PERCHLORATE REMEDIATION AT A DOD FACILITY

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1.0 INTRODUCTION

EcoMat, Inc. is a California based firm that makes and sells biological remediation systems of an advanced type. Industries to which it provides equipment include commercial aquariums, groundwater utilities, and wastewater and groundwater remediation projects. Prior to this project, EcoMat had sold a number of systems for denitrification. These were sold primarily to commercial salt-water aquariums where low nitrate levels are typically accomplished by the costly replacement of salt-water. EcoMat's system for denitrification is the only system that is sufficiently compact, efficient and inexpensive to enable continuous denitrification for these aquariums.

The bacteria that provide denitrification are readily found in nature. They are facultative anaerobes that can utilize oxygen for metabolic energy from sources other than dissolved oxygen. These bacteria will take oxygen from the easiest supply and then look for more. In water treatment they remove oxygen based upon the following preferred sequence:

Dissolved oxygen
Nitrate (product is gaseous nitrogen)
Perchlorate (product is chloride)
Sulfate (product is hydrogen sulfide)

Given this, it was natural for EcoMat to recognize the potential for perchlorate removal from water. In the following pages, we describe the system that EcoMat built, which has been successfully operating for about six months.

PROJECT SITE DESCRIPTION

The site is a Department of Defense facility located in Southern California. Under the Installation Restoration Program (IRP), Earth Tech, Inc. has a contract to provide environmental services, including evaluating the perchlorate levels in shallow groundwater under the facility. The test water that they pump from this activity is temporarily stored in Baker tanks on the site (see Figure 1). The major contaminant in this water is perchlorate, at concentrations varying from 300 ppb to 1000 ppb. Beginning in October 1999 Earth Tech evaluated EcoMat's ability to remediate perchlorate and in December 1999 they contracted with EcoMat to provide a small system for removing perchlorate from the test water.

PROJECT ACTIVITY

EcoMat designed a system to achieve the removal of perchlorate from the Baker tanks within a period of several months. At the beginning there was not sufficient information to determine the hydraulic residence time for removal of perchlorate down to non-detectable levels, so the system was designed for a residence time of approximately one-half hour with an active volume of 200 liters. Given average tank volumes of 20,000 gallons this would enable complete reduction in a period of seven days after the bacteria are firmly established.

EcoMat had designed and built an identical system and installed it in the John G. Shedd Aquarium in Chicago. The design is described in the following section. It was built on a single skid in our Hayward facility. Denitrification bacteria which had been exposed to perchlorate were placed in the reactors and then the entire skid was loaded onto a panel truck and driven down to Southern California. At the site, it was lifted off the truck and placed in a temporary shelter near the Baker tanks (see Figure 2), and started up. Within a few days it was functioning and reducing perchlorate. After the first few days the systems operation was transferred to Earth Tech, with telephone contact and advice from EcoMat.

After several months during which various operating problems were dealt with, the tanks were completely clean of perchlorate, below the detectable concentration. The system was then moved to a similar site on the base, where it remains in operation.

SYSTEM DESIGN

The system is best described using a flow diagram (see Figure 3). Water is drawn from the Baker tank into the top of the deaeration reactor. This reflects a basic understanding by EcoMat that a two-stage process works best for biological oxygen removal. In the deaeration tank is a large number of ordinary bio-balls that provide surface for bacterial growth. The reactor is designed to reduce the dissolved oxygen concentration from saturation down to a concentration of 0.5-1.0 ppm. This is the optimum concentration for either denitrification or perchlorate remediation. If the dissolved oxygen concentration rises above one ppm the remediation is ineffective, and if it drops to near-anaerobic concentrations, the threat of sulfate attack arises. Hydrogen sulfide can be injurious to the bacteria, stopping the remediation activity. Although the bacteria can be revived very easily by restarting the process, time is wasted of oxygen levels aren't monitored

From the bottom of the deaeration reactor, water is then drawn into the bottom of the Hall reactor. This patented reactor is the key element of EcoMat’s process. It is designed to hold a mass of floating media and maintain continuous circulation of the media along with the water in the reactor. This mixing is attained without any internal moving parts, but rather, by external pump re-circulation, as shown in Figure 4. Continuous circulation is extremely important as it provides for uniform, low concentrations of the contaminant under ALL influent contaminant concentrations. This factor is key to EcoMat’s success in both denitrification as well as perchlorate remediation as it puts no upper limit on the allowable inlet concentrations.

