PERFORMANCE FOR DEWATERING PROCESSES

White Paper

Reducing leachate treatment costs, but how?

Practical examples at the Hattorf and Deiderode landfills (Germany)

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Introduction

Leachate processing at landfills places significant demands on process technology. Landfill leachate contains a cocktail of various pollutants. In addition to biodegradable nitrogen compounds, this also includes a large number of other organic and inorganic pollutant groups that are fully or partially non-biodegradable. These substances have to be removed from the landfill leachate through cost-intensive physicochemical treatment. The requirements placed on the treated leachate depend on the way it is discharged. Legal framework specifications define the limits for direct or indirect dischargers.

COD	< 400 mg/l
NH4-N	50 mg/l
mercury	0,05 mg/l
cadmium	0,1 mg/l
chromium	0,5 mg/l
nickel	0,5 mg/l
lead	0,5 mg/l
copper	0,5 mg/l
zinc	2,0 mg/l
chromium (VI)	0,1 mg/l
cyanide- easily released	0,2 mg/l
AOX	0,5 mg/l

Tab. 1: Limits for indirect dischargers in Lower Saxony (Germany)

After biological pretreatment, the landfill leachate still contains pollutants that were not biologically decomposed. The pollutant with the highest concentration downstream of the biological treatment stage is the non-biodegraded or non-biodegradable COD.

Due to the non-biodegradable contents of the landfill leachate, another treatment stage must be provided downstream of the biological treatment stage; this stage removes the contents from the wastewater stream physicochemically. In the simplest case, this involves treatment of the leachate with activated carbon. Physicochemical treatment requires that the landfill leachate be treated sufficiently to prevent the discharger limits from being exceeded.

Activated carbon adsorption removes COD and AOX loads from the wastewater. This is accomplished through a concentration- and time-dependent process of adsorption of these substances onto the activated carbon surface. When the adsorption capacity of the activated carbon is exhausted, or if the prescribed limits are exceeded, the activated carbon must be replaced and regenerated. The pollutants are not actually eliminated in this process, they are just captured and stored locally when the activated carbon is replaced. The adsorption process occurs selectively, with nitrogen compounds not being adsorbed. Because the adsorption process is concentration-dependent, it is important from an economical point of view for the pollutant load be reduced as much as possible before entering the activated carbon adsorber.
Of course, high pollutant loads can be captured by the activated carbon, but the active life of the adsorber is shorter due to the faster-moving adsorption gradient. In this case, the activated carbon cannot handle as much of a load since the discharge limits are reached very quickly. When the loads are lower, the adsorption gradient moves slower and the absolute load can be higher. The activated carbon is understood to be fully-loaded

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(exhausted) when the concentration of the adsorbable substances are as high on the discharge side of the activated carbon as they are in the feed.

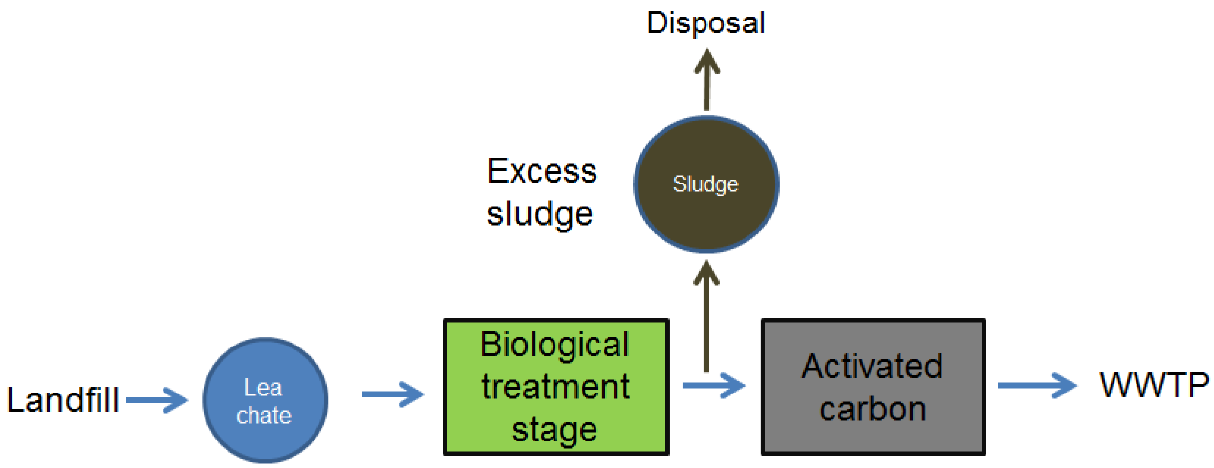

Fig. 1 *Schematic of a simplified landfill leachate treatment system with biological treatment and activated carbon adsorption*

The disadvantage to activated carbon adsorption, in addition to the high specific treatment costs, is that filterable substances from the biological treatment stage mechanically block the adsorber. To avoid this, a filtration stage should be placed upstream of the activated carbon stage. In general, this involves sand or cloth filters.

