Analysis of Total Suspended Solids and Dissolved Oxygen Concentrations of the Algal-Bacterial Selenium Removal (ABSR) system

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Abstract The Algal-Bacterial Selenium Removal (ABSR) system has been very effective at removing Selenium from agricultural drainage water that enters the water systems of the San Joaquin Valley, CA. Although selenium levels are significantly lower in the effluent of the ABSR system, Dissolved Oxygen (DO) levels in effluent water have been found to be significantly lower than normal. If DO levels dip under 5mg/L saturation, aquatic life is put under stress. At levels 1-2mg/L saturation, fish would likely start to die off. The purpose of this study was to examine the affect the ABSR system has on the DO levels in its effluent. Water samples were collected from two ABSR pond systems in Panoche, CA, where there are two systems with different pathways. The Low-cost system has influent going into a high rate pond (HS) and then goes into a reduction pond (RS), so anoxic bacteria uptake the selenium. The High-efficiency system has influent water going into a reduction pond (RN), and then put through as sand filter (NSSF). The effluent of both systems were tested for Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) levels, which are related to DO saturation levels in water. In the Low-cost system, levels from the effluent showed increases in both BOD and TSS levels. In the High-efficiency system, there are increases in BOD and TSS levels as well. Although increases in both BOD and TSS levels were found, the High-efficiency system was able to stay within EPA limits. The Low-cost system failed to meet EPA standards for TSS levels. In conclusion, the effluent coming out of the High-efficiency systems will not substantially lower DO saturation levels to dangerous limits.

Introduction

Much of the drainage water in the San Joaquin Valley is contaminated by runoff from land that is used for agricultural purposes (Green 2001). Agricultural waste and chemicals are often found in high concentrations in the discharge from agricultural drainage systems (Oswald 1988). The discharge enters the San Joaquin River by way of sloughs that lead directly to the river (Green 2001). The runoff from the agricultural land negatively affects the water quality of the river, which then affects the wildlife surrounding the river (Green 2001 and Zarate 1999).

Dissolved oxygen (DO) plays a vital role in determining water quality. Like organisms on land, fish and other aquatic organisms require oxygen in order to survive. Oxygen enters the aquatic system through several pathways. One way is from the photosynthesis process of aquatic plants (Water Shedds: Dissolved Oxygen, elect. Comm. 2002). During photosynthesis plants release oxygen, aquatic plants release this oxygen into the water. Another way for oxygen to enter is through the water-air interface where oxygen from the atmosphere is dissolved into the water. Gas solubility increases as water temperature and salinity decrease (Water Shedds: Dissolved Oxygen, elect. Comm. 2002). There are also processes that will use up the dissolved oxygen in the water. These include the respiration of organisms, and the decomposition of organic material by bacteria. If DO levels drop under 5mg/L saturation, aquatic life is put under stress. At levels or 1-2mg/L fish would likely suffocate to death (Water Shedds: Dissolved Oxygen, elect. Comm. 2002).

The site in the Panoche Drainage District, in the San Joaquin Valley uses the ABSR system. The purpose of the ABSR is to remove Selenium (Se), on top of Nitrate. It consists of three ponds. The first is a reduction pond (RP) where Anoxic Bacteria are used to uptake the selenium, which is often in the form of selenate (SeO_6^{2-}) (Quinn). In the RP organic carbon in the form of Molasses is added to promote bacteria activity. The second pond is an HRP, similar to the one in the AIWPS. Here Algae grows and assimilating carbon dioxide, ammonium and phosphates. There are two different pond systems within the Panochec system. One is the High-efficiency system, and the other is Low-cost system. The differences between the two include a different arrangement of the different ponds, and molasses is added to the High-efficiency pond as a nutrient for bacteria.

