In Situ Chemical Reduction of Hexavalent Chromium in Groundwater at an Industrial Site near Athens, Greece

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Background/Objectives. Numerous manufacturing facilities previously operated along the river delta of the Asopos River northwest of Athens, Greece. Beginning in 2007, state environmental agencies detected elevated concentrations of hexavalent chromium, heavy metals and other toxic constituents in the surface water of the river, in sediments and in groundwater. A metal-working facility identified hexavalent chromium, Cr(VI), in the groundwater at its 65-hectare site and commissioned CDM Smith to investigate the possible cause of the contamination.

Approach/Activities. Based on environmental site investigations comprising installation of approximately 40 groundwater monitoring wells and 3-D LEAPFROG modelling, several hot spots and potential preferential pathways were identified in 2014 and 2015. Because the contaminated areas are located on an active industrial site with heavy traffic and the groundwater contamination is at depths of 20 to 50 m below the ground level, an in situ remediation approach was determined to be most appropriate. Soil and groundwater samples were collected and sent to CDM Smith's Denver, Colorado laboratory for bench-scale testing. Various chemicals were tested to reduce Cr(VI) to an extremely low solubility and stable iron-chromium(III) precipitate. Based on the test results, a combination of iron(II)sulfate, molasses and emulsified vegetable oil (EVO) was selected for a pilot-scale demonstration and presented to Greek environmental authorities in September 2014. Because little experience in the field of in situ remediation technologies exist in Greece, several state agencies and the universities of Athens (NTUA) and Crete (TUC) were involved in the approval and permitting process. Based on the approval of the pilot test design, the final relevant permit was issued in late December 2016. The approved pilot test was a controlled gradient test consisting of an injection well, an extraction well and two intermediate monitoring wells. After well installation in the designated test field area, pumping and tracer tests were performed in May 2017 to investigate the hydraulic conditions in the very complex geology at the site. Between July and November 2017, the in situ pilot test was performed by injection of the mixed chemicals followed by an intensive monitoring program.

Results/Lessons Learned. Data collected during monitoring after injection demonstrated that the ferrous iron, Fe(II), in the iron sulfate immediately reduced the Cr(VI) to Cr(III); i.e., Cr(VI) concentrations were below detection limits. Furthermore, the molasses and EVO produced the necessary geochemical conditions in the aquifer to reduce Cr(VI) to Cr(III) over longer time periods. Cr(VI) concentrations in contaminated groundwater migrating from upgradient areas into the test field were decreased to nondetect concentrations continuously over the extended test period. Based on these observations, hot-spot remediation at several locations is currently being planned over the entire area in a phased approach. Because the site owner acquired an adjacent property where the contaminant plume migrates into, implementation of subsurface treatment system (e.g., a reactive buffer zone) is also planned to protect downgradient areas.