This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

Bench-scale Demonstration of a Peat Bed for Removal of Metals at the H-12 Outfall (U)

by
ERIC A. NELSON AND WINONA L. SPECHT
SAVANNAH RIVER NATIONAL LABORATORY

Approved by: ________________________________
John B. Gladden, Section Manager
Environmental Analysis Section
Savannah River National Laboratory

Publication Date: December 2005

WASHINGTON SAVANNAH RIVER COMPANY
SAVANNAH RIVER SITE
AIKEN, SC 29808

Executive Summary

The H-12 outfall cannot consistently meet the very low copper limit specified in SRS's current NPDES permit. One treatment option that is under consideration consists of diverting a portion (25%) of the H-12 flow through a peat bed and then blending the outflow from the peat bed with the remainder of the H-12 discharge. Peat will not only remove the copper from the portion of the effluent that is being treated, but will also reduce the bioavailability and toxicity of any copper present in the blended effluent, due to the leaching of dissolved organic carbon (DOC) from the peat. DOC binds metals tightly so that they cannot be transported across the gill surfaces of aquatic organisms, thereby decreasing their bioavailability and toxicity.

In order to assess the effectiveness of a peat bed for removing metals from H-12 effluent, a bench-scale laboratory study was conducted to determine removal efficiency. Two sets of experiments were conducted. The first consisted of flowing H-12 effluent through a peat bed and measuring copper concentrations in the inflow and outflow. In the second experiment, copper was spiked into H-12 effluent to a concentration that exceeds worst-case concentrations at H-12 and the spiked effluent was treated by the peat bed. The results of both experiments indicate that copper in the peat bed effluent was below the detection limit of 5 µg/L. DOC was increased by 137% after passage through the peat. Based on historical data for H-12, when the treated effluent is blended with untreated effluent at a ratio of 1:3, the resulting copper concentration should usually be below the final NPDES limit of a monthly average of 6 µg/L.

The bioavailability of copper in the blended effluent was evaluated by performing copper spiking toxicity tests on untreated and blended effluent. The results indicate that copper bioavailability in the blended effluent was reduced by a factor of 9 (when compared to untreated effluent). When compared to standard lab water, copper bioavailability in the blended effluent was reduced by a factor of 2.7. These results suggest that it may be possible to perform a Water Effects Ratio study at the H-12 outfall after construction of the peat bed to obtain higher NPDES limits, if there is a need to do so.

Introduction

The H-12 National Pollutant Discharge Elimination System (NPDES) Outfall at the Savannah River Site is periodically out of compliance with its revised copper limit in the current NPDES permit. The H-12 discharge is composed of a number of contributing sub-streams, and includes various cooling water sources, building discharges, and storm water runoff. As part of the solution to avoid future exceedences, the construction of a peat bed to treat a portion of the normal outfall discharge is being considered, both to remove copper from the water and to improve the water characteristics by addition of organic carbon to the waste stream. After treatment by the peat bed, the water would be recombined with the untreated portion of the discharge prior to reaching the compliance point. The new limit of 6 µg/L of copper that will go into effect in October 2008 may necessitate conducting a water effects ratio test to request a higher copper limit at the H-12 Outfall in the future.

Peat moss has a very high affinity for removing and holding metals and other cationic elements in water (Brown et al. 2000; Kratochvil and Volesky 1998; Couillard 1994; Veglio and Beolchini 1997). Metal removal is primarily through ion-exchange and complexation occurring on the surface of the peat material. Peat moss has a very high surface area, is polar, and has a high cation exchange capacity, especially for transition metals (Kadlec and Keoleian 1986; Twardowska and Kyziol 1996). This set of properties has made peat moss an intensively studied material for environmental improvement of aqueous waste streams. It is also a plentiful and inexpensive resource, compared to many of the more highly processed or synthetic ion exchange materials.

Metal removal by peat can be influenced by the environment in which it is operating. pH of the solution and solutions made up of more than one metal ion can alter the performance and degree of metal removal (McKay and Porter 1997; Ho et al. 1995; Ma and Tobin 2003, 2004; Ringqvist and Oborn 2002) The performance differences, however, have reduced significance in the application that is being considered for SRS. The pH of the effluent stream into the proposed peat bed is between 6 and 7, and the pH of the peat bed effluent will be between 4 and 5. This is the optimal range from published studies for the removal of many divalent metal ions, including copper. Concentrations of metals in water that will enter the proposed system are low and therefore interaction of competing ions will be minimal. The large adsorptive capacity of peat moss, coupled with this low loading rate, ensures that the effectiveness of metal removal will not be diminished.

