IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

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To cite this article: William Hogland *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **578** 012003

Baltic Phytoremediation – soil remediation with plants

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Abstract. The project Baltic Phytoremediation (BAPR), an implementing project of the Interreg South programme, aims to raise cross-border awareness about the availability of green phytoremediation technologies to remove environmental pollutants from soil or water, such as oil, industry-related contaminants, hazardous substances, heavy and toxic metals, nutrients and microplastics, through new arenas of cooperation that focus on circular economy approach. Contamination of land and soil increases and is a serious concern around the Baltic Sea region but further worldwide. The most common remedial technologies for related to the clean-up of soil is excavation, removal and disposal to a contained landfill. Therefore, heavily contaminated soils in landfills, can in some instances, mixing with another disposal of hazardous materials. In the Kalmar, a region of south-eastern Sweden, on the Baltic Sea, the glass waste dumps are removed in such old fashion way with no contribution towards the Circular Economy. The best available remediation strategy is soil washing strategy, an ex-situ technology with a chemical additive application to remove contaminants from the soil and wastewater. Recently, many studies have been carried out encouragingly the phytoremediation processes in different plant species. For instances, food crops, sunflower and Indian mustard are considered as the best plants for phytoremediation, as they have a role in phytoextraction of heavy metals. Phytoremediation research has gained the interest of the scientific society and governments over the last two decades, leading to the development of urban greening and ecology national parks. Orrefors park is one of the largest innovative urban site parks in Sweden with ecologically, socially and economically sustainable way with phytoremediation. The present project aims to explore the combination of phytoextraction with biomass generation and commercial utilization as an energy source, using the ash (bio-ore) that increase energy efficiency and reduce carbon emissions. The project includes pilot cases using innovative plant-based phytoremediation methods that cleaning of the contaminated soil.

1 Introduction

Human activity such as mining, agriculture and industry revolution has introduced directly or indirectly, substances of energy into the environment resulting in the burden of soil

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pollution to a large extent. As a result large areas facing adverse changes and problems related to heavy metal pollution. On land, different types of pollutants namely organic, inorganic and biological pollutants are showing as forms of pollution.

Sweden hosts approximately 4 000-6 000 old solid waste dumps that are polluting the ground and surface water bodies by leachate leakage from the landfills. The Swedish government has identified 25 000 contaminated sites, where the estimation in the Baltic Sea area overcomes the 75 000 old dumps. Most of the landfills "hot spots" clearly existing in the Baltic drainage basin which is rich in abundance of rivers, lakes, wetlands and the Baltic Sea itself. Above-mentioned project reports, Polish and Lithuanian land surface current environmental issues are the contamination of soil and groundwater with heavy metals, pesticides, herbicides or fertilizers and other chemicals at military bases.

Several projects have been carried out by the Environmental Science and Engineering Group (ESEG), Linnaeus University and most recent was a doctoral thesis presentation "Landfill Mining approach for resource recovery from glass dumps into the circular economy" (Mutafela, 2020). Mutafela (2020), points out that the glass dumps are a significant environmental and health risk issue, due to the fact that emissions of toxic gases are released. The release of persistent containments to soil and groundwater are causing a considerable global economic impact annually in the worldwide perspective. Mutafela's thesis proposes innovative techniques first for improvement of excavated material quality and afterwards their recovery as potential secondary resources for the circular economy. As has been approved in the Orrefors park concept, where a former dumpsite or polluted area also transformed into an interesting recreation area for the local citizens and the tourists as with an educational perspective.

Fig. 1. Orrefors Phyto-Park and the Tourist Glassworks, Photo: Barometern 3 August 2017, Emelie Forsberg

Another doctor thesis "Phytoremediation of soil contaminated with petroleum hydrocarbons and trace elements" (Marchand, 2020) presented soil remediation were reclamation of petroleum hydrocarbons (PHC) and trace elements (TE) co-contaminated soil was invistigated. Plants as L. *sativum,* M. *sativa* and H. annus were used for the remediation. Mixtures with bacterias and earthworms were additiobally tested. Pilot-scale studies showed a reduction of up to 80% of PHC and 20% of metals after 17 months. On top of soil treatment capability, phytoremediation provides a visually attractive area during the remediation process as in Orrefors park and we can learn a lot from nature.

