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Fouling in Remediation Equipment: Effectively Confronting The Most Common Operating Impediment

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Abstract

Fouling in treatment or recovery equipment is one of the most pervasive, if not the most common, operating impediment at groundwater remediation sites. The great majority of sites where groundwater is handled or treated exhibit some degree of bio-fouling, scaling or precipitation. The extent of the problem, and cost of controlling it, can range from modest to insurmountable. Historically, consideration of this problem has often been overlooked in design work, and indeed, the recent trend to perform remedial process optimizations at groundwater remediation sites rarely includes a review of available deposit control technology and associated costs. The authors' experience at over five hundred sites with fouling shows that at most sites with deposit control problems, costs can be reduced dramatically. In most cases, this requires a rigorous inventory of problem characterization, feasibility and cost estimates, and follow-up process validation.

While pump-and-treat technology has lost favor as the primary remedial process for groundwater remediation, it remains the only and best feasible option at a great many sites. Many innovative technologies have been applied as an alternative to groundwater recovery. These methods include, among others, air sparging, advanced oxidation, bio-treatments, total fluids extraction, treatment "walls" and in-well treatment. Fouling problems plague both traditional and innovative approaches. Thus, it is important for those involved in any groundwater remediation to recognize that the potential for fouling, scaling and precipitation must be considered in order to successfully apply all of these techniques.

This paper presents a protocol for remedial process optimization as it applies to reducing the costs of deposit control in groundwater remediation systems. It includes a discussion of the causes of these deposits and presents methods of properly characterizing fouling problems. The paper also includes a review of common technologies used in the past to control fouling, and presents recently developed deposit control technology. Several case studies are presented to identify costs and cost reductions possible.

Introduction

Remedial actions at hazardous waste sites often involve processing of contaminated groundwater to remove contaminants. This processing may be in-situ, as in removal of VOC's via air sparging, or by some above-grade treatment process associated with a "pump-and-treat" system. In either case, changes in the chemistry, biochemistry or thermodynamic properties of the water being treated can cause various types of deposits to occur in treatment equipment. This scaling and fouling in groundwater remediation systems has been shown to be a major operating impediment to achieving cost-effective operation of these systems.

The occurrence of various types of deposition is very common in remedial systems treating groundwater. A review of any number of sites, where groundwater is treated, shows that fouling is one of the most common operations and maintenance problems. The severity of the problems ranges greatly based upon site conditions. It is not uncommon for system operators to accept downtime events, requiring maintenance labor, every few days. The authors have spent the last fifteen years studying and developing techniques to combat these problems as they occur in remedial systems. While no one approach works in all situations, operating costs can often be significantly reduced by the application of a rigorous review of operating problems and the subsequent application of regular maintenance measures.

Technical Background

Deposits in groundwater treatment equipment may be divided into inorganic or microbial in nature. Inorganic deposits develop when naturally occurring inorganic solutes, dissolved in groundwater, precipitate and deposit due to changes in the thermodynamic and chemical properties of the subject water. The type and concentration of these inorganic ions typically relate to the geochemistry of the source of the groundwater. Changes in thermodynamic properties include changes in temperature and pressure. Chemical changes that commonly occur in groundwater treatment systems include addition of oxygen, desorption of carbon dioxide and pH changes. Inorganic deposits may be scaling or non-scaling. Scale forming deposits, such as hardness salts, actually produce a crystalline precipitate in process units and piping. Non-scaling inorganic deposits, such as iron and manganese oxides produce a fine precipitate that is non-crystalline and results in an amorphous mudlike deposit.

Microbial deposits typically consist of sessile, or adhering, bacteria. Bacteria secrete voluminous polysaccharides, commonly called slime, which enhance the adherent properties of the biomass, capture nutrients, and protect micro-organisms. Bacteria commonly found in remedial system deposits include hydrocarbon utilizers, iron related bacteria and sulfate reducing species.

In practical terms, it is not unusual to find microbial and inorganic constituents simultaneously in deposits in groundwater remediation equipment. Iron oxides, manganese oxide, hardness salts, and sessile bacteria, individually or in some combination comprise nearly all deposit constituents found in such equipment in the United States.