At this point we must say more about the EcoLink media (see Figure 5). This is a polyurethane-based sponge that is cut into one-centimeter cubes. The media last for a very long time-- up to several years. They are kept reasonably clean and capable of supporting bacteria colonies by virtue of their gentle collisions with each other and with the walls of the reactor. When functioning to produce a gas, as in denitrification, the size of the interstitial spaces within the sponge is designed to permit passage of gas out, as well as passage of water into, these spaces. At the same time, the surface area involved is sufficiently great to provide for large bacteria concentrations and high interaction efficiency.

The overflow from the Hall reactor is recycled back into the deaeration reactor during the startup period to form colonies of bacteria. In normal operation the effluent is discharged from the system. In cases where drinking water purity is desired, a post-treatment system can be added to the process to control the small amount of biosolids that leaves the system. **This is the only residual stream that results from the process.** In case of upset conditions, water can be returned to the Baker tanks.

Both reactors require feed of a carbon source (electron donor) to feed the bacteria. EcoMat has studied a variety of available sources and we find that the best one is methanol. Methanol residual of less than 2 ppm is considered non-hazardous and EcoMat's systems normally run at undetectable concentrations (below 0.5 ppm). Methanol is not only the lowest cost commercially available carbon source but it also maintains the lowest level of biosolids. Alternative carbon sources, such as ethanol, tend to “gum up” the works. The major requirement for methanol is for removal of dissolved oxygen in the deaeration reactor, as oxygen levels are so much greater than perchlorate levels in the first stage of the process. For fire safety reasons, the methanol is dissolved in water (generally 50%). The rate of feed of methanol is so small that even if it were to exit unused, the concentration would not reach hazardous levels.

It should be noted that while the bacteria involved in denitrification are hardy, best operations are realized when temperatures are controlled between limits of 8 ^{o}C and 35 ^{o}C. During normal flow, the influent water maintains adequate temperature control. During startup, when recirculation is 100% care should be taken to turn on the circulation pump in the Hall reactor for a relatively small time period each day.

The way the system works is that the bacteria can “eat” a constant rate of contaminant. Thus the flow rate of water through the system isn’t a significant parameter in the design. The most significant system size factor, which determines the basic system size, is the total amount of material that is to be removed per day. This number is the product of the flow times the concentration. For example, for a system that will remediate 1000 gpm of water having a concentration of 10 ppm, the amount of contaminant to be removed is 120 pounds per day. For this example, EcoMat estimates that it can build, own and operate this system, at the currently demonstrated sizing criteria, at total cost to the customer of $.50 per thousand gallons.

OPERATIONS

The system was built on a skid that is four feet by four feet in size (see Figure 6). Startup operations involve continuously recycling the water through the reactors while feeding methanol and assuring that there is adequate perchlorate in the water. This recirculation need not be constant, and in warm weather, when the bacteria might overheat, it is best to circulate for no more than a few hours per day. Periodic measurements are made of the dissolved oxygen levels leaving the de-aeration reactor. When the dissolved oxygen level is below 1.0 ppm the system can be opened in stages, until it is wide open. After start-up, operations remain continuous, and it is only necessary to check the system once daily to be sure that no spurious upset has taken place. The methanol source only needs to be replenished every few weeks.

At this DOD site there were a number of upsets, particularly during the early operating days. First, someone driving by pulled the main power plug! A few days passed before the operators realized that there was something wrong. During that time, the bacteria used up all of the oxygen and perchlorate and started producing hydrogen sulfide. The system turned black and smelled characteristically of that material. The system was re-started and within a few days it returned to normal operation.

