Forest Park(land) – integrated and risk based approach for management of contaminated sites

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Abstract:
In the Municipality of Tilburg in The Netherlands an area of 100 hectare is located, which was used for spreading and purification of domestic and industrial sewage water. Due to this historical use the topsoil of these 'flow fields' is contaminated with arsenic and metals (e.g. chromium, cadmium and zinc). The municipality of Tilburg planned to turn this area into a forest parkland. Conventional remediation by excavation and land filling or ex-situ treatment of polluted soil of such a large site is very expensive and would have a high impact on local community and environment. Therefore, an alternative remedial approach was developed based on integrated land and forest management with focus on controlling environmental risks on the long term.

The level of contamination of the topsoil was used in the design and planning of the forest parkland. The highly contaminated zones, near the inlets of the sewage water, were densely planted with trees. The areas for recreation (walking, biking, horse riding, etc) were planned on zones with lower levels of contamination. With this integrated and risk based approach of landscape planning risk of humans exposure was effectively reduced.

In 2000, when the trees were planted, also monitoring of the bioavailability and mobility of metals and ecological effects was started. In a developing forest acidification of the topsoil can be expected, which might lead to an increase of mobility and availability of metals. The increase of mobility and availability of metals can affect (soil) ecosystem and groundwater resources. Furthermore, a research project was started together with research institute Alterra of Wageningen University to optimize the monitoring program and future land management. In field plots effect of acidification on metal behaviour was tested using different monitoring techniques to determine and predict metal availability and ecological effects (e.g. bio-assays).

Recently, this study was finished and monitoring data showed that although pH of the topsoil has dropped with one unit there are no unacceptable ecological risks. It was concluded that active land management, for example liming, is not needed. Future monitoring can be limited to a monitoring of pH and metal on extensive basis. Only when pH drops under pH 4,5 additional ecological tests are recommended.

This project showed that integrated and risk based management of contaminated sites combined with nature/recreation development is not only cost-effective on the short term, but also result in safe and sustainable solution on the long term. Integrated site management combined with forestry; the real 'green' remediation of contaminated land.

INTRODUCTION

A sustainable and climate friendly approach for redevelopment of polluted areas is in increasing demand. Land reclamation by the removal of contaminated soil is often not a desirable option, particularly for large polluted areas. Conventional remediation by excavation and land filling or ex-situ treatment of polluted soil of such a large site is very expensive and would have a high impact on local community and environment.

By planting the Noorderbos wood on the former sewage farm complex De Zandleij, Tilburg City Council has shown that there are alternative options. In late 1990's an alternative approach was chosen; managing risks by natural reclamation and management. Because not all consequences could be foreseen in advance a site management plan was made (ref. 1).

The earlier risk evaluation carried out by Alterra (ref 2.) had indicated that the development of the woodland would cause acidification of the soil. As a consequence of this acidification, the availability of metals might lead to ecological effects and leaching into ground and surface water. Because at that time insufficient was known about the possible effects on the ecosystem (bioavailability of metals) and the effectiveness of the management measures available, a subsequent investigation was begun. This investigation, carried out jointly by Witteveen+Bos and Alterra Wageningen UR, has recently been completed.

FROM SEWAGE FARM TO WOODED PARKLAND

In 1919 the construction of a large-scale (approx 100 ha) sewage farm complex ‘De Zandleij’ for treating domestic and industrial wastewater was started on farmland just north of Tilburg. Parcels were periodically flooded via a system of feeder ditches. The water then slowly filtered down through the soil and was run through drainage pipes and subsequently drainage ditches to the small river De Zandleij. Following years of use (up to the 1980s) the top layer (0-40 cm from ground level) of these parcels was heavily contaminated with chromium and arsenic and to a lesser extent with cadmium, copper, lead, nickel and zinc. The use as a sewage farm had lead to a characteristic pattern of contamination, with high concentrations at the feeder ditches and low concentrations at the drainage ditches.

At the end of the 1990s Tilburg council decided to redevelop the location into wooded parkland. This wooded parkland, called the Noorderbos, should become sustainable woodland offering extensive recreational opportunities (walking, cycling and horse riding) and form an 'ecological corridor' between two nature areas. The plan also provided the opportunity for the management the contamination in a natural manner. A site management plan was drawn up before the woodland was planted. This site management plan described a (provisional) monitoring plan and measures to reduce the risks related to the presence of soil contaminants.

