INTENSIVE COURSE ON LEACHATE TREATMENT

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EnviCare® Engineering GmbH

Ingenieurbüro für Verfahrenstechnik

A-8042 Graz
Eisteichgasse 20/9. Stock/Tür 36

Tel. +43 / 316 / 38 10 38-0, Fax: -9
office@envicare.at

www.envicare.at

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1 A brief overview over European legislation

There are no uniform emission limits for landfill leachate in Europe. To make this clear several specific parameters are summarized in Tab. 1 for the member countries Netherlands, Spain, Austria, Germany and Italy.

All of these countries make distinctions between direct emission to a river/lake/sea and indirect emission, which means further treatment of pre-cleaned leachate in communal wastewater works.

Looking at Tab. 1 it becomes obvious that the limits and parameters are quite different.

As an example we look at the parameter COD: In Austria the limit for direct emission is 50 mg/l while in Spain this value is allowed to reach 160 mg/l!

Looking at heavy metals in Spain the longest list has to be analyzed but some limits are slightly higher than for example in Austria, Germany or Netherlands.

As it is discussed later in this article the limits have a significant influence on the best technique, which is to be chosen at the individual landfill. Therefore it is noted already here that a simple technology transfer from e.g. Germany to Portugal must not be an optimal solution – several boundary conditions have to be considered, starting at the national emission limits!

	Parameter	Einheit	Deutschland		Österreich		Niederlande		Spanien		Italien	
			Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung *	Direkt-einleitung	Indirekt-einleitung *
physikalische Größen	Wassertemperatur	°C	-	-	-	-	-	-	-		-	
	Aufheizung Vorfluter	K	-	-	-	-	-	-	3		-	
	pH-Wert	-	-	-	6,5 - 8,5	6,5 - 9,5	6,5 - 9,0	6,5 - 9,0	5,5 - 9,5		5,5 - 9,5	
	Leitfähigkeit	µS/cm	-	-	-	-	-	-	-		-	
	Abfiltrierbare Stoffe	mg/l	-	-	20	-	-	-	80		-	
	Absetzbare Stoffe	ml/l	-	-	-	-	-	-	0,5		-	
	Abdampfrückstand	mg/l	-	-	-	-	-	-	-		-	
	Glührückstand	mg/l	-	-	-	-	-	-	-		-	
organische Summenparameter	$KMnO_4$ - Verbrauch	mg/l	-	-	-	-	-	-	-		-	
	CSB	mg/l	200	*	50	-	100	-	160		125	
	BSB_5	mg/l	20	-	10	-	20	-	40		25	
	TOC	mg/l	-	-	-	-	-	-	-		-	
	DOC	mg/l	-	-	-	-	-	-	-		-	
	AOX	mg/l	0,5	0,5	0,5	0,5	-	-	-		-	
	POX	mg/l	-	-	-	-	-	-	-		-	
	Σ Kohlenwasserstoffe	mg/l	10	-	5	15	-	-	-		-	
	Fl. arom. Kohlenw., BTX	mg/l	-	-	0,1	0,5	0,005	0,3	-		-	
	Phenolindex	mg/l	-	-	-	-	-	-	0,5		-	
	Schwerfl. lipoph. Stoffe	mg/l	-	-	-	-	-	-	-		-	
	Σ anion. u. nichtion. Tenside	mg/l	-	-	-	-	-	-	-		-	
	Aldehyde	mg/l	-	-	-	-	-	-	1		-	
	Detergentien	mg/l	-	-	-	-	-	-	2		-	
	Pestizide	mg/l	-	-	-	-	-	-	0,05		-	
	Öle + Fette	mg/l	-	-	-	-	-	-	20		-	

* in der jeweiligen Indirekteinleiterverordnung bzw. Ortssatzung geregelt

Stand: 13.07.98

Table 1: emission limits in Europe (part 1)

	Parameter	Einheit	Deutschland		Österreich		Niederlande		Spanien		Italien	
			Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung *	Direkt-einleitung	Indirekt-einleitung *
N-Verbindungen	org. N	mg/l	-	-	-	-	-	-	-		-	
	NH_4-N	mg_N/l	-	-	10	-	-	-	11,67		7,78	
	NH_3-N	mg_N/l	-	-	0,5	20	-	-	-		-	
	TKN	mg/l	-	-	-	-	20	-	-		-	
	NO_2-N	mg_N/l	2	-	-	-	-	-	-		-	
	NO_3-N	mg_N/l	-	-	35	-	-	-	2,26		4,52	
	gesamt N	mg/l	70	-	-	-	-	-	-		-	
	Cyanid, CN	mg/l	0,2	0,2	-	-	-	-	0,5		-	
S-Verb.	Sulfat, SO_4	mg/l	-	-	-	-	-	-	2.000		1.000	
	Sulfid, S	mg/l	1	1	0,5	2	-	-	1		-	
	Sulfit, SO_3	mg/l	-	-	-	-	-	-	1		-	
Halo-gene	freies Chlor, Cl_2	mg/l	-	-	-	-	-	-	-		-	
	Gesamtchlor, Cl_2	mg/l	-	-	-	-	-	-	-		-	
	Chlorid, Cl	mg/l	-	-	durch G_F	-	-	-	2.000		1.200	
	Flucrid, F	mg/l	-	-	-	-	-	-	6		6	
Son-stiges	Giftigkeit geg. Fische	-	2	2	3	-	-	-	-		-	
	$K_{S4,3}$	mmol/l	-	-	-	-	-	-	-		-	
	Phosphate	mg/l	-	-	-	-	-	-	10		-	
	Phosph., Wasserschutzgeb.	mg/l	-	-	-	-	-	-	0,5		-	
	Phosphor ges.	mg/l	3	-	-	-	-	-	-		2	