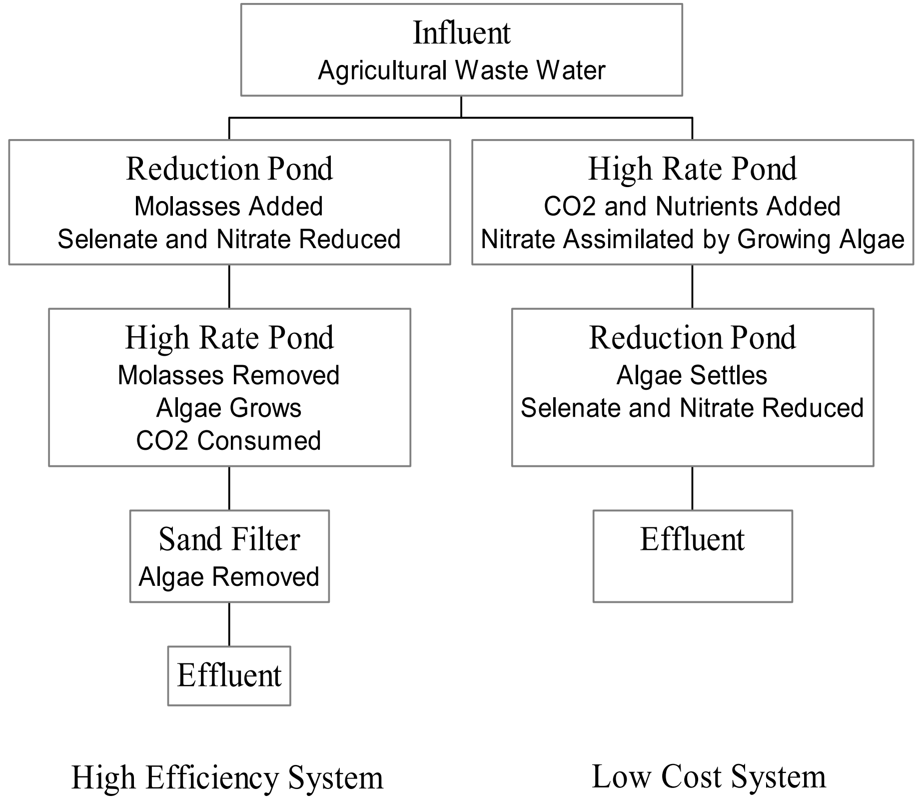

Table 1. The Panoche ABSR systems.

There have been prior research projects that have looked at the affects and usefulness of these systems. In 2001, Diana Stuart researched the ABSR system in Panoche for its effectiveness in removing Selenium (Stuart, D. 2001). Stuart sought to show whether or not the ABSR system would effectively remove the bioavailability of Selenium in the effluent water. Stuart concluded that although the system was effective in removing selenate, it did not remove Organic Selenium effecitively (Stuart 2001). Another project by Atsushi Hatano in 2001 focused on Nitrogen removal in the AIWPS in Delhi and Panoche. Hatano's goal was to find out transformation pathways and the removal rates of nitrate, nitrite and ammonium nitrogen in the AIWPS (Hatano 2001). Hatano also wanted to determine if pH, DO, and temperature had on affect on the transformation pathways and the removal rates. Hatano concluded that the AIWPS in Delhi was more effective at removing Nitrogen than a similar system in Panoche (Hatano 2001). Also, it was found that only temperature had a substantial affect on the transformation pathways and removal rates.

Previous research was also done on the cost effectiveness and efficiency of the AIWPS technology. In a study by Zarate and his group, the application of the AIWPS technology to chemically contaminated agricultural drainage water was studied using a demonstration plant. The study concluded that the technology was efficient, removing enough selenium and nitrates to meet monthly and annual load targets for the San Joaquin River (Zarate 1999). Also it proved to have low capital costs and low operational costs, with robust performance and a user friendly operational system (Zarate 1999).

This project will differ from previous projects because it will focus on the rate of removal of Biochemical Oxygen Demand (BOD) and Suspended Solids (SS) in the ABSR system in Panoche. BOD and SS are important to look at because excesses of either in the effluent water could have substantial affects on the water quality, which negatively affects the surrounding aquatic wildlife (Lundquist 2002. pers. comm.). An excess of SS could mean a production of higher levels of BOD, which would deplete the DO in the effluent water (Lundquist 2002. pers. comm.). A significantly low level of DO will put stress on the aquatic wildlife that live in the San Joaquin River, where the effluent would flow into (Lundquist 2002. pers. comm.). The objective of this study is to determine if the AIWPS in Delhi and the ABSR in Panoche reduce BOD and SS levels in the effluent down to National limits of 45 mg/L BOD and 45 mg/L Total Suspended Solids (TSS) in order for the water to be recycled for agircurlural use. Secondarily, the study will also compare the pond systems of Panoche North, Panoche South, and Delhi to see which of the systems is the most effective for reducing BOD and TSS from influent water, and whether or not temperature has an affect on the reduction rate of BOD and TSS.

