Subsurface imaging of water electrical conductivity, hydraulic permeability and lithology at contaminated sites by induced polarization - DTU Orbit (22/12/2018)

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At contaminated sites, knowledge about geology and hydraulic properties of the subsurface and extent of the contamination is needed for assessing the risk and for designing potential site remediation. In this study, we have developed a new approach for characterizing contaminated sites through time-domain spectral induced polarization. The new approach is based on: (1) spectral inversion of the induced polarization data through a reparametrization of the Cole–Cole model, which disentangles the electrolytic bulk conductivity from the surface conductivity for delineating the contamination plume; (2) estimation of hydraulic permeability directly from the inverted parameters using a laboratory-derived empirical equation without any calibration; (3) the use of the geophysical imaging results for supporting the geological modelling and planning of drilling campaigns. The new approach was tested on a data set from the Grindsted stream (Denmark), where contaminated groundwater from a factory site discharges to the stream. Two overlapping areas were covered with seven parallel 2-D profiles each, one large area of 410 m × 90 m (5 m electrode spacing) and one detailed area of 126 m × 42 m (2 m electrode spacing). The geophysical results were complemented and validated by an extensive set of hydrologic and geologic information, including 94 estimates of hydraulic permeability obtained from slug tests and grain size analyses, 89 measurements of water electrical conductivity in groundwater, and four geological logs. On average the IP-derived and measured permeability values agreed within one order of magnitude, except for those close to boundaries between lithological layers (e.g. between sand and clay), where mismatches occurred due to the lack of vertical resolution in the geophysical imaging. An average formation factor was estimated from the correlation between the imaged bulk conductivity values and the water conductivity values measured in groundwater, in order to convert the imaging results from bulk conductivity to water conductivity. The geophysical models were actively used for supporting the geological modelling and the imaging of hydraulic permeability and water conductivity allowed for a better discrimination of the clay/lignite lithology from the pore water conductivity. Furthermore, high water electrical conductivity values were found in a deep confined aquifer, which is separated by a low-permeability clay layer from a shallow aquifer. No contamination was expected in this part of the confined aquifer, and confirmation wells were drilled in the zone of increased water electrical conductivity derived from the geophysical results. Water samples from the new wells showed elevated concentrations of inorganic compounds responsible for the increased water electrical conductivity in the confined aquifer and high concentrations of xenobiotic organic contaminants such as chlorinated ethenes, sulfonamides and barbiturates.

General information
State: Published
Organisations: Department of Environmental Engineering, Environmental Fate & Effect of Chemicals, Aarhus University, Geological Survey of Denmark and Greenland
Pages: 770-785
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Geophysical Journal International
Volume: 213
Issue number: 2
ISSN (Print): 0956-540X
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.54 SJR 1.506 SNIP 1.195
Web of Science (2017): Impact factor 2.528
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.61 SJR 1.749 SNIP 1.465
Web of Science (2016): Impact factor 2.414
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.46 SJR 1.796 SNIP 1.354
Web of Science (2015): Impact factor 2.484
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1