist substances. If this waste is going to be composted, large quantities of structural material, or greater expenditure on technical procedure for transformation and ventilation will have to be accepted, otherwise a balanced supply of oxygen in biowaste piles through forced ventilation could hardly be guaranteed. A suitable anaerobic technique is available for these substances.

One considerable advantage of the anaerobic technique is the energy does not produce heat, but is saved in the form of biogas. Because oxygen is not available during fermentation, the enzyme-controlled oxohydrogen reaction in the respiration cycle, responsible for the substratum heating, cannot occur. With biogas, which consists mainly of methane and carbon dioxide, the electric and thermal energy necessary for the fermentation process is generated.

Up to now, not much attention has been given to the wastewater which is obtained during the procedure of the anaerobic waste treatment. In earlier publications, however, successful sewage purification has been mentioned. The conception and costs of such a sewage purification have not yet been convincingly presented.

For this reason the Institute for Waste and Wastewater Management at the Polytechnic of Munster together with the Oswald–Schulze-Foundation are carrying out research into the problems of process water of biowaste fermentation.

2. BASIC LEGAL FRAMEWORK

Under German legal regulations, which apply to the treatment of sewage in anaerobic plants and its discharge into waters or a public sewage plant, we can distinguish between direct and indirect discharges.

2.1. DIRECT DISCHARGE

The respective supplements to the wastewater ordinance regulate the direct discharge and define the minimum requirements concerning the discharge of sewage into a stream of water. Since no appendix to the discharge of sewage of biological waste treatment plants exists, supplement 51 (leachate) must be referred to. In table 1, the minimum requirements of supplement 51 are implicated.

Table 1

Minimum demands for leachate
(supplement 51 of the wastewater ordinance)
and indirect discharge guiding (ATV-A 115)

Paramater [mg/dm^3]	Appendix 51	ATV-A115
BOD	20	
COD	200	
NH_4–N	50	100*; 200**
PO_4–P		50
Fluoride		50
Sulphate		600
Filtered solids	20	
AOX	0.5	1
Mercury	0.05	0.1
Cadmium	0.1	0.5
Chromium	0.5	1
Nickel	0.5	1
Lead	0.5	1
Copper	0.5	1
Zinc	2	5
Sulphide		2

* Nitrogen measured as NH_4 and NH_3 < 500 I (inhabitants).
** Nitrogen measured as NH_4 and NH_3 > 5000 I (inhabitants).

2.2. INDIRECT DISCHARGE

Since the constructors of waste fermentation plant generally intend to discharge sewage into an open sewage plant, the legal conditions of indirect discharge should be given special consideration.

In Germany, for the dangerous substances (heavy metals, AOX) the requirements, as stated in supplement 51 of the wastewater ordinance, must be adhered to.

Regulations for the use of canalisation and the wastewater purification plant can also be found in instruction A 115 of the Wastewater Technical Organisation (ATV), in which guiding figures for phosphate and ammonium are given. No details concerning the COD are given.

However, it is possible, due to the local conditions, that a reduction of COD and a limitation of e.g. the biochemical oxygen demand (BOD) value as well as the total nitrogen concentration will be fixed.

3. SEPARATE EXAMINATION

Until now concrete results of the composition of sewage in various waste fermentation plants have been presented only occasionally. Due to the random samples the meaningfulness of these results is limited [3].

Table 2

Composition of sewage in various waste fermentation plants

Parameter	Dimension	Experimental plant [3]	Working plant [3]	According to [4]
COD	g/ dm^3	3.0–23.8	8.8–28.6	7.3–28.3
BOD	g/ dm^3	0.7–10.0	1.1–2.9	1.7–7.1
COD/BOD	–	2.2–18.9	4.9–9.9	2–6
TKN	mg/ dm^3	305–1558	1729–1910	–
NH_4–N	mg/ dm^3	229–963	1390–2000	510–2600
PO_4–P	mg/ dm^3	–	101–320	–
Chloride	mg/ dm^3	308–806	938–974	–
Sulphate	mg/ dm^3	50–595	4–53	–
Lead	mg/ dm^3	0.21–1.33	0.2–0.98	0.21–1.67
Cadmium	mg/ dm^3	<0.01–0.06	<0.01–0.09	0.01–0.05
Chromium	mg/ dm^3	0.28–2.36	0.08–0.54	0.44–2.49
Copper	mg/ dm^3	0.80–4.43	0.14–3.27	1.53–4.09
Nickel	mg/ dm^3	0.09–0.98	<0.10–0.42	0.29–1.12
Mercury	mg/ dm^3	<0.005–0.024	0.004–0.007	0.01–0.03
Zinc	mg/ dm^3	2.0–38.4	5.5–45.6	3.46–12.9
AOX	mg/ dm^3	0.44–1.40	0.4–2.4	0.4–8.2

