Practical Environmental Solutions

OTEK - Hexavalent Chromium Remediation

OTEK 六价铬修复服务

"Imagine the Result"

"展望成果"

OTEK is a member of the
ARCADIS Alliance Partner Program

OTEK是 ARCADIS联盟伙伴项目成员之一

ARCADIS
Infrastructure · Water · Environment · Buildings

arcadis.com otek.com.au

Corporate Overview 公司简介



OTEK & ARCADIS

OTEK was founded in Australia and is an alliance partner of Arcadis. OTEK has 20 years experience and 8 offices in Australia and China, and is recognized as one of the top consultancies in Australia and the Asia Pacific region. ARCADIS is ranked in the top 3 in the global environmental market and 16500 experts worldwide, with over 80 years experience. Together we have 120 staff in China

OTEK在澳大利亚成立， 是ARCADIS的全球联盟伙伴。OTEK有20多年的历史，在中国和澳大利亚设有8个办公室，是澳大利亚及亚太地区优秀的顾问公司 之一。ARCADIS，拥有80年的历史，位居全球环保市场的前3名，全球员工16,500人。在中国共拥有120名员工。

OTEK performs approximately 600 environmental projects per year in Australia, and with Arcadis we complete several thousand projects worldwide, meaning we have a wide range of examples to draw from with all types of contaminants, and many remediation and treatment techniques involving that latest technologies as well as refined use of proven technologies.

OTEK每年在澳大利亚进行六百多个环境项目，与ARCADIS一起，我们每年在全球进行数千个项目。这意味着我们拥有大量，针对各种类型污染物，以及在修复、整治方面最新和成熟技术的应用实例。

We bring our experience and 16,600 experts worldwide together, OTEK and ARCADIS combine a deep knowledge of the local conditions, where they work with fresh global perspectives for unique, integrated solutions using the world's latest technologies.

汇集我们多年的经验及全球16,600专业人员， OTEK与ARCADIS联手，我们将在对当地情况深入了解情况下，利用最新技术，为用户提供全球视角的独特、综合解决方案。

We focus on management and ensuring success using practical solutions, combined with experts in fields, and research and development projects to ensure the latest technology is available.

我们专注于管理，确保成功使用实效解决方案，并结合领域专家、研发，以保 证最新的技术可以得到应用。

We specialize in:
我们致力于:

- Environmental Due Diligence and Environmental Site Assessment
  环境尽职调查与环境场地评估
- Soil & Water Remediation
  土壤及水治理
  - Heavy Metals Impacted Soil 重金属污染土壤
  - Cr6+,Cd,Hg,As,Pb etc. 六价铬、镉、汞、砷、铅等
  - Petroleum and Oil Impacted Soil 石油及油污染土壤
  - InSitu Chemical Oxidation(ISCO) & InSitu Chemical Reduction (ISCR) 原位化学氧化&原位化学还原
- River/Silt Remediation
  河流、淤泥整治
  - dredging/sediment remediation 疏浚、沉积物整治
- Ecological restoration and Ecological Impact Assessment
  生态恢复与生态影响评估
- Landfill remediation
  垃圾填埋场整治
- Mining waste remediation
  采矿废物整治
- Water Treatment
  水处理
  - Industrial water 工业用水
  - Landfill Leachate 垃圾渗滤液处理
  - Impacted surface water and waste water 污染地表水及废水

Hexavalent Soil & Water Remediation
六价铬土壤及水治理

Chromium primarily exists in nature in the trivalent and hexavalent states. Due to its widespread industrial use, it has been found in many current and former industrial sites and is often found in contaminated groundwater along with complex mixtures of pollutants, which can make its remediation more difficult.

铬在自然界主要是以三价和六价形式存在的。由于它在工业上的广泛用途，铬经常被发现存在于现存和原来的工业场地中，在污染地下水中铬也经常被发现存在于复杂的污染混合物中，给修复带来困难。

Many Cr(VI) compounds are highly soluble and exist in solution as hydro chromate, chromate, and dichromate ions.

许多六价铬化合物有很高的溶解性，并以溶液形势存在于水合铬酸盐、铬酸盐和重铬酸中。

Chromium is used in a wide variety of industrial applications including the production of stainless and heat-resistant steels, refractory products such as bricks and mortars, and in pigments, metal finishing, leather tanning, and wood preservatives. Both trivalent and hexavalent forms of chromium are released into the environment as a result of these industrial uses, as well as from the production and combustion of fossil fuels, and the smelting and refining of nonferrous base metals.

铬在工业中有广泛的应用，包括不锈钢和耐热钢的生产，耐火制品如砖和砂浆，颜料，金属表面处理，鞣革及木材防腐剂。三价和六价形式的铬就是通过这些工业过程进入环境，还可通过化石燃料的制造与燃烧过程、有色金属的冶炼与精炼过程释放到环境中。

The goal of remediation schemes is to reduce the carcinogenic, soluble, and mobile Cr(VI) to the less toxic and less mobile Cr(III), which forms minimally soluble precipitates. Successful removal of Cr(VI) hinges upon the formation and stability of Cr(III) precipitates.