* in der jeweiligen Indirekteinleiterverordnung bzw. Ortssatzung geregelt

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Table 1 - Part 2

	Parameter	Einheit	Deutschland		Österreich		Niederlande		Spanien		Italien	
			Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung	Direkt-einleitung	Indirekt-einleitung *	Direkt-einleitung	Indirekt-einleitung *
Schwermetalle	Aluminium, Al	mg/l	-	-	-	-	-	-	1		-	
	Arsen, As	mg/l	0,5	0,5	-	-	0,05	0,05	0,5		-	
	Barium, Ba	mg/l	-	-	-	-	-	-	20		-	
	Blei, Pb	mg/l	0,5	0,5	0,5	0,5	-	-	0,2		-	
	Bor, B	mg/l	-	-	-	-	-	-	2		-	
	Cadmium, Cd	mg/l	0,1	0,1	0,1	0,1	0,0025	0,005	0,1		-	
	Chrom ges., Cr	mg/l	0,5	0,5	0,5	0,5	-	-	-		-	
	Chrom III, Cr III	mg/l	-	-	-	-	-	-	2		2	
	Chrom VI, Cr VI	mg/l	0,1	0,1	-	-	-	-	0,2		0,2	
	Eisen, Fe	mg/l	-	-	-	-	-	-	2		-	
	Kobalt, Co	mg/l	-	-	-	-	-	-	-		-	
	Kupfer, Cu	mg/l	0,5	0,5	0,5	0,5	-	-	0,2		-	
	Mangan, Mn	mg/l	-	-	-	-	-	-	2		-	
	Nickel, Ni	mg/l	1	1	0,5	0,5	-	-	2		2	
	Quecksilber, Hg	mg/l	0,05	0,05	0,01	0,01	0,0005	0,0025	0,05		-	
	Selen, Se	mg/l	-	-	-	-	-	-	0,03		-	
	Silber, Ag	mg/l	-	-	-	-	-	-	-		-	
	Zink, Zn	mg/l	2	2	0,5	0,5	-	-	3		0,5	
	Zinn, Sn	mg/l	-	-	-	-	-	-	10		-	
	Σ (Cu,Cr, Ni, Pb, Zn)	mg/l	-	-	-	-	0,4	2	-		-	
	Σ (Giftige Metalle)	mg/l	-	-	-	-	-	-	3		-	

* in der jeweiligen Indirekteinleiterverordnung bzw. Ortssatzung geregelt

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Table 1 - Part 3

2 Basic data for a successful design and operation of landfill leachate treatment plants

The first step to design a fully functional and cost effective leachate plant is to collect a solid data basis. In figure 1 some essential basic data are listed.

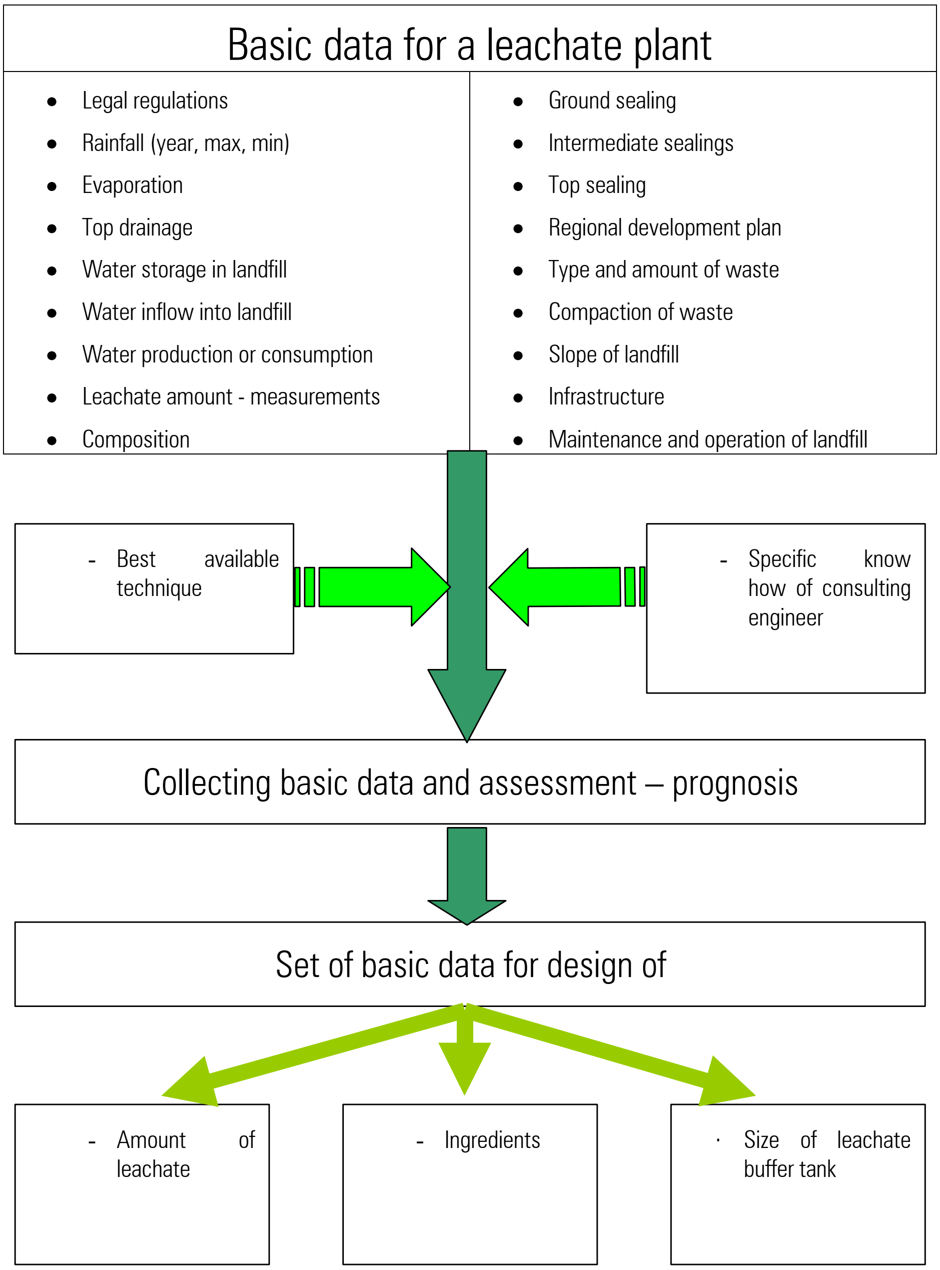

figure 1: basic set of data for the design of landfill leachate plants

As indicated in figure 1 the set of basic data has to be qualified and checked by experienced engineers and also assessed by making use of the actual status of science and technology.

