Review of Evaluating the efficiency and temporal variation of pilto scale hybrid and integrated sonstructed wetlands for treating high BOD and P concentrated dairy effluent

By: Lee, Drizzo, Rizzo, Druschel, Hayden, and Twohig

Martin,

This article is well written and quite interesting. You do a fine job of explaining the work that you have done and the results. In summary I have taken away from this article that constructed wetlands have a good ability to address several issues in regards to farm effluent that are potentially detrimental in unmanaged runoff. You showed this well with your pilot scale constructed wetlands and described the way they work, with the gravel overlain by plant life (bulrush) which essentially does a nice job of addressing BOD and TSS. However, the inability of treating phosphorous in standard constructed wetlands is a problem. Hence your experiment with the addition of slag as a filter has shown that it increases the constructed wetland's ability to remove phosphorous, making this system more ideal than standard constructed wetlands.

You summarize well your methods and results. I think the biggest addition that could improve your overall effectiveness of the paper would be justification. Justification in terms of the introduction would include some more background on why these are necessary. Farms and their runoff bring all kinds of problems and while people know this, some numbers and references would really start this off nicely. Then, in terms of discussion you can tie your results into real life a little more. This can include scale, practicality, and potential limitations to this design. I think if you add in some of this background and applicability it will really ground your work and make the results that much more effective.

Otherwise, I would like to see a photograph of one of these, just so the read can easily visualize what it is you are describing. I made some smaller comments on the text itself, so feel free to look over those. I think if you make these additions it will really smooth out the document and make this a very effective paper that should be accepted without trouble.

Good Luck,

Will

Lee Corbett
GEOL 371
2/18/09

**Review of**: Evaluating the efficiency and temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrated dairy effluent
**Authors:** M. Lee, A. Drizo, D. Rizzo, G. Druschel, N. Hayden, and E. Twohig

In this manuscript, the authors present data from a study that assesses the efficiency of using constructed wetlands (CWs) to treat high-nutrient wastewater from a dairy farm. The study investigates several different configurations of CWs (hybrid and integrated, vertical flow and horizontal flow, etc) to see how their treatments differ. Additionally, the study assesses the temporal variation in CW efficiency, which appears to be an important consideration in determining whether this wastewater treatment method is applicable in colder climates.

Overall, the manuscript does a good job describing the study in detail and providing robust analysis of all the parameters that were measured. It also appears to address some important questions in a field that has new and exciting implications for wastewater treatment and environmental management.

Please refer to the hard-copy edited version of the manuscript for small comments regarding structure and rhetoric. In addition, I have one central recommendation that will be addressed in further detail by the numbered points below. My general impression of this manuscript is that the meat of the work (study design, methods, analysis) is all very solid. However, the manuscript could be greatly improved by stringing it all together in a more accessible and persuasive way. For example, the use of less technical language, a more detailed discussion of the significance of your work, and the practice of stating the key points of your results in plainer terms will help make your research more relevant to a wider audience.

1.) In your abstract, you introduce a large number of terms and abbreviations. Can you eliminate some of these abbreviations? They're overwhelming to someone not familiar with wetland terminology. It's nice to start your paper with an overview that's accessible and enticing to all levels within the journal's readership.

2.) In the introduction, you do a nice job describing the previous work on CWs and how your work will fill in some critical gaps in the knowledge. What about a paragraph on the larger significance of your work? Why is this important? What are some of the detrimental effects poorly treated wastewater can have on the surrounding environment? Why should someone choose to use a CW over a more conventional method? I know that some of this might be "common knowledge" to the readership of this journal, but it would be nice if you could place your work in a broader context.

3.) You use a lot of terminology in this manuscript. Adding a few short, basic definitions would make it a lot more readable. I went through and circled some of these in the text. For example, what is the difference between a hybrid and an integrated wetland? What is the difference between vertical flow and horizontal flow and why does it matter? This journal isn't exclusively

about wetlands- on the contrary, it seems to have a fairly broad focus- so it would be helpful to provide the necessary definitions so that your readers can progress confidently into the rest of the manuscript.

4.) On a similar note, your Data Analysis and Results sections have a lot of statistical jargon. That's not necessarily a problem, since the statistical buffs in the crowd will want to know exactly what you did, but it would be helpful to provide a little bit of a theoretical framework for the layperson. What is auto-correlation? What is a temporal semivariogram? Why did you choose ANOVA?

5.) In both your Results and Discussion section, you often state your findings in statistical terms. Good! It seems like you can solidly back up your work with statistical analysis. Can you also add some sentences to state your findings in more general terms? Especially since your Results and Discussion are merged, it would be nice to understand what your work means qualitatively as well as quantitatively.

6.) Likewise, your figure captions would be greatly improved by giving the reader some guidance. The captions for figures 3 and 4 especially made me feel lost. What is this thing? What should I be looking for? What are some trends I should pick out? The figure caption should serve as a guide to the reader's understanding of the figure.

