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MICROBIOLOGICAL DECONTAMINATION OF CONSTRUCTION DEBRIS

Large amounts of construction wastes are still landfilled and not recycled. Main constituents of these wastes are mineral construction debris and excavated soils, possibly mixed with mineral debris and rubble. Mineral oil products are the contaminants often found in construction debris. For low mineral oil concentrations of about 10 g/kg the biological treatment is one of standard approaches to soil decontamination. An investigation was carried out to develop a practically applicable biopile method. The special problems of rubble and construction debris, such as a large coarse particle fraction, an alkaline milieu and the lack of nutrients had to be considered and overcome. Several laboratory, pilot- and large-scale tests were performed. Necessary parameters and conditions could be derived and a simple suitable biopile process was developed. Though there is still potential for optimization, especially related to the alkaliphilic microbial consortia, the process can already effectively be applied in a number of contaminations.

1. INTRODUCTION

Yearly large amounts of construction wastes are still landfilled and not recycled. In Germany, about 285 million tons of construction wastes were generated in 1997. The overall recycling rate for this waste was about 55%. It shall be increased to 70% by the year 2000. This demands a better separation of wood, plastics, textiles and fines. However, also the recycling of the mineral portion has to be remarkably improved. For mineral construction debris and rubble such as tiles, bricks, concrete, which comprise about 11% of the whole construction wastes, the recycling rate will be increased from now by about 70% to 90% in the year 2000. A similar increase in the recycling rate shall also be accomplished for excavated soils, which amount to about 75% of the

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construction wastes. These soils are possibly also mixed with mineral construction debris and rubble. Obviously new applications and/or technologies have to be found for these wastes. Especially for the contaminated portions, versatile technologies should be available or developed.

In construction debris, mineral oil products are the contaminants found in the majority of sites due to their long and widespread utilization in machines and equipment. For low contaminant concentrations (about 10 g/kg) and because of the rubble or particle sizes and their particle size distribution, washing and incineration seem not very appropriate. In addition, this could implicate problems in handling as well as clogging within such an equipment as separators and incinerator kilns. For these low mineral oil concentrations, the biological treatment is one of the standard approaches to soil decontamination. Biotreatment is even applied to rubble after crushing and separation, usually in a bioreactor to improve contaminant bioavailability and degradation rates. However, a water post-treatment is necessary. A much simpler approach would be the biological treatment in a pile, similar to the soil-pile treatment. This would also allow us to overcome the disadvantage of the wastewater post-treatment. Therefore an investigation was carried out to develop a practically applicable method for the decontamination of construction debris in a biopile or windrow.

2. MATERIALS AND EXPERIMENTAL GOALS

The principal possibility and optimal conditions for the remediation of construction debris should be tested. The debris for the investigation came from the dismantling of a mineral oil tank storage site. Primary focus was the reduction of the mineral oil contents from about 10,000 mg/kg dry substance (DS). As remediation objective generally 500 mg/kg DS are accepted in Germany.

The special problems of rubble and construction debris had to be considered and overcome. One major problem is a large fraction of coarse particles and their fragments of sizes up to several 100 or even 1000 mm. Also very fine particles could be present after crushing. Several other soil and debris treatment processes prove that for an effective treatment the particle size should be limited. Thus, e.g. in order to clean a construction debris by extraction of organic contaminants from a slurry of water and debris by solvents, a particle size less than 40 mm is proposed in a patent [3]. For the biological treatment of contaminated soil with debris another patent [4] proposes a particle size limit of 10 mm or even 6 mm. It is obvious that microorganisms need a certain settling and growing surface area and a proper pore size distribution to be effective. Crushing and sieving steps are therefore necessary. However, the approximate particle sizes should be technologically feasible and economically justified. Commercially available hammer mills or jaw breakers for construction debris easily produce particles whose sizes approach 50 mm. By sieving and recycling of the coarse fraction it is possible to obtain due to additional technological efforts and expenditures particles of smaller sizes. According to the technical sieve mesh sizes, in the study three different particle size limits have been tested:

< 16 mm,
< 32 mm,
< 56 mm, maximal particle size.