To reduce the treatment costs physical (physicochemical) separation processes are used which remove the contents, primarily the COD, from the wastewater stream. The separated contents can be disposed of as sludge. The function of the activated carbon adsorption process can at best be reduced to a policing filter (or none).

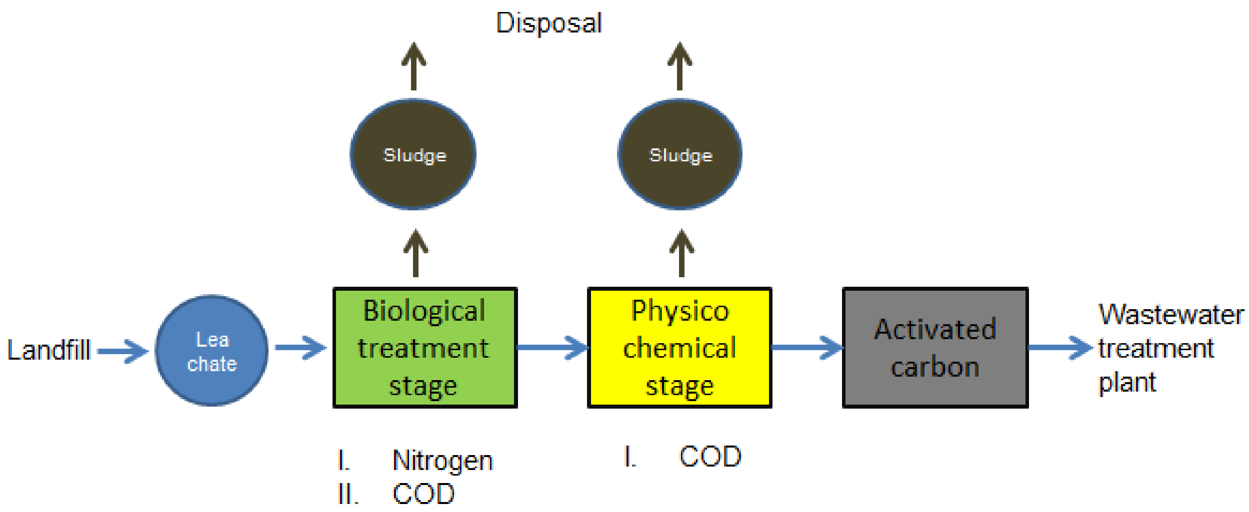

Fig. 2 *Schematic of a landfill leachate treatment system with a biological treatment stage, physicochemical treatment and activated carbon adsorption*

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To separate specific wastewater contents, separation methods such as floatation or filtration are used, for example. In these methods, it is simple mechanical filtration by gravity, as compared to floatation, centrifugation or membrane filtration, which is economically preferred because of the low operating costs. However, the disadvantage is that the separation performance relative to the filtrate is often lacking. The efficiency of the separation process is very much affected by the quality of the conditioning. A prerequisite for good separation performance is for the contents to be separated to be concentrated and joined together as completely as possible into filterable floc structures, which are thereby mechanically separable. It is particularly important to incorporate the fines into the floc structure.

The "DeSiFloc" concept for landfill leachate treatment includes a new, internationally patent-protected floccing process which can separate the pollutants much more efficiently compared to conventional processes. The separation performance of mechanical filtration processes is influenced primarily by the floc structure achieved.

The most important tool for conducting targeted floccing tests is a newly developed floccing sensor, the "FlocSens". The FlocSens uses a photo-optical measurement process based on a CCD line scan camera. The sensor makes it possible to determine, online, specific floccing characteristics such as sedimentation or filtration characteristics of the flocced wastewater. Settling tests were carried out to confirm the measurement results. A two-stage floccing process is used consisting of coagulation (micro-floc formation) and flocculation (macro-floc formation). Iron-III chloride ($FeCl_3$, 40 %) is used as a coagulant, and the solution of a cationic polymer is used as a floccing aid.