修复计划的目标是减少致癌、可溶及可移动的六价铬并将其转化为毒性较小和移动性不强的三价铬，形成很少的可溶性沉淀。是否成功移除六价铬与三价铬沉淀的结构和稳定性有关。

Hexavalent chromium is toxic to human and ecosystems as it is transported into cells via the sulfate transport mechanisms, taking advantage of the similarity of sulfate and chromate with respect to their structure and charge. Trivalent chromium, which is the more common and stable variety of chromium compounds, is not transported into cells.

六价铬对人体和生态系统有害，因为利用硫酸盐与铬酸盐在结构和电荷上相似性，六价铬会通过硫酸盐输送机制进入细胞。而三价铬这种更加普遍和稳定的铬化合物不能进入细胞。

OTEK can help by properly studying the soil, water and/or groundwater chemistry, and other pollutants that may have an affect on the chemical nature of the hexavalent chromium that is present.

OTEK可以通过适当研究土壤、水体和（或）地下水化学以及其他可能对六价铬化学性质造成影响的污染物来提供修复方案。

Treatment 处理

In general, custom-blended carbon sources may not be worth their high cost. We typically rely on lower cost reagents like alcohols, lactate, sugars, and whey as our carbon source.

一般地，定制混合碳源可能与它的高价格不相符。我们通常选择相对低价的试剂，如醇、乳酸、糖和乳浆作为碳源。

Together with Arcadis, we are committed to developing and utilizing leading-edge technologies, continually looking for ways to clean up impacted sites faster and at lower total cost than ever before.

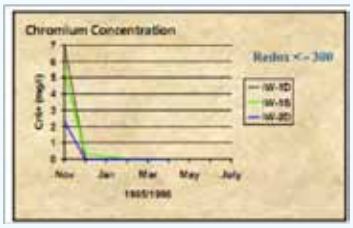
我们与Arcadis 一道，致力于发展和使用领先技术，不断探索新的途径修复污染场地，并使处理费用较低。

Our staff leads the industry in developing and publishing innovative technologies to treat many forms of environmental impacts. We hold more than 30 patents related to break-through treatment technologies, and are well known for our innovative, cost effective approaches to remediation.

我们的员工依靠发展和发布创新性的技术以处理各种环境问题而在行业中处于领先地位。我们拥有30多种突破性处理技术的专利，并以创新及经济的修复方法闻名。

Case Studies 案例

AVCO/Lycoming Superfund Site, Williamsport, PA



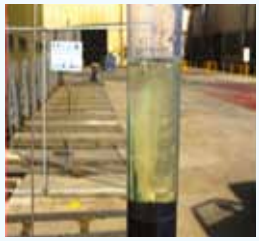
ARCADIS used IRZ™ technology to remediate a groundwater plume of VOCs, hexavalent chromium and cadmium. We successfully assisted the client with renegotiating the ROD to replace a traditional, costly pump and treat system that was expected to operate for at least 20 years. Our client saved over $3,600,000 by implementing our technology, and was allowed to terminate system operation after only three years.

Arcadis 利用IRZ™技术修复了被挥发性有机物、六价铬和隔污染的地下水。我们通过与客户的反复协商，成功地帮助客户用ROD代替了过去传统的、费用很高的抽水与处理系统，原来这个系统计划至少运行20年才能达到治理效果。通过实施我们提供的技术，客户节约了至少360万美元，并只运行了3年就获准停止运行，达到了治理效果。

Hexavalent Chromium (Cr6+) Remediation 案例：六价铬治理

- Steel Company Hexavalent Chromium Soil and Groundwater Remediation Victoria, Australia + $1.5M+ Additional $15M Rem.
  澳大利亚维多利亚州的钢铁公司六价铬土壤及地下水污染整治。$1,500,000 +额外一千五百万美元修复投资。
- 20 years of chromic acid leakage into the subsurface
  20年来铬酸渗出，造成底层土壤污染。
- Estimated 35,000 m3 of soil, and 1,260,000m3 of impacted groundwater.
  大约三万五千立方米土壤和一百二十六万立方米的地下水受到影响。

Hexavalent Chromium (Cr6+) Solution 六价铬治理方案



After all primary sources were controlled or removed: /主要来源得以控制或排除后：

- **Soil** - was treated by polylactate polymer and a benign organosulfur compound, allowing for a controlled release of its active components for long-term. Cr VI was directly precipitated as a hydroxide. The hydroxide solids were stable under the low redox potential and oxidizing conditions.
  土壤 – 使用了polylactate聚合物和良性有机硫化合物进行处理，从而长期缓慢地释放其活性成分。六价铬直接作为氢氧化物析出。氢氧化物固体在低氧化还原电位和氧化状况下得以稳定。
- **Groundwater** - treated by zero valent iron plus carbon (electron donor) mix. A sulfur component was added to facilitate the biotic reactions. The results of a recent pilot trial demonstrated remediation was effective in reducing hexavalent chromium concentrations from concentrations of up to 96mg/L to <0.002 mg/L.
  地下水 – 以零价铁加碳（电子）混合物处理。使用含硫添加剂导致生物反应。最近的一个试点试验的结果表明，在降低六价铬浓度方面效果明显，浓度由96毫克/ 升降为<0.002毫克/升。

