



Cost-Effective Design of Pump and Treat Systems

An Online Continuing Education Course for Engineers

Course Number: EN-4013

Credit: 4 Hours / 4 PDH / 4 CPD

Cost-Effective Design of Pump and Treat Systems

Introduction

An appropriately designed (pump and treat) P&T system should achieve the ground water remedy goals in a cost-effective manner for the operating life of the system. Therefore, the design of the P&T system should account for the capital costs associated with system installation as well as the annual costs for operation and maintenance (O&M). In this instance and the remainder of the course, the term “O&M” refers to activities associated with operating and maintaining a P&T system, and does not refer to any specific period of time or regulatory status associated with the remedy. For example, the Superfund program generally refers to the first 10 years of a Fund-lead P&T system as Long-term Response Action (LTRA), and the subsequent period as “O&M”. However, in this course both of those time periods are considered to be types of O&M.

System design generally occurs after site characterization has been completed and usually consists of the following steps:

- considering remedy goals and associated performance monitoring requirements
- establishing design parameters (e.g., system flow rate and influent concentrations)

- selecting appropriate ground water collection/extraction methods
- selecting appropriate technologies for treatment of each class of constituents
- determining an appropriate option for discharge of treated water
- incorporating appropriate system controls and automation

Each of the above steps is discussed in this course and design scenarios are provided in appendices for two hypothetical sites as illustrative examples of cost-effective P&T system design.

Because capital costs for installation and annual costs for O&M are significantly higher than the costs of designing a system, it is often appropriate to request a design review from a third party. Once a system is installed and operating reliably, the system performance should be routinely evaluated to determine if the performance and site conditions are as expected. Changes to the system over time are generally expected, due to evolving site conditions and emergence of innovative technologies. The system should be evaluated/optimized on a regular basis by the site team each year and evaluated by an independent party perhaps every five years.

B. REMEDY GOALS AND PERFORMANCE MONITORING

.....

P&T systems are generally constructed and operated to accomplish one or both of the following:

- *Containment* - prevent migration of a constituent above a selected concentration to a receptor or potential receptor
- *Aquifer restoration* - remove contaminant mass, including non-aqueous phase liquid (NAPL) if present, from an aquifer to achieve selected cleanup criteria

In addition, a P&T system can be designed to meet requirements for the discharged water, and possibly discharged air, depending on the system.

The design of a cost-effective P&T system considers these goals and requirements for the following reasons:

- The performance of each system generally includes monitoring and evaluation with respect to its goals, and a system can be designed to make this performance monitoring easier and less costly.
- As a remedy progresses and site conditions improve, intermediate goals and milestones may be achieved. A cost-effective P&T system is one where operation of unnecessary system components is discontinued.

Consideration of these two points during design is facilitated by the concurrent development of an exit (or closure) strategy and/or a performance-based monitoring plan. An exit strategy generally is a compilation of measurable milestones that indicates progress toward remediation goals, specific conditions that clearly indicate achievement of these milestones, and a set of actions to occur (e.g., discontinuing a component of the remedy) when these milestones are achieved. If milestones are not achieved as expected, this might be an indication that the remedial approach and/or the goals need to be revisited. A performance-based monitoring plan typically focuses on collecting information that is necessary to document achievement or progress toward goals.

The following three subsections describe how a system design and elements of an exit strategy and/or a monitoring plan can work together to result in a cost-effective P&T system that addresses the remedy goals. Containment, aquifer restoration, and meeting discharge requirements are discussed separately.

Containment

Containment generally refers to hydraulic capture of contaminants in a three-dimensional zone of the subsurface and may pertain to a dissolved contaminant plume and/or a NAPL plume.

Some containment remedies may be designed to operate indefinitely, and may not be conducive to an exit strategy. However, some of the contaminants at a site may degrade over time or otherwise fall below standards and not need further treatment. In such cases, monitoring can be reduced, and components of a treatment system may be discontinued if discontinuing them does not compromise other treatment components that are still in use. Therefore, although an exit strategy may not be applicable for a containment remedy as a whole, exit strategies for some individual components (particularly those with significant annual costs) are generally applicable.

Consideration of a performance-based monitoring plan during design could lead to reduced annual costs and a more cost-effective remedy. A performance-based monitoring program for a containment remedy will likely need to demonstrate plume capture through interpretation of water level measurements and water quality samples. In some cases, extracting more water at a site may make evaluating capture easier and less costly without substantially adding to treatment costs. At those sites, it may be more cost-effective to increase the extraction rate. Therefore, the scope of monitoring needed to evaluate capture should be considered for a variety of pumping scenarios. For each scenario, the associated costs of this monitoring and evaluation should be compared to the costs of pumping and treating water.

“... it may be more cost-effective to increase the extraction rate.”

Aquifer Restoration

For aquifer restoration, an effective P&T system design might have two components to the extraction system: extraction wells dedicated to source control (e.g., hydraulic capture of a NAPL source zone) and extraction wells dedicated to restoration throughout the rest of the plume. If feasible, this is a particularly effective strategy because controlling the source area allows the remainder of the P&T system to remediate the downgradient portion of the plume. An exit strategy associated with such a P&T system may

include discontinuing the downgradient portion of the extraction system when certain conditions are met but continuing the operation of the source area extraction system to maintain source control. With the majority of the plume restored, source control and associated monitoring can continue at a presumably lower cost. This contrasts with an approach that aims to restore an entire plume with little consideration to controlling the source area. In such a case, the source area, which may consist of elevated concentrations and/or NAPL, can increase in size, and the entire system, rather than just the source area component, will continue to operate indefinitely.

“Control the source area to allow the remainder of the P&T system to remediate the rest of the plume in a timely manner.”