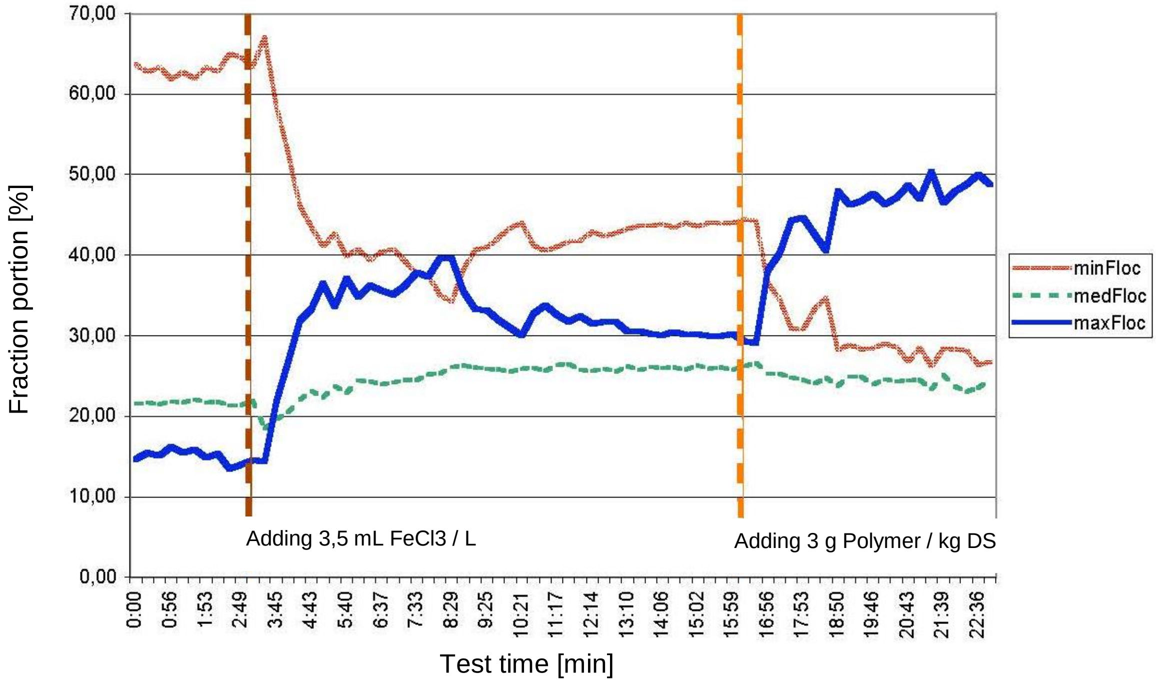

Fig. 3 *Temporal plot of the floc size fractions*

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The addition of the coagulant causes structures to form in the suspension The fraction of small structures decreases and the fraction of large structures increases. The residence time of coagulation is about 15 minutes. During this time, it is clear that the forces of attraction of the coagulant are not sufficient to render the suspension stable against shear. Over time, the structures formed erode and become smaller again. Then, the addition of the polymer causes a jump in large structures. No discernible destruction of flocs occurs during the test time of about 5 minutes after the polymer is added; thus, the flocs are sufficiently stable against shear for the separation process to take place. Fig. 3 shows the temporal plots of the floc fractions consisting of large flocs, medium sized flocs and small flocs for the laboratory tests listed. Considering the distribution of fractions and the shear stability of the flocs formed, the results are congruent with those of the COD fraction in the supernatant and with the visual appearance of the settling tests. The tests showed that the best separation results are achieved with temporally constant floc structures, which are consequently the most stables structures mechanically.

The FlocFormer as a floccing reactor is the heart of the large-scale system. By using the FlocFormer, the landfill leachate treatment process is more consistent in terms of processing and costs compared to conventional treatment. Throughout the entire system, the focus is on removing all pollutants -(apart from the nitrogen components, which must be further biologically decomposed-) efficiently from the waste water using the FlocFormer process.

The FlocFormer floccing system uses two devices; a turbo mixer for introducing the polymer homogeneously into the sludge or water in a short time, and a floc forming reactor that promotes a specific floc structure. The conditioning system has four degrees of freedom for optimizing the floc structure. These degrees of freedom are:

- flocculant dosing,
- turbo-mixer speed,
- floc forming reactor rate,
- floc forming reactor gap

The turbo-mixer unit is designed to mix a highly concentrated polymer solution with the wastewater. The polymer metering and mixing intensity of the turbo-mixer can be controlled online.