Project 项目	Contaminants 污染物	Project Highlights/Successes 项目亮点/成功案例
Former Wood Treating Facility / 原先的木料处理厂	Hexavalent Chromium / 六价铬	• 根据治理合同，执行土壤与地下水治理；项目的关停时间为合同开始10年后；项目先前的治理时间超过30年。 • 证明了可以通过萃取法提升污水捕捉效果，从而大大降低治理成本。 • 快速完成了初步现场试验并获得了地下水和土壤就地治理方面的许可。 • 完成了浅层土壤挖掘和深层土壤就地治理。 • 按照法规的标准，在四年半时间内完成了浅层地下污水治理；项目整个周期的成本是美国范围内最低的？。
Abandoned Plating Facility California Confidential Client/ 废弃电镀厂, 加利福尼亚, 客户信息保密	Hexavalent Chromium / 六价铬, TCE, DCE	• 设计并执行了初步试验和全方位项目，通过ARCADIS获得专利的就地厌氧生物治理流程，进一步对TCE进行了就地脱卤并降低了六价铬的含量 • 在整个厂区范围内使用了全方位区域治理技术，包括91座临时注入井。 • 大大降低了厂区范围内地下水中有害物的浓度：六价铬浓度降低了99%以上，铬的总浓度降低了98%，TCE浓度降低了97%；3年内将各有害物的浓度降至了实验室可检测水平以下；工厂得以合法关停，并可进行销售和再开发。
Fonner Leather Processing Facility, Eastern United States/ 原先的皮革处理厂, 美国东部	Hexavalent Chromium /六价铬	• 7个月时间完成了100%的厂区外含铬（VI）污水的治理（浓度降至了实验室可检测水平以下，即铬的总浓度不超过0.010mg/L）。 • 约18个月的时间基本完成了厂区范围内的治理。
Former Metal Plating Facility, Eastern United States Confidential Client /原先的金属电镀厂, 美国东部, 客户信息保密	Hexavalent Chromium /六价铬	• 4个月内，厂区范围内的铬（VI）浓度最多降低了95%。 • 4个月内，厂区周边的六价铬浓度降低了99%以上。 • 3年内厂区内和周边的铬（VI）浓度降至了实验室可检测水平以下。
Metal Plating Facility Midwestern United States Confidential Client /金属电镀厂, 美国中西部, 客户信息保密	Hexavalent Chromium /六价铬	• 通过可处理性研究确定了最佳的试剂和用量。 • 初步试验结果验证了方法的有效性：所有初步试验区域的铬（VI）浓度均降低了99%以上，超额完成了治理目标。 • 铬含量最高的污水区域的初步助理阻止了铬向厂区外的潜在扩散。 • 全方位治理正在进行中，于2010年夏天全部完成。
Former Chromium Plating Facility Grapevine, TX Confidential Client / 原先的铬电镀厂, Grapevine，德克萨斯, 客户信息保密	Hexavalent Chromium /六价铬	• 应用ARCADIS的技术对超过12英亩的含六价铬污水进行了治理（污水影响了厂区以外的地区和附近的一条小溪） • 地下水治理采取了碳基注入法，并挖掘了拦截沟保护小溪。 • 通过运用ARCADIS的技术，铬的总浓度降低了88%，其中，六价铬浓度降低了90%；在注入停止后，浓度仍持续降低。 • 由于铬浓度的显著降低，客户正在寻求按照“风险降低标准3”进行关停（比如通过监管机构控制进行关停）。
Abandoned Manufacturing Facility Hampton, Iowa Confidential Client / 废弃的制造厂 Hampton，衣阿华，客户信息保密	Hexavalent Chromium /六价铬	• 制定并执行了就地治理初步研究，用以评估替换（用于厂区地下已受六价铬污染的地下水的）已有泵设备和处理系统的可行性。 • 就铬的就地生物治理与分离的州政府审批进行协商。 • 治理1个月后，六价铬浓度降至了规定的清洁关停标准以下。 • 全方位治理为客户带来的收益大于治理成本。