7.) Have you thought about adding an Implications section? It seems like your work will have direct implications for the usage of CWs in wastewater treatment. It might be nice to spell it out conclusively at the end.

Good luck with edits and publication. Well done!

Lee
abcorbet@uvm.edu

**Evaluating the efficiency and temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrated dairy effluent.**

Martin Lee, Aleksandra Drizo, Donna Rizzo, Greg Druschel, Nancy Hayden and Eamon Twohig

**Review** by Andrea Pearce, 18 February 2009

This manuscript documents the treatment efficiency of a constructed wetland facility treating effluent from a small dairy operation. The primary concern is phosphorus removal and BOD reduction from the effluent prior to discharge. The test wetlands are operated in paired configurations with test cells plumbed in parallel and in series and followed by a slag filter for phosphorus removal. Influent and effluent from the wetlands was regularly monitored for BOD, TSS, nitrate, ammonium, DRP and DO, among other things. Semivariogram analysis tested for temporal autocorrelation of the sampled parameters. ANOVA was used to determine if there were significant difference in treatment efficiency between the wetland configurations. Geochemical modeling of batch reactions simulated mixing the slag and wastewater predicting theoretical concentrations at equilibrium. Data were temporally autocorrelated at several different scales with the correlation of the shortest scale possibly being shorter than the smallest sampling time interval. Reduction of BOD, TSS and SRP were significant over the two sampling periods. The integrated systems performed best. Highest nutrient removal occurred coincident with the greatest macrophyte growth in the summer

This manuscript is through and well written, providing clear detailed descriptions of the variety of methods used. Consideration of the effect of the local cold climate is mentioned several times as is the need for more research on cold weather treatment wetlands, but not elaborated. Since dairies operate year round, and exist in a range of climate conditions, you might want to briefly discuss what happens to this particular wetland in the winter months otherwise leave out the mention of climate altogether.

I recommend this paper be accepted with minor revisions primarily focusing on some rewording and clarification. Specific comments are enumerated below:

1. The introduction is very well written and thorough overview of the subject. While you mention that there are specific difficulties with cold climates, you may want to clarify what these difficulties and deficiencies in research on the subject are (related to next comment)
2. Page 2 lines 78-81, page 3 lines 86 – 88 & lines 101-103 – In each of theses sentences you mention that there is more need for research. Maybe you could either be more specific about the deficiencies in research as they apply to each paragraph or combine all the discussion on this topic to one paragraph.
3. Page 3, 2$^{nd}$ paragraph and page 4, 1$^{st}$ paragraph – These two paragraphs discuss hybrid and integrated systems. You discuss both a little in each paragraph. It may be clearer to the reader if you keep one type of system confined to each paragraph, perhaps the first paragraph entirely about hybrid systems and the

second entirely about integrated systems. You could achieve this by beginning the second paragraph with line 96 and eliminating the last sentence of this paragraph and the 1st sentence of the next.

4. Page 5 last paragraph – You reported porosities of 0.4 and 0.42 for the gravel and slag, this isn't much difference and would be more poignant if you used the same # of sig. figs.
5. Figure 1 – You might want to include some sort of scale bar that indicates the change and magnitude of the hydraulic head over the wetland on the SEEP/W output plot.
6. Page 9, line 221-222 – It's not really clear what you mean by 'significantly different time periods'. Without giving away your results, it would be helpful for the reader to have a bit more information about this.
7. Figure 3 and 4 – Do you want to include semi-variogram model type and parameters on the figure in addition to the text? I sometimes find it easier to see it all together.
8. Page 11 Lines 269 to 279 – This could all be one paragraph where you discuss the temporal partitioning you do prior to the ANOVA and why. It might read more smoothly. Also, you may want to introduce the concept behind the geostat analysis (lines 277-278) earlier in the discussion of geostats to help the reader understand why you're doing it. Alternatively you could include this in the intro or methods (maybe?).
9. Page 14, lines 341-343. You might want to specify that there is no gaseous phase of P at atmospheric temp and pressure so despite any biological transformation it cannot off-gas like N or C.
10. Figure 7 – The squares on this line are confusing. Perhaps indicate the starting point and endpoint on the line with out the squares. You could indicate how much modeled slag has been added at a couple point on the line to show that it's (probably) not linear (I'm just assuming here).

Good job Martin! Good luck dealing with all our edits…

Review of: Evaluating the efficiency and temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrated dairy effluent

Authors: M. Lee, A. Drizo, D. Rizzo, G. Druschel, N. Hayden, E. Twohig

Summary:

This paper compares the effectiveness in reducing different components of waste water from diary farms using multiple configurations of constructed wetlands. Two main types of wetlands are compared. The first is a hybrid wetland design which combines two sub-units of a wetland together beginning with either a horizontal or a vertical flow subunit, followed by a horizontal flow subunit. The second is an integrated wetland which combines an initial horizontal or vertical flow subunit with a steel-slag filter for removing P. Over two years, the results show that while the replacement of a second constructed wetland by a slag filter does reduce P output, it is not as effective at reducing organic matter or suspended solids.

