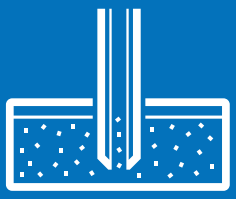
IN SITU
CHEMICAL REDUCTION

Technology for Remediation of Contaminated Sites



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PRINCIPLE

In situ chemical reduction (ISCR) uses reducing agents (chemicals capable of reducing other chemicals) to reduce harmful contaminants in place where they are present (*in situ*) without a need of pumping or excavation of the contaminated matrices. In principle, all contaminants that can be reduced to less toxic or even non-hazardous products can be treated by ISCR. This technology is commonly used to treat sites contaminated by heavy metals (especially by hexavalent chromium) and chlorinated organic contaminants, like chlorinated solvents and pesticides. ISCR is commonly combined with other remediation technologies like pump-and-treat or bioremediation.

DESCRIPTION

Direct contact between the reducing agent and the contaminant is crucial in order to achieve the contaminant reduction. Therefore, the main issue of the ISCR remediation is to ensure proper distribution of the reducing agents in the contaminated matrices. In order to treat contaminated soils and groundwater in situ, the reducing agents need to be injected into the contaminated zones of the aquifer. Alternatively, they can be utilised to create the so-called permeable reactive barriers or reactive zones through which contaminated groundwater is passing. This can be achieved primarily by direct-push application, via permanent application wells, and, in some cases, also by soil mixing or direct placement into tranches or boreholes. Reducing agents based on solid particles, like zero valent iron (ZVI), are usually mobile during their high-pressure application only, later they become immobilised in the underground and treat the groundwater passing around them.

High pressure direct push application of nanoscale ZVI using drilling rig Geoprobe 7822DT

Reducing agents are usually less reactive and efficient than oxidants used for ISCO. On the other hand, this means ISCR is less invasive and easier to combine with biological treatment. The loss of reducing agents due to high amounts of natural reducible compounds is usually also limited, although it can be problematic when using highly reactive materials, like nanoscale ZVI.

The reducing agents most often used for ISCR are based on ZVI. The reactivity and efficiency of ZVI is highly dependent on the surface area of the ZVI particles. Increasing surface area to volume ratio increases the reaction rate. Therefore, smaller particles are more reactive and efficient than the big ones. Small

particles are also easier to inject and more mobile in the subsurface. On the other hand, small particles usually don't last very long and are quite expensive. Sulphidation of ZVI seems to increase its reactivity towards some contaminants.

Other common reducing agents include polysulphides, sulphides, sodium dithionite and ferrous sulphate.

APPLICATIONS

ISCR is usually used to remediate source areas or to prevent spreading of the contamination with the groundwater flow without a need for excavation or pumping. It can be utilised to reduce and immobilise some heavy metals as well as to degrade or dechlorinate chlorinated solvents and pesticides. Usually, it is advantageous to combine ISCR with biological methods, as some bacteria are capable to re-reduce the spent ZVI into the active forms. ZVI efficiency can be increased by application of electric current into the ground.

High pressure injection of sulphidized nanoscale ZVI into injection wells

Main advantages of the technology:

- Cost-effective compared to other source zone treatment technologies
- Easy application and maintenance
- Possibility of combination with other treatment methods
- Suitable for creation of permeable reactive barriers or reactive zones

Potential limitations

- Low mobility of ZVI in the subsurface
- Low reactivity and efficiency compared to oxidizing agents
- Inappropriate in sites with high oxygen content and quick water flow
- Low permeability of the saturated zone may negatively affect the method efficiency

REFERENCES

COMMERCIAL REMEDIATION PROJECT – ZACH TEMELÍN

ISCR permeable reactive barrier consisting of 37 boreholes situated in a line perpendicular to the groundwater flow direction was installed on the edge of the pre-treated chlorinated solvent contamination plume situated in a fractured bedrock. Each borehole was 20 m deep and 1.5 m far from the neighbouring boreholes. 5 kg of nanoscale ZVI in the form of a suspension was injected into each borehole, and, then, the boreholes were filled with macroscale iron particles (250 kg) mixed with sand (250 kg). Biological reductive dechlorination (using whey as the carbon source) in combination with pump-and-treat, ISCR, heating and groundwater circulation was used for active remediation of the contamination plume. These technologies worked well together with the ISCR PRB, and prevented the contamination from leaving the treated area in concentrations above the strict remediation goals.

ISCR PRB boreholes after installation

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