Project 项目	Contaminants 污染物	Project Highlights/Successes 项目亮点/成功案例
Confidential Client New Jersey / 客户信息保密, 新泽西	Hexavalent Chromium / 六价铬	• 4个月内，厂区内的六价铬浓度降低了85~95%，厂区周边的六价铬浓度降低了99%以上；3年内，厂区内和周边的六价铬浓度均降至了实验室可检测水平以下。 • ARCADIS设计了针对整个浅层污水区域治理的现场试验；同时，对厂区周边进行了初步试验，用以阻止深层污水的扩散；现场试验成功地对浅层和深层污水中的铬进行了治理；为了应对深层污水中的铬沉降，ARCADIS正在对安装全方位注入系统的可行性进行评估。 • 现场试验于2002年5月开始；4个月内，浅层污水中的铬浓度降低了85~99%（及以上）；IRZ区域内的深层污水的铬浓度降低了99%以上。
Metal Manufacturing & Plating Site Eastern Pennsylvania /金属制造与电镀厂，宾夕法尼亚州东部	Hexavalent Chromium/ 六价铬，TCE /三氯乙烯，Cadmium/ 镉，lead /铅	• 应用了我们的培养基注入专利技术，从地下水中分离了几种金属物质；同时，该技术进一步加强了TCE的自然生物降解。 • 之前运营着一套泵与处理系统；但在其10年运营周期内的大部分时间，该系统都无法有效地从地下水中大量移除污染物。 • 设计并建造了可移动式注入系统，并对客户负责设备与注入流程的运维人员进行了培训；随后对初步系统进行了扩建，用于两个现场污水点的全面治理。 • 3个月内，TCE浓度降低了30~40%；同时，六价铬浓度降至了实验室可检测水平以下；使用试剂注入法12个月后，我们的替代治理策略将六价铬，铬和TCE的浓度降低了99%；工厂预计于治理后监测的半年后关停。
Former Laboratory Dallas, TX /原先的实验室 德克萨斯州达拉斯	Hexavalent Chromium/六价铬 PCP	• 执行了初步研究和全方位治理，通过除氯法移除地下水中的PCP，并对地下水中的铬进行了分离。 • 通过现场试验，厂区内和其他区域的六价铬和PCP浓度降低了99%以上。 • ARCADIS 负责与所有监管部门和附近的土地所有者进行磋商；成功的治理使得工厂自行按照法规要求进行了关停，简化了法定报告程序。
Castle Mountain Mine, CaliforniaViceroy Gold / 矿加利福尼亚Viceroy Gold公司	Cyanide/ 氰化物，arsenic/ 砷，mercury/ 汞，chromium/ 铬，nitrate / 硝酸盐	• 通过Heap Leach Pad 稳定法 /堆浸垫稳定，成功地在余下的金属恢复期内收集了有毒重金属和氰化物。heap leach 土壤萃取物中的氰化物的STLC浓度降低了90%，并符合了释放标准。 • 治理1年半后，固体（生产）部分被准许合法关停。 • 得益于稳定堆积区的成功，客户于2005年被升级为矿产C级；此外，客户认识到了我们的方法相较传统的耗时长且非就地的水处理方法大大节省了成本。

In-situ Precipitation of Chromium in Groundwater
Eastern U.S.

Project Goal - Regulatory closure of groundwater issues related to Cr6+.

Strategy - In-situ chromium precipitation in the source area and at the property boundary using an anaerobic IRZ.

Project Accomplishments - Source area Cr6+ concentrations reduced by up to 95% within 4 months. Greater than 99% reduction in Cr6+ concentrations at the property boundary within 4 months. Decline in Cr6+ concentrations to below the laboratory method detection limit in the source area and at the property boundary within 3 years.

Client
Confidential

Scope of Services
- Pilot Study
- Design and implementation of an in-situ metals precipitation system

Performance Period
2002 to Present

Contaminants
- Cr6+

THE CHALLENGE / BACKGROUND

This site, located in the eastern United States, was considered one of the oldest active cases with the prevailing regulatory agency. Under regulatory pressure, the client contacted ARCADIS to explore innovative and aggressive ways of remediating a plume of hexavalent chromium (Cr6+) extending off-site. ARCADIS was contracted in 2001 to implement a field test to demonstrate in-situ precipitation of Cr6+using an anaerobic in-situ reactive zone (IRZ).

Chromium impacts in site groundwater were related to historic facility plating operations. Previous investigations identified the highest concentrations of Cr6+ of over 9 milligrams per liter (mg/L) in the groundwater directly beneath the building.

In this area, groundwater is encountered at approximately 5 feet below ground surface (bgs) within a silty clay unit, with impacts extending to a depth of approximately 15 feet bgs. Downgradient of the source area, impacts were observed in an intermediate aquifer consisting of fine sand and silt unit between 15 and 30 feet bgs. The average horizontal groundwater velocities in the shallow silty clay unit and the deeper fine sand and silt unit are 30 feet per year and 100 feet per year, respectively. Cr6+ concentrations up to 8 mg/L extended to the property boundary approximately 100 feet downgradient (approximately 1 year of groundwater travel).

