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Interactive Routine for Bioreactor Design and Evaluation
Transcript

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Cyd Curtis
Hi, all. This Cyd Curtis with US EPA. And I would like to welcome you to the ninth in our webisode series that stemmed off our initial Nutrient Strategies Workshop back in June of 2011. Today we have Richard Cooke with the University of Illinois talking about the interactive routine for bioreactor design and evaluation. I can see people have been using the polls below so it looks like we've got a nice mix, but predominately federal, state, and university folks for now on the line. So without any more delay I'd like to hand it over to Richard.

>>Slide: Protocol and Interactive Routine for the Design of Subsurface Bioreactors in the Midwest
Richard Cooke
Okay, thank you much for this opportunity to present. Today I want to talk about routine we that have developed for the design and evaluation of subsurface bioreactors. And it says in the Midwest because in addition to the routine we have developed a database for sizing and evaluating these systems across the Midwest.

>>Slide: Third Generation Bioreactors
Now this is based on the bioreactor design which we have used and has been used by several people across the Midwest where we have a bioreactor at the end of the tile system. So there is a structure there, a diversion structure, which is used to divert the water into a subsurface trench filled with wood chips, a capacity control structure to adjust the residence time in the system. And this is our third generation bioreactor. We have made several changes to the design over time based on now, the results. And this is the one that we think works best and probably we will use it for a while.

>>Slide: Top View
You can look at it in plan view and you can see this would be the normal tile, it's diverted, there's the manifold there to spread the incoming water across the width of the bioreactor and then the water flows through the wood chips. It is collected in this manifold and then back into the ditch.

>>Slide: Combined System (animated)
We have developed systems where we have combined the structures together into one. And this is an example of such a system. And I will show you how the system works. The water comes. We have a set of gates. Water is diverted, it spreads out across the width of the inlet manifold and it flows down through the system and into the outlet manifold and flows out back into the system. With this design we only use one structure and we have to intercept the tile in one place. And we don't have to create a second outlet.

And so in the design of the system, what we want to do is to size the system so that we get most of the water flowing through the system. It various -- if the incoming rate exceeds the capacity of the system then there would be some water which bypasses directly out of the system. And we want to reduce the bypass flow by adjusting the capacity of the system. But we also want the water to stay in the system for a certain period of time so that the bugs have enough time to break down the nitrates in the system.

>>Slide: Photo Slide (Top view of system, 3 gates circled in red)
This shows an example of one system. You can see three sets of gates. The first set of gates can be used for drainage water management so we can use these systems for both the drainage water management and for bioreactors. So this would control the water level in the field. This is the bypass, this is where the water -- this causes the water to bypass and go into the bioreactor. And then this is the third gate. And then the difference in the elevations between this second and the third gate determines what the flow rate would be through the system. The height of these determine what the capacity of the system is.

>>Slide: Photo Slide (Water flow in the bioreactor, water inflow and v notch circled in red)
And this is a picture taken from a bioreactor which is actually working. So this is where the water comes in. It flows over through this v-notch there so we have our systems instrumented so we can measure the flow. It goes into the bioreactor and then it comes out of the bioreactor. If you look at the water I guess the difference is in the color of the water to show how the system is working in this particular case.

>>Slide: Bullets (Bioreactor Design, Historic Weather Data, Operational Settings)
Now this protocol that we have developed and the routine we recognize that bioreactor design is a complex balance between flow rate and residence time. We want high flow rates through the system so that we don't get much bypass. At the same time, we want the water to be in the system for a specified period of time so that we can get the greater breakdown of the nitrates.

So what we have done in this routine is to use historical weather data, soil, and drainage system layout to evaluate the bioreactor performance. We didn’t specify levels of uncertainty.

In the design the operational settings that is the stop logs setting as to how the bioreactor will be operated are incorporated into the design procedure.

>>Slide: Main Interface
This is the main interface for the system. And you know there are a series -- each one of these buttons, it's a new interface where one can go and make some adjustments to the system. And we are going to go through these in a little while.

>>Slide: http://www.wq.illinois.edu/dg/
But first, I want to mention that one can go and download the program. If one goes to the Illinois Drainage Guide and the website is given here. It is www.wq.illinois.edu and you can Google the drainage guide online and you'll get to there.

