Phytoremediation on HCH-contaminated soils

Siegfried Johne[1], Roland Watzke[1], Konstantin Terytze[2]
[1] TRITON Umweltschutz GmbH, Zörbiger Str. 24/25,D-06749 Bitterfeld, Germany
Phone: +49 3493 73900, Fax: +49 03493 73909, Email: triton@tpnet.de
[2] Umweltbundesamt, Bismarkplatz 1, Postfach 330022, D-14191 Berlin, Germany
Phone: +49 30 8903 2351, Fax: +49 30 8903 3105, Email: konstantin.terytze@uba.de

The present technologies with regard to HCH remediation can be divided in physical, thermal, chemical and biological techniques.

The type of treatment depends on soil characteristics, distribution of the pollutants, and on many other factors.

To date, full scale biological applications in-situ (biorestoration) and ex-situ (e. g. slurry reactors) have not been put into practice. In the last years we have investigated the aerobic and anaerobic biodegradation of HCH and related compounds in soils, sediments and slurries. Summarising our own and the results of many other investigations: the full scale experience of HCH remediation is limited by many factors, e.g. by its (high) costs, the extra investment by thermal treatment for flue gas treatment in order to avoid emissions of toxic by-products and so on. Low-thermal techniques (volatilisation), liquid extraction (in *ex-situ* slurry reactors) and other require a further optimisation. Biological treatment will be difficult due to the slow degradation rates especially when beta-HCH is present or the way HCH is adsorbed in the soil. At this moment, no successful treatment has been reported.

Because it is now possible to eliminate at present the HCH in an economical and environmental effective way we focus our efforts on the emerging concept "phytoremediation", the use of plants to remediate contamination of soil with organic or inorganic wastes (heavy metals etc.). According to D.E. Salt et al. (1) we investigate and use the phytostabilisation and the plant assisted bioremediation as subsets of the phytoremediation technology. The aim is to use HCH-tolerant plants to reduce the mobility of HCH, thereby reducing the risk of further environmental degradation by leaching into the groundwater or by airborne spread.

The movement of an organic contaminant in soil depends on the chemical's relative water solubility, vapour pressure, molecular size, and load and on the presence of other organics in the soil. The ability of soil to absorb and sequester organics is directly associated with the organic matter content of soil, the type and amount of clay present, soil structure, and the pH as well as with the age of the spill and water flux through the profile.

Our special interest is focused on the relations between plant roots in conjunction with their rhizospheric microorganisms, especially with *mycorrhizal fungi*. These fungi are among the most ubiquitous soil organisms found in terrestrial ecosystems. They form symbioses with a broad range of plant species and can contribute to plant growth and survival by reducing stresses associated with nutrition, water/aeration, soil structure, pH, salt, toxic metals and organics and biotic factors such as pathogens, hyphal feeders, and organic matter. Although studies involving the occurrence of *mycorrhizal fungi* on mining wastes are numerous, few studies have attempted to understand the interaction between this type of fungi and plant communities in revegetation success. Most current operational revegetation practices ignore *mycorrhiza*-plant community dynamics and have had limited success in establishing self-sustaining plant communities. There is an urgent need to understand *mycorrhiza*-plant community interactions on disturbed and undisturbed systems and to apply this knowledge in developing more innovative, cost effective and successful revegetation practices (2).

We are involved in the project MYCOREM QLR 3 - 1999 - 00097 (The use of *mycorrhizal fungi* in phytoremediation projects) sponsored by the EU: Our task is to explore and exploit naturally occurring arbuscular and *ectomycorrhizal fungi*, specifically adapted to HCH-contaminated soil. We will investigate their capacity in conferring tolerances to plants suitable for phytoremediation both in the greenhouse and at selected field sites. The most efficient isolates will be used for demonstration projects in soils polluted by HCH. Another aim is to efficiently produce inocula at low costs, which can be sold to applicants at the end.

HCH polluted soils usually lack established vegetation cover due to the toxic effects of HCH or recent physical disturbance. Barren soil is more prone to erosion and leaching which spread the HCH in the environment. A simple solution would be the stabilisation of this soil by revegetation with HCH-tolerant plant species.

