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11 Years of Operational Experience of a Floating, Walk-on Biofilter (45,000 m²) for Reducing Emissions of the Grube Johannes in Wolfen/Bitterfeld (a Flooded Opencast Lignite Mine)

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In 1995 the method and equipment for this innovative floating, walk-on Biofilter were developed using economical means with the purpose of reducing emissions (especially H_2S) of toxic and foul smelling viscous sludge of the Grube Johannes (Silbersee). A continuous layer of Biofilter was installed on gas-permeable floats over an area of sludge covering 45,000 m². Now, 11 years later, the Biofilter is still operating in the open nature in a self-optimizing manner: 85% of the valid immission-measurements drop below the limit of detection (1,4 µg H_2S/m³) and less than 1% of the immission-values lie over the WHO-limit (7 µg/m³).

1. Introduction: Historical Background

The opencast lignite mine Grube Johannes located at the southern edge of the city of Wolfen has been used as a landfill and settling pit by the local industry, above all by the photochemical combination Wolfen (later film factory Wolfen) since about 1920. It became the international symbol for a threatening chemical pollution in the Bitterfeld area and the object of numerous press revues under the name „Silbersee“ („Die Leute werden dun im Kopf“ – “The people are becoming dull in the head”; Spiegel, 8. January, 1990)

With an average depth of 10m, about 3 million m^3 of gel like pulpy waste sludge can be found here, about 1,100,000 m^3 beeing cellulose-lignine sludges. At the time of investigation (Barkowski, 1992) the sludge mixture was covered by a 1m thick layer of water. Different rehabilation variants taken into consideration at the time of investigation could not as yet be realized (Feiler, 1992, Scheffler et al., 1993).

2. Changed Emission Situation 1994/ 1995

A significant change took place mid 1994, when the dam had to be filled up to stabilise the embankments of Lake Silbersee as this was necessary for constructing the State highway that ran past its eastern shore. If at first 120 m³ to 180 m³ of building rubble was unloaded per day, it was almost double at the beginning of 1995; in 1995 alone

Fig. 1. Newly formed sludge surface on the "Grube Johannes" by dam-filling measures, as in: July 1995

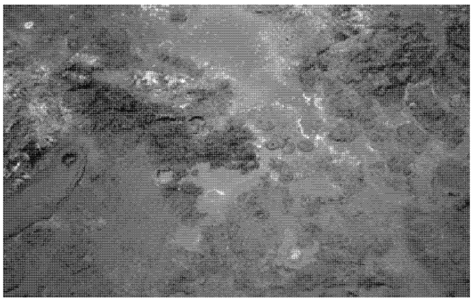

Fig. 2. Sludge surface with geyser-like areas and eruptive release of gas

about 230,000 m³ of building rubble was supplied to fill up a 580m length of dam. These measures caused a shift of the deep-sludge to the surface, new large areas of sludge were formed and gases were released. With every cubic meter of unloaded rubble, 0.8 m^3 sludge rose to the surface pushing aside the water cushion (Fig. 1). These fields of sludge covered an area of about 45,000 m² and could not be walked on. There were zones with fresh sludge that could flow and apart from this, geyser-like patches with eruptive release of gases (Fig. 2). The main component of the gaseous emissions was hydrogen sulfide (H_2S). Concentrations of almost 100,000 µg/m³ were measured directly on the sludge surface, which with about 70 ppm corresponds to 6.6 times the MAK-value (maximum allowed concentration at the place of work) which is 10^5 above the corresponding bench-mark value of 7 µg/m³ H_2S given by the WHO. Olfactory measurements showed an order of magnitude of 800,000 units of odor per cubic meter, in peak summer even 2.3 million OUE/m^3. This odor pollution exceeded that at high performance industrial sites by a factor of 100 to 1.000 (Hanert et al.,1995a; Hanert et al., 1995b). How hazardous these extreme gases are could be proved by laboratory tests done for purifying exhaust gas, by which the gas emitted from the sludge even after dilution with normal air as per experimental requirements, showed an average H_2S concentration of 1.540.000 µg/m³ . Such an exhaust air containing 1.000 ppm H_2S is not only extremely toxic for plants but also highly toxic for humans – symptoms of unconsciousness and cramps and even death can occur within minutes (Burmeier et al., 1990).