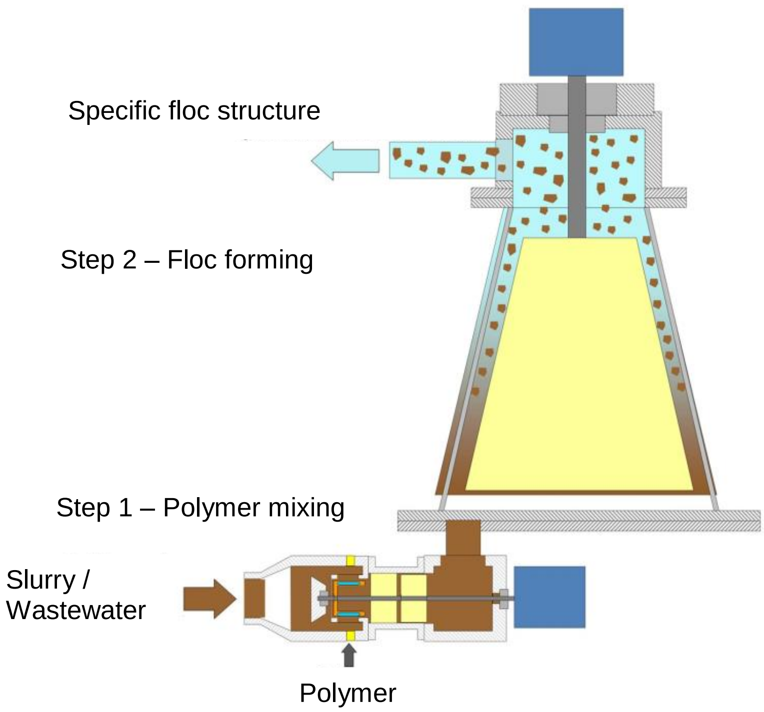

Fig. 4 *Schematic FlocFormer design*

The floc forming reactor is a modified conical agitator in which the specific floc structures are formed. An inner cone rotates concentrically inside an outer conical shell. Between the two conical elements is a constant gap. Because of the varying cone radii, the distribution of centrifugal forces is not constant along the axis of rotation. This means that different flow conditions can exist next to one another during flow within the gap. The sludge flows from the base of the cone through the gap between the concentric cone surfaces to the cone tip. The floc structure is initially destroyed by the high shear rates at the larger diameter. When the mixing intensity decreases corresponding to the axial position, the flow regime changes. The flocs can roll down along the cone walls and one another, and are compacted in this way. The gap can be changed during operation since the inner cone can be shifted in the axial direction. This degree of freedom allows the reactor to be able to treat a broad spectrum of different volumetric and mass flows.