As a result we obtain a specified range for

- the amount of leachate
- ingredients
- size of the buffer tank.

Making use of these results a first design approach should be made. In this basic engineering study several possible technological solutions should be compared in terms of technological and economical feasibility.

I am personally convinced that the main focus should be laid on:

- efforts for maintenance and stable operation of the whole plant – the simpler the better!
- Overall costs consisting of operational (manpower, supply of energy, disposition of by-products etc.) and investment costs

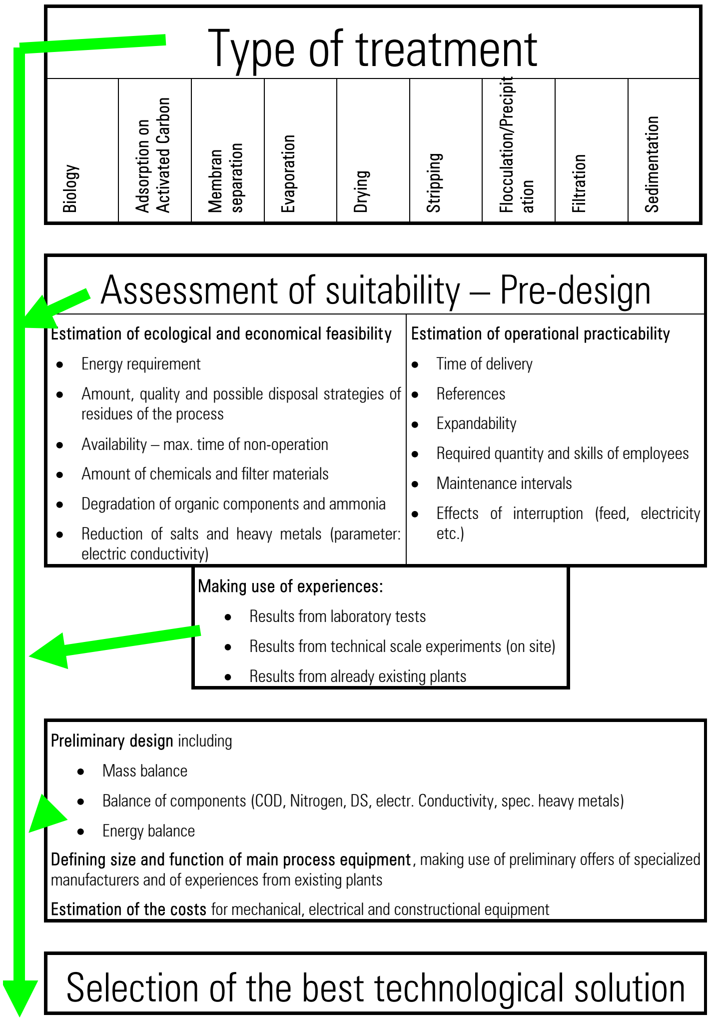

figure 2: From basic processes to the best coupled process solution

2.1 Formation and amount of leachate

Landfill leachate is one main parameter in hydrological system. A mass balance of rainfall, evaporation, surface drainage and storage in the landfill defines the amount.

Several parameters show a great influence on the formation, amount and concentration of the leachate, among those are

- surface (re-cultivated or open)
- re-infiltration or back-pumping and spraying
- rainfall (426 mm/a [Madrid] – 613 mm/a [Lisbon] – 1.400 mm/a +Ennstal/Austria])
- temperature – climate
- composition of waste (household, incinerated, industrial slacks)

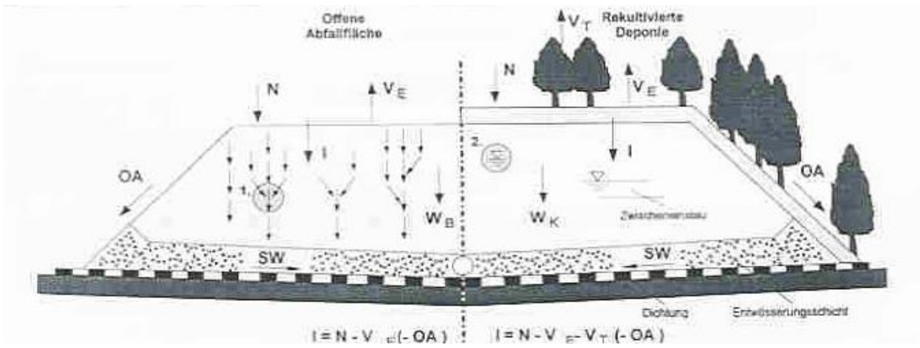

figure 3: balance of the water

I	net "production" of leachate	O_A	drainage on the surface
N	rainfall	W_B	biochemical uptake/production
V	evaporation	SW	leachate

As a first estimate on the amount of leachate we use a so-called drainage-coefficient (Abflussbeiwert) c_F. This factor gives the percentage of leachate, which is pouring out, related to the rainfall on a yearly basis.