Additional investigation downgradient of the property boundary has revealed that Cr6+ has been detected at concentrations up to 8.5 milligrams per liter (mg/L) in the deeper unconsolidated and bedrock aquifers.

THE APPROACH

A pilot demonstration was implemented to treat Cr6+ in the source area via biologically stimulated pathways. Specifically, the injection of degradable carbohydrates was used to stimulate microbial activity and support the reduction of Cr6+ to trivalent chromium. The pathways involved in this process include direct microbial reduction with Cr6+ serving as a terminal electron acceptor, abiotic reduction by reaction with by-products of iron and sulfate reduction (ferrous iron and reactive sulfide) and abiotic reduction in the presence of organic acids (humic and fulvic acids). The primary end product of these reactions is chromic hydroxide [Cr(OH)3], a precipitate that forms readily under alkaline to moderately acidic conditions (5<pH<12).

The pilot demonstration was designed with two rows of injection wells (13 wells) in the upper formation to address chromium in the source area and one row of injection wells (2 wells) in the lower formation to address chromium migrating from the source area to the lower formation. The injection wells were installed as 1-inch wells using direct push drilling methods. One row of injection wells in the upper formation and the two wells in the lower formation were installed inside the on-site building to target the highest chromium concentrations. The pilot study was conducted from June 2002 through January 2003 and consisted of monthly injection events and periodic performance monitoring.

THE RESULT

The pilot system was considered sufficient to meet the needs of a full-scale on-site remedy. Hexavalent concentrations in the performance monitoring wells downgradient of the three lines of injection wells have been reduced to less than 0.010 mg/L. Source area treatment has been discontinued based on the results. Currently, off-site impacts are being delineated with the maximum concentrations (8.5 mg/L) observed several hundred feet downgradient of the property boundary. Plans for the next phase of the project will include delineation and remediation of the off-site impacts.

Biological Reduction of Nitrate, Perchlorate, Chromium and TCE Hollister, CA

Project Goal - Minimization of client's long-term financial risk.

Strategy - Implement the lowest life-cycle cost groundwater and soil remedies. Proactively communicate with regulatory community to implement remedies. Resolve existing fate and transport data gaps to support remedy implementation.

Project Accomplishments - Successfully pilot tested and implemented in-situ biological reduction of perchlorate, VOCs and Cr6+ in site groundwater. Successfully pilot tested first commercial application of in-situ biological reduction of perchlorate in vadose zone soils via direct push injection. First commercial bioreactor to treat nitrate, perchlorate and Cr6+ simultaneously.

Client
Whittaker Corporation

Scope of Services
- Pilot Study Design & Implementation
- Full-Scale Remedial Design Groundwater Modeling

Performance Period
2000 to Present

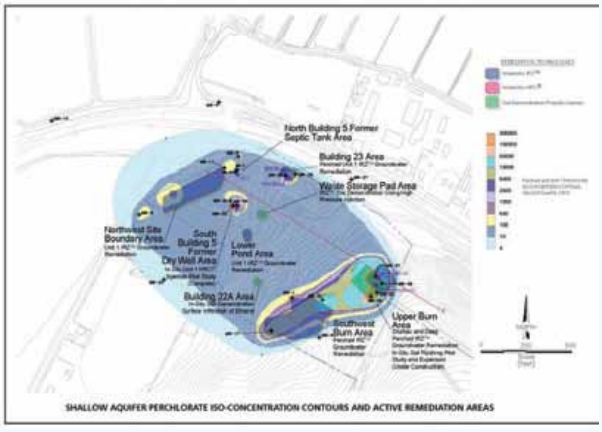
Contaminants
- TCE
- Perchlorate
- Chromium
- Selenium
- Nitrate

THE CHALLENGE / BACKGROUND

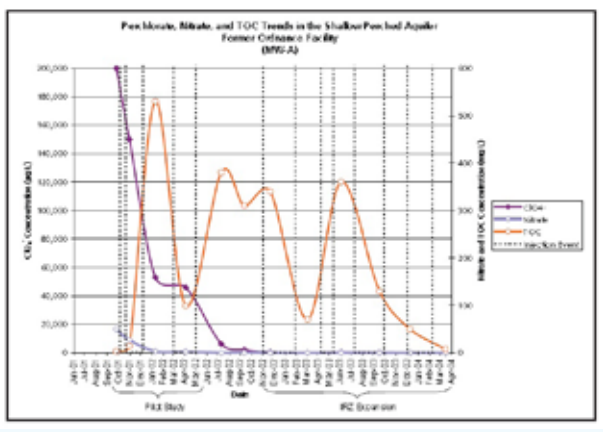
This 94-acre facility in Hollister, California consisted of an operating dairy farm prior to 1957. From 1957 to 2007 the site operated as an ordnance manufacturing facility. Soil and groundwater at the site has been impacted by perchlorate, chlorinated VOCs (volatile organic compounds) and hexavalent chromium (Cr6+). The site lies in an area with many perchlorate-impacted properties regulated by the Central Coast Regional Water Quality Control Board.