>>Slide: Screenshot (Drainage Guidelines, Sample Files, MS Controls)
And then if one goes to the conservation drainage to that area then right now if you go you will come up with this program on the bioreactor design and also a setting for webinar files. So if one wants one can go in and click on this link and download this program and a couple of sample files and can run -- they can run the program either now or at the end of the webinar. I should also mention that to run this system there are a couple of Microsoft controls that are required. Particularly the MS Chart 20 control and if this is not on the computer already then whenever one tries to one the programs you will get an error message saying that this is missing. And then here on the drainage guide one can go and download this and then run the program as well. If it's already on your computer then you won't get that error message.

>>Slide: Dropbox Screenshot
So on that, if one clicks on the webinar files then there would be these three. This is the actual

executable program. Here is a file daily drain flows for Champaign with one soil type Drummer for 30 years. And then this other sample file from Minnesota. Its 90 years of daily flow, simulated daily flow from Waseca, I think, which was supplied by Dr. Gary Sands.

>>Slide: Run-time Error Pop-up Example
And as I mentioned, when one opens the program you will probably get an error such as this is the Microsoft chart control is not already in your computer.

>>Slide: Run as Administrator
And then if this error comes up, you know, it's in that webinar file, one can just download that chart control. Right click on it and run as administrator. And then it will be on your computer from then on. And then one can run this program or many other programs that are on the drainage guide.

>>Slide: Pop-up Help Screens
So in addition to these boxes with the different aspects of the program, there are these kind of help boxes and the help boxes are this other blue color. I don't know how to describe this color. This darker blue color. And almost for each command or everything there is a pop-up box. And this is based on feedback we had with Dr. Ruth Book from the Illinois NRSC who thought we should add these to make it more user friendly. So for example, there is a thing there for bioreactor thickness and if you click on it, it gives you some information about what this does.

>>Slide: Contributing Area (Size and Slope of Outlet Pipe)
So in the program there is opportunity for determining the contributing area of the bioreactor that one is going to do the design for. There are different ways that the contributing area can be determined. It can be based on the size and slope of an outlet pipe. So nothing is known about the system except looking at the outlet pipe and there is a link there so that one can determine what the contributing size would be based on the size and the slope of the pipe. Now that may be a little misleading since contractors tend to use a bigger pipe at the outlet of the system. So on a system with an 8-inch pipe they might use a 10-inch outlet typically. But at least that is an estimate of the -- that is an estimate of the size.

>>Slide: Contributing Area (Tile Lengths and Intersection Angles)
Another estimate is based on the layout of the system if one knows like the length of the tile and intersection angles of the tile then there is a routine in the system for estimating the area based on this.

>>Slide: Contributing Area
So if one chooses and clicks on the contributing drainage system and clicks this option then it's just a matter of counting up the length of the tile, see what the tile spacing are, the number of tile ends excluding the outlet and the intersection angle. If the intersection angle is unknown then it uses like a 45-degree angle. Otherwise you can put in the known angles if they are perpendicular then you can specify that as well. And it will come up with an area based on that. And then this number will be incorporated into the main screen.

>>Slide: Woodchip Properties
Another thing which the design of a bioreactor, we need information about the woodchips and properties, particularly the flow properties. What is the drainable porosity of the woodchips and then what is the hydraulic conductivity of the medium, the water through the system. One thing that we are working on is a low-cost piece of equipment to measure woodchip properties. And this is shown here, one of our original designs. So we developed this and then we determined some woodchip properties and those are listed on the routine. And with this instrument, one can load it so if for example, you are going to have your bioreactor on 2 feet of soil you can put in the woodchips and load it with an equivalent to 2 feet of soil and determine the properties on that configuration.

With this device we developed it and sent it off for review. And then the reviewers they had some problems with the system. There are a couple of comments that they asked why did you use one which was only 20 inches high? And so what we are going to do is experiment with different lengths of system. Different sizes and to see how that makes the difference. There are also some comments about putting in these millimeters. In our original model, we use the millimeters to determine the upstream and downstream. And in our final prototype we left them off. But it seems like they would like to see these back on. And then there was -- we proposed using measurements at three different heads to determine the hydraulic conductivity of the material. And what the reviewers were saying that their previous experiments show that there is a nonlinear relationship between head and hydraulic conductivity especially at low heads so three might not be enough. But right now our system, we had originally updated this nonlinear relationship and we went in and changed the plumbing to remove this nonlinear relationship. So we are continuing to work on this and over the summer we will continue to come up with such a device so that woodchip properties can be measured fairly inexpensively and quickly. And we can obtain data which are specific particle sample of woodchips.