In general, construction debris is known for its alkaline milieu, the lack of nutrients and pH values up to 12, in general from about 9 to 10. In this study, only adapted standard microorganisms tolerating pH up to about 8.5 have been tested in order to estimate their suitability for remediation of debris. Therefore appropriate neutralizers, fertilizers and limited amounts of substrate materials could enhance their bioactivity very much. Besides the usual phosphate and urea fertilizers also ammonium sulphate $(NH_4)_2SO_4$ was tested. As substrate and supplementary material the following additives in different concentrations were used:

soil,
bark pieces (and wood chops),
light (up-floating) residues from soil washing.

In order to achieve a sufficient homogenization and to overcome the known problems associated with mixing technologies, an optimized pre-treatment technology was developed. Crushing, sieving, adding materials and microorganisms in certain appropriate ratios, mixing and homogenization are adequately accomplished and controlled by a semi-automated procedure (patent pending).

3. METHODS

Several laboratory, pilot- and large-scale tests were performed (ACKSEL [1]). Starting from the tests in laboratory columns (1 m length, 0.06 m diameter, about 2 kg debris) and pilot-scale boxes (1 m^3 volume and about 1000 kg debris), also biopile tests (windrows with 3 m height, 8–10 m base width, about 100 t) with different conditions and parameters have been performed.

Figure 1 shows as an example the sketch of the experimental equipment for the laboratory tests in columns. The designs of the pilot-scale tests in boxes and the windrow tests were similar. The tested construction debris and material mixtures were placed in the columns and boxes and held under the specific experimental conditions for the periods between 100 and 180 days. For the column tests the temperature was held at 30 °C to achieve optimal conditions. The room for the boxes was heated to temperature ranging between 5 and 10 °C to reduce the strong influence of external weather in winter. Air supply for the aerobic degradation and water content was controlled and corrected if necessary. The exhaust air was cleaned by a biofilter and subsequently by activated carbon filter. The latter was also true for the windrow tests. The adjustment of water content and/or temperature as well as addition of allochthone microflora were much more restricted to the start and to one or two dates during the test period.

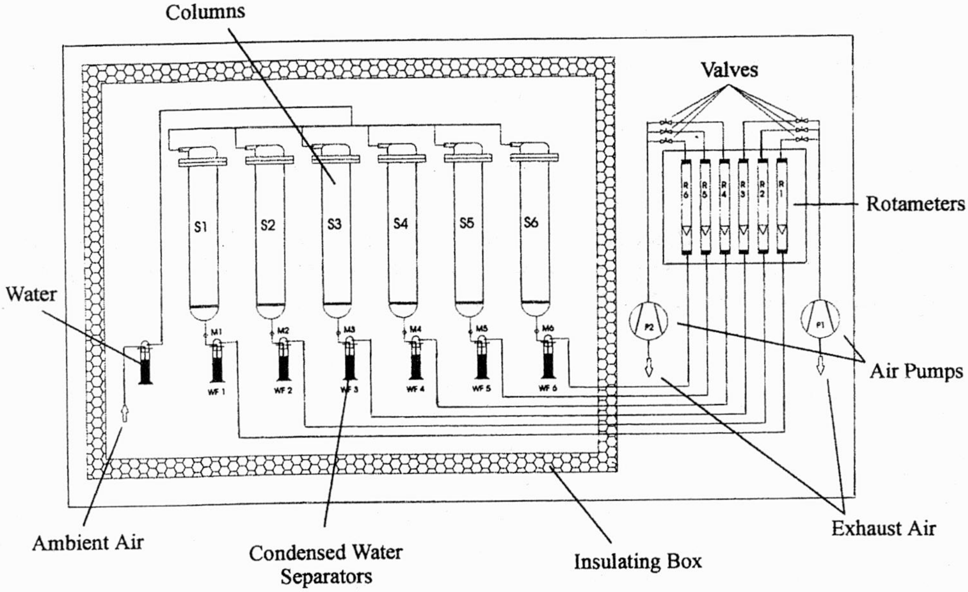

Fig. 1. Sketch of column tests

Compliance and provisions for a proper sampling and analysing during the study are not the focus of our interest. However, sampling and analysing problems are very specific for such coarse particle matrices. Usually, large sample masses (up to several kg, characterising and representing the original particle distribution) are necessary and indispensable in standard methods. Also sample processing, division, preparation and analysis require special care, which was duly given in these investigations (ACKSEL [1]). The following parameters have been measured or analysed according to the German or international standards:

mineral oil content by IR spectroscopy and GC,
certain contaminants (heavy metals, BTEX, PAH) content,
water content and water holding capacity,
nutrient content (N, P),
soil oxygen demand (Isermeyer method) (ALEF [2]),
pH value and conductivity,
dry substance weight and ignition loss,
inhibition (toxicity) test,

colony forming units,

particle size distribution,

oxygen, CO_2 and CH_x (volatile organic components) contents and volume flow in fresh and exhaust air.

4. RESULTS AND DISCUSSION

As all papers dealing with extensive tests, this paper presents only some selected results which are mainly based on the column tests. In figure 2 there is presented the mineral oil content (IR method) in 6 columns during the test period of 110 days. The curves link the given experimental data of the same test. They do not represent the actual dependence between the data points.

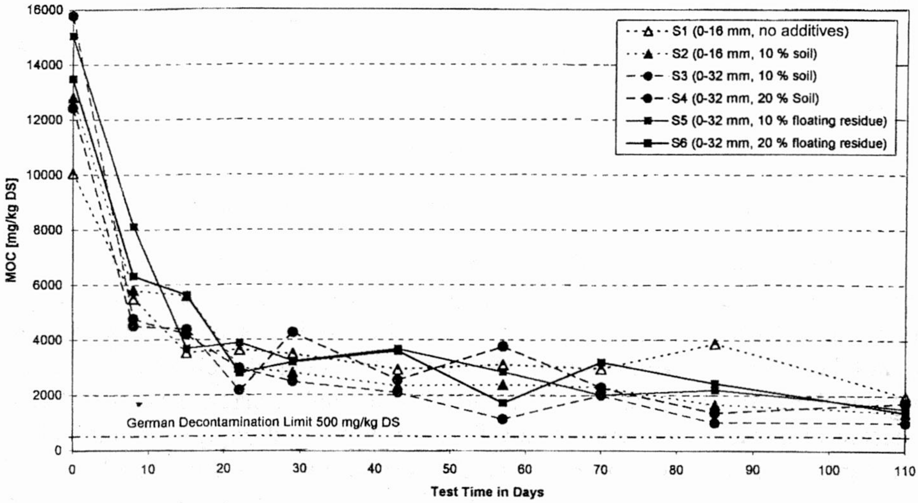

Fig. 2. Mineral oil content (MOC) in columns (IR method)

A degradation of the mineral oil over the total testing time is obvious. In the columns, the decrease in contaminant concentration was remarkable in the first 20 days. Then a flattening of the curves could be observed. However, sometimes an enhanced data scattering can also be seen. That was especially evident in the box tests with larger particle sizes without additives. It is extremely difficult to guarantee taking and analysing representative samples. A further influence is the actual location of contaminants in or on the debris (sorbed or at the surface). The experimental data in figure 2 are mean values of at least two different analyses from an adequate basic sample of several grams after proper sample dividing and preparing. If these two analytical results differed extremely, two further analyses of the basic sample were carried out once again and included into the data calculation. This procedure was also applied to the box and windrow tests. However, several kg were taken for an original sample and three different analyses were carried out.