Equilibration rates of metals in solution with peat moss are very rapid (Crist et al. 1996; Gosset et al. 1986; Gardea-Torresdey et al. 1996). In experimental systems, copper equilibrium is reached within 30 minutes of contact with peat moss. This is also the case with other metals that can be removed. There are differences in the binding strength of divalent metals (Gosset et al. 1986; Brown et al.; Crist et al. 1996). The order can vary slightly, based on the exact conditions of contact, but the usual order of affinity of removal is Pb>Cu=Ni>Cd=Zn. Calcium, Mg, Mn, and Na are also weakly held on the peat surface, but easily displaced by metals with greater equilibrium constants for peat moss. It is important for this application that copper is among the most effectively removed of the heavy metals.

There is a clear potential to use peat moss as a treatment media for the H-12 Outfall at SRS. It has a high affinity for the metals that need to be removed, has a high capacity to hold them once removed, removes them rapidly, and is inexpensive to acquire and maintain. A study to assess the potential of a peat bed at the bench-scale was established to document performance and effluent characteristics of the system.

Methods

Bench-Scale Peat Bed

A bench-scale peat bed was constructed using a rectangular plastic tub (test chamber) containing commercial peat moss. An initial determination of the void volume and water content at saturation of the peat was calculated gravimetrically to estimate the percent water contained in the saturated peat. A measured volume of dry peat moss was brought to water saturation, and the changes in volume and weight of the peat/water combination determined. Saturated peat used in this study was 68% water by volume. This was used to calculate the water volume in the bed and determine the retention time at measured flow rates. Approximately 3600 cubic centimeters of peat/water was used for the bench-scale system and the target retention time was approximately 8 hours.

The testing apparatus consisted of a reservoir (25-liter carboy) of H-12 effluent, a fluid pump, a test chamber containing peat moss, and a sample collection container (Figure 1). The peat bed was approximately 22.9 cm wide, 35.5 cm long and 4.4 cm deep. The aspect ratio of the bed was 1:1.6:0.19 compared to the 1:2.5:0.05 of the conceptual design full-scale bed (40 ft x 100 ft x 2 ft). Commercial peat moss (Lambert Peat Moss, source Quebec, Canada) was place in a bucket to saturate with deionized water for 48 hours prior to construction of the test bed. An elbow was used as the outflow device from the bed, and placed so that water would be collected from the lower portion of the peat profile and flow out at a level near the surface of the peat. With this configuration, no standing water on top of the peat bed was present, but the bed was saturated up to the surface. The outflow configuration essentially acted as a stand pipe to remove water from a peat medium saturated to near the surface. A filter of inert porous material (aquarium filter floss) was placed around the opening of the exit device in the peat moss to prevent plugging by the fines within the peat moss. The bed was constructed by carefully placing saturated peat moss around the exit structure and then filling the container to slightly above the exit level of the container. A rock was placed in the inflow portion of the bed to dissipate the energy of the influent water into the bed. The same peat bed was used in all tests performed.

