Carbon footprint on soil remediation

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Abstract:
Together with a consortium of Dutch consultants, contractors and large soil remediators Tauw developed a model for the calculation of CO_2-emissions caused by soil remediation projects. General reason for this instrument is the attention of Dutch governments and companies for sustainability and good housekeeping and the world wide attention for climate change and energy topics.
The carbon footprint tool needs to be used during the multi criteria assessment of soil remediation concepts in the preliminary phase, for example within the framework of remediation investigation or design & construct tendering. The carbon footprint can also be used for defining a stop criterion for operational soil remediation systems on base of contaminant mass removal versus environmental burden (finding the break even point between merit and burden).
The model includes the use of different types of fuels, electricity, materials and chemical and biological oxidation/reduction reactions. The model is built around proven soil remediation techniques, for which CO_2-emission is a consequence of installation, maintenance, use of chemicals/additives/waste, oxidation/reduction reactions and transport. The output of the model consists of quantification of the CO_2-emission of each component expressed in kg CO_2 and quantification of the CO_2-emission of the total project expressed in Dutch household equivalent, kg CO_2 per kg removed contaminant and kg CO_2 per m^3 treated soil. Because of the use of graphs on the output screen it will be clear at a single glance what techniques and what components of techniques have the largest carbon footprint.
We used the model to calculate the carbon footprint of five actual cases. From this we learned among other things that large soil remediation projects can emit up to 1,000 Dutch household CO_2-equivalents and that thermal treatment of excavated soil (off site) is by far the most CO_2-emitting activity of soil remediation.
The model will get a certain status in The Netherlands because it will be launched by the Dutch Centre for Soil Quality Management and Knowledge Transfer (SKB). One of the things to be done in the nearby future is to translate the model into English. Furthermore the carbon footprint model should be integrated into multi criteria analysis models.

INTRODUCTION

Reason for development

The environmental merit of some soil remediation projects seems hard to find. This is caused by the effectiveness of the process and the shift of efficiency during the remediation period. Sometimes it feels like removing one liter of petroleum hydrocarbons from soil and groundwater takes hundreds of liters of fuel, often as well petroleum hydrocarbons. Besides other criteria for soil remediation projects, quantification of the carbon footprint is necessary to give flesh and blood to this feeling. A quantified carbon footprint needs to be part of the multi criteria analysis for soil remediation projects.
The time seems to be right to introduce a tool for quantification of the carbon footprint of soil remediation projects. All governments in The Netherlands need to purchase on a sustainable basis for at least 50% in 2010. One of the things to be purchased by governments is soil remediation. Also industries and other companies like contractors transform their operational management to be sustainable (good housekeeping). And on the other hand there is a worldwide attention for climate change and energy topics.

CO_2 is a great parameter to express a part of the environmental footprint of soil remediation projects. Not only the use of fuel and electricity can be expressed by CO_2, but also the material use and oxidation/reduction processes in soil and groundwater. So apples and oranges can be expressed in one sum parameter. Another advantage of CO_2 is its economic market value (CO_2-emission trade), which for that matter does not restrain the customer from giving an even higher economic value to the CO_2 footprint.

Field of application

As said before, the carbon footprint tool needs to be a part of multi criteria analyses (decision supporting), for example within the framework of remediation investigation or design & construct (D&C) tenders. For the awarding of D&C-tenders sustainability can be a part of the EMVI-score (economically most favourable tender), which means that the contractor's offer is artificially reduced by rewarding the sustainable components (or alternatives) with economic values.

An alternative way of using the tool is at the end of a soil remediation, when the client wants to compensate for the total CO_2-emission of the work.

Another application of the tool is to use it for defining a stop criterion for operational in situ soil remediation projects on base of efficiency (mass removal of contaminants) versus environmental burden (CO_2-emission). Is the yield of contaminants still worth the environmental burden at a certain moment?

The end users are foreseen to be environmental consultants, contractors and initiators of soil remediation projects.

METHODS

CO_2-components in model

As said before the model is built on base of energy use, material use and oxidation/reduction reactions. All these issues are expressible in CO_2. This means that the model has certain limits: it does not include other environmental issues like noise, smell or left product in soil.

The model includes several fuels, from which not only the CO_2-emission as a result of combustion is accounted for, but also the CO_2-emission as a result of mining or extraction, transport and preliminary treatment.

Furthermore the model includes various forms of electricity. None of them have a zero emission, though 'renewable' energy is officially marked as CO_2-neutral. For example, a part of the green current consists of energy generated by bio fuels that also lead to CO_2-emission as a consequence of production (conversion), transport and combustion. For yielding wind energy, solar energy and hydropower materials are used. The production of these materials is accounted for as well, though the contribution to CO_2-emission is little.