3. Measures Of Danger Prevention

Due to the gaseous emissions from the new sludge-fields, it was at first attempted to siphon out the sludge and to deposit it after specific treating. However this was very expensive in the long run. On the other hand conventional measures for preventing emission could not be applied to such large areas of sludge – one could not walk on the surface, and it was not possible to collect gas technically. For this reason the Technical University of Braunschweig began to develop an extended floating, surface biofilter in the spring of 1995.

The idea was to connect a series of floats covering the whole area to a layer of biofilter material, in which the harmful matter and smells would be degraded to a large extent thus reducing the emissions. Laboratory experiments intended to simulate the emissions caused by filling up the dam were carried out as column-experiments.

4. Developing A Concept For A Floating Walk-On Bio-Filter As Safety Measure For A 45.000 M² Area Of Sludge

These experiments showed that, by taking an average starting concentration of 1.540.000 µg H_2S/m^3 in the crude gas the highest state of pollution was simulated. The concentration directly above the sludge surface is about one decimal power lower.
Surprisingly this experiment was possible with the minimum bulk height of the filter material which still allowed sufficient elimination of harmful and smelly emissions (s. Fig. 3). According to technical requirements, biofilters for purifying exhaust air should have a minimum bulk height of 1m – a value which cannot be taken into consideration for a floating construction. Experiments with 6 cm, 10 cm and 17 cm material thickness showed that under the given conditions a minimum height of 10 cm was necessary for a sufficiently effective filtering. For the large technical implementation, a filter height of 12 cm was chosen in the end (with conventional biofilter materials) – a surprisingly low value for a biofilter. Microbic processes are responsible for elimination the hydrogen sulfide in the filter. A mass development of sulfide oxidizing microorganisms appears with-in a short time, these oxidize the H_2S to sulfate thus detoxifying it. At first neutrophilous sulfide oxidants are formed with an increase in the number of bacteria to 10^5 to 10^6 (upto 5 x 10^6. germs/g filter material) and finally a population decrease followed by a population of acidophilous sulfide oxidants with a similar concentration of millions per gram of filter material. The change from neutrophilous to acidophilous obviously causes the acidifying of the filter material connected with the sulfide oxidation, to pH-values around 2. Sulfate deposits increase from milligrams to grams. (Hanert et al., 1995a; Hanert et al., 1995b).

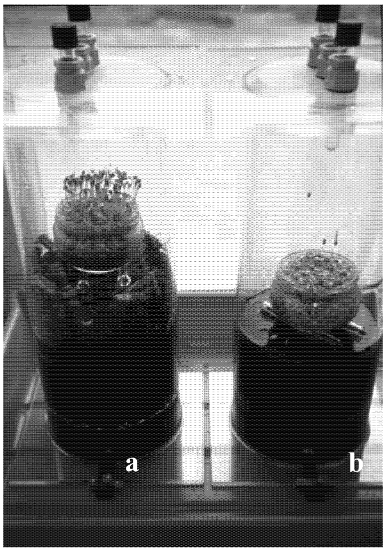

Fig. 3. No growth of L. sativum within the sludge emissions (**b**); good growth above a 10 cm biofilter layer (**a**)

5. Conception Of The Area Filter (Reference Field)

The floating, walk-on bio surface filter for which a patent having been assigned in June 1995 (published by the German Patent Office), is comprised of two chamber-sack elements with a 12 cm thick filter layer having a styrofoam with double the thickness as float (see Figure 4). The load capacity of the system was dimensioned such that on being completely saturated with water, the filter-material has enough reserves for additional extra-load such as snow and an ageing of the styrofoam chips can be compensated. These reserves have the significant side-effect that the filter can be walked upon – an extremely important feature for the installation of the filter system and for surveillance of the physiological and mechanical functions.

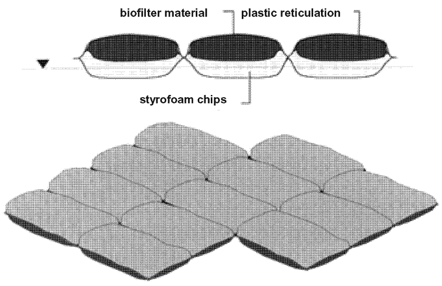

Fig. 4. Cross-section and view from the top of the floating two-chamber sack surface filter

Fig. 5. Installing the biofilter of the extended area without boats from an already existing field

A possibly large resistance to the influences of weather and the environment were taken into account while selecting the filter material. Practical experiments done on a 300 m² reference field helped to improve the material selection.