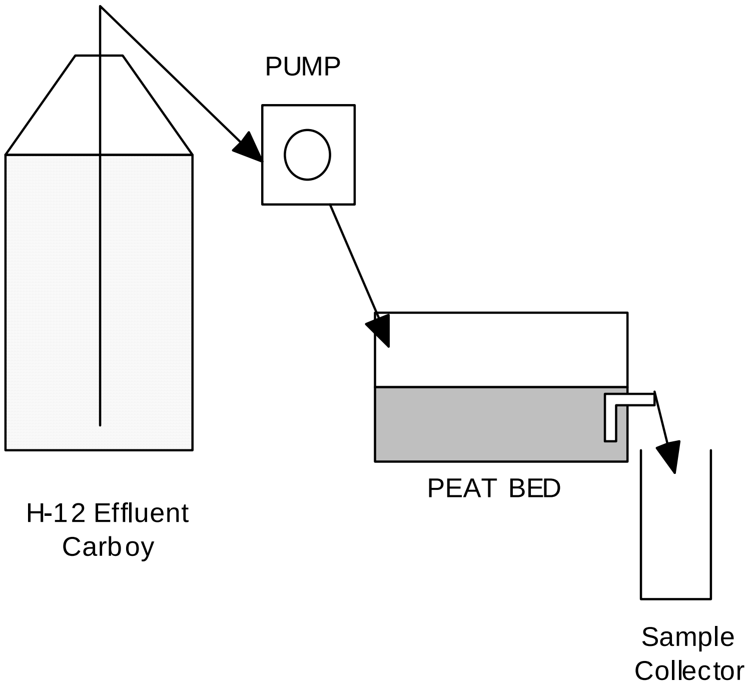

Figure 1. Schematic of Experimental Design

Water was collected from the H-12 Outfall in 25 L carboys for use prior to beginning each test run. Sufficient H-12 effluent was collected at one time to provide enough water for the entire 10-day treatment. The water was refrigerated until it was needed for influent into the test system. The test chamber was fitted with a tygon inflow line at one end and a tygon outflow line at the exit device. The inflow line was connected to a pump that fed H-12 effluent into the test chamber at a constant rate. The effluent flowed through the peat bed and was collected at the outflow end of the test chamber. At the

beginning of an experiment, approximately four volume exchanges of water using the H-12 influent were allowed prior to collecting samples for analysis.
Two sets of treatments were evaluated using different influent water. The first was conducted on unaltered H-12 effluent. Samples were collected daily for analysis of the concentration of copper in the influent and effluent over the 10 day test, and pH of the effluent was measured at the time of collection. Samples for metal analysis were acidified with ultrapure nitric acid when collected. Samples were analyzed by WSRC Analytical Laboratories. Samples of the influent and effluent were collected for analysis of dissolved organic carbon (DOC) mid-way through the 10 days and at the conclusion of each test. A composited sample of one part peat bed effluent and 3 parts H-12 influent was made for DOC analysis to represent the anticipated recombined effluent from the design plan for the full-scale model representing reblending of peat treated effluent with the main stream of H-12 discharge. Water samples were sent to ETT Environmental, Inc. (ETT, Greenville, SC) for DOC analysis.

Influent and effluent were collected on the 7th day of the test run for toxicity testing. A sample of H-12 discharge water (influent) was evaluated and compared to a sample that was composed of one part peat bed effluent and three parts H-12 discharge. This was to simulate the anticipated discharge of H-12 with treatment of 25% of the normal flow by a peat bed. Samples were sent to ETT for toxicity evaluation.

Flow rate into the peat bed during the first test was between 6 and 8 ml/min and represents a retention time in the peat system of between 6.8 and 5.1 hours. These are somewhat shorter than the conceptual design retention time of 12 hours, but represent a more conservative assessment of peat performance. A lower flow rate pump was obtained before the second test, and flow into the system was regulated at approximately 5.4 ml/min for a retention time of 7.6 hours.

The second treatment involved spiking copper (as copper sulfate) into the H-12 effluent to a nominal concentration of 100 µg/L (ppb) of copper, approximately 12 times the average concentration in the H-12 effluent. This was designed to determine the effectiveness of the peat bed in removing higher concentrations of copper. The concentration of copper in the influent and effluent were measured daily for 10 days, and pH and dissolved organic carbon (DOC) were measured in the influent and effluent as in the first test.

Copper Spiking Toxicity Tests

Not only is the peat bed expected to remove copper from the H-12 effluent, but the peat also adds dissolved organic carbon to the effluent, which binds to the metals and reduces their bioavailability and toxicity. Toxicity testing/copper spiking studies were conducted by ETT Environmental (Greenville, SC) using the test species, *Ceriodaphnia dubia*. An acute (48 hour) copper spiking study was conducted on lab water, untreated H-12 effluent and on H-12 effluent that was treated by the bench-scale peat bed and then diluted 3:1 with untreated effluent to simulate the dilution that will take place before the H-12 effluent reaches the compliance point (subsequently referred to as “blended effluent”). Copper was spiked into MHSF (moderately hard synthetic formula) lab water at five concentrations ranging from 2.9 to 22 µg/L. Because copper toxicity is inversely related to hardness and H-12 water has considerably lower hardness than lab water, a lower range of copper concentrations was chosen for untreated H-12 effluent (2.9 to 24.5 µg/L). For the blended effluent, a somewhat higher range of copper concentrations