Cleanup at the site began in 1991 when VOCs, including trichloroethene (TCE), were detected in samples collected from an on-site water supply well. Initial groundwater monitoring and remediation activities conducted between 1991 and 1997 focused on VOC-related impacts and included the installation of a groundwater extraction and treatment system (GETS) for shallow groundwater and multiple irrigation well-head treatment systems. The emergence of perchlorate as a chemical of concern (COC) prompted a review of perchlorate impacts at the site in 1997. Subsequent investigations of the extent and magnitude of perchlorate in soil and groundwater confirmed that perchlorate represented the most significant site COC and thus the primary regulatory driver.

Soil investigations found perchlorate concentrations as high as 1,500,000 micrograms per liter (µg/kg), TCE as high as 6,500 µg/kg and Cr6+ as high as 81 µg/kg. Shallow groundwater has up to 500,000 µg/L of perchlorate, 90,000 µg/L of TCE and 250 µg/L of Cr6+. COC migration was previously influenced by two off-site irrigation supply wells that served as vertical conduits and have now been shutdown. COC plumes have commingled to form a large diffuse groundwater plume extending to approximately 350 feet below ground surface (bgs) and 300 ft downgradient of the site. Seven source areas have been identified with soil impacts to 80 feet bgs and groundwater plumes intercept three stratigraphic units.



SHALLOW AQUIFER PERCHLORATE ISO-CONCENTRATION CONTOURS AND ACTIVE REMEDIATION AREAS



THE APPROACH

ARCADIS was selected to work on the project in 2000 to evaluate potential applications of in-situ remediation and to better understand the complex site hydrostratigraphy. ARCADIS implemented in-situ bioremediation and oxidation interim measures that met regulatory- driven objectives to treat source areas while a long-term comprehensive remedial strategy was developed. A series of investigations resolved key conceptual model data gaps and demonstrated that the off-site wells were vertical conduits. The client then negotiated shutdown of the wells and is currently working on permanent provision of alternate water supplies.

In completing the interim measures the ARCADIS approach included:

- Reductions of perchlorate in groundwater to cleanup goals within two years using in-situ biological techniques.
- Vadose zone in-situ treatment to remediate source area perchlorate.
- Vadose zone and groundwater modeling to refine risk-based soil clean-up goals and provide a design basis for a proposed groundwater containment system.
- Completed fate and transport modeling to determine lowest cost alternatives for the off-site VOC and perchlorate plumes.

ARCADIS conducted a bench-scale test of a dynamic suspended bed bioreactor for treatment of nitrate, perchlorate and Cr6+. Revised surface water discharge standards have forced an evaluation of selenium treatment options and we are currently completing a bench-scale scale test of a modified bioreactor to treat selenium. Full-scale construction is scheduled for 2008.

THE RESULT

ARCADIS project role has evolved from innovative technology applications to overall risk management strategy development to a re-focused effort as part of a larger consultant team on implementation of the most technical portions of the site remedy. Financial risk for our client has been minimized through the application of innovative biological treatment methods at bench-and field-scale. Our adaptive design approach has provided simultaneous treatment of multiple contaminants in a single process while allowing for treatment of other contaminants as treatment requirements evolve.

In-Situ Biological Reduction of Pentachlorophenol and Chromium Dallas, Texas

Project Goal - Regulatory closure of environmental issues related to Cr6+ and PCP in soils and groundwater.

Strategy - Site investigation of soil and groundwater impacts, remedial approach evaluation through pilot testing and subsequent full scale implementation. Excavation and off-site disposal of Cr6+ and PCP impacted soil satisfying Texas Risk Reduction Program (TRRP) requirements.

Project Accomplishments - Reduction of dissolved Cr6+ and PCP to below TRRP Protective Concentration Levels through creation of an in-situ treatment.

Client
Confidential

Scope of Services
- Remediation and Regulatory Support

Performance Period
2001 to 2008

Contaminants
- PCP
- Cr6+

THE CHALLENGE / BACKGROUND

The Former Hayman Estate Property (the Site) was leased by the client between 1960 and 1972. During this time a chemical blending operation in support of the water treatment industry resulted in releases of hexavalent chromium (Cr6+) and pentachlorophenol (PCP) to the environment. The Site investigation identified an underground storage tank (UST) during a Phase I Environmental Site Assessment (ESA) at the Site conducted in July 1994. Based upon investigations related to closure of the UST in September 1995 and subsequent soil sampling events, approximately 5,000 cubic yards of chromium- impacted soil were excavated and removed from the area of the former UST. The Texas Commission of Environmental Quality (TCEQ) issued a No Further Action (NFA) letter for chromium in soil related to the former UST in June 1997. Additional investigations (unrelated to the UST) conducted in August 1997 identified PCP in soil beneath the Site building and along the northwest wall of the building. The PCP soil excavation activities were described in the ARCADIS March 2001 Closure Report for PCP in Soil. The TCEQ issued a NFA letter for PCP in soil in January 2003. Elevated concentrations of PCP and Cr6+ in groundwater still required remediation.