2 BSAM project

To raise cross-border awareness of available green phytoremediation technologies to clean soil from pollutants such as oil, industry-related contaminants, heavy metals, nutrients and micro plastics, through new arenas of cooperation that focus on a circular economy approach the project was created. Phytoremediation has been tested a lot but must still be in the early stages of development and its potential for recovery of contaminated soil is little known. As mentioned earlier microorganisms can be added but organisms occur naturally in the soil and they can be utilized in the cultivation process and so the natural environment is maintained.

The project consists of a 3-step process (see below) including a regional strategic and technical analysis and the implementation of pilot cases will include evaluation of installed solutions from a technical, social and economic perspective as well as the promotion of the most promising results.

The cross-border approach will broaden the knowledge through experiences from several Baltic Sea Region countries and also taking into consideration different settings which mean political and economic as well as others.

1. **Initial phase**: technical and strategic analysis of the type of equipment/economic viability and others based on the chosen site and its pollution. Stakeholders as SME´s decision-makers and potential future implementing municipalities/regional authorities are invited to give their input join.
2. **Phase 2:** installation and running of the pilot cases. Together with stakeholders have technical study tours and training sessions to increase understanding and knowledge about phytoextraction where scalability and transferability are keywords.
3. **Final phase:** project evaluation of the pilot installations and further development of the dissemination of results. Cross-border knowledge exchange seminars and promoting BAPR Standards. Stakeholders from the entire Baltic region are invited to seminars/workshop to broaden the network of partners and associated organizations.

The project is a cross-border cooperation and the **BAPR Project Partners** are**:** LNU – Linnaeus University; NSR AB; Gdańsk University of Technology; Klaipeda University; ZU-Zakład Utylizacyjny Sp. z o.o.(Gdansk Municipal Waste Management); LAMMC – Lithuania Research Centre of Agriculture and Forestry; Hassleholmmiljo-Water, waste management and district heating company in Hässleholm and **BAPR Project Associated Partners** are**:** GOV – Swedish Embassy in Warsaw; LLU-Latvia University of Life Sciences and Technologies; IUC Syd; RU-Roskilde University

3 Pilot Cases

Three pilot cases practically focusing on innovative plant-based phytoremediation technologies and methods for cleanup contaminated soil and groundwater. In addition, the production of energy crops for energy production by combustion is planned. Baltic Phytoremediation (BAPR) study is based that plants are grown on a contaminated site take up the contaminants and consequently clean the soil from any form of toxic substances. During the process of cleanup, the plants store the pollutants in their biomass which biomass can be utilized as an energy resource of biogas or by incineration. Valuable metals may even be recovered, reused or stored for future in so-called “Bank Account Cells”.

The idea is to combining phytoextraction with biomass generation and its commercial utilization as an energy source and recovers the ash as ‘‘bio-ore’’ and by this handling increase, energy efficiency and is an alternative energy source lowering CO_2-emissions. For more information about the project and project area visit: **Lnu.se/en/bapr** and the literature suggested in the list below.

The common denominator of the pilot cases is the phytoextraction and energy efficiency approach by using bio-ore as a potential fuel source for lowering primary fuel use. Each installation will also have a high degree of innovation from a technical perspective, but at the same time tackle different types of pollutants and be located in different countries to evaluate and optimize the project strategies and processes based on political/regional differences in the participating countries. Strategic communication for the creation of awareness/incentives will also be a key component in the cases and BAPR.

Pilot case description PP2 (NSR AB, Helsingborg Sweden): Different types of compost source from maize or sewage sludge are used as compost supplementation with nutrients in restoration processes with different contexts, including landfills. The actions of restoration to enhance the landscape of Helsinbory will be performed. Vegetation restoration plan is used for restoration of organic matter levels in soil as well as for soil carbon restoration.

Different plants in combination with an appropriate maintenance program including disposal of the biomass are included in the study. The final landfill cover has a high content of Nitrogen and Phosphorus, which gives high pollutant concentration in the surface water from the landfill. This, has had to be handled in NSR's system for purifying leachate instead of being discharged directly to the recipient. The purpose of the method by phytoremediation is to reduce the nutrient levels in the landfill's protective and plant layers, leading to reduced pollution of leachate and identify a way to utilize harvested biomass. Literature survey and field trials will be carried out.