(12.3 to 90 µg/L) was chosen because it was anticipated that the copper would be less biologically available, and therefore less toxic. A 48-hour toxicity test was then conducted on each of the three sets of spiked samples. The results were used to calculate an LC50 (Lethal concentration, 50%, which is the concentration of copper that kills 50% of the test organisms) for the untreated H-12 effluent, the blended sample, and the lab water. The ratio of the LC50s of the untreated H-12 effluent to the blended effluent to the lab water provides a Water Effects Ratio (WER) for the untreated H-12 and the blended sample. WERs that are greater than 1 indicate that copper is less toxic in an effluent than in lab water. For example if the LC50 for a metal is 50 µg/L in an effluent and 5 µg/L in MHSF lab water, the WER is 10 (50/5). A complete WER study consists of at least three sets of metal spiking studies conducted on one species (usually *Ceriodaphnia dubia*) performed at least 1 month apart and another metal spiking study performed on a second species (usually *Pimephales promelas,* the fathead minnow). Favorable WER results indicate that a metal is less bioavailable in an effluent than in lab water. WER study results can be submitted to SCDHEC to request higher NPDES limits. While these results are encouraging, they are based on a short study duration and single species. A full scale WER will need to be conducted after the peat bed is in place to support regulatory modification.

Results

Effluent Characteristics

The pH of the effluent from the peat bed was generally between 4.0 and 4.6 during the tests, and generally tended to go up over the course of the 10 day tests. The H-12 discharge had initial pH values between 6.5 and 6.7 when collected. The pH reduction after passage through the peat moss is expected, since many of the binding sites are occupied by hydrogen ions that are displaced as cations are bound. Values of effluent pH on collection days are shown in Table 1. When the effluent was blended back to represent anticipated discharge from H-12 for the DOC samples, the pH increased to between 6.3 and 6.5 for the blended sample, which is well within discharge limits for the outfall. A slight brown coloration of the water exiting the peat bed was common and probably represents the release of tannins and humic substances from the peat moss.

Table 1. pH of effluent water from the peat bed during the 10 day test.

Day	Test 1 (H-12)	Test 2 (Cu spike)
1	4.01	4.21
2	4.03	4.25
3		3.96
4	4.13	3.87
5	4.16	4.24
6	4.16	4.27
7	4.19	4.34
8	4.36	4.28
9	4.38	4.26
10	4.60	4.35

Copper Removal

The peat bed performed as expected in regard to metal removal from the influent water. Values for copper in the influent and effluent for the two test runs are shown in Table 2. In calculations of mean values for a test, the detection limit was used as the value if the result was below the detection limit.

Table 2. Copper concentration in influent and effluent samples of Tests 1 and 2, values are mg/L of copper.

	Test 1 (H-12)	Test 1 (H-12)	Test 2 (Cu Spike)	Test 2 (Cu Spike)
Day	Influent	Effluent	Influent	Effluent
1	0.0094	<0.005	0.1110	0.0082
2	0.0063	<0.005	0.1009	<0.005
3	0.0063	<0.005	0.1045	<0.005
4	0.0093	<0.005	0.1092	<0.005
5	0.0064	<0.005	0.1012	<0.005
6	0.0092	<0.005	0.1051	<0.005
7	0.0066	<0.005	0.1008	<0.005
8	<0.005	<0.005	0.1185	<0.005
9	<0.005	<0.005	0.1029	<0.005
10	<0.005	0.0063	0.1169	<0.005
Mean	0.0076	<0.005	0.1071	<0.005

Copper concentrations in the H-12 discharge that was collected for Test 1 were at the low range of the typical level reported for that outfall (5 to 16 µg/L). Average influent copper in Test 2 was 107 µg/L due to the spiking of the influent water. In each test, the effluent was reduced to the detection limit of copper, indicating that copper removal was essentially complete after passage through the peat media. Removal rate of the copper spiked solution was greater than 95% for the high copper concentration solutions and indeterminate for the low concentrations water. The extent of copper removal from the influent was typical of previous reports, indicating that copper has a high affinity for binding to the peat moss surface. This affinity for binding to peat is surpassed only by lead in most reported studies.