Based on our experience in reclamation of partial areas of the open-cast mining and afforestations with hardwoods (supported by the German government, BMBF) our main research activities in the MYCOREM project will include:

- the physical and chemical soil characterisation of the field site,
- investigation on the plant communities present on this sites and on their indigenous arbuscular mycorrhizal fungi
- glasshouse experiments on the bioavailability of the HCH
- verification of greenhouse results in large-scale field experiments
- infection of plants (e.g. *Sorbus aucuparia, Acer platanoides, Prunus avium*) with arbuscular and ectomycorrhizal fungi
- development of an innovative and cost effective successful revegetation method for high-contaminated sites, which has low impact and is visually benign and environmentally sound.

For our experiments (2000 - 2002) we have selected a partial area (150 m^2) at the "pheasant dump" near Bitterfeld. The historical background of this site is documented very well. This dump is a pit from brown coal mining, which had been refilled with excavated material, construction waste, domestic and industrial waste and residues from the HCH production. The exhaustive characterisation of the site included examination of subsoil and subsoil contamination in drilling cores, aquifer tests to determine the degree of groundwater contamination, geophysical measurements and so on.

Representative data from the physical and chemical characterisation of the test site is given in Table 1. The HCH isomers mixture consists of 83 % alpha-, 15 % beta- and 1 % gamma-isomer. The content of the other isomers is very low in the same way as the content of toxic heavy metals. The area is heterogeneous in appearance and the HCH-contamination is also not homogeneous.

The experimental site is covered only with some species of *Calamagrostis, Festuca* and *Agropyron*. *Echium vulgare* was also found (Figure 1). The investigation of their fungi communities and the detection of *arbuscular mycorrhizal fungi* from some plants is in preparation. After the taxonomic characterisation of the fungi we will propagate and use these fungi for the production of *mycorrhizal* inoculum.

Figure 2 shows the plantation scheme. These species of deciduous trees were selected because they showed positive growth responses after inoculation with *mycorrhizal fungi* in pot experiments. The 210 seedlings are 2 years old and between 20 and 40 cm high (Figure 3). We used an inoculum of *Glomus intraradices* (given by Prof. Bothe, Univ. Cologne), another inoculum (*G. etunicatum*) given by Dr. Grotkass/Dr. Feldmann (Institute for Cultivated Plants, Schnega). The Triton inoculum is a mixture of G. *intraradices, mosseae* and *etunicatum*. In all cases the fungi are fixed on expanded clay.

Various types of measurements can be made to quantify tree growth. Typically, basic measurements of tree height and/or stem diameter are taken. These parameters will be used for the calculation of the "biovolume" ($\pi \bullet r^2 h$).

This method is faster than the destructive determination of dry matter. In the worse case we will determine the survival rate of the trees, but we hope that this will not be necessary.

Treatment of HCH is not the main goal at this site. In addition to the scientific investigations it is making and keeping the site natural and reducing the HCH entry into the groundwater. The owner accepts the innovative solution, preferring the forest to a barren plastic layer or other things.

References

1. D. E. Salt et al., Biotechnology 13, 468 (1995)
2. F. L. Pfleger et al., in: *Mycorrhizae* and Plant Health (ed. F.L. Pfleger and R. G. Linderman), Amer. Phytopathol. Soc., St. Paul, Minn., 1994