Deposit Characterization

Solving the complex problem of deposits in groundwater remediation systems involves a basic understanding of the types of deposits commonly found in such equipment as well as adequate characterization of the nature of the deposits. This characterization involves information regarding both the treatment process and the deposits themselves. The choice of an appropriate deposit control technique necessitates the collection of this information. Important parameters characterizing the nature of deposits, or potential deposits, include physical observations and analytical data. Physical observations include the deposit color, deposit texture and approximate deposition rate. Chemical analyses of water to be treated should include pH, iron and manganese concentrations, and hardness levels. Microbial analyses might include total bacterial plate count and

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identification of the presence of iron-related or sulfate-reducing bacteria. Important parameters regarding treatment process include water flow rate and type of treatment process units in the treatment train.

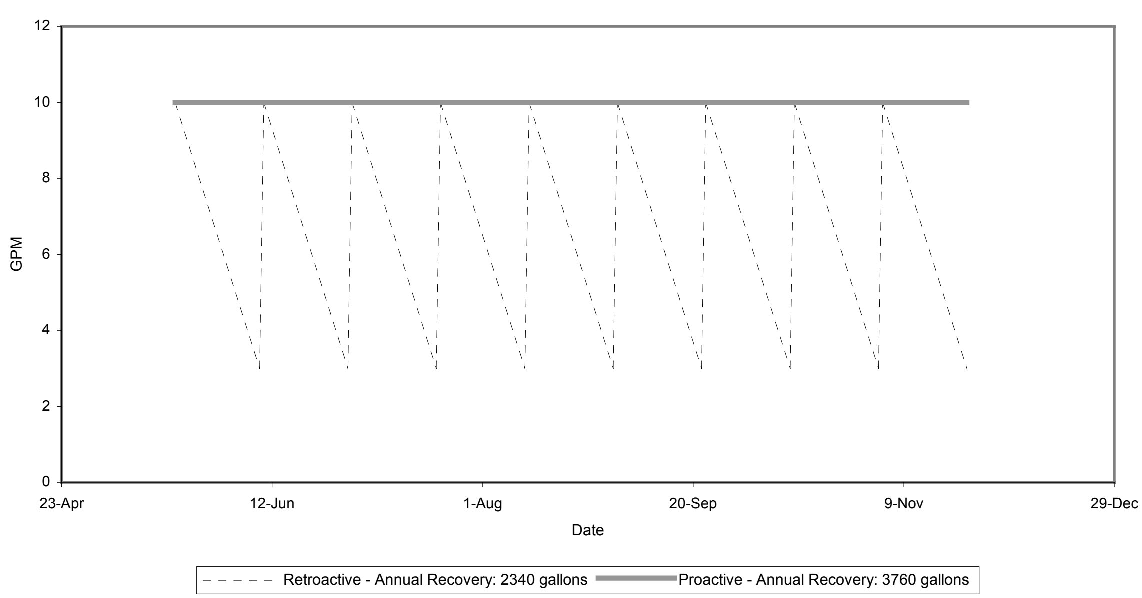
Traditional Deposit Control Options

Deposit control technology, as it regards groundwater remediation equipment, can be divided into approaches that are retroactive and those that a proactive. Retroactive approaches are those techniques that allow deposition to occur to some point defined as unacceptable, with subsequent removal of deposits through a treatment system "cleaning" process. Proactive approaches are those that might be termed preventative.

Retroactive deposit control technologies currently in use include replacement of system components, such as packing or carbon vessels, or periodic system cleaning. Repacking of air stripping towers was the most common response to deposits in that remediation equipment until recent years. This response is labor intensive, requires disposal of fouled packing and can involve significant ongoing capital expense. Periodic system cleaning has gained popularity as remediation system designers have become more aware that deposit control is an important design consideration. Vendors have begun to offer systems that are simpler to clean and site designers have often included recycle loops in treatment equipment to allow cleaning with an appropriate aqueous solution. Cleaning solutions commonly used include various acids, chelating agents, oxidizing agents and biocides. This approach has the disadvantage of producing a wash-water that requires treatment and/or disposal. Costs include chemical usage and disposal costs. Retroactive methods in general require treatment system downtime, and are difficult to automate.