Type of surface	drainage- coefficient c_F	
Rainfall, climate	Appr. 600 mm, warm	Appr. 900 mm, cold
Re-cultivated	0,01	0,1
Open area (not yet in operation, no waste dumped or waste layer < 4 m	0,8	1,0
Waste layer 4 m < 10 m	0,3	0,7
Waste layer > 10 m	0,1	0,5

Table 2: drainage coefficient as function of yearly rainfall and climate conditions

All numbers given in Table 2 are only valid for a proper sealing.

It is also important to understand that the landfill is acting as a large storage buffer. In other words a strong and short rainfall will not lead immediately to a strong increase in the effluent, but the amount of leachate will increase over the period of several hours or even days, depending mainly on the altitude and geometry of the landfill.

2.2 Average, minima and maxima of contamination

Landfill leachate of communal landfills shows a wide variety of ingredients, of course depending of the kind of waste, which is disposed on the particular landfill.

The are some summarized parameters characterizing the organic compounds, such as:

- COD – chemical oxygen demand
- BOB_5 – biological oxygen demand (after 5 days)
- AOX – adsorb able halogenated organic compounds (expressed as Cl)
- TOC – total organic carbon

Another important parameter is the amount of

- Nitrogen, mainly as Ammonia (NH_4-N)

On the other hand we have several an-organic substances, such as

- Non harmful: Cl, SO_4, Na, K, Mg, Ca, Ba,
- Heavy metals: Zn, Sn, Cr, Cr^{VI}, Pb, Hg, Cd, Cu

Two other summarizing and very important parameters are

- pH value
- electric conductivity

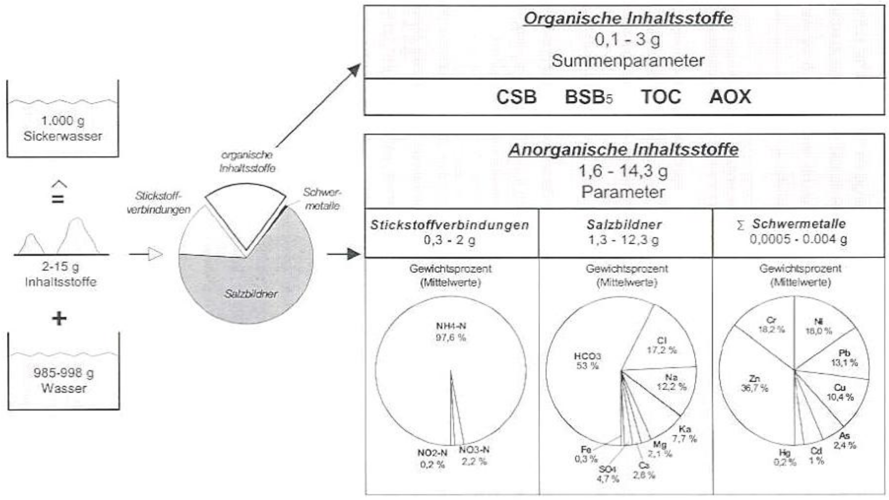

figure 4: schematic sketch of the ingredients in landfill leachate

In Table 3 a range of concentrations for the most important leachate parameters are given:

Parameter	Dimension	Konzentrationsbereiche (höhere Werte als die Maximalwerte treten nur vereinzelt auf)	erforderliche Reinigungsleistungen bezogen auf 51. VwV (%)
CSB	mg/l	100 - 10.000	0 - 95
BSB_5	mg/l	20 - 5.000	0 - 99
NH_4^+ -N	mg/l	40 - 2.500	0 - 98
AOX	mg/l	0,1 - 5	0 - 90
GF	mg/l	2 - 100	0 - 98
Cr	µg/l	n.n. - 500	0
Pb	µg/l	n.n. - 200	0
Cu	µg/l	n.n. - 300	0
Ni	µg/l	n.n. - 400	0
Zn	µg/l	n.n. - 1.000	0
Hg	µg/l	n.n. - 20	0
Cd	µg/l	n.n. - 50	0
Leitfähigkeit	µS/cm	2.000 - 25.000	-
Abdampfrückstand	mg/l	1.000 - 15.000	-
Glührückstand	mg/l	800 - 10.000	-

n.n. : nicht nachweisbar

Table 3: range of significant parameters

In some specific cases this ranges might be passed over, for example an Austrian landfill shows COD values up to 40.000 mg/l, NH_4-N = 4.000 mg/l, Cr^{III}=5 mg/l due to dumping significant amounts of waste from leather production.

It can also be stated that the concentrations are higher in arid regions.

We know from experience of several landfills that the amount of leachate is indirectly related to the concentration. In other words the load of ingredients is to some extend quite stable, which is important for the design of a leachate treatment facility.

3 Tailor made treatment systems for individual landfills

From our experience it can be stated that it will always be necessary to collect all relevant data for the individual landfill and to compare the specific demands to the capabilities of the possible processes.

During the lecture we will try to estimate the dimension of a storage basin and the possible lay out of a leachate treatment facility, depending on the quality and quantity of leachate.

Besides the technical parameters it is also important to take a close look at other “boundary conditions”:

- availability of skilled workers
- availability of electricity
- possibility to discharge the cleaned water – special requirements?
- Acceptance of the solution by workers and management and public authorities
- Possibility to dispose the refuse (sludge, concentrate, used filters etc.)

All these variables have to be matched with the possible solutions. In some pros and cons of the different processes are listed – the solution matching the individual demands best is to be chosen.