The woodland was planted in such a way that people are discourage to enter heavily contaminated areas, paths were made through the lightly contaminated zones and account was taken of the degree and type of contamination when types and location of trees were selected.

For example beech trees were not planted in the heavily contaminated zones, because leaf mould etc from beech trees does not decompose well and leads to acidification.

STUDY OF CHEMICAL AND ECOLOGICAL EFFECTS

The final aim of this investigation was to reach a definitive management plan and monitoring programme aimed at optimal and cost-effective site management of the Noorderbos. The investigation focussed on: sustainable alternatives (including metallic iron and zeolite) for liming, effects of extreme (artificial) acidification, speciation of metals (particularly chromium) and warning levels (critical limits) at which point action must be taken (ref. 3, 4 en 5).

The ecological risks were evaluated using an integrated approach based on comparison of the following elements: chemistry, toxicology and ecology, the so-called TRIADE approach (ref. 6). Here the usefulness of various bioassays (including Microtox, Biomet and earthworms), ecological testing (including bacteria, fungi, springtails and nematodes) and chemical analyses was investigated. In addition several model simulations were used to predict long-term developments. Below is a short summary of the most important investigation results covering in particular the way in which the pH, bioavailability and leaching of metals in Noorderbos has developed over the past years and what the expectations are for the future.

pH: Since the tree planting in 2000 the pH of the soil has dropped by approximately half a pH unit to a pH of 4.8. On the basis of simple model calculations the pH of the soil is expected to drop by an additional half pH unit over the next 10 years.

Availability of metals: In the period 2000-2008 the acidification led to a small increase in the concentration of metals in solution. From investigation of metal speciation in solution it appeared that the vast majority of Cr(III) was bound to dissolved organic matter and the concentrations of inorganic Cr(III) and Cr(VI) in solution were low.

Ecological effects: Measurements taken in 2000, 2005 and 2008 showed no significant ecological effects. In 2005 a number of artificially acidified (pH 4) plots resulted in measurable negative effects on earthworms, bacteria and nematodes. However, these results were not confirmed by measurements in 2008.

Spreading to groundwater and surface water: Monitoring of groundwater quality indicated that there is no leaching of metals into the 'deeper' aquifer, below a loam layer that is present at 2,5 meters below surface level. Only in a few locations where, instead of a loam layer, a clay layer was present or where a loam layer is not present at all, minor seepage into the deeper groundwater was observed. Investigation of ditch and stream beds in Noorderbos indicated no accumulation of metals. Increased metal concentrations were found in stream beds downstream in the adjoining part of the Zandleij. It is not clear whether this contamination was caused by historic pollution from the sewage farm or whether this is still spreading.

CONCLUSION AND PERSPECTIVE

The following lessons have been learned from the planting of the Noorderbos, active measures and the monitoring carried out.

- The planting of the Noorderbos is a sound way for management of the soil contamination. Detailed study had indicated that there are currently no unacceptable risks for the ecology or of further spreading of contamination. Although, metal concentrations in soil moisture will increase, due to the relatively slow development of the woodland and the acidification related to this, in the short term (5 to 10 years) no unacceptable ecological effects or further spreading are expected and active soil management by for instance liming the area is regarded not necessary.
- Monitoring the contamination will remain essential, but the monitoring can be considerably improved and simplified by the use of a systematic step-by-step approach. At first instance it is sufficient to monitor only changes in soil chemistry caused by acidification. This by measuring on an extensive basis a limited set of components (pH, DOC and metal concentrations). If the acidification of the soil increases to a critical level, a pH of 4.5, then effect-oriented tests will be carried out (earthworm and bacteriological testing).
- For controlling risks in the long term it is desirable that site management of Noorderbos is further optimised in the coming years. Essential in the process is good communication with all stakeholders.

With sound site management 100 hectares of contaminated soil become a natural habitat and provide a valuable recreational function. In addition a great deal of expertise has been gained by the planting, monitoring and management of woodland on contaminated soil.

This case showed that (re)forestation can be a cost effective and environmental friendly alternative for the management of brown fields. This concept also gives opportunities for production of biomass for green energy. In short, Tilburg's Noorderbos; the example of green remediation!

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