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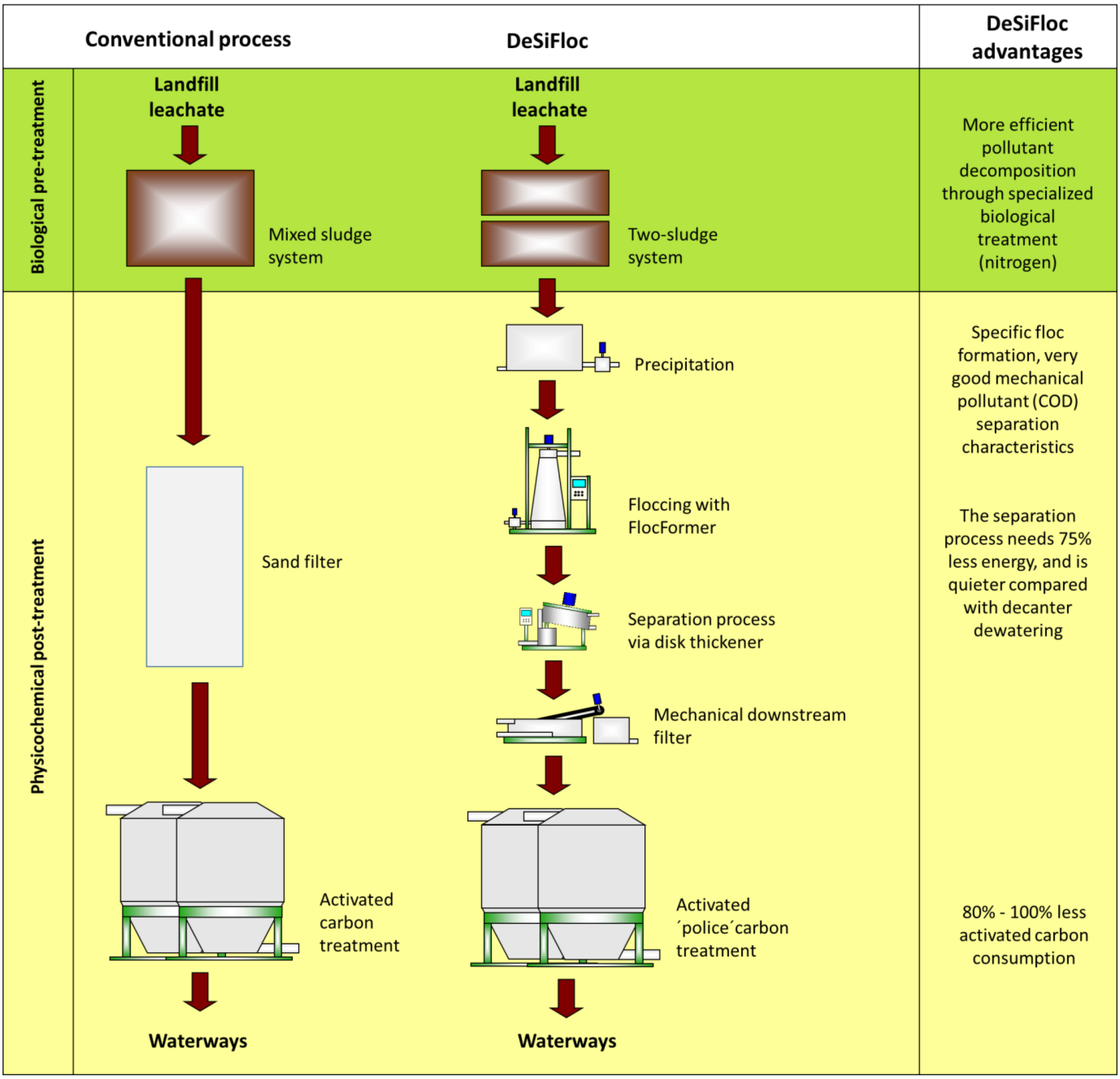

Fig. 5 Comparison of conventional landfill leachate treatment and the DeSiFloc method

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DeSiFloc - Functional schematic and components

The installed system agglomerates and flocculates the contents of the process water and then separates the filterable materials. Fig. 6 shows the schematic of the process. The function of the components used is explained below.

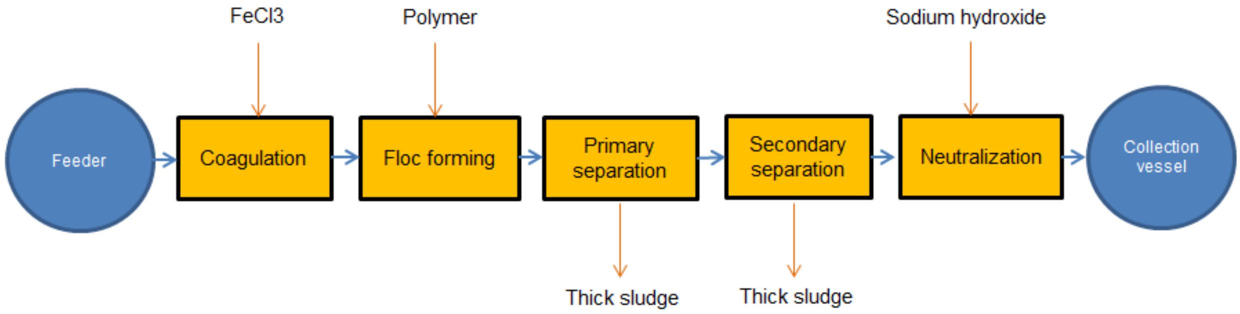

Fig. 6 Schematic of the DeSiFloc treatment stages

Coagulation

In this stage, the biologically pre-treated landfill leachate is electrically destabilized. Organic materials precipitate as a result of the destabilization, which results in a reduction of COD and AOX, and microflocs form. The iron chloride lowers the pH, which can be used as a control parameter. The target pH is relatively high for a coagulation process. The advantage of this is that the amount of coagulant used can be low.

Floccing

By adding flocculant (synthetic polymers), the microflocs which have formed are converted to stable macroflocs in the FlocFormer. Two phases form; the floc structure which contains solids and pollutants, and the relatively clear residual liquid. By tailoring the floc structure, the downstream separation process can be significantly improved.