With the anaerobic treatment of solid biological waste, the production of fermentation residue containing ca. 50–60% of a dry substance content [5], [6] is striven for. Since the source materials are considerably moister and liquified for the fermentation process, a separation of the solids and liquids must be carried out at the end of the treatment. With this separation there is an accumulation of organic and inorganic process waters with a high nutrient content.

The ammount of sewage produced through fermentation is substantially determined by the following factors:

water content in source material,

drainage density of the aggregate used for solid–fluid separation,

water taken out by the extraction of disruptive fractions.

It is therefore independent of the procedure used and can vary enormously depending on waste composition.

4. EXPERIMENTAL

In order to gain supplementary data concerning the composition of process water from biowaste fermentation plants, preliminary tests under laboratory standards were carried out. The fermentation test took place in four reactors with the following basic equipment:

reactors of circa 10 dm^3 capacity (6 dm^3 of inoculum, 0.5–1.0 dm^3 of test substrate, 2–3 dm^3 of gas collecting area that also collects any foam which may be produced),

bags for collecting the biogas produced,

gas analyser for CH_4, CO_2 and H_2S,

electric heaters covering the outside of the reactor.

The tests were carried out on two different types of waste (biowaste from the separate collection and industrial kitchen waste).

Table 3

Analysis results of mesophilic laboratory tests

Parameter	Biowaste [mg/dm³]	Kitchen waste [mg/dm³]
COD_{filtr}	2900–6400	2800–12400
$N_{total\ filtr}$	640–1140	1300–1600
NH_4–N_{filtr}	500–1070	1170–1470
P_{filtr}	49–51	36–38
Cu	2.9	1.3
Zn	0.9	0.4

Sewage compositions, similar to those reported in literature, were measured in particular for the nitrogen and phosphorus contents. The content of copper and zinc was lower than the quote given in [3]. Here we can certainly stress that because of the lack of circulation of the process water, no accumulation took place. Therefore, continuous tests with regard to the problems of heavy metals in particular were urgently needed.

For this reason, single-stage wet fermentation processes are presently running in a semi-technical plant consisting of four reactors, each with a 100 dm^3 capacity.

The reactors are almost continually loaded and the ferment residue produced is drained off using a draining aggregate (centrifuge). The centrifugate is, according to the test phase, cycled in varying amounts by adding to the process in order to mash up the substratum for the fermentation. The reactors are loaded with biowaste delivered at compost plants, or with industrial kitchen waste. The ferment substratum remains in the reactors for at least three weeks. The treatment period of up to 20 days, which is normal in technical plants, is thus ensured.

Table 4

Test programme for a semi-technical test

No. of reactor	Type of waste	Temperature of process
1	biowaste from separate collection	mesophilic
2	waste from industrial kitchen	mesophilic
3	biowaste from separate collection	thermophilic
4	waste from industrial kitchen	thermophilic