The sack-segments were at first placed from the water-side with the help of pontons and boats and connected to form a floating surface filter. The placing of segments was then continued from the land-side over the already walkable filter surface (Fig. 5). With the help of this technique, the sludge fields were covered up with the surface biofilter without leaving a single open space and the liquid landfill body was degassed. After having been used on the reference field, the whole 45,000 m² large surface filter was placed on a flat construction in the same way.

It was shown that the effectivity of the biofilter was just as high in the open air as with the laboratory experiments. Over an observed period of time of half a year, the hydrogen sulfide concentration was reduced to 94% and 99%, the organic emissions between 87% and 96%. Exact measurements of odor reduction were difficult due to wind influences but a reduction of between 74% and 86% could still be proved (by means of a sampling hood, s.Figure 6). A drop in toxicity of 80% was shown with the help of bioluminescence-tests.

Only a biofilter garantees a long stability due to its biological degradation of pollutants, whereas the filtering effect on the basis of physico-chemical adsorption wears out the filter capacity with time finally leading to a permanent, irreversible rupturing. Corresponding tests to determine the germ count as well as measurements on the change in sulfur content and pH-value gave proof of the biological degradation of H_2S. Infrared spectroscopical and gas chromatographical investigations to establish the absorption /adsorption of organic materials in the filter material showed negative results as expected.

6. Full-Scale Filter System

After satisfactory investigations of the reference fields and making the necessary optimizations, the GÖS mbH, Wolfen/Thalheim, having also been in charge of filling up the dam, brought the full scale floating surface-filter system on the Lake Silbersee. Altogether 45,200 individual hand-made double sacks were laid. With this, mainly the strong hydrogen sulfide emissions could be reduced to a large extent and

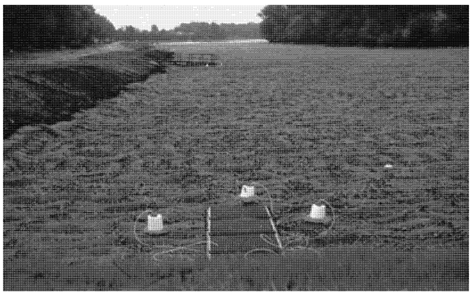

Fig. 6. The photo taken in May 1996 shows the condition of the filter and also gives an impression of its dimensions (in the foreground 3 sampling hoods).

an odor-free condition in the sense of local environment protection, could be created for the inhabitants. Compared to the 6 million Euro that would have been necessary for the installation of conventional aspiration techniques, 500,000,- Euro for this method of solving the problem was extremely profitable. Figure 6 shows the condition of the biofilter in May 1996. Laboratory investigations estimated a long-term stability of seven years initially.

7. Functionality Of The Extended Area Bio Filter After An Operating Time Period Of 11 Years

Nevertheless to date the floating 45,000 m² large biofilter has been operating for about 11 years. Being the outer connecting layer of the sludge fields of the north-hose of the Grube Johannes, it was practically unprotected and subjected to very different and at times extreme weather influences in the region. It had to withstand very dry periods and strong sun as well as periods of stormy rainfall. Added to this, periods of frost, sleet and sudden downpours were also a strain on the mechanical and biological features of the filter system.

The extended, floating biofilter on Lake Silbersee was intended as a tentative, interim solution for safeguarding the 45.000 m² extensive sludge fields against odor and hydrogen sulfide emissions. It was therefore surprising that the filter still existed after 11 years in operation and still functioned. Fig. 7 - an aerial view of the Grube Johannes - clearly shows the dimension of the biofilter once more, and also prove that the layer of filter covering the whole area is still intact. In the meantime however, the external appearance of the surface filter has changed considerably. Reeds and humid biotopic plants cover large areas of the filter, and have overgrown certain areas of the sack-construction (s. Fig. 8). Starting from the waterside at the south-end of the lake and