Process	**Pros**	**Cons**
Conventional biological treatment	Well known	Not well suited for landfill leachate No stand alone Problem of washed out particles Low elimination rate Large volume/space investment costs no stand alone solution biological sludge
Biological membrane bioreactor (MBR)	Good degradation of organics Nearly 100% oxidation of ammonia Particle free effluent Adsorption of heavy metals possible	investment costs no stand alone solution biological sludge
Chemical oxidation	Destruction of organic compounds	High energy costs no stand alone solution
Activated carbon	Cost effective polishing of effluent of MBR Elimination of AOX Stable and easy to operate	Living time of carbon, costs of changing
Precipitation/flocculation	Necessary after conv. biol. Process Low investment	Need operational experience Chemical sludge
Reverse osmosis	Relative low investment Prefabricated solution Stand alone solution Limited space	Disposal of concentrate Living time of membranes Experienced personnel necessary

Table 4: assessment of unit processes

4 Leachate re-infiltration – evaporation

During the lecture the paper by Dr. Thomas Peters (partly given below) will be discussed.

4.1 Summary

Proceeding from reflections on water needs in landfills and on the correlation of effects, which are responsible for the accelerated immobilization of organic components in the landfill body acting as bioreactor, aspects concerning technical facilities for the controlled injection of infiltration water into a landfill are described. From the limiting boundary conditions for the infiltration of leachate is derived the infiltration of leachate concentrate and explained the use of the membrane filtration process reverse osmosis with the open channel module DT for the purification of landfill leachate. Examples of landfills on which the controlled infiltration of leachate concentrate is operated and the thereby achieved results are completed by the discussion of a concept according to which the infiltration water is to be used for the short-term inactivating and later for the long-term securing of a landfill.

4.2 Introduction

Within the measures of the waste management to translate the conditions of the second and third administrative directive regarding the law on waste ("TA Abfall" and "TA Siedlungsabfall") as well as the demands in the council directive *1999/31/EG* of April 26, 1999 on the landfill of waste, which came into effect on July 16, 1999 and thus is compulsory for the countries of the European Community, certain landfill-specific aspects became the limelight of specialized discussion recently, which so far have been observed only here and there or whose meaning has been assessed very differently for an environmentally harmless and economic operation of waste disposal facilities when co-coordinating with technical authorities. Part of this is the question how the best decomposition of organic components can be guaranteed in the landfill body despite the rapid minimizing of landfill gas and leachate emission caused by the surface sealing system dictated by "TA Siedlungsabfall".

4.3 Landfill as Bioreactor

A lack of water leads to the standstill of the microbiological decomposition and alteration processes of the organic components in the waste and thus to an unwanted "dry stabilization" respectively "mummification" of organic contents in the landfill body. This reduces respectively terminates the production of usable and therefore valuable landfill gas, increases the danger of uncontrolled gas emissions and extends the aftercare phase to immeasurable periods.

Wide areas of the landfill body of the majority of presently operated landfills do not show the humidity content that is necessary for the microbiological decomposition of organic components. 15 to 25 % are usual, 35 to 40 % would be required.

These correlations in effect being discussed nationally and meanwhile increasingly internationally refer to today's almost exclusively operated old waste landfills, i.e. the classical municipal solid waste landfills, in which leachate and gas problems must be seen completely different than with the mostly inert waste landfills demanded and provided by legislature. Unlike with these future, considerably inert standard waste landfills, it is possible to compare the old waste landfills looked at here with bioreactors in spite of all restrictions. In view of the biochemical decomposition, the efficiency of those bioreactors is considerably intensified by the infiltration of additional water.

Here the accelerated decomposition of organic fraction simultaneously effects the reduction of the aftercare phase. This circumstance is of special importance as hereby a contribution can be made that today's problems of disposal will not be transferred to the coming generations.

The biochemical decomposition processes do take place during the operating phase, which is provided with trained personnel and an active de-gassing system, and can come to an end latest during the aftercare phase provided by legislature as far as possible.

In the meantime findings from this total correlation have increasingly been converted by the authorities with the effect that the deposition of leachate and residues from the leachate purification into the landfill body, which is not allowed according to "TA Siedlungsabfall", can be approved after an individual case check, if corresponding conditions have been fulfilled.

In addition to the partly longer published "Technische Hinweise fur Planung und Errichtung sowie Betrieb und Abschluss von Deponien im Rahmen der Umsetzung der TA Siedlungsbfall in Bayern" (technical instructions for planning and building up as well as operation and closure of landfills within the conversion of the TA Siedlungsabfall in Bavaria), "Empfehlungen zur Ruckfuhrung von Sickerwasser in Deponien" (recommendations on the infiltration of leachate in landfills) from Lower Saxony, the "Merkblatt zur Anwendung der TASiedlungsabfall bei Deponien" (notice for the use of TA-Siedlungsabfall in landfills) from North Rhine-Westphalia and the technical information "Infiltration von Wasser auf Siedlungsabfalldeponien" from Saxonia-Anhalt (infiltration of water into municipal solid waste landfills), an ad-hoc working group of LAGA (Federal States Working Group on Waste) sent by all federal states worked out a fundamental paper in which the "infiltration of water into the landfill body" is supported for above-mentioned reasons on compliance with certain conditions. One of these conditions concerns the presence of qualified bottom sealing or of another possibility to safely collect leachate, e.g. an inward-directed hydraulic gradient.

4.4 Controlled Infiltration

Depending on the local boundary conditions and on the technical circumstances of a landfill it is possible to use leachate or leachate concentrate as infiltration water for the controlled infiltration.

The "controlled infiltration" describes here an introduction of infiltration water into a landfill body, which can be monitored, by technical equipment that enables the control of the dosage, the quantitative detection of infiltrated volumes and the change of position including the depth. This flexibility must be guaranteed, as the optimizing of adjustment, control and monitoring of infiltration parameters depends among others on long-time accumulation effects. These cannot be prognosticated so that their effects on the total system have to remain susceptible.