Methods

Data collection The site for sample collection was in Panoche, from an ABSR system. The site was visited once a week and samples were collected from various parts of the system. There are actually two ABSR systems right next to each other and the samples were labeled High-efficiency and Low-cost to distinguish them apart (Green, F.B., Lundquist, T.J., 2001). Every part of the High-efficiency system was labeled with an N in front (i.e. NHRP), and an S was used for the Low-cost system (i.e. SHRP) (N and S were used because of their location, N for north, and S for south). Samples were collected from the reduction ponds and high rate ponds of each system. Samples were also collected from the North Sand Slope Filters (NSSF) for the High-efficiency System. Samples were collected in plastic bottles and placed in a cooler for transportation and water temperature will be recorded.

Once all the samples were collected, they were brought back the Lawrence Berkeley National Laboratory, located in Berkeley, California, where BOD and SS levels were determined. The methods used for BOD analysis were similar to those outlined in *Standard Methods For the Examination of Water and Wastewater.* Using a Dissolved Oxygen Electronic Reader, equipped with two metal electrodes in contact with a supporting electrolyte that is separated from the test solution by a selective membrane, the DO of the sample was determined. The DO reader was placed in samples that were prepared. The DO samples were different dilutions of samples from the various sites at Delhi and Panoche. Dilutions were determined in the lab according to how much BOD is estimated in the sample, and the dilution is with water that had been given nutrients so that Bacteria can feed on it. Each dilution was in a 305 mL glass bottle. There was also a blank sample that was all water. An initial reading for DO was taken from each sample. The bottles were then be stored in the dark for 5 days, at 20 degrees celcius in order for the bacteria to be active and undergo respiration. After five days, another reading was taken for DO. Taking the difference of the final and initial DO readings and then dividing it by how much sample was diluted the BOD levels were determined.

For TSS, methods outlined in the *Standard Methods* book were used. To start, each sample was filtered through a Whatman GF/C glass fiber filter, using an air pump. Each filter was than placed on a tin tray (the tin trays and glass fiber filter should be previously dried in a 105 degree F oven and weighed), and placed in a 105 degree F oven for no less than 2 hours (in most cases the samples will be left over night). The trays and used filters will than be weighed again. The difference between final weight and initial weight will give us the amount of SS in the sample.

Statistical techniques For most of the results, bar graphs were used to show how the levels of BOD and TSS are affected in each sample site. The Wilcoxon signed rank test was used to examine the differences in effluent levels between the Hig-efficiency system and the Low-cost System. A comparison of the results with the EPA limits of 45 mg/L BOD and 45 mg/L TSS was used to show the effectiveness of the systems at removing BOD and TSS. A regression test was used to analyze any relationship between BOD and TSS levels.

Results

During the period of the study, the mean influent level of Biochemical Oxygen Demand (BOD) for both the High-efficiency system and the Low-cost system was .83 mg/L with a standard deviation of .32. The mean BOD level for the High-Efficiency system's effluent was 7.3 mg/L with a standard deviation of 1.96, and the mean BOD level for the Low-cost system's effluent was 4.33 mg/L with a standard deviation of .95. Both the High-efficiency system and the Low-cost system showed an increase of BOD saturation in the effluent from the levels present in the influent, a 6.47 mg/L increase in the High-efficiency system and a 3.5 mg/L increase in the Low-cost system. Both systems had levels of BOD in their effluent that were well below the Environmental Protection Agency's (EPA) safe level of 45 mg/L.