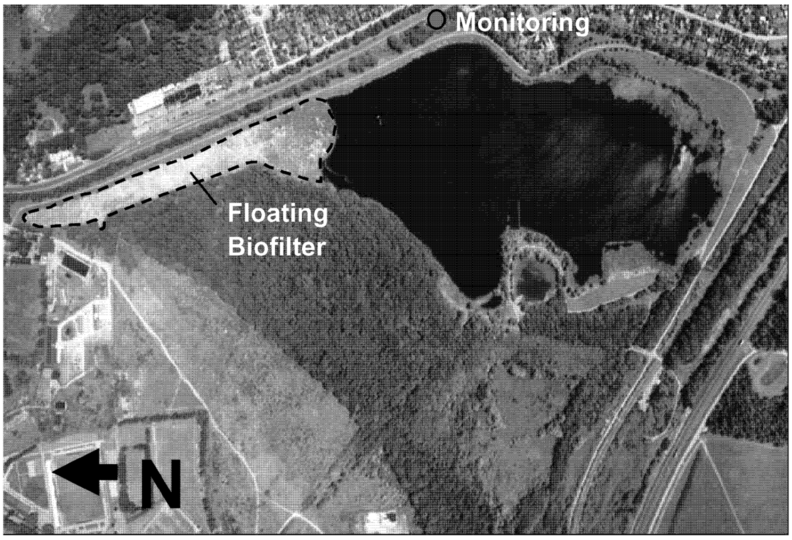

Fig. 7. Current photo of Silbersee taken from the air (2006) with intact biofilter area

the western shore-side an increasing aggradation process becomes obvious. Bushes and small trees have already started growing on the lake-side, so that this area has the appearance of floating bushes.

Altogether, a complex, thorough network of filter-sacks, roots, leaves, mulch etc. have built up over the whole filter-area. If the sacks got torn and opened in the course of time, the styrofoam chips were not scattered as feared but got integrated and baked into the new matrix.

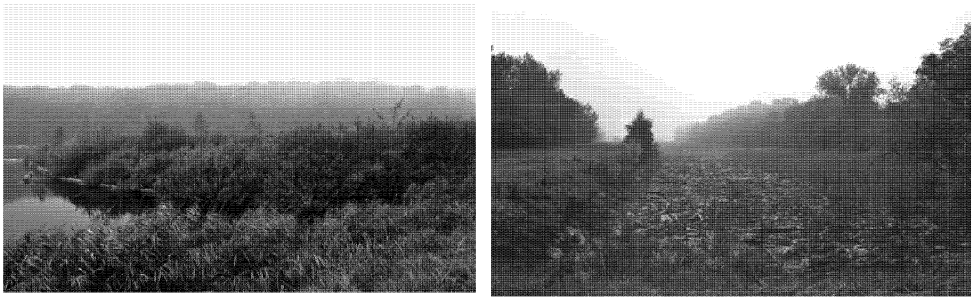

Fig. 8. Photos taken in the autumn of 2006 show the advancing aggradation process of the biofilter after 11 years in operation (left: from the lake / right: on the western shore)

8. Continuous Filter-Function Over The Whole Validity Period Including Self-Optimization

From August 1992 continuous immission measurements (H_2S and CH_4; CH_4 data not shown) were conducted within the course of a routine monitoring, using a measuring

trailer. This monitoring station was located about 300m south of the biofilter, directly on the shore of the lake Silbersee (see marking Fig. 7).
With the exception of a gap caused by technical failure in 2000/2001, a continuous set of data is available for the whole operational period. An overview of the development of the H_2S immissions at the Grube Johannes in the past 14 years is depicted in Fig. 9 giving the monthly average values. For a better understanding of the graph, the most important technical measures and observations have also been included.

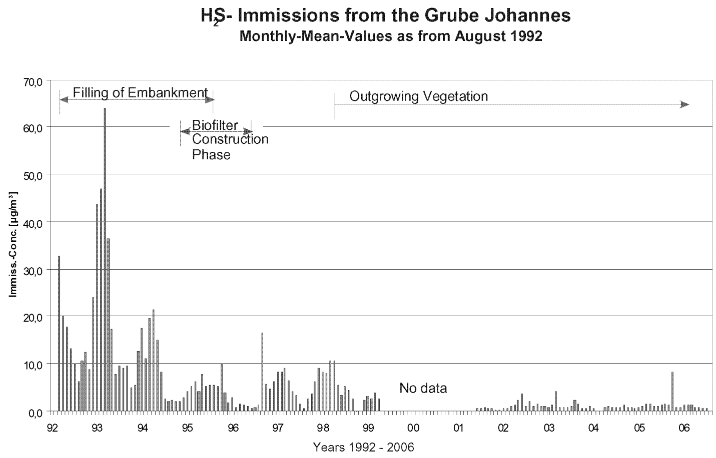

Fig. 9. Long term monitoring of H_2S immissions at the Grube Johannes from 1992 to 2006 prove the continued improvements in the biofilter effect on the Grube Johannes upto this day (Location of the measuring station see Figure 6)