A significant drawback of a retroactive response to deposits is often overlooked by system operators: This is the fact that allowing a system to foul, rather than preventing deposition, renders the treatment system less than fully effective for much of its operating time, as deposits build up to some level deemed unacceptable. For example, if we measure system flow for a 10 gpm system that requires cleaning every three weeks, we might see that the system runs at close to full design flow immediately after cleaning, and at some unacceptable, lower flow, just prior to cleaning, with flow versus time depicted below.

Proactive Control vs. Retroactive Control



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With an effective proactive deposit control method in place, flow is constant at 10 gpm, giving much greater annual recovery. For most groundwater treatment systems, this enhanced recovery rate is significant, and reduces required system life-cycle accordingly, greatly reducing total clean-up costs.

Proactive technologies for deposit control involve either removal of depositing constituents or the use of deposit control additives. Removal of depositing constituents is appropriate only for inorganic deposits, and usually employs precipitation of depositing constituents, followed by filtration of precipitate. The most common application of this approach involves the use of an oxidizing agent such as sodium hypochlorite, with bag filtration being the most common precipitate removal option. The disadvantages of this process are those of storage and handling of oxidizing agents, production of sludge, which may be deemed hazardous, and the labor intensive nature of small filtration equipment such as bag filters. The use of deposit control additives has gained popularity in recent years and is appropriate for inorganic and microbial deposits. This technology involves the use of a variety of deposit control agents in conjunction with a chemical feed pump to meter appropriate amounts of agent into the "front end" of a treatment process.

The Application of Deposit Control Agents to Remedial Systems

As the sophistication of design of groundwater remediation systems has developed over the past decade, so has the technology of deposit control. Deposit control chemicals have, in very recent years been aggressively marketed to the remedial field. This method of deposit control has become more popular in recent years. Until recently, virtually all of the chemicals which have been applied to the groundwater remediation field were actually developed for other markets, namely municipal drinking water market or the boiler and cooling water market. Because of this fact, most of the chemicals used in this application are inadequate for broad application to groundwater remediation systems.

Traditional deposit control chemicals for control of microbial deposits have been oxidizing biocides, such as sodium hypochlorite, hydrogen peroxide or ozone. While these oxidizing biocides are the least expensive biocides, they are not highly effective on sessile bacteria, the type most problematic in groundwater remediation systems. More importantly, these biocides, in applications involving groundwater, will cause the oxidation of the inorganic constituents, such as iron or manganese. Thus, the use of these biocides may actually cause inorganic deposits in treatment equipment.

Traditional inorganic deposit control chemicals are sequestering agents, which chemically bond to depositing ions, rendering them soluble, and carrying them through treatment systems. The most commonly used sequesterants, historically, are polyphosphate-based. These materials have several disadvantages, which render them inappropriate for many applications in groundwater remediation. Polyphosphates act as nutrients, feeding bacterial growth in treatment systems and at discharge points. Many states, therefore, limit the allowable discharge of polyphosphates. The second shortcoming of polyphosphates is that they are not effective in situations where depositing ion concentrations are high, at levels widely found at groundwater remediation sites. For example, polyphosphates have enjoyed wide popularity and success in treating iron in drinking water systems, where iron levels rarely exceed several parts per million. They are not capable, however, of controlling iron concentrations greater than ten to twenty parts per million, not unusual at groundwater remediation sites.

In light of these technical issues the authors has proposed, formulated and tested various deposit control chemical formulations which are specifically aimed at overcoming the shortcomings of existing deposit control chemicals currently available and in use at remedial sites. These alternative formulations have now been used at over five hundred operating remedial sites in nearly every U.S. State and Canada.