Other Metals

As part of the analysis by the Analytical Labs, a number of other metals were also reported in addition to the copper values. Aluminum, chromium, manganese, and nickel were not detected in any samples submitted. Lead, arsenic, and zinc were detected in low levels in many influent samples and were generally below detection in the effluent samples. Calcium and sodium were also reported in the analytical results. Calcium was reduced from an average of 1.917 mg/L to the detection limit of 0.4 mg/L in all samples analyzed, and sodium was reduced from an average of 6.61 mg/L to 3.87 mg/L in samples analyzed. Calcium is bound to peat at only about 10% of the strength of copper, indicating the large capacity of the peat to remove cations from the water.

Sodium is bound very loosely, and would be displaced if divalent metal cations were present in concentrations large enough to do so. Zinc and lead present in the influent water were typically low, and were removed to the detection limits for these elements after passage through the peat bed. Both these elements are strongly adsorbed by peat moss. The concentration of iron in the influent was low in the Test 1 H-12 discharge (average 0.05 mg/L), but higher in the collection for Test 2 (average 0.13 mg/L). In the Test 2 samples, an average of 67.4% of the iron was removed by the peat bed. Iron is also only loosely held and an additional indication of the potential removal capacity that is available on the surface of peat moss. Complete analytical results of the samples are included in the Appendix of this report.

Dissolved Organic Carbon

Samples of influent and effluent of the peat bed were collected over the study period and analyzed for dissolved organic carbon (DOC) by ETT. The effluent from the peat bed contained higher levels of DOC, as expected. The initial effluent from the peat bed contained the highest level of DOC, and probably represents the easily dissociated organic acids present on the dry peat and eluted during the first several volumes of water to be removed from the bed. As additional volumes of water interacted with the peat matrix, the concentration of DOC in the effluent became more stable and uniform. This concentration is representative of the level of DOC that can be expected to be discharged from the peat bed on a continuing basis. Based on the average levels of DOC in the last 5 samples collected in the study, the DOC in the water was increased by 137% (from 3.26 mg/L to 7.72 mg/L). This is extremely important in understanding the water quality parameters that are assessed on the discharge. The levels of DOC have a direct effect on the toxicity testing performance since it will reduce the amount of bioavailable metal ions. This is described in the recent report of the relationship of the biotic ligand model to understanding toxicity issues at SRS (Specht 2005). Samples of blended effluent and influent at a 1:3 ratio were also analyzed and the average DOC for the last 5 samples was 4.70 mg/L. This was slightly greater than would be calculated based on the influent and effluent values of the component parts of the blend.

Table 3. DOC concentrations in influent and effluent samples from the peat bed, values are mg/L.

Date	Influent	Effluent
10/27/05	3.5	30
10/31/05	3.7	15
11/3/05	3.8	9.6
11/20/05	2.8	5.9
11/25/05	2.3	6.2
12/4/05	3.1	8.9
12/9/05	4.3	8.0

Copper Spiking Toxicity Tests

The results of the copper spiking tests (Table 4) indicate no mortality in either the raw H-12 effluent or the sample of H-12 effluent that was treated by the peat bed and then blended with untreated H-12 in a ratio of 1:3. However, when copper was spiked into both waters, the copper was considerably more toxic in H-12 effluent than in the blend. The 48-hour LC50 for H-12 was <2.9 ug/L (estimated at ~2 µg/L), while the LC50 for the blend was 18.8 ug/L. These results indicate that the untreated, unblended effluent is approximately nine times more toxic than the blended effluent. The LC50 for the spiking test conducted on MHSF lab water was 6.9 µg/L. These results suggest that it may be possible to obtain a WER of approximately 2.7 (18.8/6.9) if a WER were conducted subsequent to the construction of a peat bed.
However, the results also indicate that copper is quite toxic in both the treated and untreated effluent. The current limits for copper at H-12 are a monthly average of 25 µg/L and a daily maximum of 35 µg/L. Since monthly averages are based on an approximation of chronic toxicity, while daily maximums are based on an approximation of acute toxicity (LC50), it appears that the current NPDES limits may be underprotective (too low to protect the receiving stream). This single set of spiking tests suggests that a more appropriate daily maximum for copper would be a concentration less than 18.8 µg/L. Therefore, any decision to proceed with a WER after the peat bed is operational should be made with the understanding that when SCDHEC reviews the results, they may conclude that the existing NPDES limits for copper are too high and that the limits should be reduced.