Material use is also part of the calculated carbon footprint, though not all material is accounted for to limit the proportions of the model. The process energy requirement (PER) of machinery, for example the production of trucks, is presumed to be minor to the consumption of energy (fuel in the case of trucks) by the machinery during its technical life span. For all other materials, like sheet piles or chemicals, the model uses PER-values.

Last CO_2-component in the model consists of oxidation/reduction reactions which take place in the soil as a consequence of stimulated biological and chemical processes. In the case of air sparging for example, the contaminant is being oxidized as well as a part of the natural organic matter in the soil. This leads to CO_2-production, from which a smaller part will be buffered in water as bicarbonate and the largest part will be added to emission.

Soil remediation elements in model
The model can deal with CO_2-components of the following soil remediation techniques:

- Excavation of soil, including on site and off site treatment of soil
- Extraction of groundwater
- On site purification of groundwater
- Air sparging and soil vapour extraction
- Multi-phase extraction
- In situ chemical oxidation
- In situ biostimulation
- In situ thermal treatment (steam, conductive heating, heater elements)
- Environmental supervision and monitoring

For every technique you are able to fill in or select detailed information on materials, chemicals, distance, energy, flows, periods, etc.

How the model is built up
The model is made in Microsoft Excel and consists of a convenient input screen with folding subscreens ( and  buttons), 3 databases in which you can find the quantitative resources, a calculation screen (product of input and database) and an output screen with surveyable quantitative and graphical results per technique. Of all the selected soil remediation techniques the CO_2 emission as a consequence of installation, maintenance, use of chemicals/additives/waste, oxidation/reduction reactions and transport is calculated. In the output screen not only these components are quantified in ton CO_2, but also in Dutch household equivalent, kg CO_2 per kg removed contaminant and kg CO_2 per m^3 treated soil. From the graphs it will be clear at a single glance what techniques and components of techniques have the largest carbon footprint.

RESULTS

After finalizing the concept-model, we used it to calculate 5 cases:

- Excavation and off site treatment of soil (thermal and extractive), 2 cases
- Excavation, off site treatment of soil (thermal), groundwater purification and air sparging
- In situ air sparging and bioventing
- In situ chemical oxidation and air sparging

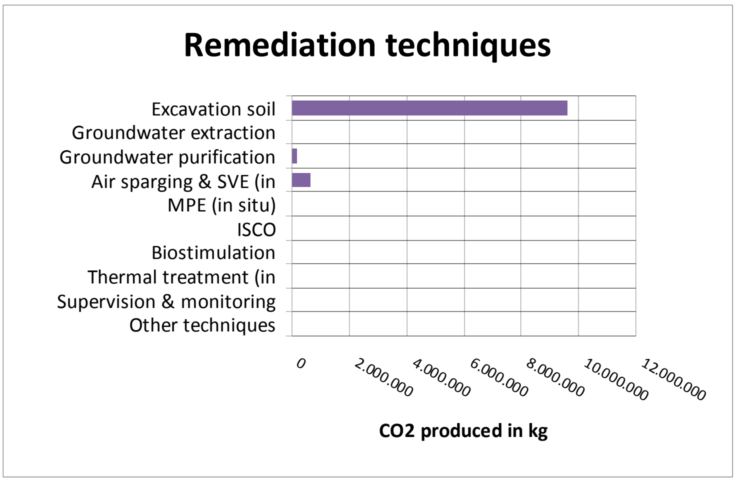
The graphical results of one of the cases are shown on page 4 to get an impression of the output of the model.

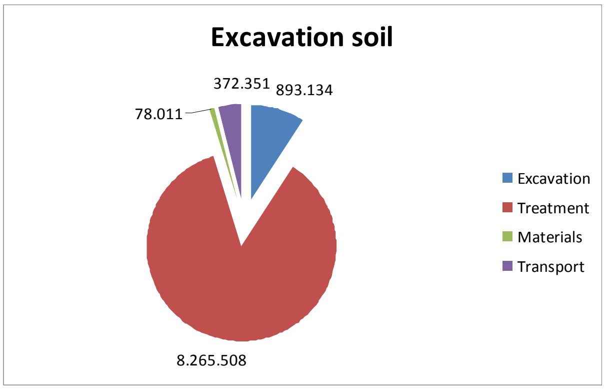
From the calculations we executed we know that large soil remediation projects in The Netherlands can emit as much CO_2 as 1,000 Dutch households do in one year. Other things we learned are:

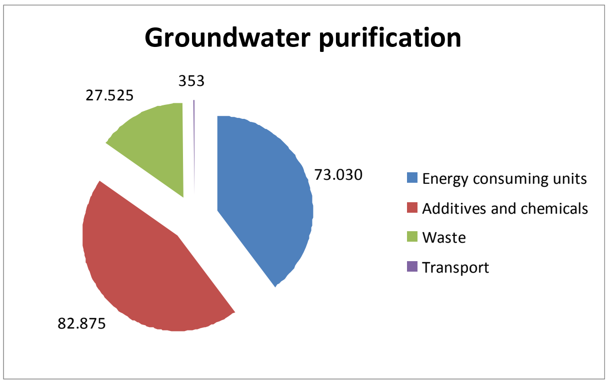
- Thermal treatment of excavated soil (off site) is by far the most CO_2-emitting activity of soil remediation. This is caused by the fuel necessary for heating the soil and burning the off gasses and the oxidation of natural organic matter in that soil
- In general, transport of material and personnel during implementation, operation, maintenance and monitoring are marginal
- For air sparging the crucial factors are operational energy (compressors) and the aboveground piping. The oxidation of organic carbon will be important above 1%
- For ISCO the crucial factors are the production of oxidizing chemicals and the oxidation reaction itself. Only when the injectors are made of stainless steel, material will get important
- For biostimulation on base of injection of additives the crucial factor is the biological degradation of substrate in soil. When piping is used the above ground system as well
- For on site groundwater purification the use of activated carbon is crucial (to be more specific: the production of activated carbon). Other parts of the groundwater purification plant might be crucial as well (like energy use for filters), but depend on the construction of the plant

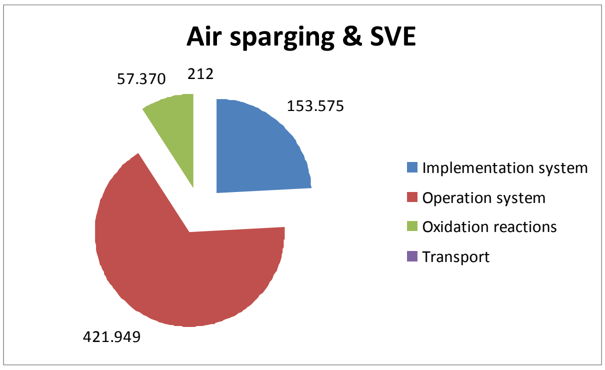
Example of the output of one of the cases

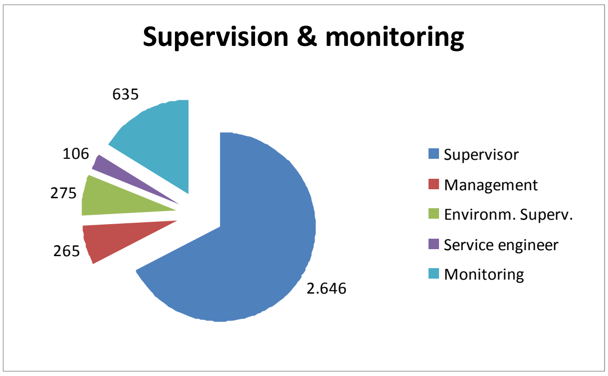
Removed contaminant mass	155.728	kg
Treated soil volume	315.000	m^3
EMISSION :	10.429.817	kg CO_2
	1.146,1	household equivalents
	67	kg CO_2 per kg removed contaminants
	33	kg CO_2 per m^3 contaminated soil











Of course, we need more experience with other cases to be able to pick out the crucial factors for the carbon footprint of the various soil remediation techniques. We also need more experience to be able to quantify the break even point of efficiency of the technique (mass removal) and the carbon footprint of it.

FUTURE SCOPE

With this instrument, we make a step forward on good housekeeping with regard to soil remediation projects. The model will get a certain status in The Netherlands because it will be launched by the Dutch Centre for Soil Quality Management and Knowledge Transfer (SKB), which receives its basic funding from the ministry of Housing, Spatial Planning and Environment (VROM).

Until now the model has not been translated into English. This is one of the things to be done in the nearby future. Furthermore the carbon footprint model should be integrated into multi criteria analysis models, in which costs, risk reduction and other environmental performance parameters are present. The carbon footprint model itself will be updated once in a while depending on new technologies and demands or wishes from the market. One of the ultimate challenges could be to find ways to 'negatively' score on the carbon footprint, for example by using more than the released CO_2 by growing new vegetation or by generating more renewable energy than necessary for the soil remediation project itself. For this, it is necessary to widen the scope and integrate the remediation project in future uses of the land.

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