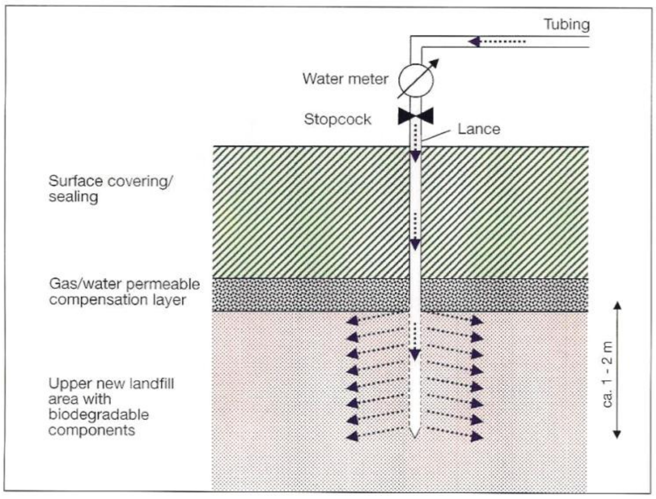

figure 5: Vertical infiltration system

Examples for the technical equipment which is mostly run under pressure are vertical irrigation systems such as injection well, probes and lances (Figure 5) or horizontal systems with several drain lines (Figure 6) or flat infiltration body of coarse material or glass fragments.

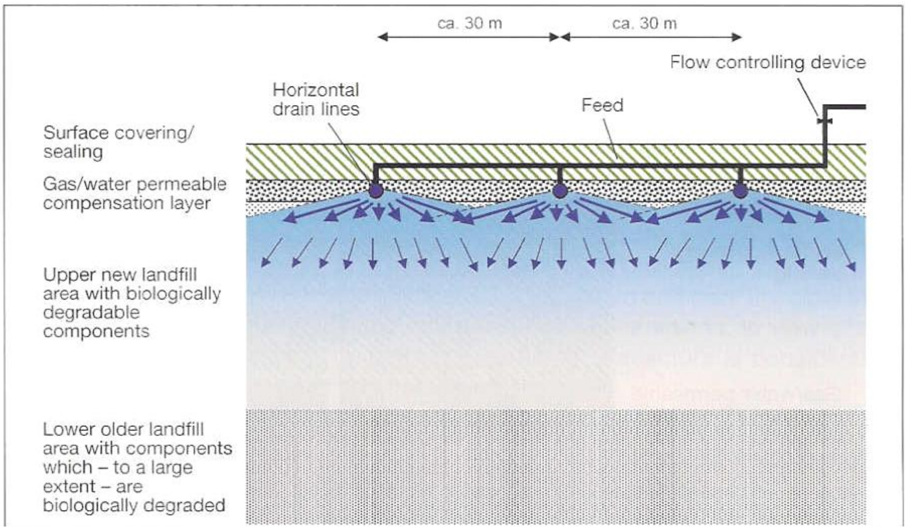

figure 6: Horizontal infiltration system for moistening a landfill section

The dimensioning of these systems and their designs, including the question of arrangement below an intermediate cover or the surface cover and/or sealing as well as of a water-passable compensating layer, which is possibly lying beneath, has to be made from case to case taking the respective specific landfill conditions into account.

4.5 Infiltration of Leachate

Extensive studies on the infiltration of leachate -which is not to be mixed up with a leachate re-circulation - have been carried out among others within a large-scale technical project realized in Bavaria since the end of 1993. The results demonstrate that the infiltration led to an increased biological activity that resulted in a drastically higher quantity of extractable gas. Negative effects in the form of a higher concentration of the components in the leachate in the draining leachate could not be detected. With the parameter BOD a partly reduction was determined by the waste body acting as a fixed-bed reactor.

However, the use of leachate to accelerate the processes of mineralizing and thus the immobilization of the landfill body, which is right to be rated as very useful in this examined case, is limited to disposal systems in which it is possible to maintain the water balance of the landfill in this way. Variables are here, besides the infiltration amount, the amount of rainfall or diffuse water entry seeping into the landfill body, the water consumption and the water production respectively by biological activities as well as amounts of water delivery through the condensate discharge with the landfill gas, the evaporation and the quantity of draining leachate.

In most cases this balance will not appear, since the leachate leaving the landfill body is far above the amount that is required for the controlled infiltration of leachate. For this the infiltration of leachate concentrate can be used as another appropriate way with the same final result.

This leachate concentrate will be produced when using the membrane filtration process reverse osmosis for the purification of leachate. The partial stream (permeate) of all arising leachate amount cleaned by the reverse osmosis membrane in the range of 75 to 80 % can be fed to the next receiving water without any further treatment and thereby de-ballasts the water balance of the landfill. The remaining concentrate is used for infiltration and thus for acceleration of immobilizing processes in the landfill body. Here too, the already described correlation's and positive effects have been confirmed by the results of extensive studies, especially however by results and experience having been accumulated on a number of landfills, which have been operated with this kind of technique.

4.6 Infiltration of Leachate Concentrate

As the infiltration of leachate concentrate which has been applied in Germany since 1986 is considered as a component of the purification of leachate with the membrane filtration process reverse osmosis, several technical backgrounds will be discussed for the purpose of classifying the correlation's in this connection.

Infiltration of Concentrate as Sink for Pollutants

The results of extensive studies, especially however the findings and experiences of many years on a number of landfills -the oldest plant since 1986 -which are operated with the controlled infiltration of leachate concentrate confirm that even on the long-term basis no remarkable changes can be detected in the draining leachate.

The landfill body serves as a sink for pollutants; whereby individual components are de-composited and/or discharged with the landfill gas and other components deposited which can not be eluted anymore. This is based on a number of complex biochemical and physical processes and their interaction in the landfill body which, due to the disposal of the waste in layers -and the thus arising zones with a different permeability -is crossed horizontally to a large extent and thereby with a high residence time by infiltration water. The most important processes are:

- biochemical decomposition processes in the landfill body, which reduce the content of organic components in the waste and in the infiltrated concentrate itself, whereat a toxic effect which would be deduced from the higher level of the individual components in the leachate concentrate, could not be detected so far
- decomposition of organic and inorganic material in the form of oxides, sulphides and carbonates, which are produced by micro-organisms during the metabolisation of waste
- adsorption of heavy metals at different surfaces in the waste such as clay minerals and humus substance compounds
- crystallization processes, in which insoluble salts arise and deposit
- arising of carbonates, sulphides and sulphates by chemical-inorganic processes.