Table 4. Results of copper spiking toxicity tests

H-12		**Blended effluent**		**Lab Water**	
Cu (µg/L)	**% Mortality**	**Cu (µg/L)**	**% Mortality**	**Cu (µg/L)**	**% Mortality**
1.0 (baseline)	0	4.5 (baseline)	0	1.0 (baseline)	0
2.9	70	12.3	5	2.9	0
4.0	100	17.5	50	4.0	0
6.2	100	24.5	70	6.2	55
8.3	100	35	90	8.3	100
12.3	100	50	100	12.3	100
17.5	100	71.4	100	17.5	100
24.5	100	90	100	22.0	100
Calculated LC50 = <2.9 µg/L		Calculated LC50 = 18.8 µg/L		Calculated LC50 = 6.9 µg/L	

Conclusions

Passing the H-12 Outfall effluent through a peat moss bed effectively removed copper from the water to below the detection limit of the analysis performed. The test using elevated copper influent showed that the system continued to effectively reduce copper to detection limits even when copper concentration was many times greater than should ever be discharged from H-12. The effluent pH was around 4.5 when exiting the peat bed and was raised to between 6 and 7 when recombined with the anticipated proportion of untreated effluent before discharge. DOC in the effluent was increase due to contact with the peat moss, and reduces the toxicity of the reduced metals present in the discharge. Samples of the blended effluent were tested for ability to buffer copper effects in toxicity tests and found to be non-toxic, even with elevated levels of copper, when compared to the current H-12 discharge. The use of peat bed treatment of a portion of the H-12 discharge appears to be a viable method to reduce copper concentrations in the effluent to acceptable levels. However, given the very low final copper limit for H-12 (6 µg/L) that will be in effect by October 2008, it may be necessary to perform a water effects ratio study to obtain a higher copper limit for the H-12 Outfall.

References

Brown, P.A., S.A. Gill and S.J. Allen. 2000. Metal removal from wastewater using peat. Water Res. 34:3907-3916.

Couillard, D. 1994. The use of peat in wastewater treatment. Water Res. 28:1261-1274.

Crist, R.H., J.R. Martin, J. Chonko, and D.R. Crist. 1996. Uptake of metals on peat moss: an ion-exchange process. Environ. Sci. Technol 30:2456-2461.

Gardea-Torresdey, J.L., L. Tang and J.M. Salvador. 1996. Copper adsorption by esterified and unesterified fractions of Sphagnum peat moss and its different humic substances. J. Hazardous Materials 48:191-206.

Gosset, T., J.-L. Trancart and D.R. Thevenot. 1986. Batch metal removal by peat. Kinetics and thermodynamics. Water Res. 20:21-26.

Ho, Y.S., D.A. John Wase and C.F. Forster. 1995. Batch nickel removal from aqueous solution by Sphagnum moss peat. Water Res. 29:1327-1332.

Kadlec, R.H. and G.A. Keoleian. 1986. Metal ion exchange on peat. In: C.H. Fuchsman (ed.) Peat and Water, Elsevier Publ. Ltd., pp61-93.

Kratochvil, D. and B. Volesky. 1998. Advances in the biosorption of heavy metals. Tibtech 16:291-300.

Ma, W. and J.M. Tobin. 2003. Development of multimetal binding model and application to binary metal biosorption onto peat biomass. Water Res. 37:3967-3977.

Ma, W. and J.M. Tobin. 2004. Determination and modeling of effects of pH on peat biosorption of chromium, copper and cadmium. Biochem. Engineer. J. 18:33-40.

McKay, G. and J.F. Porter. 1997. Equilibrium parameters for the sorption of copper, cadmium and zinc ions onto peat. J. Chem. Tech. Biotechnol. 69:309-320.

Ringqvist, L and I. Oborn. 2002. Copper and zinc adsorption onto poorly humidied *Sphagnum* and *Carex* peat. Water Res. 36:2233-2242.

Specht, W.L. 2005. Evaluation of the biotic ligand model for predicting metal bioavailability and toxicity in SRS effluents and surface waters. WSRC-TR-2005-00377, Savannah River National Laboratory, Westinghouse Savannah River Co, Aiken, SC.

Twardowska, I. and J. Kyziol. 1996. Binding and chemical fractionation of heavy metals in typical peat matter. Fresenius J. Anal. Chem. 354:580-586.