First of all, the line graphs of the average values in the period from 1992 to 1994 clearly show that the dam-filling measures during this period are reflected in the immission values. It is thus shown that in the „peak year“ 1993, 73% of all the recorded values exceed the tolerance value (7 µg/m³) specified by the WHO. Even though the intensity of filling up the dam was doubled in 1995 by working in two shifts, the biofilter layer which even though set up with a slight delay, was able to compensate this effect. Only 12% of the measured values exceeded that specified by the WHO.
The constantly remaining effect of the filter becomes obvious in the years 1995 to 1999, the average monthly values had all been reduced to the tolerance value specified by the WHO (7 µg/m³) barring a few exceptions. The high recordings in the previous years giving double digit figures was repeated only once for a very short time (in the spring of 1997).
From 1998 onwards an increasing outgrowth on the filter surface could be observed (see Fig. 9). Even though a continuous immission data was available only from 2002, the graph clearly shows that the emissions from the sludge field do not increase after expiry of the prognosed running time of 7 years. Quite the contrary: obviously the inhabitation and the aggradation processes going on within the filter system are responsible for a self-optimization of the biological system, i.e. gaps in the filter layers close naturally – in the same way the activity of the thiobacteria is stimulated and the oxygen supply in the mulch layer is ensured by the roots.

Even to date, the odor pollution even for those living in the direct neighbourhood of the Grube Johannes is very low, as the threshhold value of (7 µg/m³) as specified by the WHO is not generally exceeded in more than 1% of the cases. Approx. 80% to 85% of the valid recordings are in fact below 1,4 µg/m³ (further data are reported in the lecture).

9. Conclusions

This stable, weather resistant, floating and not housed-in biofilter system covering an area of 45,000 m^2 is the largest of its kind. In the 11 years of its operation it has proved its worth as a long-term security measure, its efficiency is getting better every day. Hence, the immediate neighbourhood has the advantages (compare Fig. 7) to be able to live since years now without pollution at Lake Silbersee (proved by the many new and upcoming residential buildings).

10. References

Barkowski, D. (1992) Investigations for restoring Grube Johannes (Silbersee) in Wolfen/Bitterfeld- Characterization of the landfill content -in:Hille, J., R. Ruske, R.W. Scholz, F. Walkow, (Hrsg.)"Bitterfeld, model ecologic inventory of a contaminated industrial region" Contributions of the 1st Bitterfeld environmental conference; in: Pollutants and environment, Volume 10, Erich Schmidt Verlag GmbH & Co., Berlin

Burmeier, H., R. Dreschmann, J. Ganse, R. Rumler (1990) Working hazard –free on abandoned sites Arbeiten. focon-Ingenieurgesellschaft für Umwelttechnologie und Forschungsconsulting mbH, Aachen – Society of Engineers for environmental technologie and research consulting mbH, Aachen

Feiler, W. (1992) Application oriented investigations on thermic disposal and energetic utilization of lignine sludge fromt the Grube Johannes mine (Closing Report) DBI/EWI, Freiberg

Hanert, H. H., D. Dietzmann, C. Gloistein, P. Harborth, M. Kucklick (1995a) Closing Report on the process optimization and investigations of effectiveness about the operation of surface biofilter for minimization of toxic and badly smelling surface and viscous sludge-fields of the Grube Johannes caused by dam-filling measures, Institut für Mikrobiologie der TU Braunschweig;

Hanert, H. H., D. Dietzmann, C. Gloistein, P. Harborth, M. Kucklick, Ch.Waschke, M. Wittmaier (1995b) Biological purification of gaseous emissions in exhaust air in waste treatment. In: Mechanical-biological treatment of waste, Booklet 10, Centre for waste research of the TU Braunschweig

Patent Nr. DE 4440464 C1 (1994) „Process and Appliance towards reducing the emission of environmental pollutants, Deutsches Patentamt München, angemeldet am 14.11.1994

Scheffler, H.; R. Scherbeck, G. Otto, A. König, R. Sonnenberger (1993) Immediate security for the sludge pond Grube Johannes der Filmfabrik Wolfen, Hrsg. Jessberger, Sicherung von Altlasten (Security at abandoned and hazardous sites), Verlag A. A. Balkema, Rotterdam.