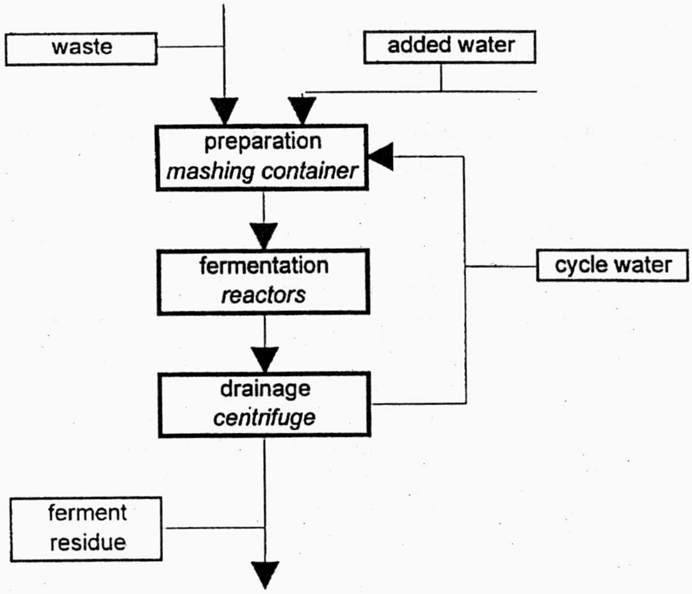


Fig. 1. Block circuit diagram of the semi-technical tests

The results (figure 2) show that both bio- and kitchen wastes in the thermophilic reactors have considerably higher carbon and nutrient concentrations in the process water in comparison to those in the mesophilic reactors. This indicates a better substance turnover during the hydrolyzing phase in the thermophilic processes. With regard to the treatment of effluent this may mean that sewage purification in the thermophilic ferment plants will be more expensive than in the mesophilic ones.

Nitrogen and phosphorus concentrations in the process water are substantially higher in mesophilic and thermophilic kitchen waste reactors than in biowaste reactors. The nitrogen contents during the kitchen waste fermentation are roughly similar to BOD levels. This means that in fermentation processes with a large share of kitchen waste rich in protein, the reduction of total nitrogen concentration in the sewage by biological methods (nitrification and denitrification) will only be possible to a limited extent without the addition of external carbon sources. If the external carbon (e.g. methanol) is not added, other methods (e.g. stripping) will have to be used. Should the Local Authority only require that the ammonium nitrogen content must be reduced, a biological sewage treatment will probably suffice.