The effective mechanism and the combination of these processes which are partly dependent on temperature and/or concentration is regarded to be the reason for the fact that, with the controlled infiltration of leachate concentrate, no remarkable changes in the pollutant content in the leachate leaking from the landfill can be observed.

According to the available experience by now, significant changes in the composition of the discharging leachate can be led back to extreme situations in the landfill. Part of this are "concentrate short circuits" where concentrate prefers to leach through channels formed in the landfill body ("channeling") or the contact of the infiltrated concentrate with sectors in the landfill body, in which preferentially industrial waste is deposited with a high concentration of pollutants or salts. Both troubles can be prevented by technical measures.

4.7 Waste Moistening as Basis for Inactivation and Long- Time Safeguard

Within the efforts of the landfill in Halle-Lochau, which is considered as an example here, to reduce the aftercare phase and to guarantee the long-time safeguard a strategy was worked out, according to which inactivation of the landfill body in several phases is proposed. During the first phase of 2005 until 2024 it is aimed an accelerated biological reduction of the organic substances by increasing the water content by means of infiltration and optimized de-gasification.

In this way the landfill inventory would be changed in a way that a need for monitoring and repair in the aftercare phase becomes unnecessary, as the non-combustible and mineralised remainders do not contain environmental impact potential anymore.

In this connection and with measures with short-term prospects, i.e. in the period from 2000 to 2005, one has to take into account that the water content of the waste, which is presently deposited in the landfill body of the Halle-lochau landfill, is 24 weight per cent on average in the domestic waste and 16 weight per cent on average in the commercial waste, and thus far below that water content which is optimum for the microbiological reduction of organic substances. The installation, planned from 2005 onward, of a high dense MBA output or other inert waste will intensify this effect of the presence of dry-stabilised waste, as hereby no more remarkable amounts of rainfall water will penetrate into the landfill body that must be inerted.

At this time the leachate arising on the Halle-lochau landfill is purified with a reverse osmosis system that has been in permanent operation since February

5 Overview over leachate treatment in Europe

Slides will be presented at the lecture.

6 Leachate treatment with reverse osmosis

The desired far-reaching purification of leachate can only be obtained by the filtration through reverse osmosis membranes, as it is shown by operating results, achieved on most different boundary conditions, with an increasing number of plants; at the beginning of 1999 this were more than 140 units. From here one can infer that the reverse osmosis is a very efficient instrument for the purification of leachate, if the variables which are specific for all leachate have been taken into consideration when designing the plant, and membranes, modules and systems, which are adjusted to this kind of wastewater, are used.

The basis for this is also that the presently available reverse osmosis membranes are able to retain all organic and inorganic substances dissolved in water for 98 to 99 %.

With the reverse osmosis the leachate to be treated is split by a "dense" solution diffusion-membrane into a partial stream of purified permeate and into residual water respectively concentrate. This concentrate contains the water components retained by the reverse osmosis membrane. The permeate -the liquid permeating through the membrane -is water purified to a so large extent due to the high rejection rate of the reverse osmosis membrane that it can be discharged directly into a receiving water.

As the reverse osmosis membranes function as barriers, the purification process can be monitored reliably and with high reproducibility by means of the easy and simultaneously precise measurement of electric conductivity. Furthermore, the use of reverse osmosis membranes enables a high reliability, since the start up and shutdowns of plants are initiated by pressing a button and are put into practice within a few minutes. The driving force for the process is an operating pressure produced by feed and re-circulation pumps. According to that neither delays nor special instructions have to be observed during start up and shutdown. At the same time this enables an easy handling of plants in case of shorter or longer standstills.

Caused by the high rejection rate for all pollutants dissolved in leachate, also a large flexibility is given referring to the change of concentration of the individual components. The thereby arising permeate always shows a high quality, as this process is based on a reproducible high efficiency during purification.

This technique shows the same flexibility even with considerable changes of leachate to be treated. The modular structure of reverse osmosis systems allows a rapid increase or reduction in purification capacity by extension or reduction of installed membrane surface.

In addition to the fact that highly resistant membranes are necessary for the purification of leachate with reverse osmosis, also the use of modules with open channels is an indispensable condition. These have to be able to be cleaned with a high efficiency to prevent problems with scaling (deposits on the membrane by the precipitation of inorganic components), fouling (formation of deposits on the membranes by organic particulate constituents including colloids) and bio fouling (formation of a bio film on the membrane surface).

For this purpose the tubular module was used in the first plants. Then in 1988 the disc-tube-module DT was introduced in this market segment. At the beginning of 1999 already more than 120 plants were equipped with this module for the purification of leachate in Europe, North America and in the Far East. This corresponds to over 80 % of the total capacity of reverse osmosis systems installed on landfills for the purification of leachate.

Here it should be emphasised that it is possible to obtain a permeate recovery rate between 90 and 95 % by using the reverse osmosis in combination with high-pressure reverse osmosis developed on the basis of the DT module technique with operating pressures of 120 and 150 bar respectively. Accordingly, the residual water remaining on the raw water side of the membranes, which is denominated as concentrate, can be reduced to between 10 and 5 % of the whole volume fed into the plant.

7 treatment process 1: reverse osmosis – reinfiltration of concentrate

All of the Austrian reverse osmosis plants were started in this cost efficient way.

After approximately 1 – 5 years several RO-plants had to change to a external disposal of the concentrates, only the plant “Hettegger” and the two plants with a combined MBR-reverse osmosis treatment are still running the infiltration to a 100%.