Review:

It is clear that the science that went into this paper is very solid and that the results can have real impacts on waste water treatment. And although this is a very technical paper, I think the end result is clear. What I think gets a little lost in the details is why each of your analyses is important. I think in this regard, the end of each subsection of your results and discussion should include a sentence about what the results mean in terms of water quality or waste water treatment in general.

Admittedly I am unfamiliar with much of this literature, but from the beginning I felt like things could be simplified at least in terms of terminology. Although the title does get at what you are examining in this study, it gets confusing with too many words. Perhaps something more along the lines of “Evaluating the effectiveness of hybrid and integrated constructed wetlands in treating concentrated dairy effluence” may be clearer.

Although I know that you did talk about temporal variation, I don't really feel that it needs to go into your title.

In the abstract, although it's convenient, if you are unfamiliar with many of the acronyms this is a little tough to get through. If there is any way to avoid using so many acronyms right off the bat, it would be helpful. Perhaps changing CW to just "wetlands" at some point in the paper would get rid of a lot of them. Also, if there is no difference between DRP and P, maybe that one can be gotten rid of too. What I think all the acronyms really overshadow is your overarching theme which is to compare hybrid and integrated systems in terms of their ability to mediate different compounds.

I thought your Introduction was well written and clear and made the case for the use of constructed wetlands well. I felt after this section that I would understand at least most of what you were trying to say later on and that I knew what was important.

In the methods section, I thought that the diagrams of the different wetlands helped a lot in understanding your experimental set up. Additionally, I though the explanations of the laboratory and collection methods were very clear. I'm assuming this are all pretty standard operating procedures for this type of study. Once I got to the Data Analysis though, I had a question. Perhaps this is better addressed in the results, but what should the semivariograms be telling me? What information can they give? Is it purely for autocorrelation or is there more to it?

As for your results and discussion section, I was a little confused by the break up of the sections. Some were titled by the method employed and some for what they were hoping to tell you. I think in terms of this, it should be kept constant. More specific questions refer to the section 3.2 lines 307-ish. I kept wanting to find out why the early and late summer differed in their removal efficiency and I don't think it was ever addressed. I also wanted to know how this impacted the overall effectiveness of the CW. In the "ANOVA" section, you were very good about reporting the results of each ANOVA, but I never felt like I knew what the overall result was. Sometimes this was because sometimes it was unclear what the ANOVA was between, whether it was an early/late summer comparison or a 2007/2008 comparison. In regards to the last sentence of this section, I thought a statistic addressing the effect that each degree of temperature decrease has on the decrease in the % efficiency. Perhaps you could get one from the

literature and one from your own study to compare. My final questions are more big picture I think. They are:

1) How did changing the input flow (pulse vs. continuous) effect efficiency?

2) Wouldn't we expect a wetland with ½ the area to absorb ½ the BOD and TSS?

3) What structure would you recommend? Could you combine a 2-tiered CW with a slag filter?

4) Did the diameter of the slag filter make a difference?

Overall, very nice job. Obviously a lot of work and statistics went into this paper.

**Evaluating the efficiency and temporal variation of temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentration dairy effluent**

**02/18/09**
**Review by Christina Syrrakou**

The manuscript presents the differences in the performance of three hybrid and three integrated pilot-scale constructed wetlands tested for treating dairy farm effluent. To evaluate the temporal variation in the performance of the CWs the writers use semivariograms and for the evaluation of the variation in the concentrations of the parameters under study, between sampling locations, one-way ANOVA is used.

Overally, the paper is well-written and presented. Although there is a large amount of information provided concerning the experiment and the statistical methods used the writers manage to effectively present the main ideas of this topic. I found the introduction very good, first laying some general information on the subject, then presenting the designs of CWs which will be studied and finally giving the scope of the specific research and the methods used. The part presenting the methods had a good flow and I found it easy to read. The final part of the results and discussion contained a lot of information but was overally well-written as well.

I have to admit that a point that as a reader I didn't capture very well is how the system would be affected in case of a snowfall which is a usual case in Vermont. However, the paper is of good quality and I believe it should be published with minor revisions (which are mainly clarifications).

- p6, l 159-160 : It would be good to clarify whether the interval between the two operating periods of the CWs was due to the heavy snowfalls in Vermont that might affect the performance or for some other reason.

- p6, l 161-162 : You mention that first a pulse flow was used and then you changed it to continuous flow. Do you think you could specify the reason for that change? Was it maybe something that would increase the performance of the systems?