>>Slide: Sizing Criteria
In terms of the bioreactor sizing, how one designs a system, the protocol can be used to size a system based on three different criteria to optimize it based on the flow rate, the residence time, and the performance. So one can decide what criteria you want to use for all three. One or more of these criteria can be used in sizing the system.

>>Slide: Design Flow Rate (10-year, 24-hour)
We recommend a design flow rate for the system ideally based on a 10 year, 24 hour drain outflow event. And this way this way if we use this value we can assign some probability of exceedance or some level of uncertainty with the design and this is not unheard of in the design of systems. For example, in the design of grass waterway the 10 year, 24 hour runoff event is used for sizing grass waterways and also used for constructed wetlands. Now it might be -- it's a much easier to determine the 10 year, 24 hour rain runoff event than the drain outflow event.

>>Slide: Design Flow Rate (DRAINMOD Simulations)
And so what we have done is to incorporate simulations using DRAINMOD which most people are familiar is a program for doing drainage design based on historic weather data for a given solid properties and with the drainage system layout. And we have incorporated the running of DRAINMOD in the program and to this end we have built a database of weather files, climate data for daily rainfall and maximum and minimum temperature across the stations -- across the Midwest.

We have one station at least one station for every county in a 10-mile, 10-state region of the Midwest.

>>Slide: Midwest Database
And the states that we have this database up for it is North and South Dakota, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Ohio, and Michigan.

>>Slide: NRCS Midwest DWM States
And one of the reasons why we chose these states is based on a map produced by the NRCS that shows the suitability of cropland for drainage water management in the Midwest and we thought that this is an area where we have drainage and areas that are suitable for drain water management and we can typically use bioreactors there as well. So we developed the database for all of these counties in these particular states.

>>Slide: Select a State Menu Screenshot
So then if one wants to do a simulation for a particular county and a particular soil type then the first step is to select the county -- I mean select the state.

>>Slide: Select a County Menu Screenshot
After the state is selected it comes up with a county map and then one can get through and select the particular county

>>Slide: Select County-specific Weather and Soil Data Menu Screenshot
and then also look at the soils which are typically drained in that county. And we get this from the list of hydric soils, the National Hydric Soil List and then when can select the particular soil or any soil in that state for that matter.

>>Slide: Generate Daily Flows Tool
And then the next step then would be to do a drainage simulation. So if one selects the particular county, there is a rainfall file and temperature file formatted for DRAINMOD for running the model and there and then one can specify what the drainage depth and spacing would be and then the crop they typically do for corn, soybean simulation. And we don't have much soil data from across the Midwest. In Illinois we have representative soils -- 24 representative soils that we have detailed information for and we use those to simulate most of the soils that require drainage. What we have done in the routine and we have it as an external routine on the drainage guide and we are in the process of incorporating it into this routine is the ability to come up with some estimate for the soil properties.

>>Slide: DRAINMOD Soil File from Soil Texture Menu
And what this does, it uses -- one can go to the NRCS official website and then it can get information about the texture of each layer of the soil and then based on that, using the principles and the ROSETTA model and then there is a link here to the model as well then one can come up with more or less an estimate of what the soil properties would be just based on the texture. And then if one has more detailed information then it's possible to do that as well. But this at least is a first cut to determine what the soil properties would be.

>>Slide: EDF for Daily Flow
And then after that one there is a simulation. It simulates it for the length of the period, typically 30 years or more. And then based on that it comes up with the relationship between drain flow and the probability of exceedance of what the daily drain flow would be over that period. It does it for the entire year and it also does it for

>>Slide: Monthly Design Flows
each month of the year as well because the probability of getting a certain drain flow varies according to the month. And you get different patterns in different years. This would be rainfall pattern, drain flow pattern for Champaign in Illinois. And you can see this would be the main with a 10% probability of exceedance, and then this would be the monthly flows with a 10% probability of exceedance as well. Alternatively what this can be done if one wants to use like a given value for the design of the system, say I want to use a certain flow rate through the system then this routine can be used to determine what is the return period associated with that drain flow and what the corresponding monthly drain flows would be for that system.