The specific conditions for shutting down any part of the system or the whole system should be considered during system design and clearly defined before operation begins. If other remedial technologies that can help meet these conditions are available at the time of design or become available during O&M, a cost-benefit analysis could be conducted to evaluate continued P&T versus implementation of these other technologies.

Given the above scenario, an appropriate performance-based monitoring program would likely include limited ground water quality sampling in the source area. Because the source area would be controlled and not necessarily restored, substantial water quality sampling in the source area may not provide valuable information regarding the performance of the remedy.

Meeting Discharge Requirements

Monitoring of the process water, and in some cases, treatment system off-gas, is often conducted to evaluate performance and document that discharge standards are met. Because process monitoring can be a significant portion of annual O&M costs, system design should consider how system performance can be cost-effectively demonstrated by process monitoring.

Monthly or quarterly sampling is typically specified by discharge permits to demonstrate that effluent is meeting standards, but additional process monitoring is generally determined by what is needed to operate the plant. Because frequent sampling and laboratory

analysis can become expensive, treatment plants, when possible, should be designed to operate based on readings from sensors and less frequent sampling with laboratory analysis. Turbidity, oxidation-reduction potential, and pH (in conjunction with influent and effluent samples) often provide sufficient information to operate a metals precipitation system. The pressure differential across filters is often used to indicate fouling. Air flow rates and pressure are generally sufficient to indicate an air stripper's performance. The use of sensors is generally more cost-effective than frequent sampling with laboratory analysis, and the sensor data are provided in real time.

System designers should incorporate various sampling ports throughout the treatment plant. Ports should be located for samples to be collected from the influent and effluent of each major treatment component so that the efficiency of each unit can be determined. This is especially helpful during system startup, when more frequent sampling is appropriate, and is also helpful for less frequent sampling throughout the duration of the remedy.

Because site conditions change, the influent concentrations of some constituents may fall below discharge standards over time, and/or some extraction wells may be taken offline. System designers should anticipate the conditions that would allow discontinuing the use of treatment components (or a treatment system) so that these components are not operated unnecessarily. The conditions that would merit restarting or reincorporating those components could also be determined, if changing site conditions lead to an unexpected increase in influent concentrations.

An onsite laboratory for frequent chemical analysis is costly to install and operate and is rarely appropriate once system operation is stable. Designers should thoroughly consider the use of sensors before including an onsite laboratory in the design. During system startup, more frequent sampling may be appropriate, but a short-term solution, such as sending samples offsite or using a temporary mobile laboratory, is generally more appropriate and cost-effective in the long term than installing and operating a permanent laboratory.

“An onsite laboratory is costly and is rarely appropriate...”

C. SYSTEM DESIGN PARAMETERS

.....

Proper evaluation and selection of treatment equipment during design requires reliable estimates of the extraction system flow rate and influent characteristics. System designers, however, should note that changes in the values of these parameters will likely occur during system operation, particularly in the first five years. These changes in parameter values might result from a change in site conditions related to the operating remedy, such as modifications to the extraction system or source control/removal. Ideally, a system is designed to minimize equipment that becomes unnecessary soon after operation begins. Regardless, system components that are initially needed may later become unnecessary. In such circumstances, the system should be sufficiently flexible to allow these components to be bypassed so that unnecessary materials and labor costs do not continue. In some cases, it may be appropriate to lease a particular treatment component if the designer believes that the component will only be needed for a short time. In other cases, it may be appropriate to install equipment that is appropriate for the reduced mass loading that is

expected over the long term. In such cases, the system would operate with increased cost and/or modified extraction in the short term to accommodate the initially elevated mass loading and meet discharge standards.

Selecting appropriate design parameters reduces the likelihood that installed treatment equipment will be unnecessary. Common design parameters are discussed below. Terms in **bold** are summarized in Exhibit 1.

System Flow Rate

Design Extraction Rate

Based on the remedy goals for plume capture and source control discussed above, a system design flow rate and extraction well locations can be developed. The **design flow rate** should be the actual flow expected based on well yield data, pumping tests, and, if appropriate, modeling using site-specific conditions. Modeling can also help determine the optimal locations for extraction wells. The design flow rate is used for estimating initial contaminant mass loading, and, depending on the system, items such as granular

Exhibit 1

Summary of Design Terms Used for Purpose of this Course

Design flow rate: expected flow rate of P&T system calculated from estimated extraction rates necessary to achieve remedy goals (e.g., plume capture).

This value should be used to select treatment components and to calculate the design mass removal rate.

Hydraulic capacity: maximum expected flow rate of P&T system, generally calculated by multiplying the design flow rate by a factor of safety greater than 1.0.

This value should be used to size pumps, piping, and tanks but should NOT be used to calculate the design mass removal rate.

Design influent concentration (for each constituent or class of constituents in system influent): expected blended influent concentration from all extraction wells based on concentrations obtained from sustained pumping conditions (e.g., after more than 24 hours of pumping) and not from routine monitoring data.

This value should be used to calculate the design mass removal rate.

Maximum influent concentration (for each constituent or class of constituents in system influent): maximum expected blended influent concentration from combined extraction, typically calculated by multiplying the design influent concentration by a factor of safety between 1.0 and 2.0.

The treatment system should be able to handle this concentration. Therefore, this value should be used to help select a treatment process but should NOT be used to calculate the design mass removal rate.

Design mass loading rate (for each constituent or class of constituents in system influent): estimated mass loading rate (pounds per day) to the treatment plant of contaminants in extracted ground water, calculated by multiplying the design flow rate by the design influent concentration (Exhibit 2).

This value should be used for estimating materials/utilities usage when analyzing costs of various treatment options.