- p12, l 295 : It is stated that the CWs experienced an increased removal efficiency of $BOD_5$ and TSS during late summer of 2008. From figure 5 however, it seems that the removal efficiency for $BOD_5$ was also large at the first part of the early summer. Maybe you could add this information so that you strengthen your argument that the parameters changed from early to late summer may have been influenced by changes in the CW treatment performance.

- p12, l 306 : “The removal of DRP by the slag systems is shown to be 100% during 2007 and 2008”. Is that inferred from figure 5?

- p13 : Maybe just one sentence on how one-way ANOVA works would help readers with no background on the method.

- Figure 1 : A legend explaining the different colours could be visually helpful. However the flow pattern (with the arrows) is quite clear.

Finally, I believe that it was a very good paper with strong arguments and the statistics to back it up and on an interesting topic.

Good Luck!

Review of

**Evaluating the efficiency and temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrated dairy effluent**

**Martin Lee**

This paper is about constructing artificial wetlands on dairy farms to treat wastewater that is created on the farm. Six sets of wetlands, three hybrids and three integrated were constructed. The hybrids had two wetlands in each set and were either vertical flow followed by horizontal or horizontal followed by horizontal. The integrated had a wetland flowing into a electric arc furnace with steel slag. It is well known that artificial wetlands can remove a lot of the contaminants from wastewater but a major problem on farms is removing Phosphorus. This experiment has shown that integrated wetlands with the steel slag remove a significant amount of Phosphorus compared to hybrids. While hybrids removed more BOD at least during one period of time.

The data is very good and makes makes sense considering all of the variables in the experiment, the only problem I can see is that the incoming wastewater possibly needed to be tested more. The interpretations make sense and, I think, were expected from the beginning, which bodes well for the integrated system being an accepted method of treatment. The writing was good but at some points very hard to follow and I think it could be made clearer for a wider audience. I really like the illustrations, for all of the difficultly there is in reading the paper the illustrations clear most of this up in a very pleasing way.

I believe the paper should be accepted with minor revisions. First off, having grown up in Iowa and having a lot of family friends that are farmers I think this research could revolutionize farming and make it much more environmentally friendly. Second, the research

was really well done. So, it is important an well done research that should defiantly be published. I do believe that a few things could improve the paper.

1. I think the writing needs to be clearer so that the general public can understand it considering the topic. Another possibility would be a second publication directed toward the farming community.
2. You need a map of your study site.
3. One thing that could clear up the paper, is cutting down on the amount of abbreviations. You may need to double space the abstract.

Charles Trodick

Eric Portenga
Writing Seminar
2/18/2009

# Review of Lee et al.

The paper by Lee et al. compared two different styles of treating dairy farm wastewater by filtering it through two different set-ups, or constructed wetlands. In the hybrid system CW, the water flows either horizontally or vertically through one system before moving on to the second system where it flows horizontally followed by another horizontal flow system. This was contrasted by an integrated system which is comprised of either a horizontal or vertical flow system followed by filtration through porous steel slag which contains various mineral phases likely to remove phosphorus from the wastewater through means of mineral precipitation. The two systems were monitored for their efficiency of removing phosphorus and ammonium and measured for its biochemical oxygen demand, total suspended solids, and pH.

Given that I do not really understand a lot of the mechanics of this manuscript, I thought the purpose of the experiment was well set up and thought out, clearly explained, and the interpretation and discussion of the results was logical. The figures which accompanied the manuscript were easy to read, though some fidgeting with layout might make them a bit clearer.

Even though some parts of this paper went over my head a bit, I was able to understand the importance of a study of this kind because it not only has local and regional water quality implications, but it is of global interest since water quality protection laws are becoming stricter as water resources become limited. With this in mind, I would support this manuscript for publication.

There were a few things I would take a look at, however:

- I did not understand some of the terms and notation such as “$p < 0.05$” in the abstract and the same on page 13, line 326. Another term I was not familiar with and was not fully explained until later in the paper was “ANOVA” and would have appreciated a definition of it somewhere earlier on in the paper before section 3.3. It is fully possible, however, that the intended reader would understand to what these would refer.
- Early in the paper the importance of these systems’ ability to function properly in cold climates and briefly mention how the climate conditions were different in the two operating years; however, the climate conditions were never discussed at length and how the different climates affected the effectiveness of the systems. I would have maybe liked to see a bit more about that.

Joe Bartlett

2/18/09

**Review of Lee et al.**

This project tested the efficacy of multiple constructed wetland configurations at treating waste from a dairy farm in Burlington Vermont. Three configurations of hybrid constructed wetlands and three integrated wetlands utilizing a steel slag filter were operated over 2 years and were monitored for removal efficiency of BOD, TSS, NH4, and DRP. The electric arc furnace steel slag filters are a relatively new method for removing phosphorous. The study found that the steel slag filters greatly increased the phosphorous reduction over the hybrid wetland systems. The 2 stage hybrid systems were better than the integrated systems for removing organics, but were not as effective with phosphorous. The study also found that time of year influenced BOD and TSS and may be an important consideration for future use.