>>Slide: Performance Curve
And then there is an option here for determining some kind of performance and what we have here is we have input the performance of bioreactors in Illinois, the relationship between the loading density in terms of how many acres per 100 square feet of bioreactor to get a certain load reduction. And this was based on some field work done here Illinois. And it is such that if they are information -- there's information on performance from a different state then one can go in and change these parameters to represent that particular curve or if there is no information on performance then, you know, this can be left out.

>>Slide: Illinois Performance Curve
And this shows some of the data which we use to develop our curve. And each year as we get more data then this curve is updated and so we can use that for performance.

>>Slide: Cost Analysis
The routine also has an option for determining the cost allowance. And here it uses based on the cost, expected life of the system, the capacity, the cost of the woodchips, etc., installation costs, and based on the historic record it determines what average annual drain flow is over that period. And so far we have to specify what the average nitrate concentration is. One of the things we hope to do is to do simulation based on DRAINMOD and where we can get this as well. But for now one has to specify that. And then based on the performance it determines how much nitrate has been removed and then come up with a cost of nitrate removal. It's just like an estimate of the cost of the system.

>>Slide: Length/Width Effects
Then we can use the system to look at length and width affects. So here, you know, on this screen we can look at like a critical period of the system. So say for example, we say the critical period of upstream gates are 24 inches and are downstream is 7 inches, we can do like an update here and it tells us that based on the properties of woodchip properties or area, etc. then our actual flow capacity in this setting would be that whereas our design flow is based and give us an idea of the anticipated -- this as a function of the flow and then the hydraulic residence time.

>>Slide: Length/Width Effects 2
And then we can like adjust the length and the width so that if we can -- if we increase the flow rate then that leads to a decrease in the residence time. And what we have done is included a type for performance analysis so that we can optimize together over the residence time and the flow, we can size it to optimize both of these conditions.

>>Slide: Manual Optimization
In this screen we go there and we say this is how the stop logs would be set at different times of the year. So this is where we can incorporate actual operations. So we are designing the system based on how the stop logs will be set and we have up to six settings over the year -- one can use less than these. And based on these settings, if we press our update button it uses our monthly flow and then the probability -- the percentage of the flow on any given day in the year based on historic record to come up with an estimate of the bypass based on our monthly design flows. And then the load reduction is adjusted based on the percent that bypass the system. We have the option also –

>>Slide: Automatic Optimization
we have automated optimization procedure which would immediately optimize the system to meet both residence time to size the system based on residence time and flow rate criteria so that we are always above our maximum monthly flow rate and above our critical residence time which we specified in the system. Our critical values are in red and then the actual bioreactor performance of flow here is the capacity of the system at any given time based on these gate settings are here. And then we can adjust the gate settings and do the optimization again and then we can do that.

Now we also have the option of changing the size based on a load reduction if we have performance information. We can change it either based on the bypass flow or based on -- we can design a system to get a certain percentage bypass or we can come up with a load reduction.

>>Slide: Incorporating Performance
Typically we try to design the systems so that we get between 50-80% nitrate reduction. And that's because we don't want to remove all the nitrates because if we remove all the nitrates then the bugs will

have to find some other source of food. They tend to break down the sulfates and that can lead to other problems as well. So this is how we have the system. So we can size the system so that for example, the minimum design flow is 80% of the maximum monthly flow. So we can play with this and then we can adjust the size of the system that way. Right now we don't have any penalty for residence time and that is one thing that we are working on. I will talk about that in a little minute -- in a minute.

>>Slide: Report Generation
And then after the design has been done there is an option then to create a report. This report is in the form of an Excel file with all of the information that we have done in our sizing.

>>Slide: Report Generation 2
And this is what the report would look like. It's an Excel file. It is more or less three pages and there's an option to add more. And actually we are going to add more information depending on some feedback that we have gotten from some others as well.

>>Slide: Future Work: Residence Time
And some other things that we are doing -- future work we are doing is how do we add penalties for reducing the residence time. Right now in our design we typically use 3.6 hour residence time based on some of our field work. And, you know, we use the same residence time throughout the entire year.

>>Slide: Aerial Image (3603 S Race St, Urbana, IL)
Some of what we are trying to determine, you know, what would be -- how does temperature, air temperature and water temperature affect what the residence time would be. And we have set up a system where we have bioreactors at the outlet of three different drainage systems and different drainage system layouts, and we are monitoring these overtime.

This past year was a very dry year so we did not have flow in the tiles but we started having flow in the tile system sometime in December and what we did when we did not have flows was we pumped water from the pond into the tanks which we passed through the bioreactors. We can adjust the flow rate and the residence time to the bioreactor and we see how that varies with temperature.