Figure 1. "Pheasant dump": the view of the experimental site

Table 1. "Pheasant dump": Chemical and physical soil characterisation

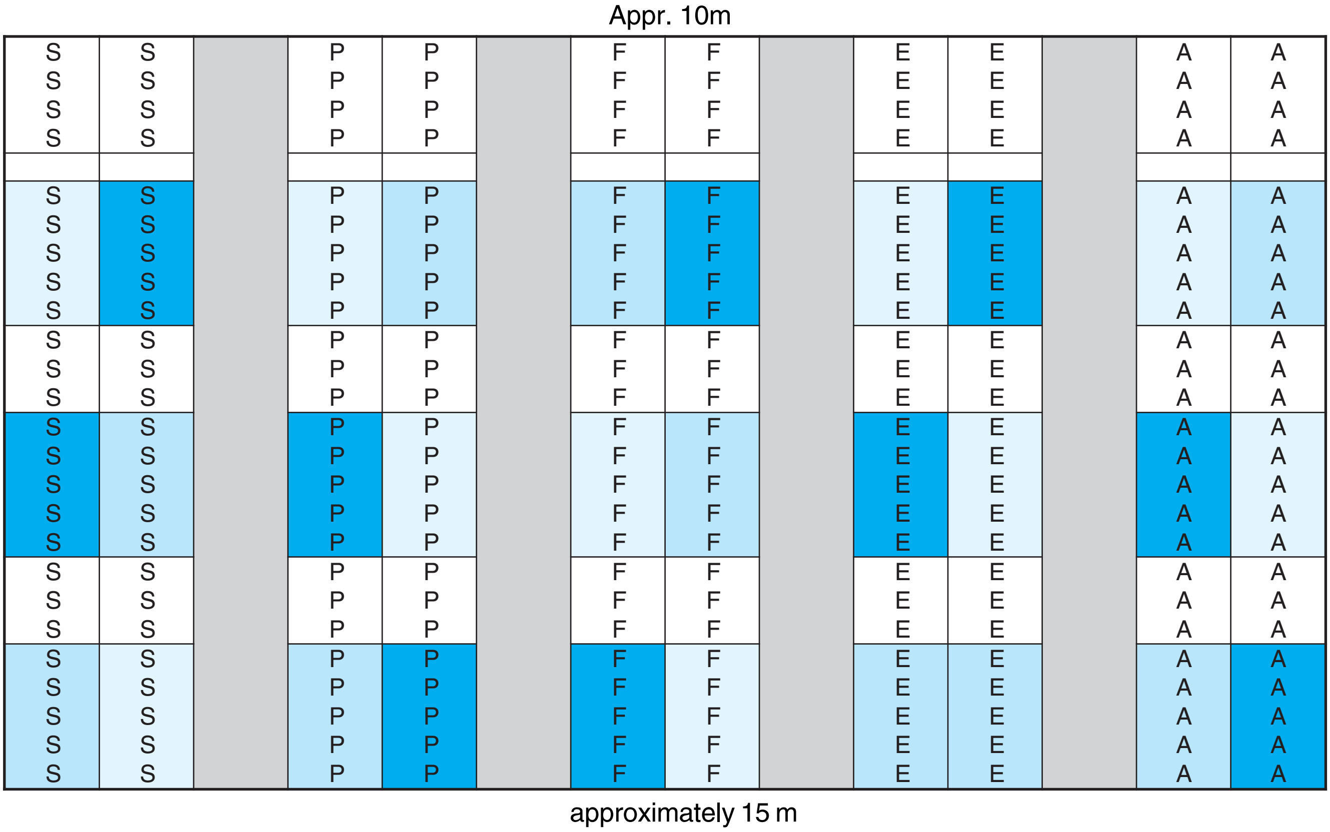
Topsoil (depth 0-30 cm)	
Sand	83 %
Silt	12 %
Clay	5 %
PH	6.42
Organic matter	11 g/100 g
Organic C	5.0 g/100 g
HCH	(83 % alpha, 15 % beta, 1 % gamma)
P (mg/100 g)	1.0
K (mg/100 g)	3.34
Mg (mg/100 g)	5.91
NH_4-N (mg/100 g)	0.20
NO_3-N (mg/100 g)	0.11
Electric conductivity mS/cm	2.3
Field capacity	12 % vol.
Useful field capacity	8 % vol.
Wilting point	10 % vol.

Particle size (in %):

630 - 2000 µm	200 - 630 µm	63 - 200 µm	20 - 63 µm	6.3 - 20 µm	2 - 6.3µm	< 2µm
12.6	14.9	7.0	< 0.1	17.0	25.4	24

Brooks parameter

kf m/d 0.093; ws 0.349; wr 0; ha 1; lamda 0.064



species:
A = *Acer platanoides*
E = *Eleagnus angustifolia*
F = *Fraxinus excelsior*
P = *Prunus avium*
S = *Sorbus aucuparia*

inoculum:
IFP
Glomus intraradices
Triton
control

Figure 2. "Pheasant dump" - Plantation scheme

Figure 3. Inoculations of 2 years old seedlings