The article is very well written and makes a strong argument for further research into steel slag filters for incorporation into constructed wetland systems. The abstract is good but is a little bogged down with acronyms that could be omitted since they are covered in the introduction. The Introduction contains a thorough literature review, but could use more information on cold climate applications and on the use of constructed wetlands for dairy waste treatment. The introduction also contains several sentences that are grammatically correct, but are far too long and would read better if split into two sentences. The methods section is very good and concise. The results are well written and are fairly clear, except for the semivariogram descriptions. I am not familiar with these and was not able to ascertain their meaning from the description provided in the article. The only major improvement needed in this article is more discussion. If the results and discussion are split into 2 sections it would be easier to elaborate on the discussion. The conclusions are good and the final sentence is an excellent conclusion for the article.

The paper should be accepted with moderate revisions to the Science of the Total Environment journal. The use of constructed wetlands in cold climates and as treatment for dairy waste needs to be covered better in the introduction and a paragraph should be added to the discussion to describe future research needs and potential complications/concerns. Specific recommendations for improvements are as follows:

- L48 hold off on all of the acronyms until the body of the paper, they make the abstract cumbersome and I don't think you typically see acronyms in the abstract
- L63 the abstract could use a better ending sentence
- L90 Don't start a sentence with a citation
- L108 the section on EAF slag filters is choppy but a good lit review
- L249 The figure caption says log scale so you don't need it here
- L256 I am no familiar with semivariograms but this makes no sense to me…consider adding in some explanation of semivariograms
- L315 Can you give a more accurate retention time estimate? Did you or can you test this?
- L329 Need to add some numbers to Table 1, not just the ANOVA categories
- L365 Elaborate more on this citation
- Consider adding subheadings for each water quality parameter in the R&D

February 17, 2009

UVM internal review of:

> Evaluating the efficiency and temporal variation of a pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrated effluent
>
> Authors: Martin Lee, Aleksandra Drizo, Donna Rizzo, Greg Druschel, Nancy Hayden, and Eamon Twohig

This paper is used to show the performance of 6 small scale constructed wetlands used as a dairy waste water treatment system. The wetlands were comprised of two main system types hybrid and integrated systems. The systems were run for two sessions during the summer of 2007 and 2008. During this time the injection method was modified from a timed injection to a continuous injection system reducing the retention time by upwards of 50%. To analyze the performance of these systems by measuring the reduction in total suspended solids, ammonium, biological oxygen demand, dissolved reactive phosphorus, and changes in pH. The findings of this paper show that seasonal temperature changes may affect the performance of constructed wetlands in regards to total suspended solids and biological oxygen demand removal. Although differences in performance were seen throughout the study times it was statistically significant difference for the later part of the 2008 summer, showing that the superior performance of the hybrid wetland systems. In addition to these finding are two items of further interest. During times when there was a large amount of macrophyte biomass there were higher levels of organics removal. The slag filters that were used in the hybrid systems were also shown that pH levels could be drastically increased; showing average effluent pH levels of 11.

This paper shows a wealth of valuable information that has been provided in a logical manor. The first illustration showing the system is quite well displayed showing how the wetlands are systematically arranged and the sampling points that were used in the data collection. The illustrations allow the reader to easily assimilate the information that was collected. The quality of writing in this paper is quite good with little confusion throughout the entirety of this paper; with the exception of a few sentences. The organization of this paper does need some improvement; particularly in the results and discussion, and the conclusion sections. In the results section the author gracefully displays the findings of the report however seems to hold off any interoperations until the very end of the conclusions section. That being said this section could easily be renamed as the results section and move the discussion to a separate section. Additionally some items from the results and discussion section could be moved up to the introduction to answer some questions that the reader develops earlier on.

This paper has a great data set showing the changes in the 4 tested variables and how they change over time. It also shows how steel slag may be integrated into a waste water treatment facility to lower the reactive phosphorous load in effluent. It also gives most all information necessary to set up an identical system and sampling scheme so that it may be exactly repeated. Due to these I believe that this paper should be accepted with minor revisions.

- The author does a wonderful job showing all of the results that were taken from that data collected at these sites. However this section needs a bit more organization. On pg 11 lines 274-279 the author goes through an explanation of the underlying principals that govern ANOVA. This seems the most out of place and should be brought into the introduction or data analysis section of this report.
- The author clearly presents the changes between the influent and the effluent by showing the percent reduction of the variables in a well laid out illustration. There are two things that must come into mind when looking at this plot. The first is that it will most likely be reduced in size when being printed in a journal making reading them more difficult. To combat this it may be necessary to separate it into two illustrations. Although this shows the performance of the system it leaves the reader questioning if there were significant changes in the

concentration of the influent and how the magnitude of these concentrations may have effects on the overall performance of the systems. An additional plot of the total concentrations in the effluent for the same time periods would allow the reader to make their own interpretations, but it would be necessary to note that there is a time lag between the fluid at the inlet and at the sampling points.