>>Slide: Preliminary Results
And this is some of our preliminary results and you can see the relationship between temperature and the percentage reduction in our nitrate concentration. And we are continuing to do this for the entire year at different residence times to see what that relationship is. And we will use these data to inform or to improve our routine.

>>Slide: Future Work: Nitrate Loads
Another thing is nitrate loads, as I mentioned. This has to be supplied by the user and we are trying to come up with a simulation using DRAINMOD. So right now we use simulations to determine the daily flow -- the distribution of daily flow with the start record. And what we are going to do is we have developed more or less properties for 12 Illinois benchmark soils and then we are going to do some simulations with DRAINMOD and compare that with our actual observed data to see if we can come up with some calibrations to determine on a different depths spacing for different size, different historic rainfall pattern what this average would be so that we can update the costs of the system.

>>Slide: Acknowledgements
So this is then what the routine is all about. I was hoping that I could run the routine if we can get it to show on the screen. And we can probably -- others can probably run it together on the site I mentioned. We have a couple of sample files, etc. I would like to acknowledge some of the support for this. Initially developed for the Illinois NRCS as part a Conservation Innovation Grant and then we have supplements from others such as like the Sand County Foundation and the initial concentration of

bioreactors was funded by the EPA. And the development of our database was funded or has been funded by the Great Lakes Regional Water Quality program.

All right, with that I would like to say thank you. And I could probably answer any questions.

Cyd Curtis
All right, thank you, Richard. So we are going to shift gears a little bit. We've already gotten a couple of questions that came in through the chat box. For those of you that are also listening in this is a good time to if you have questions that came up through the presentation, we can certainly type them in now and answer them. So the first one came from LT and the question is: are there any concerns for bioreactor maintenance either for prolonged saturation or in the case of last year's prolonged dryness?

>>Webcam: Richard Cooke
Richard Cooke
We learned a lot last year with the drought and I guess we probably have to update what we think the life of the system would be because in our bioreactors last year it was very dry. We saw a rapid decrease in the quantity of woodchips. So we've lost a lot of woodchips. We lost more of last year in a dry year than we did, you know, over say probably four or five wet years. So that is something that we didn't even think about but we have to say what do we do in the system when it is dry. Do we fill the systems and leave them fermenting and the woodchips are not? So that's the question and we welcome answers, some answers to that.

Cyd Curtis
All right, the next question is from Mark Dietrich. Managing stop log heights. If the land owner is interested in a bioreactor, must the DW agreement accompany adjacent fields or is this system designed so there is no impact on the adjacent farm fields?

Richard Cooke
Okay, so what we did is one can adjust the stop log settings based on what is recommended for drainage water management so that we would not be in violation of these rules. And then it depends, the stop log then should be set so that there is no impact on the adjacent fields. So the question is how would the farmer adjust his stop logs and then based on what these adjustments are which he thinks, for example, he thinks that before some time in spring I'm going to load these things way down so that there is no backup water in the field then that is taken into account in the design if that is specified a priori when we are doing the design. If the bioreactor is in a much lower area than the field, then one can adjust the stop log difference. So the option is at design time to adjust the stop logs as to what the farmer thinks is best or what is in line with the drainage water management plan on that field.

Cyd Curtis
All right. The next question is from Keegan. Once you download the program does it automatically update or does it need to be done manually?

Richard Cooke
Once you download the program, I don't know if you mean update the program or update the database. The download of the database is separate and on the website there is a link for downloading the database. And once you download the database, that's it. However, one can go in and update the database if you have more, if you have actual observed data flow over a long period of time or if you have more up to date weather or closest station than one can go in and add that to the database and change that. In terms of the program, the optimization, etc., that is done at runtime. So once you click the “Optimization” button, it redoes all the calculations for you. And if you change the widths and say you adjust the width or the area then you just click the button to optimize and it redoes that.

Cyd Curtis
So Richard, if you had updates in the actual routine program, they would need to re-download it from your site?

Richard Cooke
No, once you have the program -- so okay, when you say update you mean, you know, there are a couple of things. Does he mean updates to the database or updates to the program?

Updates to the program. Okay, so the latest program we always put it on the website. And so, you know, what I would recommend if one wants to run the program is just go on the website and get the latest version. It does not automatically update.