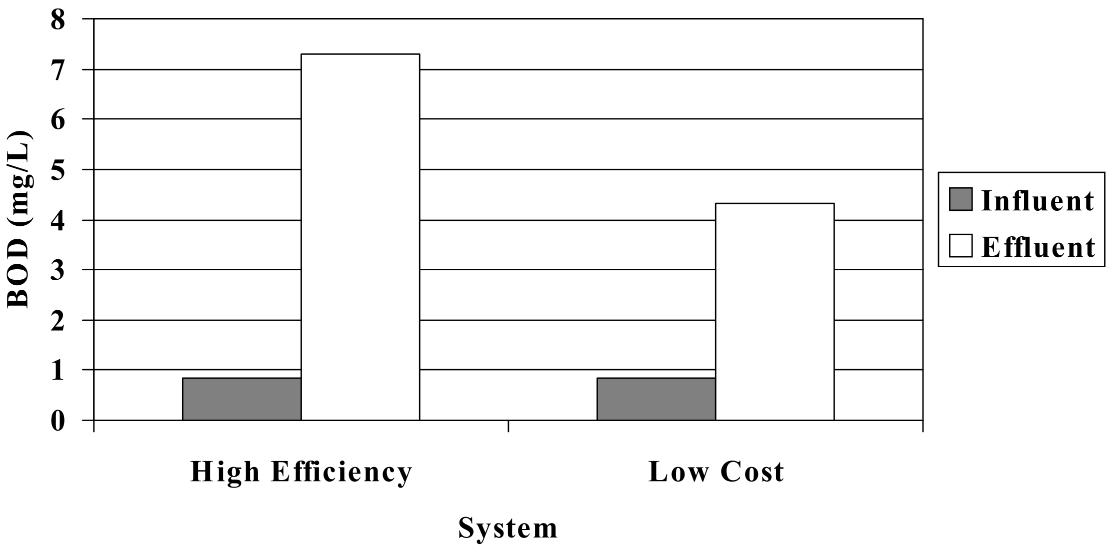

Fig. 1 The mean BOD levels for the High-efficiency and Low-cost systems at Panoche. Both systems show an increase BOD levels in the effluent. Both systems have effluents under EPA safe levels of 45 mg/L BOD.

The Wilcoxon signed rank analysis for the matched pairs of the BOD effluents gave a p-value of .1088. The high p-value showed that there was not a significant statistical difference between the effluent BOD levels of the High-efficiency system samples and those of the Low-cost system samples that were taken on the same day.

The mean influent level of Total Suspended Solids (TSS) for both the High-efficiency and Low-cost systems in the Panoche Drainage District was 18.8 mg/L with a standard deviation of 5.5. The mean TSS level for the High-efficiency systems' effluent was 37 mg/L with a standard deviation of 6, and the mean TSS level for the Low-cost system's effluent was 48.1 mg/L with a standard deviation of 6.6. Again, both systems showed an increase of TSS in both systems' effluent from the levels present in the influent. The mean increase in the High-efficiency system was 18.2 mg/L and the mean increase in the Low-efficiency system was 29.3 mg/L. The mean level present in the High-efficiency system of 37 mg/L was below the EPA's safe level of 45 mg/L. The mean level present in the Low-cost system of 48.1 mg/L was above the EPA's safe level. With a sample size, N=7, the effluent exceeded the EPA's safe value three times, and the four other samples were just below the limit of 45 mg/L.

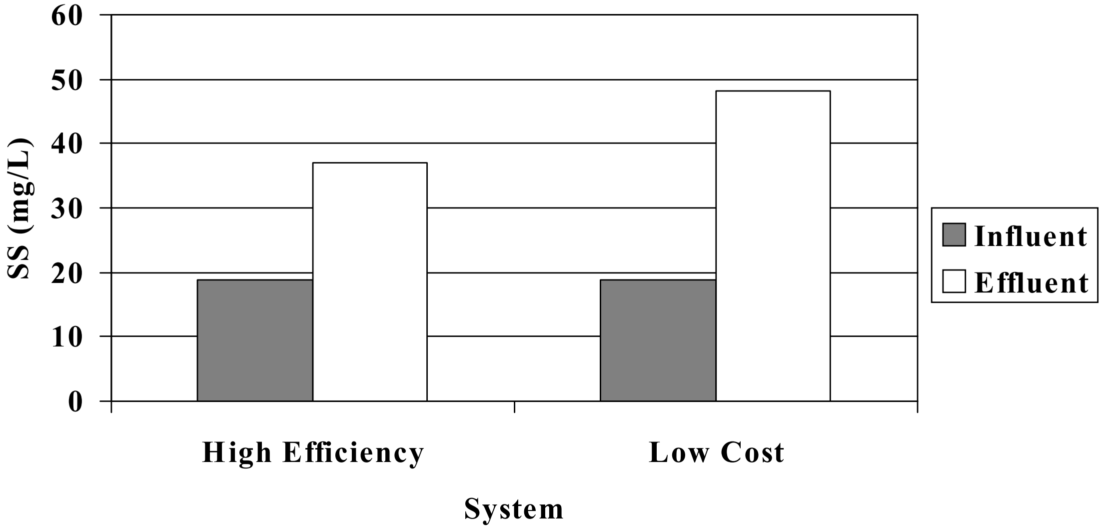

Fig. 2 The mean TSS levels for the High-efficiency and Low-cost systems at Panoche. Both systems showed an increase of TSS levels in their effluents. The Low-cost system exceeded the EPA safe level of 45 mg/L TSS.

