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Groundwater Remediation: Extraction and Removal of TCE & Cr⁶⁺ at an NPL Site
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This case study focuses on the engineering analysis of a treatment process used in a National Priority Listed (NPL) site in a midwestern State within the continental United States. The primary contaminants intended to remove from the groundwater at this site are Trichloroethylene (TCE) and hexavalent chromium (Cr⁶⁺)

The groundwater treatment plant, for this site belonging to an aircraft repair and paint company, is designed for a flow rate of 150,000 gal./day (567 m³/day). The cleanup period is estimated to be 30 years. The treated water is planned for industrial reuse at the same facility.

The waste characteristics of this NPL site are very common to many aerospace industries and other industrial sites. The cleanup method used at this site for TCE and Cr⁶⁺ removal could be used in similar other sites since it renders a high (99.99%) contaminant removal efficiency and offers an environmentally clean method with very minimal sludge/waste generation.

Based upon the result of a study, involving a complete engineering analysis of several different processes that are available for removal of organics, mainly trichloroethylene (TCE), and metals, primarily hexavalent chromium (Cr⁶⁺), the following treatment train was selected for this NPL site.

- ◆ Organic Removal Process
- ◆ Metals Reduction Process
- ◆ Metals Precipitation process
- ◆ Final polishing process

The treatment processes for the groundwater treatment plant (GWTP) are summarized below:

1. The Organic Removal process consists of the Aquadetox system, developed by Dow Chemical and patented for removal of high boiling organic compounds. This process has been found to be effective in removal of most of the organic compounds, which are listed as hazardous by the U.S. Environmental Protection Agency (EPA). The stripping technology, whether an air stripper or a steam stripper, can provide 99.9999% removal efficiency. The effluent from this process is expected to have non-detectable concentration (less than 1 ppb) of the organic contaminants. The Aquadetox process is also accepted under the EPA's Superfund Innovative Technology Evaluation (SITE) program. This technology, working at over 10 locations, eliminates any carbon polishing of the effluent water. The conventional air stripping provides only about 90-95% removal of volatile organic compounds.

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2. The Metals Removal Process consists of the following:

The incoming groundwater contaminated with hexavalent Chromium (Cr^{6+}) is treated by a reduction process first. This reduces the Cr^{6+} to the trivalent form, Cr^{3+} . The metal is then removed as precipitate from the groundwater.

In the first stage of treatment, the pH is lowered to 2.5 by the addition of 98% Sulfuric acid (H_2SO_4); a pH probe in the tank controls this addition. The stream is made acidic to facilitate the reduction reaction. The reducing agent to be used in the process is sodium metabisulfite ($\text{Na}_2\text{S}_2\text{O}_5$). This chemical reduces the hexavalent chromium, Cr^{6+} , to trivalent chromium, Cr^{3+} .

The automatic addition of sodium metabisulfite is controlled by an Oxidation Reduction Potential (ORP) measuring instrument. Proper reduction of chromium can be seen readily by a color change from yellow to blue in the treatment tank.

After being reduced, the stream from the first stage flows to the second stage tank for primary precipitation treatment. The pH is raised to 9.0 to precipitate the trivalent chromium as a chromium hydroxide. This is accomplished by adding a 50% sodium hydroxide solution; the amount of addition is controlled by a pH probe. Chromium is an amphoteric metal which means that it is highly soluble at both a low pH as well as at a high pH. For this reason the pH is maintained at the optimum value of 9.0. Practically, this value can not be precisely controlled due to the addition of the sodium hydroxide in large quantity. If the pH differs greatly from this value, excess trivalent chromium remains in the solution. At a pH of 9.0 the trivalent chromium and other heavy metals precipitates as metal hydroxides. The sludge generated by this process is expected to be 75% less than that generated by the Ferrous Sulfate process, which is commonly used in old metal processing/plating industries.

A secondary precipitation of these metals occurs in the pH adjustment tank, where the pH is maintained at 9.0 (for further precipitation) by adding sodium hydroxide or sulfuric acid as required. Thus if the pH goes to a value of 10.0, it is lowered to 9.0 by adding sulfuric acid. Likewise, if the pH falls to 8.0, sodium hydroxide is added to raise the pH to 9.0. This addition is controlled by a pH probe located within the tank. The precipitated metal hydroxides exists as light density particles.

The treated water is then transferred to the flash mix tank of the clarifier, using a centrifugal pump. The pumping is controlled automatically by a level monitoring probe which cycles the pump on or off. To promote flocculation, a polyelectrolyte is added to the stream.

The effluent from the precipitation process has a chromium concentration of about 20-50 parts per billion (ppb). The effluent then passes through the final polishing process to further reduce the concentration of chromium and other heavy metals to 10-15 ppb.

3. The Fine Filtration Process involves a Polymer Enhanced Cross Flow Sand Filtration.

This sand filtration system, Dynasand™ is a patented process. It has some unique features in sand filtration. It is a continuous, backwash, upflow, deep and granular media filter. The filter media is continuously cleaned by recycling the sand internally through an airlift pipe and sand washer. The regenerated sand is redistributed on top of the sand bed allowing for a continuous uninterrupted flow of filtrate and reject water.