Cyd Curtis
Okay, thank you. All right, next question is a two part question from Chad Ingles. I saw in one of the slides an open top for the woodchips rather than covered with soil. Is this typical for the sites you are studying? Would this increase decomposition rate?

Richard Cooke
Okay, we do what we can get. If the bioreactor -- we look at both types of systems. There are some cases where the bioreactor is at the edge of the field in like a vegetative field district where the farmer will allow us to leave it, the top open. And this would be the best choice I think. One because it's easier to top off the system with woodchips and there is no compaction, there's no soil overburden and that increases the flow through the soil to the woodchips. However, there are instances where this is in an area where the farmer wants the farm over the system. And we have several of those as well. And, you know, in that case, on top of the woodchips we put some type of geo-textile material and then put the dirt back on top. And we are evaluating both types. I would say the first choice is an open top system because it is much easier to work with and the next choice then would be, if we can't do that then we would go with one with some soil cover.

Cyd Curtis
All right. Thank you. It looks like we've got a couple more questions coming in. I'm going to give them a second to finish. All right, here we go. We've got -- what nitrate reduction rates were used? That question is from Keegan.

Richard Cooke
Okay, nitrate reduction rates, I am trying to understand the question. Nitrate reduction rates were used where typically in all systems we do, we put in -- we look at inflow nitrate concentrations of about 12 milligrams nitrate concentration or 12 milligrams per liter. And then depending on the residence time we vary the residence time, we very the loading rate in terms of acres per square foot of bioreactor and determine what kind of reduction and then based on that we developed our performance curve which we keep updating as we get more data. I don't know if that helps.

Cyd Curtis
Yes, thank you. Mark Dietrich asks: Discharge of water from bioreactor, the oxygen level is very low. Do you design a waterfall and rocks to re-oxygenate the outflows?

Richard Cooke
Not yet but you are right the oxygen coming out is really low. So that would be an option but we have not designed that. That might be something that someone else can do and we can incorporate that into the design.

Cyd Curtis

All right. The next question is from Scott Tompkins. Have you studied any phosphorous removal capability utilizing bioreactors?

<u>Richard Cooke</u>
Oh yes, we are looking at phosphorous removal in bioreactors and I've one student who is working with that now. What we did in some of our earlier experiments, we looked at the synergistic relationship between phosphorus and nitrate removal in bioreactors. So we typically added a section with some type of iron filings and then we determine, you know, does it matter if I put the iron filings upstream of the woodchips or downstream of the woodchips and we have some results from that based on a little lab test or a pilot test. And we are looking at phosphorous removal in our field systems as well to see if the results we get in the field is anything like that but typically we use iron to precipitate out the phosphors and we are looking at iron filings and then some other engineered material for phosphorous removal. And then how do we actually put these in the field. What we are working with is more or less converting one of the stop logs into kind of a filter so that we can filter the water through this for phosphorous removal but we separate the nitrate removal and the phosphorous removal because the life of these materials might be different so we have been doing that.

<u>Cyd Curtis</u>
All right. It looks like we've got still a couple more questions coming in. While those questions are getting formulated I was thinking if you want, we will move over to your questions to the group if that sounds good to you, Richard.

<u>Richard Cooke</u>
Sure that works for me.

>>Question 1
<u>Cyd Curtis</u>
So we will get back to the questions that you all have but Richard has a couple pop quiz for you all. Question number one, when designing a bioreactor, and you can read the A, B, C, or D. Decide what do you think is the correct answer. There might be more than one answer.

And so I am showing the results as people are answering so far and Richard if you want to comment on the question. And what the answer is.

<u>Richard Cooke</u>
Typically it is I would say probably either C or D is correct as most people say you want to balance both the flow rate and the residence time. And with this routine we have provided a tool that can be used to balance both and have an idea of what the performance would be within a certain specified uncertainty and typically it's routine to design for a 10 year return event.

>>Question 2
<u>Cyd Curtis</u>
Great. All right, question number two. Operational settings can be incorporated into the design procedure. Know how you're going to operate the system and that will inform the design. Is that true or false?

So I will start showing the results as they are coming in. And Richard, again if you want to comment on that.

<u>Richard Cooke</u>
I think this is one of the critical things and one of the reasons why we did this routine is because, you know, different people are going to operate the system differently and the final analysis is that we don't

want to have an adverse effect on the crop or the field. So if we can take this into account at the design stage then that will increase the effectiveness of the system rather than assuming that we are going to have a certain optimum setting and this never occurs.