There were several reasons why the stand alone reverse osmosis solutions had to quit the re-infiltration mode, mainly because of increasing concentrations (apparently in contrary to the paper by Dr. Peters!) or due to problems with smell emissions (H_2S).

New legal regulations could soon oblige all operators of leachate treatment plants to an external disposal of the concentrates.

8 Treatment process 2: reverse osmosis – drying of concentrate

This costly process solution was realized several times in Germany, but failed in praxis.

The reason was that the dryers were extremely complicated to run and that in the dried product some unforeseen exothermal chemical reactions took place, leading sometimes to fires in the plants.

9 Treatment process 2: reverse osmosis – incineration of concentrate

This “total termination” of leachate is done in Austria at the sites:

- Riederberg
- Ahrental
- Roppen
- Lavant
- Partly at Kröpfel

It has to be noted that before the concentrate is incinerated it is treated in a high-pressure module (150 bar); therefore only about 8 % of the original leachate is burned in an incineration plant for hazardous wastes.

10 Several case studies

10.1 Austrian case studies with reverse osmosis plants

During the lecture the following plants will be presented:

- Ahrental

- Riederberg
- Hettegger
- Roppen
- Lavant
- Kröpfel
- Combined to a MBR: Halbenrain, Erzberg

10.2 Examples for Landfills with Controlled Infiltration of Concentrate

For landfills operated with controlled concentrate infiltration it is possible to give following assessment after an observation of many years: when the system for the controlled infiltration of leachate concentrates were designed considering the characteristics of the corresponding landfill, there were no changes for the concentration of pollutants in the discharging leachate. This is proved by results, which have been and are achieved on different landfills in various countries. With one of these references one has relevant experience since 1986.

Pre-condition is that the concentration factor for the leachate components respectively the amount of permeate and the thus resulting concentrate amount is supported by the selection criteria which include site-specifically technical and ecological aspects as extensive as possible -which may be different for every landfill -to find the optimum solution for every case.

When observing the values determined for the concentration of components of the discharging leachate it is necessary also to observe the guide parameters which have to be fixed from case to case for the concentrate to be infiltrated, the amount of infiltrated concentrate and the rainfall events.

In Germany there are at present approx. 15 plants for the controlled infiltration of concentrates from reverse osmosis systems for the purification of Leachate in successful operation, an increasing number abroad. Particular examples are:

10.2.1 "Hintere Dollart" Landfill

The "Hintere Dollart" landfill is near Gaggenau-Oberweier, approx. 40 km south of Karlsruhe, district of Rastatt. The landfill possessing 19 ha disposes waste of approx. 200.000 people, whereat the deposited waste amount was in 1986 to 1995 between 100.000 and 280.000 t/a. According to the present tendency the smaller depositing amounts have been in the last years.

On this landfill a reverse osmosis system has been installed in 1986 for the purification of Leachate. Thus it was the first plant in Germany. The output of the reverse osmosis system was designed for 80 %, whereas in the last years values between 75 and 79 % have been achieved. The concentrate is infiltrated into the landfill body through injection wells on top of the landfill, after it is pumped up through a frost-resistant laid pipeline.

A temporary short-term increase in the electric conductivity could be led back to constructively caused short circuits during infiltration. After the removal of these influences the value for the electric conductivity stabilizes within a range of around 20.000 µS/cm.

10.2.2 "Goda-Buscheritz" Landfill

The "Goda-Buscheritz" landfill that was taken out of active operation in 1990 is near Bautzen, approx. 50 km east of Dresden. The here deposited waste materials are, to a large extent, ashes from the nearby power plant, mixed with commercial and domestic waste.

The leachate purification system is designed for 0.6 m3/h and works with a recovery rate of approx. 70 % .The reverse osmosis concentrate is infiltrated into the landfill body by two special injection wells. Since the start up in July 1993 no changes could be determined in the concentration of pollutants. Thus, for example, the electric conductivity stays with values of 14,000 µS/cm and the value for the COD between 1,800 and 2,000 mg/l.

The only important change was the reduction of the ammonium content that was measured in 1993 with values of 1,000 mg/1 and in 1995 with 240 mg/l.

10.2.3"Helvesiek" Landfill

The "landfill of the district of Rotenburg" is near Helvesiek, approx. 90 km Southwest of Hamburg. Approx. 9.5 ha (of the 12.5 ha available area) is covered with waste at the moment. The annual deposit of domestic and commercial waste is between 60,000 and 80,000 t.

During the past years the daily leachate formation varies between 10 and 15 m3. The reverse osmosis system is in operation only on workdays. The reverse osmosis concentrate is stored in closed containers and from there pumped with a maximum quantity of approx. 0.6 m3/h into the concentrate infiltration system. The levels in these storage tanks control the pumps.

For the electric conductivity of the leachate values between 12,000 and 19,000 µS/cm have been measured during the past few years, whereby these values are influenced by the rain quantity and the treatment of leachate from another landfill.

The system of the controlled infiltration of concentrate from the reverse osmosis plant has been in continuous operation since June 12, 1993, while up to now no significant changes have been determined in the concentration of leachate components, which could be derived from the infiltration.

10.2.4Landfill in North Germany

On a landfill in North Germany the controlled infiltration of leachate concentrate from a reverse osmosis system has been in operation since 1992.

The very clear variations of the electric conductivity here are dependent on the weather. At the beginning of 1997 and beginning of 1998 extremely high amounts of rainfall resulted in an increased discharge of easy soluble components. Effects of the controlled infiltration of leachate concentrate on the concentration of particular components in the draining leakage were not detected.

As in the case of other comparable landfills it becomes apparent here too that the chronological concentration course of components in the Leachate is not determined by infiltration but by weather factors and the landfill operating conditions.