Primary COD separation

The stable floc structures are separated from the residual liquid using a mechanical separation in the form of a screen.

Secondary COD separation

Another, very fine downstream filtration further separates agglomerated solids from the clear phase. This filter is primarily a protection function for the next stage, which is activated carbon adsorption

Neutralization

After mechanical separation, neutralization of the treated mixture of landfill leachate and MBA process wastewater to a pH of about 6.5 takes place using a base. This is done through the addition of sodium hydroxide (50% NaOH).

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Example of the Hattorf district waste landfill site - direct discharger

Up until 2007, at the district waste landfill of the Osterrode am Harz (Hatttorf) district, the leachate was treated through a biological pre-treatment followed by physicochemical treatment (coagulation, separation, activated carbon adsorption). The pollutant with the highest concentration downstream in the feed to the physicochemical treatment stage is the non-biodegraded or non-biodegradable COD. This is between 30 % and 70 % of the original COD, depending on the leachate composition.

The relatively high water load in Hattorf at the time often resulted in operational disruptions in the biological treatment stage and in the downstream filtration stages of the leachate treatment plant. This circumstance necessitated a significant reduction in the treatable flow volume. This led to an expensive disposal process of the leachate in Hattorf.

Problem: The physicochemical treatment and downstream activated carbon system being designed must treat the landfill leachate economically enough to ensure that the direct discharger limits are not exceeded.

Solution with the DeSiFloc process:

In 2007, the landfill leachate treatment plant in Hattorf was retrofitted from the ground up. In addition to bolstering the biological treatment stage, the DesiFloc process was used for the first time as a physicochemical treatment stage. The newly developed “FlocFormer” floccing system, in combination with a simple disk thickener as a separation stage to reduce the COD, proved that this combination is very economical to operate and is also a very safe process. The FlocFormer provides a tailored floc structure during the floccing process. This makes it possible to bind a large fraction of the pollutants into the flocs, thereby making mechanical separation of them possible.