Importantly, Earth Tech was not concerned with optimizing the time for performing the remediation of the water from the Baker tanks. With a retention time of one half-hour, the remediation proceeded sufficiently rapidly. However, based upon EcoMat's denitrification experience, much shorter retention times may be feasible for perchlorate remediation, further reducing the cost of new systems. EcoMat is pursuing this possibility.

RESULTS

Measurements were made by Earth Tech on a regular basis. As a result of the “closed loop” feature, it was possible to control the outlet so that only when the effluent perchlorate concentrations were below the allowable level (ND) would water be discharged to a cleaned water baker tank. Initial results during the startup period were as follows (in micrograms per liter):

DATE	INLET	OUTLET
2/17	350	210
2/18	390	160
2/21	390	410 *
3/06	350	ND
3/07	370	ND
3/08	340	9
3/09	320	ND
3/10	320	19
3/15	260	24 **
3/23	300	ND

- *   Power loss
- ** New Tank

When the Baker tanks were emptied, the system was moved to another location at the DOD site, where it is presently in operation.

FUTURE PLANS

Reactors 15 times the size of the subject reactor are currently in operation, and EcoMat has designed reactors as large as 100 cubic meters. The reactors may be ganged together to provide adequate volume for any flow rate. EcoMat plans to offer its perchlorate remediation process to customers as a build-own-operate package, with pricing in the range of $.50/1,000 gallons.

CONCLUSIONS

It appears to EcoMat that this system is one of the most inexpensive ways to remediate perchlorate from water. For very large systems it would be cost effective to implement on-line measurement capabilities with SCADA systems to transmit data to a remote operations enter, facilitating satisfactory operations.