Feed is introduced into the bottom of the filter, then flows upward through a series of riser tubes and is evenly distributed into the sand bed through the open bottom of an inlet distribution hood. The influent flows upward through the downward moving sand bed with solids being removed. The clean filtrate exits from the sand bed, overflows a weir, and is discharged from the filter. Simultaneously, the sand bed, along with the accumulated solids, is drawn downward into the suction of an airlift pipe which is positioned in the center of the filter. A small volume of compressed air is introduced into the bottom of the airlift. The sand, dirt, and water are transported upward through the pipe at a rate of about 200 gpm/ft². The impurities are scoured loose from the sand during this turbulent upward flow. Upon reaching the top of the airlift, the dirty slurry spills over into the central reject compartment. The sand is returned to the sand bed through the gravity washer/separator, which allows the fast settling sand to penetrate, but not the dirty liquid. The washer/separator is placed concentrically around the upper part of the airlift and consists of several stages to prevent any short circuiting. By setting the filtrate weir above the reject weir a steady stream of clean filtrate flows upward, countercurrent to the sand, through this washer section and acts as a liquid barrier that carries away the dirt and reject water. Since the sand has a higher settling velocity than the dirt particles, it is not carried out of the filter. The sand is redistributed by means of a sand distribution cone. The sand bed is continuously cleaned while both a continuous filtrate and a continuous reject stream are produced.

For an effluent of 10 ppb to 20 ppb at a flow rate of 65 to 70 gpm, a Filter with a Polyblend emulsion polymer feed system is recommended for the polishing process. This proven process has been successfully used at an AT&T plant in Mesquite, Texas and in a Groundwater treatment plant of Stauffer Chemical Co. in Martins, California. The effluent chromium level of 10 ppb was attained by using just the sand filters at that treatment facility. A simplified flow chart of the proposed groundwater treatment process is shown on Figure 1.

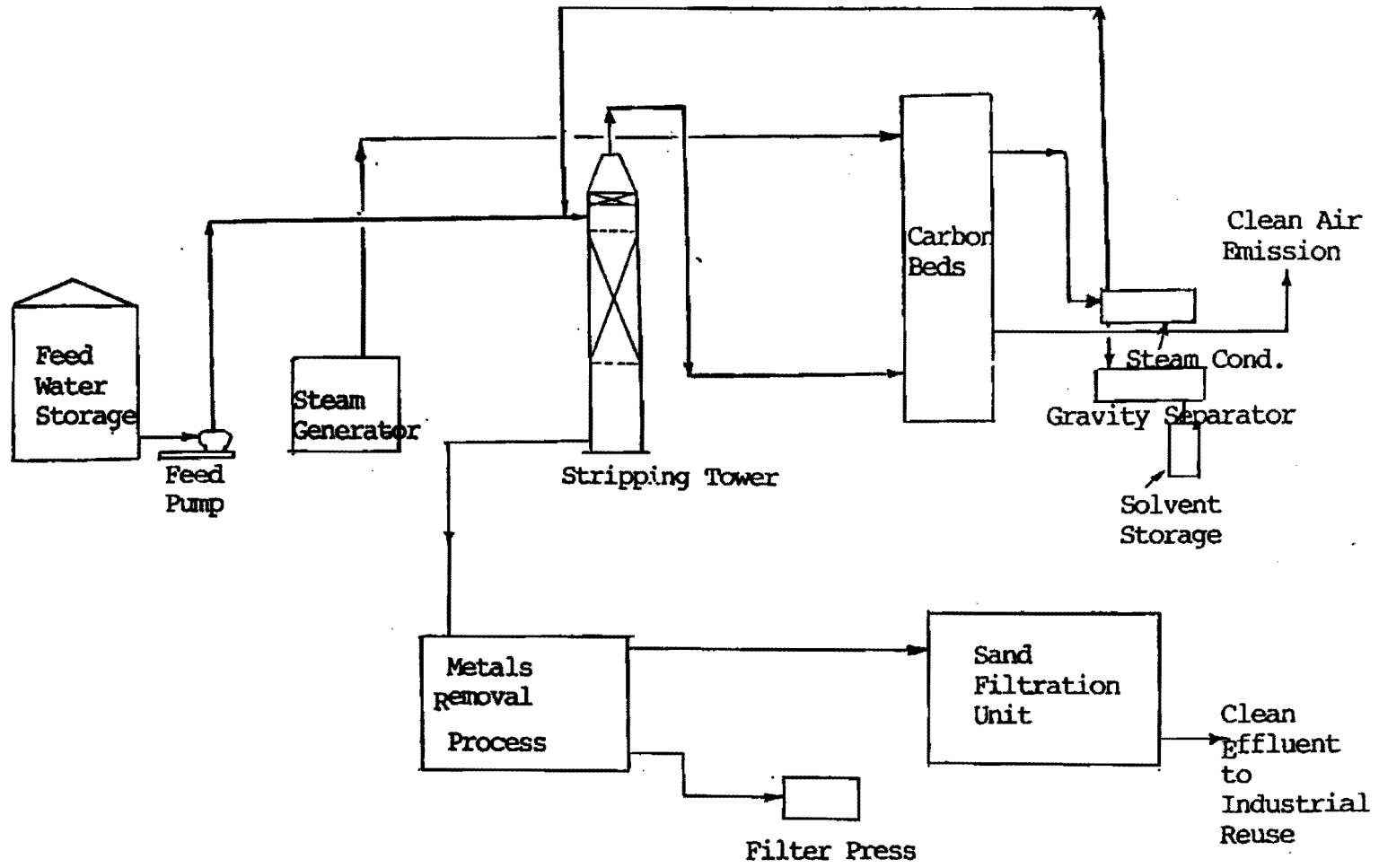


FIGURE 1 Flow chart of the proposed groundwater treatment plant

The annual operating cost of this system is very low compared to the reverse osmosis or ion exchange systems, since the Dynasand™ system gets continuously regenerated. The only operational cost involved in this process is the electric utility cost and the polymer cost. Labor cost is minimal in this operation.

The automated control mechanism routes the water through the optional polishing process if, and only if, the concentration of chromium in the effluent is over 50 ppb, or any other desired value. The polishing process involves fine filtration. The whole process is completely automated which cuts down a significant cost of this long-term cleanup operation.

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