- The semivariogram shown in illustration 3 does show that there is a seasonal difference in the performance of the wetlands. However prior to reading this report I had no knowledge of semivariograms and how they are used only after some careful reading through a geostatistics textbook did I have a limited understanding of how this works and how to interpret the graph. I can only assume that other people have similar limitations in their statistical knowledge showing that this is an area of the paper that needs improvement. If the reader had some knowledge of this system beforehand the caption on the graph would probably be sufficient. It would be nice to have an additional paragraph in the analysis section of the report that explains this system to the reader so that they may make their own conclusion.
- I enjoyed seeing the modeling that was done using SEEP/W but did not understand how they related to the rest of the paper or why they were not mentioned again in the discussion section. This particular part should be elaborated on in the discussion section of the report as using the ideal flow for this system seems to be taken for granted. The percent solids and viscosity of the liquid going into the wetland will most defiantly change the flow pattern due to the development of preferential flow paths. In anaerobic systems using a similar influent these preferential flow patterns have been seen to reduce the residence time of to less that 30% of ideal.

After reviewing the journal's submission guidelines everything in the paper seems to be in order with one exception. Figures must be presented in a way that would allow up to a 50% reduction in size so restructuring of figure three is strongly recommended. Best of luck with your submission.

Sincerely,

Jaron

Paper Title: **Evaluating the efficiency and temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrationed dairy effluent**
Paper Authors: M. Lee, A. Drizo, D.M. Rizzo, G. Druschel, N. Hayden and Eamon Twohig

Reviewer: **Lance E. Besaw**
Date: February 18, 2009

**Summary**
The authors have designed and built several constructed wetlands with different hydraulic loading schemes for treating farm effluent. In addition, they implement a steel slag filter in attempt to remove phosphorus (P) from the effluent. By collecting data over two summer sampling periods, the authors analyze the treatment efficiencies of the different constructed wetland designs. This comparison was completed using finite element models, time series analysis and analysis of variance (or ANOVA). They found that the different constructed wetland configurations do have significantly different nutrient removal rates and the steel slag filter successfully removed P from the farm effluent.

**Evaluation**
In the introduction, the authors highlight the need for greater understanding of how these systems operate in cold climates. They even state that treatment efficiency is reduced during winter months. This appears to be motivation for their research, but this study only used data from the summer months.

In the methods section, more detail should be provided about the wastewater influent being treated. In the Adjusted Hydraulic Loading Rate section, the authors present an equation to approximate the flow out of the CWs. Does this equation hold true at the scale of the CWs (areas equaling 1.87 $m^2$). Was this equation developed for use at this scale? How does the assimilation of data from multiple scales (e.g. precipitation and relative humidity are hourly while solar radiation is monthly average for the given latitude) affect the results? Why wasn't $Q_{out}$ measured?

Time series analysis was used to separate CW systems with different characteristics. The efficiency of these different groups was then compared using ANOVA. I though we already had categorized CW systems. Why are these further being grouped by time series characteristics? Don't we want to test for example: does hybrid CW "A" do a better job than integrated CW "B"? Looking at Table 1 it appears that the author have in fact grouped CWs by category (hybrid vs. integrated) and loading direction. It is unclear to me why time series analysis was used.

Regarding the data quality. The data collection and analysis methods appear scientifically correct. Did the authors perform any repeat sampling to determine the amount of variability in their sampling/laboratory methods?
The figures provide a lot of information to the reader. Figures 3 and 4 could use some work as they take up lots of space. In addition, the authors state Figures 3 and 4 are

representative of the semivariograms, could the author instead provide the ensemble variograms for the different constituents? This would provide the reader with more information and provide evidence of the authors' claims that they operate at similar/dissimilar scales.

In addition, some comments about the relative "pay-off" for the various treatments would be useful to the reader. For example, by passing the effluent through 2 HF CWs in series (effectively doubling the CW area) instead of 1 HF, the TSS is reduced from 2310 to 550 (influent was at 22000). So doubling the area results in reducing the TSS by a factor of 40 (22000/550=40), while the single area only reduce by a factor of ~2 (22000/9820=2.24). This could be an important component of this paper.

**Recommendation**

Overall, I think the manuscript is well written and it contribution is significant. The breadth of methods and analysis is very impressive and provide distinct evidence that particular CW systems operate more effectively than others. I recommend the manuscript be accepted with major revisions. Those revisions being presented previously and in the following section.

**Specific Comments**

Stay consistent with CW as an acronym for constructed wetlands.

In the methods section you mention feedlot runoff concentration varies with precipitation, but I think you should also provide a range of concentrations to give the reader an idea of the variability associated with these systems. Is the mass loading rates generally similar (only to be more or less diluted by rainfall)?