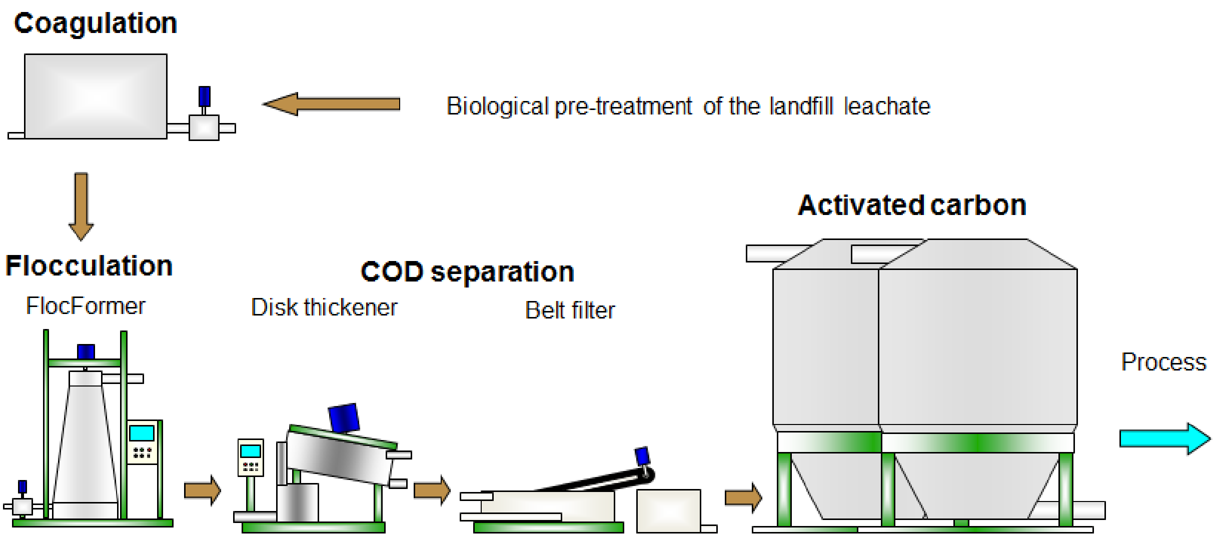

Fig. 7 Schematic of the DeSiFloc treatment stages

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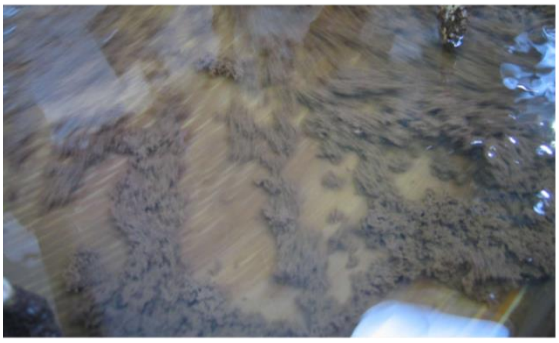
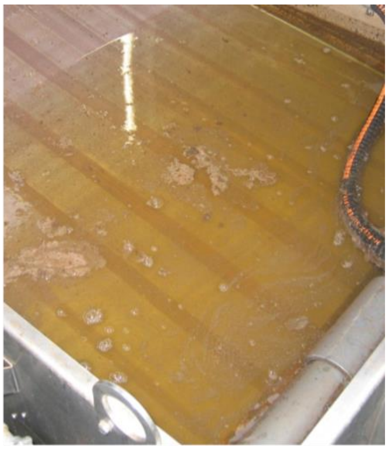
The use of the FlocFormer has two effects that result in a lowering of the operating costs:

1. The actual COD separation process can be done using a technically simple gravity filtration process. The COD elimination no longer needs to be done in the upstream biological treatment stage.

2. The COD separation performance can be significantly improved by using the FlocFormer. The burden on the downstream activated carbon stage was reduced by 90 %.



1. Disk thickener



2. Belt filter

Fig. 8 Flocced landfill leachate in the process

After the disk thickener, a belt filter was provided that removes any possible remaining suspended material from the DSW using a very high-mesh filter medium. After the mechanical filtration of the leachate pollutants, there is an activated carbon adsorption stage. Full adaptation and efficiency of the flocculation-initiated separation process reduces the function of the activated carbon stage to a policing filter for the COD parameter.

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Left to right:

Fig. 11 Treatment and clarification stages for the landfill leachate in the DeSiFloc system

Fig. 12 Partial view of the DeSiFloc system in Hattorf

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Example of consumption cost calculation for chemicals and activated carbon for Hattorf - direct discharger

Consumption of $FeCl_3$	3.7 l/m3
$FeCl_3$ costs	0.24 €/l (0.17 €/kg)

Consumption costs for $FeCl_3$	0.89 €/m3
Consumption costs for polymer	0.04 €/m3
Consumption costs for activated carbon	0.26 €/m3
Thus, the specific consumption costs in the physicochemical treatment stage is only	**1.19 €/m3**

Compared to the former cost (with high carbon consumption): a cost reduction of approx.. 80%.

Economical benefits:

The ecological advantages of a safe separation are inestimable even considering increasing environmental restrictions.

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Example of the Deiderode district waste landfill site – indirect discharger

The landfill leachate plant in Deiderode is part of the district waste landfill of the district of Göttingen and was originally built to treat incident leachate from the landfill heap. The leachate treatment facility is an indirect discharger of the treated leachate. The mechanical-biological treatment plant (MBA) of the Abfallzweckverband Südniedersachsen (*Southern Lower Saxony Waste Disposal Association*) also sends water to the leachate treatment plant to lower the hydraulic load on its system. This relatively high water load causes operational disruptions in the downstream filtration stages of the treatment plant and results in high costs in the activated carbon area.

The existing landfill leachate treatment plant at the Deiderode landfill of the district of Göttingen was expanded to include an additional separation stage in order to safely allow the MBA of the Abfallzweckverband to send wastewater to the leachate treatment plant. Initially, a maximum of 1.5 m^3/h of MBA wastewater could be added to the treated amount in the leachate treatment plant, but it was desired to be able to send about 6 m^3/h. To achieve this goal, the treatment plant was bolstered by an intermediate DeSiFloc processing stage. This additional treatment stage was situated downstream of the existing biological treatment stage and upstream of the existing activated carbon treatment stage. The amount of water to be sent and the landfill leachate treatment plant concentrations to be adhered to remain the same.

The treatment stage treats a maximum daily biologically-pretreated leachate amount of 288 m^3. The maximum throughput per hour comes to 12 m^3 and the maximum throughput per second is 3.33 litres.

The DeSiFloc process is designed to be scalable. Each module has a base throughput for landfill leachate of 6 m³/h. Parallel operation of multiple modules can be done easily. To achieve the maximum output of 12 $m^{3/}$h, the separation technique was installed in two parallel lines. The advantage to this is redundancy and a partial load system range, also making it easier to operate. Fig. 13 shows the schematic of the two lines. The filtered landfill leachate and the separated thick sludge are further treated centrally.