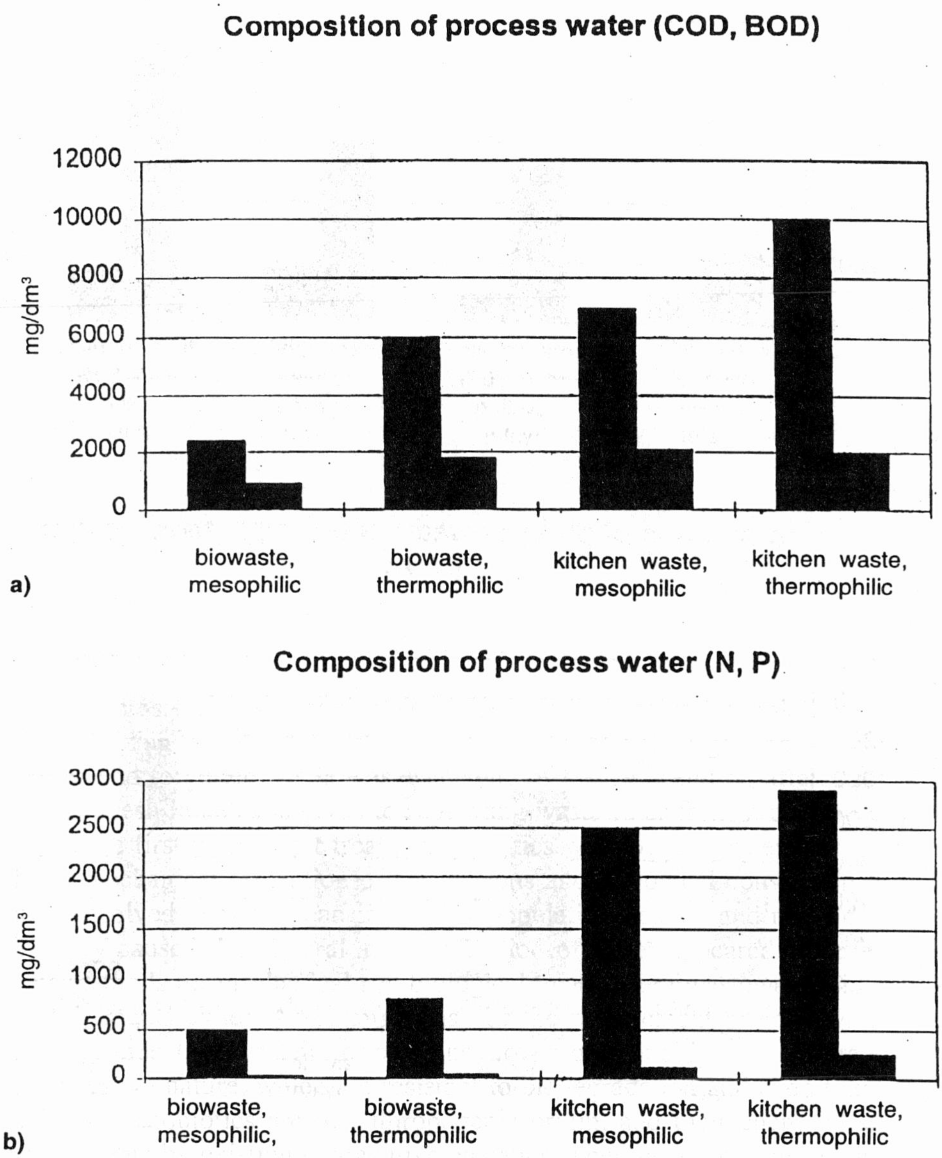
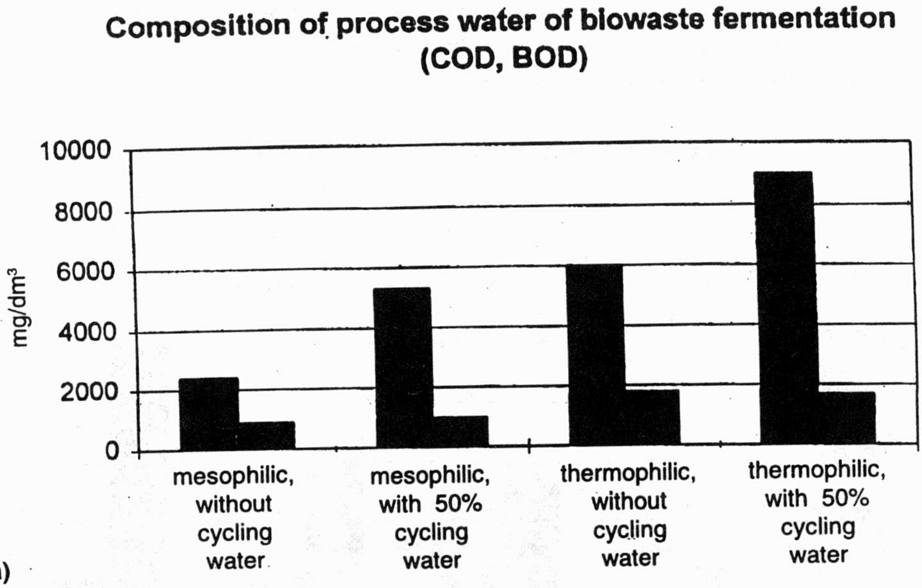
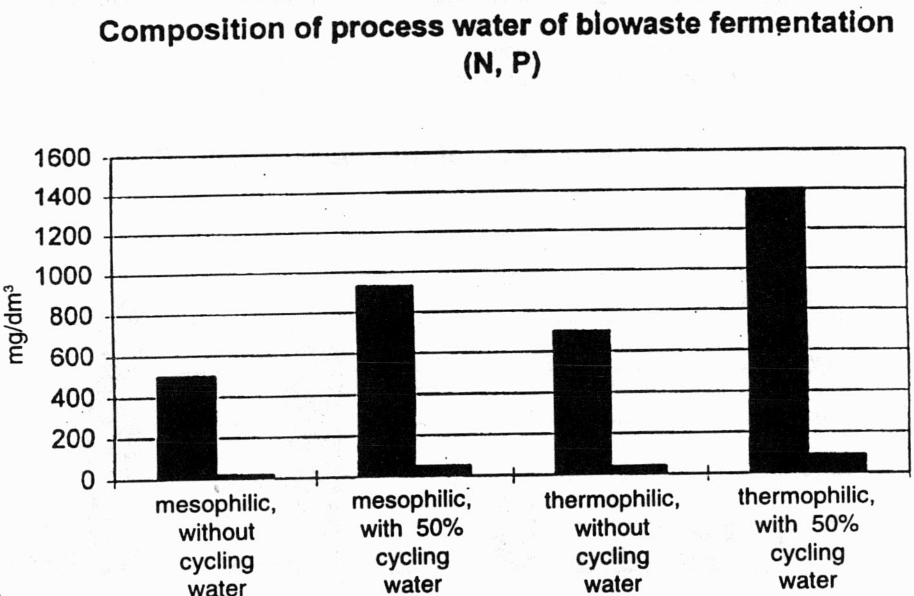


Fig. 2. Composition of process water (without cycling process water)
a) the left column – COD, the right column – BOD
b) the left column – nitrogen, the right column – phosphorus



a)



b)

Fig. 3. Composition of process water without
and with a 50% cycle of process water
a) the left column – COD, the right column – BOD
b) the left column – nitrogen, the right column – phosphorus

The investigations carried out up to now and concerning the heavy metal content in the process water also show that in thermophilic reactors the concenrations of these metals are higher than in mesophilic reactors.