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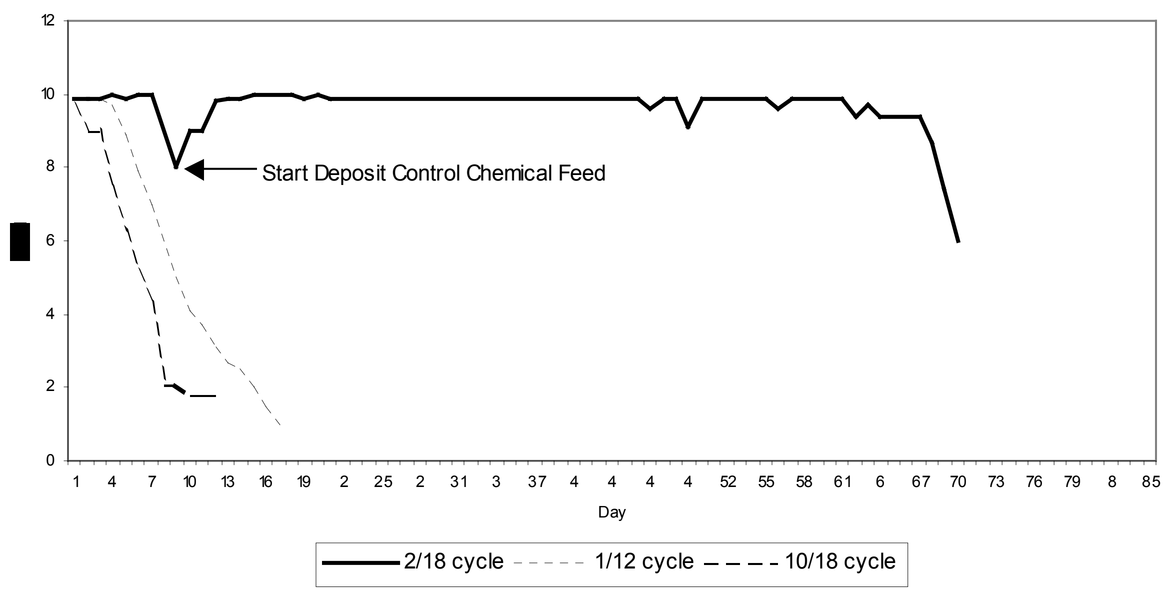
Case Studies

The Boeing Corporation's Western Processing Waste Management Operation has become a major superfund site near Seattle, Washington. Several years ago a short term remediation alternative was implemented. This system consisted of multiple recovery wells using submersible pumps recovering up to 100 gpm. Analytical data, showing dissolved iron at 20 ppm to 30 ppm and hardness at about 400 ppm, indicate that system fouling would become a major operating cost. In response a precipitation system was designed and constructed at a cost of several hundred thousand dollars. Treatment for VOC's was accomplished by a tray type air stripper after the precipitation step. Air stripper discharge was routed via a 1000 foot pipeline to sewers.

After operation of this system for some period, it became apparent that the cost of operating the precipitation system was substantially higher than expected. Alternatives for control of fouling were investigated by system engineers. It was determined that deposit control chemicals could be cost competitive in this application, in spite of capital costs already expended on pre-treatment equipment. Pilot studies comparing various deposit control chemicals were conducted, and a chemical feed system implemented. The system has been operating successfully for several years. Operation data has verified that the deposit control chemical technology reduced operating costs so much as to justify mothballing the metals pre-treatment system.

In another application, A major chemical manufacturer has been operating remedial systems for several years at one of its now inactive plant-sites in New Jersey. The remedial actions involve groundwater recovery from multiple wells distributed over an area of several square miles. Fouling in pumps and miles of pipelines created major operations headaches, requiring pipeline cleanings and pump replacements regularly. The authors have developed a deposit control program for the site, which greatly extends the operating lifespan of pumps, prior to their requiring rebuilding. The chart below shows a pilot application of a blended deposit control agent to extend pump life (prior to removal for cleaning and rebuilding) by about five times. This chart also illustrates that the deposit control agent was able to recover pump capacity by cleaning a pump that had already begun to foul.

Extension of Cleaning Cycle: Recovery Pump at New Jersey Superfund Site



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Conclusion

The problem of deposits in groundwater remediation equipment is clearly a significant operating expense and operating expenses are clearly a significant portion of total life-cycle costs for remediation projects. Thus it behooves remedial design engineers and scientists to understand the nature of deposits and deposit characterization. As well, conscientious environmental consultants need to have, at least, cursory knowledge regarding solutions that have proven effective in recent years. The state of the art in this area has developed rapidly in recent years as the costs of the problem and the remediation market as a whole have become more obvious. More and more, proactive solutions have gained favor as the method of choice in combating deposit problems as knowledge has flowed into the remedial field from other areas of engineering. Specifically, deposit control chemicals have been developed which are designed solely for groundwater remediation application and make the use of these products more cost effective than ever.

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Biographical Sketches

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