THE APPROACH

The ARCADIS approach to remediation of groundwater was to implement two overlapping IRZs, one for the chromium and another for the PCP. Once a carbohydrate addition (such as a dilute solution of molasses and water) is introduced to an aquifer, the native microorganisms preferentially utilize this substrate in a metabolic pathway.

Under reducing conditions, Cr6+ is reduced to trivalent chromium (Cr3+). It is precipitated and immobilized in the soil matrix as a geochemically stable and insoluble chromic hydroxide precipitate. The chromic hydroxides readily precipitate out of solution under alkaline to moderately acidic conditions. Only under extreme changes to pH or oxidation state (not typically observed under environmental conditions) in the aquifer could the precipitate possibly resolubilize.

More strongly reducing conditions created in the second IRZ enhanced PCP reductive dechlorination (degradation) rates. During the reductive dechlorination of PCP, numerous mono-, di-, tri- and tetrachlorophenol degradation products are formed. However, because of the many different species formed, these intermediary forms are generally not present at detectable levels. Ultimately, PCP degradation leads to lesser chlorinated compounds, eventually ring cleavage and finally mineralization to carbon dioxide and chloride.

THE RESULT

Based upon the success observed as a result of the 2001 pilot scale program, the program was expanded to a full-scale system in May 2003. The results from the October 2007 sampling event indicate that Cr6+ and PCP have been reduced below the applicable regulatory standards in all wells monitored as part of the site monitoring program.

In-situ Treatment of Hexavalent Chromium
Eastern U.S.

Project Goal - Remediate a Cr6+ plume in groundwater extending off-site under a residential neighborhood.

Strategy - In-situ anaerobic chromium reduction and precipitation.

Project Accomplishments - 100% of the off-site Cr6+ plume remediated in 7 months (concentrations under the laboratory detection limit of 0.010 mg/L), total Cr within only 12 months. Source area remediation nearly complete within approximately 18 months.

Client
Confidential

Scope of Services
- Remedy Design & Implementation
- Regulatory Interface
- Strategy Development

Performance Period
2005 to present

Contaminants
- Cr6+

THE CHALLENGE / BACKGROUND

In 2005, during redevelopment activities at a former industrial facility in the eastern U.S., which was historically used for commercial and retail leather processing, hexavalent chromium (Cr6+) was discovered throughout the 2-acre site. Understandably, discovery of Cr6+ brought redevelopment to a standstill. The site is underlain by a thin sequence of overburden beneath which lies the regional shale and sandstone bedrock formation. Groundwater occurs within the bedrock at an average depth of approximately 20 feet below ground surface, with flow controlled by secondary porosity features (fractures, bedding planes, joints and faults).

Remedial investigations identified Cr6+ through the entire overburden soil profile at concentrations ranging up to 2,200 milligrams per kilograms (mg/Kg). Dissolved Cr6+ concentrations in the shallow fractured bedrock ranged up to 12 milligrams per liter (mg/L), with a corresponding groundwater plume approximately 600 feet long by 500 feet wide, extending well off- site beneath a residential neighborhood.

THE APPROACH

ARCADIS was selected to remediate the site. After assessing the extent of the impact, ARCADIS selected in-situ precipitation to treat the Cr6+ impacts in groundwater using its patented anaerobic reactive zone technology. This technology employs an easily degradable source of organic carbon to stimulate microbial activity in the aquifer, eventually developing anaerobic and strongly reducing conditions. Under these conditions, Cr6+ is readily reduced to Cr3+ by direct chemical reaction with ferrous iron and reactive sulfide formed in the reactive zone, as well as direct microbial reduction (with Cr6+ serving as a terminal electron acceptor). At a pH above 3.5, the resulting Cr3+ undergoes hydrolysis to form various chrome hydroxide species. What forms depends largely on pH and ionic strength, but the goal is to form solid precipitates, such as pure amorphous chromic hydroxide [Cr(OH)3] and mixed iron-chromic hydroxide. These precipitates subsequently become fixed in the aquifer matrix through filtration, sedimentation and/or adsorption.

Prior to implementation of the technology, injection testing was completed to verify the ability of the aquifer to accept the injection solution, the relationship between injection volumes and delivery radius, groundwater flow rates and groundwater flow direction. The results indicated that an on-center well spacing of 120 feet could be supported, the groundwater flow rate was between 1.5 and 3 feet per day and the flow direction was approximately 45 degrees different from what would have been assumed by the hydraulic gradients alone. This information provided the critical basis for completing the design of the in-situ remediation system.