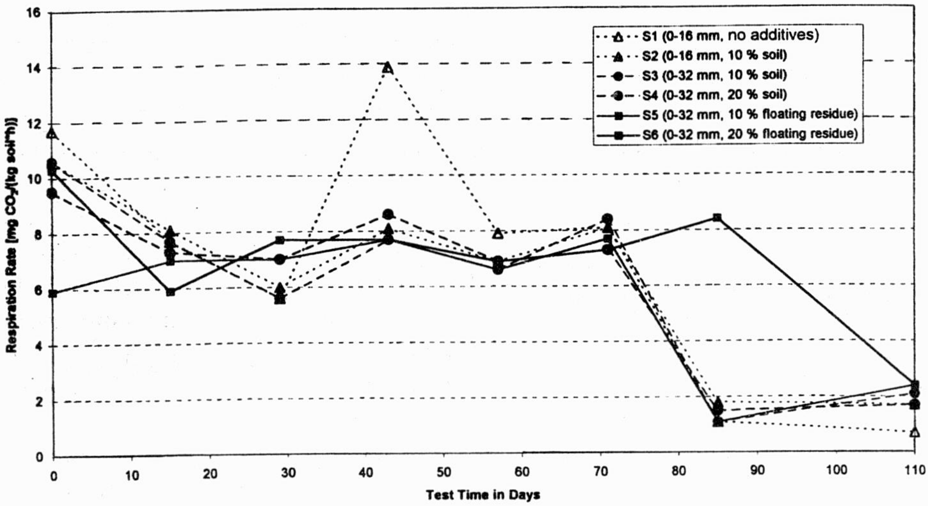

Fig. 3. Respiration rate in columns (25 g soil, Isermeyer method)

The remediation is principally possible; however, it takes longer than standard biological soil remediation in windrows (MUELLER [6]). Under the conditions given a complete remediation less than standard remediation limits of at least 500 mg/kg could not be achieved within about 180 days. The degradation rates usually slow down after the first 20–30 days for the particles of smaller sizes. This correlates with a reduction in particle numbers (colony forming units) and oxygen demand (ACKSEL [1]). In figure 3, the respiration rate, i.e. CO_2 generation by a soil sample (according to the Isermeyer method for assessing the bioactivity) versus the treatment time is plotted. A relatively constant value in the range of about 6 to 8 mg CO_2/(kg dry soil and hour) was found for most samples during the first 70 days of the test. There was only one exception, a value of about 14 mg CO_2/(kg h) for column S1 and 44 days. Considering the measuring errors, there was no obvious difference among various column tests. Only at the very beginning of the tests, higher values, up to almost 12 mg CO_2/(kg h), were observed. At the end of the tests the CO_2 generation dropped in practically all columns to a level of about 1 to 2 mg CO_2/(kg h), indicating the decrease in quickly available organic matter.

The shown flattening of degradation for the columns was not observed for any box and windrow tests (ACKSEL [1]). Instead, for most of the large particle size (maximum particle size 56 mm) tests a retardation of degradation was found. In the respective two box tests without additives, the adaptation period took about 30 to 50 days almost without or with very low biological degradation and bioactivity. However, both tests showed relatively high degradation rates from about the 60th up to the 100th test day. That behaviour was also proved by measuring the oxygen demand and the colony forming units.

The indicated apparent increase in the mineral oil content (figure 2) between two consecutive analyses of the same column is obviously caused by the discussed sampling and analysing problems of larger particles. This gives also a possibility to assess the relative errors for the mineral oil analyses at about 20% or even 40%, whereas for inhomogeneous samples and a large portion of large particles the analysing error could be even bigger. That estimation was also supported by accompanying comparison analyses of samples with known contaminations and compositions (JESCHKE [4]).

Obviously, due to lower temperatures the differences in the box tests were more emphasized. The box tests without addition of substrate material and supplementary additives showed an improvement of the remediation effect with the decrease in the maximum particle sizes. Thus, degradation rates in the start period and the achievable reduction of contaminant concentration in a given time were the best for the test with particle sizes ranging from 0 to 16 mm. The results of the tests with particle sizes from 0 to 32 mm were still remarkably better than those in the tests with 0–56 mm particles. With 10% addition of soil and 10% addition of floating residue there were not any clear improvements, respectively. Generally, additives support degradation. A mixture of 70% soil and 30% construction debris (which could be found after demolition works of basements) gave better remediation effect than a comparable mixture with particle sizes less than 56 mm and without additives. Good results have been achieved by adding 10% of bark pieces, which obviously support the moisture, substrate and nutrient requirements, buffer alkalinity and offer a sufficient settling area for the microorganisms.