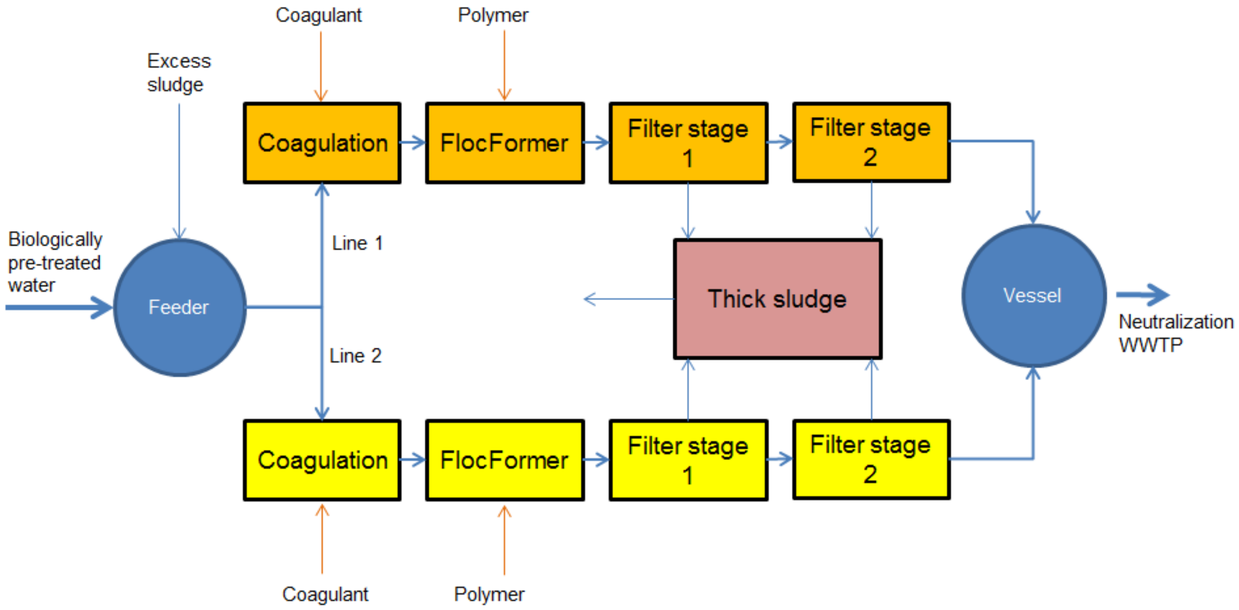

Fig. 13 Process schematic for the DeSiFloc plant in Deiderode

To make sure that the flocs approach the screen as carefully as possible, the landfill leachate flows through the separation stages by the force of gravity following the FlocFormer, see Fig. 13. The plant is designed in such a way that the separating machines are installed on a platform and the corresponding vessels for the individual components are installed at ground level. This ensures good access for cleaning the system parts. Fig. 14 shows a partial view of the installed system.

Fig. 13 One line of the DeSiFloc plant in Deiderode

Fig. 14 Partial view of the DeSiFloc system

The landfill leachate treatment plant in Diederode is an indirect discharger. The water is sent to the district wastewater treatment plant in Göttingen. After start-up of the DeSiFloc system, it was possible to take the existing activated carbon stage out of service. The profitability of the process is very positive.

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Example of consumption cost calculation for chemicals at Deiderode - indirect discharger

Consumption of $FeCl_3$	3.0 l/m3	
$FeCl_3$ costs	0.24 €/l (0.17 €/kg)	
Consumption costs for $FeCl_3$		0.72 €/m3
Consumption costs for polymer		0.10 €/m3
Consumption costs for activated carbon		- €/m3
Thus, the specific consumption costs in the physicochemical treatment stage is only		**0.82 €/m3**

The original operation of the landfill leachate treatment plant at reduced volumetric flow resulted in a calculated cost for the activated carbon stage of about 5.30 €/m^3.

However, the actual number was probably higher since the capacity of the activated carbon could no longer be achieved due to blockage by solids.

The expansion of the plant to include a newly tailored biological treatment stage and the physicochemical DeSiFloc stage made economical treatment of the entire amount fed to the landfill leachate treatment plant possible. The annual savings in comparison to pure activated carbon adsorption are considerable.

Economical benefits:

The ecological advantages of a safe separation are inestimable even considering increasing environmental restrictions.

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