LIST OF FIGURES

Figure 1: Baker Tanks on Site

Figure 2: Drop Box Holding System

Figure 3: Flow Diagram

Figure 4: EcoMat Perchlorate Removal System

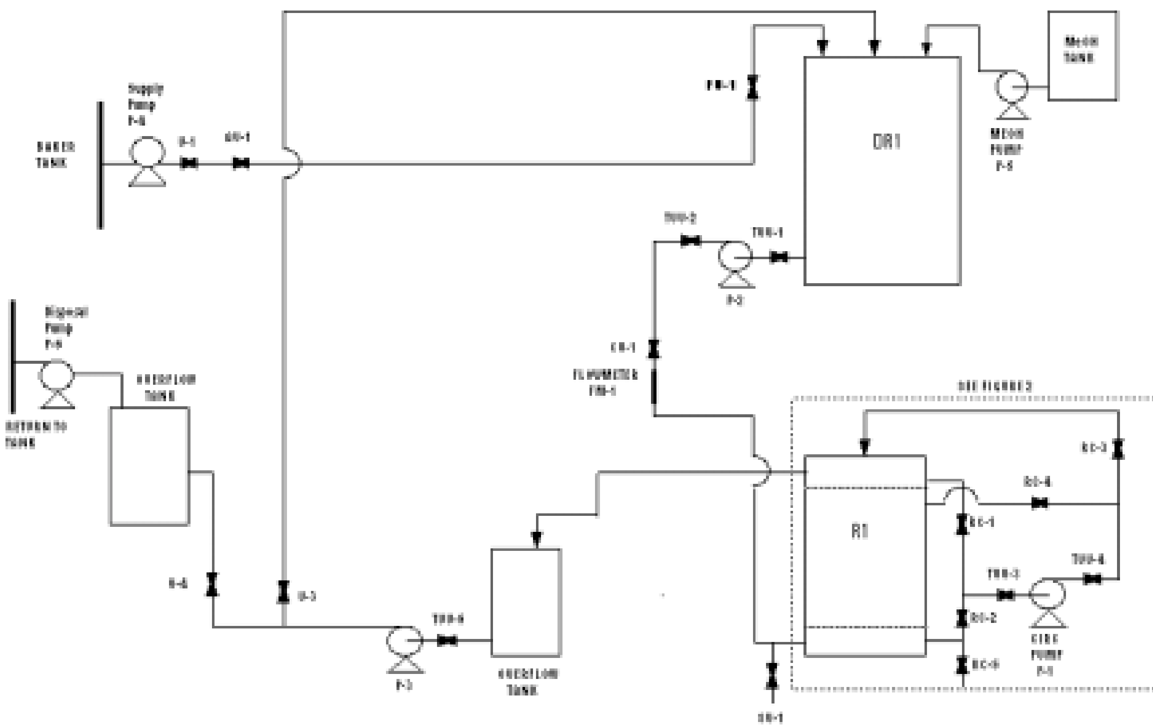

Figure 4: Hall Reactor

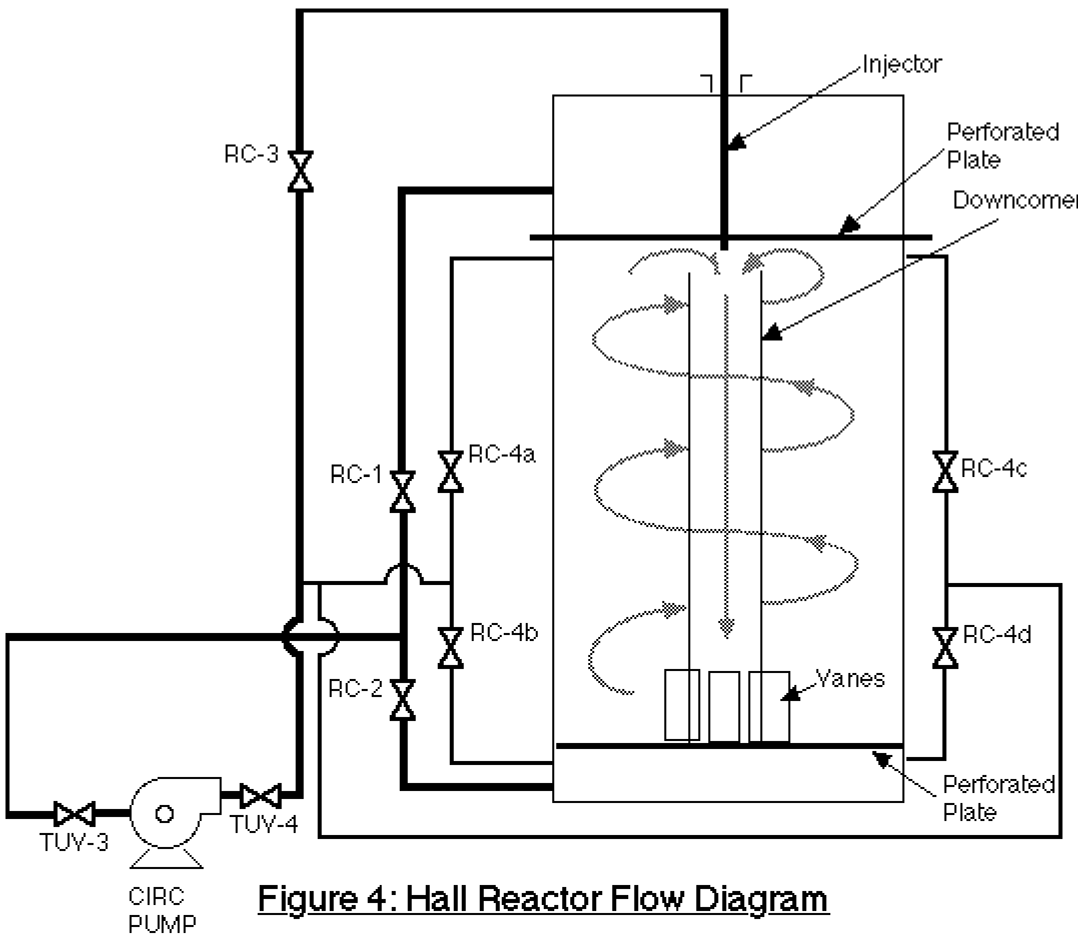

Figure 4: Hall Reactor Flow Diagram

Figure 5: EcoLink Material

Figure 6: Skid Mounting