How do the different flow regimes (pulse in 2007 and continuous in 2008), and subsequent hydraulic retention times (5 and 2.5 days respectively), affect the results of this study?

In the results section, you state the CWs perform significantly different at the beginning and end of summer, as determined by way of semi-variogram analysis. I would prefer to see some other statistical tests run to come to such a conclusion (e.g. t-test). Are there physical justifications for this (i.e. temperature)?

Meredith Clayton
18 February, 2009

Evaluating the Efficiency of Temporal Variation of Pilot-scale Hybrid and Integrated Constructed Wetlands for Treating High BOD and P Concentrated Dairy Effluent

This paper illustrates the results of a study conducted to evaluate the performance and temporal variation of pilot-scale constructed wetlands. More specifically, the study included a total of 3 hybrid and 3 integrated saturated flow constructed wetlands. Hybrid systems consisted of a total of 2 constructed wetlands in series that were either vertical flow followed by horizontal flow, or both horizontal flow CWs. The integrated systems used in this study consisted of either a vertical or horizontal flow CW followed by an electric arc furnace steel slag filter for removing phosphorus. During the first year of operation, August to December 2007, the systems received a daily pulse of wastewater with a hydraulic loading rate of 0.038 m/day with a nominal residence time of approximately 5 days. In 2008, during the months of April to September, the mode of operation for the CWs was changed from pulse to continuous flow with an HLR of 0.081 m/day. Throughout both years, weekly monitoring of five day $BOD_5$, TSS, $NH_4^+$, DRP, and pH were carried out. The treatment performances of the CWs were evaluated for both trial periods. This was done through the use of time series analyses, one-way ANOVA analysis, and geochemical modeling of the minerals that formed on the steel slag. Time series analyses indicated that measurement points are not totally independent and should be separated into two groups. This also revealed that TSS and $BOD_5$ had a similar range of correlation to temperature suggesting that temperature may affect performance in constructed wetlands. ANOVA results show that hybrid systems are more effective at organics removal than other CW systems; however, integrated systems consistently outperformed alternative systems for phosphorus removal. Geochemical modeling demonstrated that EAF steel slag P removing filters can be used to achieve high phosphorus removal to supplement TSS and BOD removal, but that additional research should be conducted to address the problem of high pH effluent that occurs as a result of the filters.

Overall the organization of this paper appears to be well thought making it easy for a reader to follow the sequence of events reviewed in this manuscript. The writing clarity is also good but I have noted several places in the text where the use of run-on sentences detracts from the paper. You have provided logical interpretations of the data presented and this is further emphasized in the figures appended to the document. Despite the fact that these interpretations were logical, I had many questions arise, surrounding the analysis, including the figures. These questions are described below.

1) the effect of differences in climactic conditions on the performance of the CWs. This question is addressed in this paper (time-series analysis, etc), but I was not adequately convinced that this comparison was sufficient. You have identified that measurement points are not completely independent and therefore should be separated into May-June, and July-September but what about 2007 vs 2008. You have acknowledged a difference but I would like to see more about what other affects might be present here on a year to year basis, particularly with respect to precipitation, (which you have indicated as a factor

that influences performance). There were major differences in the precipitation during these two years. Overall, the yearly total is similar; however, a closer look at monthly variation yields substantial differences. How might this have affected your results?

2) Yearly differences. I have touched on this in the previous point but I wanted to explain that the yearly difference seems important as a whole, because your conclusions are so heavily dependent upon your 2008 results. In fact, you only reference results from 2008 in your abstract and conclusions.

3) Implications for the use of CWs in cold climates: you have indicated that this research is intended to aid in the design and use of CWs in cold climates however, you have not elaborated on how these results support this cause

4) Figures: you should consider having more info about how to interpret variograms. To an outsider these are pretty strange looking! Also, it would be nice to see your log scales match to compare the results more easily between trials.

5) Discussion section: I think you should have a separate discussion section to discuss the results. A discussion section would likely contain answers to many of the questions I posed above.

6) I think that you should elaborate on the decision to switch your mode to continuous flow for 2008.

Overall, I think that this is a well-written paper that should be accepted by the journal following some revisions such as those described in my in-text review. Nice work!

Mark Isselhardt

Critical Writing (Geology 371)

2/18/09

Lee, M. et. al, 2009 Evaluating the efficiency and temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrated dairy effluent **for submission to Science of the Total Environment**

Two constructed wetland (CW) designs are compared in terms of dairy wastewater nutrient removal capability in this paper. The CWs were monitored over two years of operation and the data used for temporal analysis. The two CW designs (hybrid and integrated) were additionally characterized by the flow regime (horizontal or vertical flow) within each CW's two cells. The hybrid CW design is referred to as a well established technology. The integrated CW includes a steel slag filter (not present in hybrid CWs) to remove phosphorous. These systems were run for two seasons (2007 and 2008). The influent flow regime was changed from pulse to continuous flow in 2008. Analysis of %BOD, DRP and TSS reduction is presented for each year. The results show that the integrated CW is very effective at removing DRP from the influent. Additional analysis was undertaken to characterize the mode of phosphorous removal. The results of the hybrid systems efficiency at removing BOD were mixed.