Pilot case description PP 6 (Lithuanian Research Centre for Agriculture and Forestry): development and pilot case preparation to evaluate the potential of various plant species to accumulate heavy metals in biomass. Fertilization will be made by sewage sludge from city wastewater treatment plants. The main objective is to assess the accumulation potential of energy plant species by fertilizing them with sewage sludge;-to determine the effect of leguminous plants inoculated with bacterial Rhizobiumpreparation in combination with liming (CaCO3) to increase the accumulation potential. Studies will be carries out on heavy metals (Zn, Cu, Cr, Pb and Ni and Cd) in the biomass. The use of sewage sludge will enable to enrich the soil by organic carbon and other mineral nutrients.

Pilot case description PP5 (Gdansk University of Technology)

The pilot case is located in Poland is realized in co-operation by PP3 and PP5 (the Gdańsk University of Technology, GUT, and Zakład Utylizacyjny sp. z o.o., ZUT –Gdańsk Municipality Waste Management Facility). The study includes conduction of phytoremediation in open-field conditions as well as in model conditions using greenhouses. Additionally, a small field laboratory will be localized at the Pilot Installation, enabling for sample preparation for further analyses. Selection and testing of a plant species useful for phytoremediation of leakages from landfill to their biological detoxification is done. The assessment on phytoextraction from the soil of pollutants included in the leakages, e.g. heavy metals (especially Cr at various oxidation states) as well as organic pollutants, including PAHs, dioxins or PCBs is done. The aim is selection and characterization of the soil for pot experiments; characterization of the soil exploited in the field experiment; characterization of the leakages as well as compost or waste sludge. Physicochemical analysis will be necessarily perform for the characterization of the above listed components during the experiments, included the determinations of following parameters: distribution of particle size of soils, pH, S, N, K, Mg, P, Ca, Cr, Ni, Cu, Zn, Cd, Pb. Other goals of importance are the dissemination of knowledge in the field of phytoremediation and the search for new directions for use and new partners for the proposed methods.

The main outputs of the BAPR project will be the creation of a Baltic Phytoremediation standard to promote the methodology. BAPR Structure of the pilot case is study background, the groundwork for permits, pilot case implementation, management and monitoring,

network development, study tours, workshops to evaluate new cases and learn from existing. The strategic tools take into consideration costs, permits, procurements, environmental performance, social/health benefits, and interested parties' network for the installation and more methods for implementation, risk analysis tools, current case study, further investigation, technical/economic/social evaluation, comparative analysis between pilot cases, criteria of assessment e.g. Sustainability, applicability, resources saving, added-value products/valorisation the strategic communication plan includes; cross-border knowledge exchange approach, transfer of knowledge, training modules/course preparation (Industrial experts/network contribution), manual preparation. Regional mapping reports of potential cases which also includes Denmark, AP- Roskilde University as well as mapping of potential new pilot cases for the BAPR approach, creation of the Project Data, Standard and Tool.

4 Remediation technologies for contaminated soil with heavy metals

There are various techniques for remediation of soils and groundwater contaminated with organic chemicals or heavy metals. Those techniques are

- Excavation of polluted soils and their further treatment (soil excavation)
- pumping and treating groundwater
- landfilling
- Incineration

However, many of these technologies have some limitations in their application, ie they are expensive or costly to operate (eg excavation of polluted soils and chemical/natural consolidation) or do not achieve an extreme deadline or elegant solution and are not accepted from the local communities.

The phytoremediation is an innovative alternative economic method for the recovery of contaminated soils and groundwater, based on the plants' ability to recruit and break down toxic organic substances. Plants can weaken or degrade organic pollutants, or remove and stabilize metal pollutants. This can be achieved by a method or combination of phytoremediation methods.

The BARP project aims to inform and raise public awareness of the pollution of soils by heavy metals, as it causes a serious environmental problem with immediate consequences on both the ground and aquifer system.

The study of the above, in combination with the focus on the effects of polluted areas, will allow for evasive actions, economic and safer options to address this pollution issue.

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