Veglio, F. and F. Beolchini. 1997. Removal of metals by biosorption: a review. Hydrometallurgy 44:301-316.

APPENDIX

Peat Bed Demo Treatment 1 – No amendments (Units are mg/L)

Sample ID	**Date**	**Al**	**As**	**Ca**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Na**	**Ni**	**Pb**	**Zn**
H-12 SPL	10/24/05	<0.05	<0.005	1.795	0.0011	<0.005	0.0078	0.0862	<0.01	7.333	<0.01	0.0051	0.0319
1st Eff	10/25/05	<0.05	<0.005	<0.4	0.0011	<0.005	<0.005	0.1109	<0.01	2.865	<0.01	0.0044	<0.01
In	10/26/05	0.5816	<0.005	1.962	0.0019	<0.005	0.0094	0.5954	0.091	4.770	<0.01	0.0178	0.0601
Out	Day 1	<0.05	<0.005	1.823	0.0013	<0.005	<0.005	0.0703	<0.01	7.467	<0.01	0.0028	0.0149
In	10/27/05	<0.05	<0.005	1.800	0.0025	<0.005	0.0063	0.0696	<0.01	7.414	<0.01	0.0022	0.0142
Out	Day 2	<0.05	<0.005	<0.4	0.0018	<0.005	<0.005	0.0836	<0.01	2.957	<0.01	0.0035	<0.01
In	10/28/05	<0.05	0.0081	2.084	0.0025	<0.005	0.0063	0.0536	<0.01	7.230	<0.01	0.0037	0.0172
Out	Day 3	<0.05	<0.005	<0.4	0.0026	<0.005	<0.005	0.0616	<0.01	3.417	<0.01	0.0043	<0.01
In	10/29/05	<0.05	0.0051	2.191	0.0030	<0.005	0.0093	0.0509	<0.01	7.312	<0.01	0.0060	0.0193
Out	Day 4	<0.05	<0.005	<0.4	0.0027	<0.005	<0.005	0.0643	<0.01	4.208	<0.01	0.0029	<0.01
In	10/30/05	<0.05	0.005	2.164	0.0014	<0.005	0.0064	0.0603	<0.01	7.274	<0.01	0.0048	0.0192
Out	Day 5	<0.05	<0.005	<0.4	0.0022	<0.005	<0.005	0.0454	<0.01	3.883	<0.01	0.0053	<0.01
In	10/31/05	<0.05	<0.005	2.166	0.0030	<0.005	0.0092	0.0594	<0.01	7.186	<0.01	0.0052	0.0190
Out	Day 6	<0.05	<0.005	<0.4	0.0030	<0.005	<0.005	0.0424	<0.01	3.985	<0.01	0.0039	<0.01
In	11/1/05	<0.05	<0.005	1.974	0.0029	<0.005	0.0066	0.0383	<0.01	6.509	<0.01	0.0041	0.0172
Out	Day 7	<0.05	<0.005	<0.4	0.0027	<0.005	<0.005	0.0355	<0.01	4.279	<0.01	0.0044	<0.01
In	11/2/05	<0.05	<0.005	1.732	0.0028	<0.005	<0.005	0.0374	<0.01	5.511	<0.01	0.0027	0.0147
Out	Day 8	<0.05	<0.005	<0.4	0.0033	<0.005	<0.005	0.0353	<0.01	4.305	<0.01	0.0026	<0.01
In	11/3/05	<0.05	<0.005	1.894	0.0013	<0.005	<0.005	0.0819	<0.01	6.165	<0.01	0.0031	0.0154
Out	Day 9	<0.05	<0.005	<0.4	0.0014	<0.005	<0.005	0.0355	<0.01	4.464	<0.01	<0.002	<0.01
In	11/4/05	<0.05	<0.005	1.475	0.0013	<0.005	<0.005	0.0339	<0.01	4.668	<0.01	0.0035	0.0114
Out	Day 10	<0.05	<0.005	<0.4	0.0011	<0.005	0.0063	0.0269	<0.01	3.604	<0.01	0.0027	<0.01
In	MEAN	<0.05	0.005	1.942	0.0023	<0.005	0.0074	0.0539	<0.01	6.585	<0.01	0.0039	0.0164
Out		<0.05	<0.005	<0.4	0.0023	<0.005	<0.005	0.0478	<0.01	3.900	<0.01	0.0035	<0.01