The Wilcoxon signed rank analysis for the matched pairs of the TSS effluents of Panoche gave a p-value of .018. The p-value is less than .05, which indicates that there was a significant statistical differenece between the effluent TSS levels of the High-efficiency system samples and those of the Low-cost system samples that were taken the same day.

A regression plot was used in order to determine if there was a correlation between TSS and BOD in the effluents both the High-efficiency system and the Low-cost system. The regression line in the plot showed that there was a positive correlation between the TSS and the BOD levels with 11 points plotted on the graph. The R^2 value was .332, indicating that only 33% of the samples showed a strong correlation.

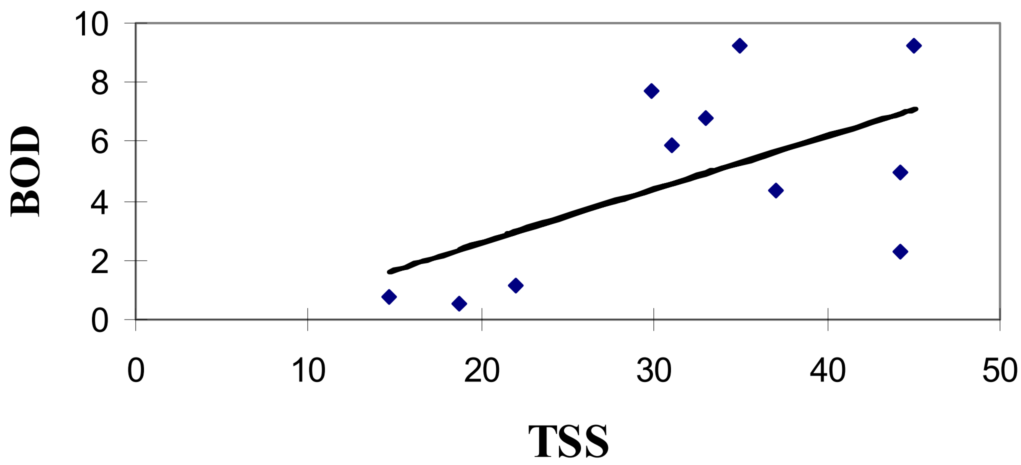

Fig. 3 Regression plot for TSS and BOD. The regression line shows a positive correlation between TSS and BOD levels. R^2 = .332, indicating a weak relationship with only a 33% correlation between TSS and BOD.

Discussion

The results for the mean BOD levels of the Panoche systems showed that there was an increase in BOD levels for the effluents of both the High-efficiency system as well as the Low-cost system. This shows that as the agricultural drainage water enters the Panoche systems the BOD levels are fairly low, if there are any all, but as the water moves through the system, through the various ponds, the BOD levels increase. This is due to the mechanisms within each pond. As bacteria breaks down the Selenium and Nitrates, they also increase. Also as the Algae levels increase and then decompose, they also add BOD levels to the water. The system could be responsible for adding BOD to the water where there might have been none before. Although both systems showed an increase in BOD levels in the effluent, neither system exceeded the EPA safe levels of 45 mg/L BOD for effluent water. This means that when only considering BOD levels, the Algal-Bacterial Selenium Removal (ABSR) system does not have great increases in BOD and would therefore be able to maintain dissolved oxygen (DO) at a safe level.

Using the Wilcoxon signed rank test to compare the differences in BOD levels between the effluents of the High-efficiency system and the Low-cost system, it gave p-value of .1088, indicating that there was no statistically significant difference between the two. This result might not be accurate due to the small number of samples that were used for analysis. A sample size of 3 matched pairs was used to run the Wilcoxon signed rank analysis. Such a small number doesn't give much power to the results.