Under optimal laboratory conditions in columns at high temperatures (about 30 °C), strict control of moisture content (to about 10%, corresponding to about 80% of water storage capacity) and nutrient content (approximately C : N : P = 100 : 5–10 : 0.5–1), degradation is very much improved (ACKSEL [1]). Evidently the biopile remediation of construction debris is more critical than that of soil. All tests (especially the practical windrow tests) prove that deviations from optimal conditions strongly reduce degradation rates and achievable decontamination. The decrease in bioactivity can somewhat be improved by windrow turning up and adding some fresh nutrients and fertilizers (eventually also fresh microorganisms).

5. SUMMARY AND CONCLUSIONS

Several laboratory, pilot- and large-scale tests were carried out for the remediation of construction debris contaminated by mineral oil. The remediation process is controlled by the microorganisms adapted to slightly alkaline environment. Besides mineral oil content (determined by IR and GC methods) several other parameters were measured and analysed. To achieve a stable remediation, especially the moisture, nutrient and additive contents have to be strictly controlled. The best results have been achieved at temperatures of about 30 °C, moisture content of about 10%, nutrient ratios C : N : P = 100 : 10 : 1, 10% addition of bark pieces and maximum particle sizes of 16 mm. Nevertheless, the remediation is slower than that of soil. During the tests lasting for about 100 or 180 days, a complete remediation poorer than standard remediation limits of at least 500 mg/kg could not be achieved. Repeated windrow turning up and adding some fresh nutrients and fertilizers (eventually also fresh microorganisms) can improve bioactivity. Some specially developed and controlled pre-treatment supports guarantee remediation. Crushing, sieving and adding some nutrients and additives are necessary. The economics of these efforts have to be taken into account for specific remediation cases. The technology was tested under economic and legal constraints with respect to authority permit. It proved to be a versatile alternative to other treatment processes for low to moderate contaminations of about 10 to 20 g/kg mineral oil in debris. The applied standard and adapted microorganisms were able to accomplish degradation. However, there is still a potential for optimization, especially related to the alkaliphilic microbial strains. A corresponding study is currently under way.

Special procedures had to be taken and improved in order to solve the sampling and analysing problems of larger particle size materials. Furthermore, also the influence of the actual location of contaminants (sorbed or at the debris surface) had to be investigated in more detail. Thus, the reliability of tests and the prediction of remediation results for different practical contamination problems could be enhanced.

ACKNOWLEDGEMENTS

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MIKROBIOLOGICZNE OCZYSZCZANIE GRUZU BUDOWLANEGO

Znaczna ilość odpadów budowlanych jest wciąż składowana na wysypiskach i nie ulega recyrkulacji. Podstawowe składniki tych odpadów to przede wszystkim budowlany gruz mineralny i wykopana gleba zmieszana z gruzem mineralnym i kamieniami. Również olej mineralny i jego pochodne są powszechnymi zanieczyszczeniami gruzu budowlanego. Jeśli stężenia oleju mineralnego jest niewielkie (około 10 g/kg), to proces biologiczny jest jedną ze standardowych metod oczyszczania gleby. Przeprowadzone badania miały określić praktyczną przydatność metod biologicznych. Należało uwzględnić specyficzne problemy związane z przeróbką gruzu kamiennego i budowlanego (frakcja cząstek o dużych rozmiarach, odczyn zasadowy, brak składników pokarmowych). Przeprowadzono szereg testów w skali laboratoryjnej, pilotowej i technicznej. Określono niezbędne parametry i warunki stosowania prostej metody biologicznej. Chociaż nie wyczerpano procedury optymalizacyjnej, zwłaszcza w odniesieniu do zawartości mikroorganizmów, może ona być już z powodzeniem stosowana do usuwania wielu rodzajów zanieczyszczeń.