Peat Bed Demo Treatment 2 – Cu spike at 100 µg/L (Units are mg/L)

Sample ID	Date	Al	As	Ca	Cd	Cr	Cu	Fe	Mn	Na	Ni	Pb	Zn
H-12 Outfall	11/15/05	<0.05	<0.005	2.109	0.0009	<0.005	<0.005	0.1407	<0.01	7.201	<0.01	0.0028	0.0177
Cu spike	11/15/05	<0.05	<0.005	2.025	0.0036	<0.005	0.139	0.1559	<0.01	6.937	0.0113	0.0064	0.0212
In	11/16/05	<0.05	<0.005	2.049	0.0031	<0.005	0.111	0.1380	<0.01	7.027	<0.01	0.0040	0.0189
Out	Day 1	<0.05	<0.005	<0.4	0.0038	<0.005	0.0082	0.0676	<0.01	4.028	<0.01	<0.002	<0.01
In	11/17/05	<0.05	0.0103	1.998	0.0023	<0.005	0.1009	0.1253	<0.01	7.1	<0.01	0.0033	0.0196
Out	Day 2	<0.05	0.0064	<0.4	0.0015	<0.005	<0.005	0.0465	<0.01	3.474	<0.01	<0.002	<0.01
In	11/18/05	<0.05	0.0101	2.035	0.0018	<0.005	0.1045	0.1250	<0.01	7.113	<0.01	0.0027	0.0187
Out	Day 3	<0.05	<0.005	<0.4	0.0012	<0.005	<0.005	0.0506	<0.01	3.569	<0.01	<0.002	<0.01
In	11/19/05	<0.05	0.0097	2.082	0.0025	<0.005	0.1092	0.1270	<0.01	7.262	<0.01	<0.002	0.0195
Out	Day 4	<0.05	<0.005	<0.4	0.0008	<0.005	<0.005	0.0509	<0.01	3.669	<0.01	<0.002	<0.01
In	11/20/05	<0.05	0.01	1.936	0.0023	<0.005	0.1012	0.1180	<0.01	6.822	<0.01	<0.002	0.0175
Out	Day 5	<0.05	<0.005	<0.4	0.0012	<0.005	<0.005	0.043	<0.01	3.731	<0.01	<0.002	<0.01
In	11/21/05	<0.05	0.0082	1.765	0.0016	<0.005	0.1051	0.1099	<0.01	6.262	<0.01	<0.002	0.0154
Out	Day 6	<0.05	0.0093	<0.4	0.0012	<0.005	<0.005	0.0383	<0.01	3.662	<0.01	<0.002	<0.01
In	11/22/05	<0.05	0.009	1.79	0.0011	<0.005	0.1008	0.1117	<0.01	6.281	<0.01	<0.002	0.0146
Out	Day 7	<0.05	0.0054	<0.4	0.0017	<0.005	<0.005	0.0356	<0.01	3.723	<0.01	<0.002	<0.01
In	11/23/05	<0.05	0.0061	1.826	0.0015	<0.005	0.1185	0.1681	<0.01	6.415	<0.01	0.0028	0.0149
Out	Day 8	<0.05	0.0055	<0.4	0.0016	<0.005	<0.005	0.0333	<0.01	4.234	<0.01	<0.002	<0.01
In	11/24/05	<0.05	0.0099	1.676	0.0018	<0.005	0.1029	0.1051	<0.01	5.961	<0.01	0.0024	0.0136
Out	Day 9	<0.05	0.0087	<0.4	0.0014	<0.005	<0.005	0.0296	<0.01	4.196	<0.01	<0.002	<0.01
In	11/25/05	<0.05	0.0091	1.752	0.0019	<0.005	0.1169	0.1726	<0.01	6.109	<0.01	0.0025	0.0141
Out	Day 10	<0.05	0.0073	<0.4	0.0012	<0.005	<0.005	0.0292	<0.01	4.187	<0.01	<0.002	<0.01
In	MEAN	<0.05	0.0092	1.891	0.0020	<0.005	0.1071	0.1301	<0.01	6.635	<0.01	0.0026	0.0167
Out		<0.05	0.0063	<0.4	0.0016	<0.005	<0.005	0.0425	<0.01	3.847	<0.01	<0.002	<0.01