THE RESULT

During the first phase of implementation, preferential focus was given to the off-site plume. This was in large part due to access limitations precluding more aggressive action in the source area. To facilitate remediation of the off-site plume, four injection wells were installed along the downgradient property boundary. The regular and repeated injection of carbohydrate reagent solution began in February 2006, observing the volume requirements determined by the injection testing. By August 2006, injection wells positioned to treat part of the on-site plume were also brought into service.

In response to the remedy, concentrations of Cr6+ (and total Cr) in groundwater were reduced dramatically. In fact, 100% of the off-site Cr6+ plume was eliminated in 7 months (concentrations under the laboratory detection limit of 0.010 mg/L). Remediation of total Cr followed shortly after, dropping below 0.010 mg/L throughout the off-site area within only 12 months. The result was a reduction in the plume footprint by approximately 74%. In addition, significant progress was made in the on-site portion of the plume within the limited areas that were accessible for treatment.

As part of the soil remediation in the source area, excavation flooding was completed to target residual Cr6+ within the unsaturated bedrock and the shallow groundwater, as well as continued injections through wells. The majority of the on-site plume has since been remediated, with both redevelopment and regulatory closure of this site expected in the near term.

Practical Environmental Solutions

OTEK Global Headquarters

National

OTEK, Level 1
222 St Kilda Road
St Kilda, VIC 3182
Australia
T: +61 3 9525 5155

OTEK Principal Offices:

Sydney

OTEK, Level 4
146 Arthur Street
North Sydney NSW 2060
Australia
T: +61 2 9417 4499

Brisbane

OTEK, Level 1
9/44 Station Road
Yeerongpilly QLD 4105
Australia
T: +61 7 3426 5200

Melbourne

OTEK, Level 1
222 St Kilda Road
St Kilda, VIC 3182
Australia
T: +61 3 9525 5155

Perth

OTEK, Level 1
79 Hay Street
Subiaco WA 6008
Australia
T: +61 8 9381 5500

Adelaide

OTEK, Level 5 City Central
121 King William Street
Adelaide SA 5000
Australia
T: +61 8 8423 4480

Beijing

OTEK 北京市海淀区蓝靛厂南路25号
牛顿办公区706室100097

Suite 706 Newton Office Building
25 Lan Dian Chang South Road
Haidian District, Beijing 100097
China
T +86 10 8840 0302

ARCADIS Global Headquarters

ARCADIS NV

'Symphony'
Gustav Mahlerplein 97-103
1082 MS Amsterdam
The Netherlands
T +31 20 2011080

ARCADIS Principal Offices:

Belgium

ARCADIS Belgium
Posthofbrug 12 (City Link)
2600 Berchem – Antwerpen
Belgium
T +32 3 3286286

Brazil

ARCADIS Logos Ltda.
Rua Libero Badaró, 377-11° andar
CEP 01009-906, São Paulo
Brazil
T +55 11 3117 3171

Chile

ARCADIS Geotécnica S.A.
Av. Eliodoro Yañez 1893
Providencia, Santiago
Chile
T +56 2 3816000

China

ARCADIS Asia
Zhongrong Plaza, Unit 1203
1088 South Pu Dong Road,
Pudong New Area
Shanghai, 200122
China
T +86 - 21 587 61 451

Czech Republic

ARCADIS CZ a.s.
Na Strži 1702/65
140 62 Prague 4
Czech Republic
T +42 296 330111

France

ARCADIS ESG
9 Avenue Réaumur
92354 Le Plessis-Robinson Cedex
France
T +33 1 46 01 24 00

Germany

ARCADIS Deutschland GmbH
Europaplatz 3
64293 Darmstadt
Germany
T +49 6151 3880

Italy

ARCADIS SET s.r.l.
Via Piemonte 32
20090 Buccinasco (MI)
Italy
T +39 02 48841600

The Netherlands

ARCADIS Nederland BV
Piet Mondriaanlaan 26
P.O. Box 220
3800 GV Amersfoort
The Netherlands
T +31 33 4771000

Poland

ARCADIS Polska Sp.zo.o.
Ul. Pulawska 182
02-670 Warszawa
Poland
T +48 22 203 2000

Romania

ARCADIS Eurométudes
Strada Gheorge Manu, nr. 20,
Sectorul 1
71106 Bucharest
Romania
T +40 21 31 22699

Russia

ARCADIS Rus OOO
111524 Moscow
Elektrodnaja Str. 13, building 16
Russia
T +7 9262416032

United Kingdom

ARCADIS UK Ltd.
10 Furnival Street
London EC4A 1YH
United Kingdom
T +44 207 2161000

United States

ARCADIS US Inc.
630 Plaza Drive, Suite 200
Highland Ranch
Colorado 80129-2379
United States
T +1 720 3443500

OTEK is a member of the
ARCADIS Alliance Partner Program

ARCADIS
Infrastructure · Water · Environment · Buildings

This Alliance is an association of cooperating independent companies established to network services world-wide for the benefit of its Clients and no legal association is expressed, except through written agreements with such Clients.