The results for the mean TSS levels for the Panoche systems showed that there was an increase in the TSS levels for the effluents of both the High-efficiency and Low-cost systems. This indicates that the system is creating more TSS as the water moves through it. There could be several reasons for this increase. One possibility was that as the algae decomposes in the system the particles released become suspended in the water and move along with the flow of the system. Other possibilities were that there was an increase in bacteria in the system or that the molasses was not completely used up by the bacteria. All of these possibilities could have been responsible for the increase in suspended solid levels. There could have also been other possibilities that were not considered, but could have also led to the increase of TSS levels. The results for the Low-cost system also showed that the mean levels of TSS for the its effluent at 48.1 mg/L was above the EPA standard of 45 mg/L TSS. The sample size was six, and two of the samples were above the EPA standard at 55.7 mg/L and 56 mg/L. Two more of the samples barely cleared the standard at 44.3 mg/L. The results show that the Low-cost system does not meet the EPA safe levels and would not be allowed to be discharged into the San Joaquin river, but again due to the small sample size, the power of the statistics was not strong.

Using the Wilcoxon signed rank test to compare the differences in TSS levels between the effluents of the High-efficiency system and the Low-cost system, it gave p-value of .018. This indicated that there was a statistically significant difference between the two systems. This result was important because the mean level for the High-efficiency system was able to meet EPA standards, while the mean level for the Low-cost system did not. This could lead to the conclusion that the High-efficiency system was better than the Low-cost system, and it the effluent from it can be safely discharged.

A regression test was used in order to determine whether BOD levels were dependent on TSS levels. The plot in Fig. 3 showed a positive regression line, indicating that there was a positive relationship between BOD and TSS. This would have meant that as TSS increased, so did the BOD levels, but the R^2 for the regression was .332. This meant that the strength of the relationship between TSS and BOD was weak, with only a 33% correlation. Again the sample size was small at only 11 matched pairs to make plot points.

In conclusion, there was only one analysis that showed any statistical significance, that of the Wilcoxon analysis to analyze the difference of TSS levels between the effluent of the High-efficiency and Low-cost systems. It can be concluded that because only the High-efficiency system was able to meet that standards for both TSS and BOD, it was superior to Low-cost system. Although there was a higher mean for BOD levels in the effluent of the High-efficiency system, the difference between the High-efficiency and Low-cost system was insignificant. As for the other tests, further study needs to be done in order to develop solid conclusions. This study suffered due to the time constraints. The study was done over only two months and should be done over at least a year. A longer study period would allow for more samples, allowing for stronger results. Also with a longer study period, other factors, such as temperature, sunlight exposure, and other factors associated with change in seasons could be studied. Those further studies could lead to results that look much different, or they might strengthen the power of this study.

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References

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Greenberg, A.E., Trussell, R.R., and Clesceri, L.S. Standard Methods For the Examination of Waste and Wastewater. 16th ed.

Green, F.B., Bernstone, L.S., Lundquist, T.J., and Oswald, W.J. Advanced Integrated Wastewater Pond Systems for Nitrogen Removal. Wat. Sci. Tech. Vol. 33, No. 7, pp. 207-217, 1996.

Green, F.B., Lundquist, T.J., Zarate, M., Zubieta, I., Anderson, G., Ku, A., and Downing, J. Drainage Treatment Bulletin. University of Califonia, Berkeley , Lawrence Berkeley National Laboratory. October 2001.

Hatano, Atsushi. Analysis of Nitrogen Removal Efficiency of Advanced Integrated Wastewater Pond Systems (AIWPS). Investigating the Environment: Research for Environmental Management. 2001.

Lundquist, Tryg. Lawrence Berkeley National Laboratory, Berkeley, CA 2002. personal communication.

Oswald, William J. The Role of Microalgae in Liquid Waste Treatment and Reclamation. Algae and Human Affairs. Cambridge University Press 1988.

Quinn, N.W.T., Lundquist, T.J., Green, F.B., Zarate, M.A., Oswald, W.J., and Leighton, T. Algal-Bacterial Treament Facility Removes Selenium from Drainage Water. California Agriculture, Volume 54, Number 6.

Stuart, Diana. Bioaccumulation Study of the Algal-Bacterial Selenium Removal System. Investigating the Environment: Research for Environmental Management. 2001.

Water Shedds: Dissolved Oxygen. http://h2osparc.wq.ncsu.edu/info/do.html accessed February 19, 2002.

Zarate, M.A., Lundquist, T.J., Brent, A.R., Ku, A.Y., Green, F.B., and Oswald, W.J. The Application of the AIWPS Technology to Chemically Contaminated Agricultural Drainage Water. University of California, Berkeley, Environmental and Health Sciences Laboratory. 1999.