This paper is clearly written, has a strong organization and presents interesting and original work. The introduction was able to effectively set the stage for the experimental work to come. The methods section (field and lab work) were detailed and included relevant information. The results section is large as would be expected with an experiment of this complexity. The conclusions section seems a bit short considering the amount of data collected. The figures provided help to illustrate the experimental setup and the resulting data.

This paper deserves to be published with major revisions. Here are a few suggestions that would not fit into the margins of the paper. Please refer to the corresponding number on the marked up paper copy. A few broad areas could be strengthened to the benefit of the entire paper. First, it is acknowledged that the experimental design violates the assumption of sample independence for ANOVA. How was this conflict resolved? There was some discussion of a cold climates impact on the CWs ability to function. It seemed like the subject was dropped in the results and discussion. The nutrient reduction data for 2008 included some cold weather months but no mention of air temperature. Some inclusion of temperature data along with figure 5 would make for a more direct connection to the climate. Is the use of the semivariogram necessary? It seems to be the least compelling part of the paper and the one more open to interpretation. How do the results of temporal analysis change what CW design is used?

1. This section is heavily dependent on figure 1. Could the CWs be identified as Hybrid 1, H2… and Integrated 1, H2 etc? This way the reader can learn about the flow regime once and refer back when necessary.
2. Why is evapotranspiration added to the flow out rather than subtracted?

3. Why is the influent data from figure 4 fitted to a linear model? Did you try fitting the data to other curves?
4. A. This section is a little hard to follow given that the X axis on figures 3+4 are in days and the text talks about the results in terms of weeks.
   B. The graphs (and data) for temperature should be included in the results/discussion. The reader should have a chance to see what is being reported.
5. How was the lack of independent samples in an ANOVA resolved?
6. This paragraph could use a table of summary stats. It would help the reader to see what the various CWs mass loading rates were and how they compared between one another.
7. Where samples taken of the steel slag before and after? How quickly is the slag become saturated with phosphorous?
8. Make sure the caption for Figure 7 clearly describes what is being measured and where the samples were taken. Is this a single event or are these samples from an entire season?
9. Where the measured parameters and CW designs placed in a correlated with other broader environmental variables (mean air temp, precip, etc.)?
10. In figure 5 there appears to be a gap in the data collection from the third week of June 2008 and august 22-23. Did the lack of data between these dates contribute the presence of two periods?

It appears that the manuscript deviates from the guide to authors in the headings for sections. Review this section and the section on reporting values of statistical significance to bring the text more in line with the journals requirements.

Great paper, nice work Martin.

Paper: 'Evaluating the efficiency and temporal variation of pilot-scale hybrid and integrated constructed wetlands for treating high BOD and P concentrated dairy effluent' by Martin Lee

Reviewer: Nikos Fytilis – 02/18/09

Constructed wetlands are used worldwide to effectively remove organic matter and total suspended solids. The motivation of this research lies in the fact that there is no data on the performance of systems treating dairy effluents, especially in cold climates. Also, there is need for additional research to improve the nutrient treatment performance of dairy wetlands and to expand their longevity in cold climates. The performance and temporal variation of 3 hybrid and 3 integrated CWs were tested and the weekly results as well as the monthly monitoring results were evaluated for each operation period and each mode of operation. This study introduces a new integration method of CWs with slag phosphorus filters in pilot-scale systems by controlling at the same time the inflow, the adsorption and precipitation reactions. After using statistical methods, it is clear that integrated CWs remove significantly more phosphorous and ammonium but the hybrid CWs were more efficient for removing BOD.

The abstract I believe that it could stand alone and presents perfectly your research. I believe that the introduction is big but it is well organized. My opinion is that you mention all the necessary information for your experiment. I really liked the fact that at the end of each paragraph of the introduction, you describe some difficulties which in the next paragraph you overcome using recent related researches (page 3). The part where you describe the methods is well-written and the subsections are perfectly organized. I would like to see more information about your experimental setup (Why you change the mode of operation? ,Are there any other ways to analyze your samples? )

The results and discussion were well supported from the figures but in some of them I couldn't clear understand how you come up with some numbers. I would like to see what ANOVA in general does and what other applications has this method. On page 14 in the last paragraph, you point out a difference in BOD concentrations between the two operation periods but it would be helpful to mention the related figure so the readers can easily justify your result.

Due to the fact that I heard about your project many times and I particularly interested in waste water treatment systems I found this paper extremely interesting and helpful. I think that this paper can be published with minor revisions. Good luck.