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Science for Environment Policy

Using microwaves to clean polluted soil could lead to energy savings

Researchers have experimented with microwave heating as a way of cleaning soils polluted with fuels, such as diesel and petrol. Soil type and moisture levels, as well as the strength of microwaves used, had a strong bearing on the overall effectiveness of the cleaning. The research shows that, at certain depths and in certain types of soil, microwaves can be a cost-effective way of cleaning polluted soils.

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Contact:
ppfalci@dica.unict.it

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Industrial and economic activities have resulted in considerable amounts of soil being polluted by petroleum products, which contain chemicals called hydrocarbons. Remediation refers to the removal of contaminants such as these from the environment.

Microwave heating is a potentially useful way of cleaning soils polluted by petroleum hydrocarbons, and could reduce treatment times and energy costs compared to traditional remediation methods, such as chemical treatment. Microwaves can also lessen the risk of further soil contamination posed by some chemical treatment methods, and requires relatively simple equipment.

The ability of microwaves to penetrate and heat soil (which depends on a combination of soil density and microwave strength) is one of the main factors that determines the usefulness of microwaves in soil remediation. Soil moisture levels are another important factor, as water absorbs microwaves and helps to strip pollutants from the soil by way of steam, which is produced as it is heated by the microwaves. Pollutant removal is also strongly influenced by soil texture, as denser soil permits less microwave penetration.

In this study, researchers experimented with microwave treatments to assess the influence of soil moisture, soil texture and microwave strength on diesel removal, and also to assess the energy requirements and economic costs. Four soil types (medium, fine, silt and clay) were artificially contaminated with diesel fuel and treated with microwaves at varying power levels (12.5, 22, 30 and 50 kilowatts per kilogram of soil ($kW\ kg^{-1}$)) and for various periods of time (ranging from 5 to 60 minutes). For the fine soil, the treatments were applied at four different soil moistures (0%, 8%, 10% and 12% water content). The diesel content of the soils was measured before and after the treatments to determine how much was removed by the treatment.

During treatment of the fine soils, there was an increase in soil temperature between 0% and 10% moisture content (although there was no significant difference between 10% and 12%). More contaminants were removed as the temperature increased, as higher temperatures increase the amount of steam produced, through which contaminants are stripped from the soil. Clay soils also reached high temperatures; however, the dense layers present in clay soils limited microwave penetration which meant maximum microwave power levels were required to achieve high levels of diesel removal.

Overall, pollutant removal was generally high compared to other methods of remediation of diesel-polluted soils, such as conventional heating or chemical treatment. Due to the penetration depth of the microwaves, the researchers suggest a soil layer no greater than 70 cm should be considered when designing mechanisms to treat polluted soil.

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Furthermore, the energy analysis indicated that maximum microwave power (50 kW kg^{-1}) should be avoided in order to make energy savings. An energy range between 5 and 35 kW kg^{-1} should be used for contamination levels of between 1 500 and 5 000 milligrams per kilogram (mg kg^{-1}).

Variations in soil moisture and texture resulted in varying costs of remediation, between €20 per tonne (0% moisture fine soil, at a level of contamination of around 750 mg kg^{-1}) and €160 per tonne (0% moisture fine soil, at a level of contamination of 5000 mg kg^{-1}).

Clay and fine soils had overall higher costs than sandy soils (clay soils cost twice as much as sandy soils to treat) and the researchers, therefore, suggest using microwaves may not be cost-effective for these soil types. Moisture content reduced cost by up to €70 per tonne, making it a key factor for the future optimisation of microwave remediation treatment.

Energy costs of below €160 per tonne and relatively short remediation times make microwave heating a suitable alternative to conventional heating or chemical treatments. The researchers suggest that once the treatment process is optimised, microwave technology may become an economically viable method of treating soils polluted by diesel and other fuels.