Heavy metals are mainly connected to solids. The heavy metal concentration in the filtered sample is thus reduced by up to 90% in comparison with the unfiltered samples. As a result of this, the heavy metal concentration may be sufficiently reduced by flocculation and the addition of polymers; tests like these are being carried out at the moment.

The contents of adsorbed organic halogen compounds (AOX) (< 0.5 mg/dm^3) measured up to now are unproblematic. Nevertheless, the results of the tests with a raised cycle of process water must be awaited.

Table 5

Copper, zinc and AOX concentrations in the process water of the biowaste fermentation

Type of biowaste	Metals and AOX	Without cycling process water	With 50% cycling process water	Demands for leachate (Appendix 51, ATV-A115)
Mesophilic biowaste	copper [mg/dm^3]	0.2	0.6	0.5
	zinc [mg/dm^3]	0.4	2.2	2.0
	AOX [mg/dm^3]	0.1	0.2	0.5
Thermophilic biowaste	copper [mg/dm^3]	1.1	1.6	0.5
	zinc [mg/dm^3]	5.0	6.4	2.0
	AOX [mg/dm^3]	0.2	0.3	0.5

The expected accumulation of nutritive and harmful substances in the process water occurs when the cycle of process water takes place (figure 3). Both COD and concentration of nutritive substances are raised throughout this process. In contrast, BOD is unchanged, which may be traced back to better biological turnover. This makes biological purification of sewage possible to a very limited degree only, so that, depending on the desired level of purification, more complicated and more expensive methods will have to be used.

5. CONCLUSIONS

For every biowaste fermentation plant the Local Authority in each case lays down the requirements which must be met before discharging the sewage into the public sewer system. The available results prove that of the dangerous substances, copper and zinc as well as the adsorbed organic compounds are significant. Further investigations will be carried out to show to what extent the required discharge levels can be maintained by "simple" sewage treatment, as e.g. flocculation with the addition of polymers.

Should in view of carbon and nutrient compounds only a reduction of the concentration of ammonium-nitrogen and phosphate be necessary, this should be possible by biological treatment with additional flocculation.

It could be that because of the public sewage purification plants working at full capacity, also a reduction of the carbon and nutrients is necessary. In this case, high COD levels and large amounts of nitrogen and phosphorus might make a comprehensive sewage purification necessary. Because they cannot be easily biologically degraded, additional methods have to be used. With regard to nitrogen elimination, the BOD/N proportion will be incapable of adequate denitrification, so that additional measures such as additional external carbon sources or nitrogen stripping will be required. Should it not be possible to eliminate the phosphorus sufficiently by biological sewage treatment, the phosphorus may be removed by flocculation.

Because of the scant available data it is not yet possible to determine the size and range of sewage treatment in biowaste fermentation plants nor to outline the resultant economic consequences. The results of further investigations, regarding the composition of effluents from anaerobic waste treatment plants dependent on the ferment substrata as well as the process and procedure technology, must thus be awaited.

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JAKOŚĆ ODPŁYWU PO FERMENTACJI OSADÓW ŚCIEKOWYCH

Zwiększająca się liczba budowanych oczyszczalni ścieków z zastosowaniem metody fermentacji osadów ściekowych wymusza rozwiązanie problemu oczyszczania wód powstających w tym procesie. W artykule zamieszczono podstawowe dane o składzie i ilości tych wód oraz wysokości ponoszonych

kosztów w zależności od wymaganego stopnia ich oczyszczania. Często ich skład jest zbliżony do składu ścieków, zwłaszcza duże jest ChZt oraz stężenie azotu i fosforu. Przedstawiono również wyniki badań laboratoryjnych składu chemicznego wód pofermentacyjnych powstających w warunkach mezofilnych i termofilnych. Dla każdej oczyszczalni ścieków z procesami fermentacji osadów władze miejscowe ustalają wymagania, które powinny być spełnione przed ich odprowadzeniem do miejskiej sieci kanalizacyjnej. Najbardziej szkodliwe są: miedź, cynk oraz substancje organiczne zawierające atomy halogenów.