>>Question 3

Cyd Curtis

So question number three, another true false. It is not feasible to evaluate bioreactor performance within specified levels of uncertainty since weather data is highly variable.

So we are getting the answers in. Again, Richard, do you want to comment on the answers.

Richard Cooke

Typically the answer is false because it's just like any other thing which we design. In a lot of our designs we acknowledge that there is variability and we can assign some level of risk and the level of risk is dependent on the nature of the system. So for example, we are designing a system for storing nuclear waste that we might use 1,000 year or 10,000 year event because the consequence of failure is great. Typically in agricultural systems we use a 10 year return period and what we have tried to do is based on historic rainfall as long a record as one has possible then we can do our simulation and then assign this level of risk based on those simulations.

>>Question 4

Cyd Curtis

Great. Question number 4. Do you plan on using the interactive routine for bioreactor design and evaluation or promote its use outside of this webinar?

I don't think you need to comment on that. You can just look at the results. And if you also notice below there's a question number five. What needs to be improved within the routine to make it usable for you? I mean as Richard had hoped perhaps in the future he could have a time where you all sit down and play with the routine to get more direct feedback but if there's something that you noticed that you would like to give him feedback, and of course you can certainly enter it there. And also under the -- go-ahead. Sorry.

Richard Cooke

I should mention we are developing a users guide for the routine that would do this this overall help function that goes along with the routine. However, we did not get it done in time for this presentation. But it should be done according to the person who is doing it by May or thereabouts. That would be --

>>Question 5

Cyd Curtis

And one other thing if people would like to input, I will leave this area open is also under that same question to consider any input, how might you use the routine in the future. So just if you have some specific uses in mind I think Richard would be very interested in just kind of having a sense of what people are thinking about in terms of application. Just go ahead and put that in there. And from there we've gotten a couple more questions that came in.

Let's see. Where were we? So Richard, Chad Ingles was asking: what is the acreage of contribution areas for the bioreactors you are studying?

Richard Cooke

Okay, the bioreactors we are studying, the contributing area varies from 70 acres to about 2 acres. One of the things that we are looking at is loading rate, acres per square foot of bioreactor, how that affects the performance. And so we use a wide range of contributing areas. Typically I don't think that I would want to see a bioreactor for more than 70-80 acres. It's just because of, you know, the engineering to get things uniform, to get the water spread across the manifold and not have dead areas in the bioreactor, stagnant areas, areas of no flow. So that is a consideration. But if one can get the engineering right, then it could be as big as possible. But based on our limitations that would be as big as I would go right now.

Cyd Curtis
All right. The next question is from Al King. Dr. Cooke, what are the typical total and soluble phosphorus input concentrations at the sites you have studied?

Richard Cooke
For our phosphorus work, as I mentioned, that has been done in our pilot system in the lab and in our systems we usually spike the phosphorus concentration up to about 3 milligrams per liter which is the higher than what we have observed in our tile systems but we just wanted to know what would perform at that. But the thing is we can vary this if necessary. And we are just starting our field tests with phosphorus now and I would welcome any kind of suggestions as to what levels and what type of phosphorus we should be use.

Cyd Curtis
Next question is from Mark Dietrich. What are the current estimates of longevity, operation, and maintenance?

Richard Cooke
Every time I talk about the life of the system I seem to be decreasing it. Initially we said 15-20 years and I would say in that 10-15 years. But based on last year I think if there is a prolonged drought and the system is completely empty we will have some oxygenation of those woodchips in the systems which are open to the atmosphere. So I would think there is probably some way to -- although we have an open system to cover them during the drought periods then I would say 10-15 years would be the life of the system. And then it would just be a matter of the structures and everything are already in place it would be a matter of digging out the woodchips and taking out the line and then putting back in new ones.

Cyd Curtis
All right. Next question is from Keegan. Any drawbacks to under sizing a bioreactor for a tile system other than lower overall load production? For example, into load production.

Richard Cooke
Okay, we believe that under sizing is better than over sizing the system. And the reason why we don't want to oversize the system is that what we have found, and this is something we are working on. If we remove all of the nitrates then, you know, we are going to get a breakdown of the sulfates and we might have mid-tile mercury production in the systems. And so we say under sizing it. We have looked both in the lab and in the field -- what look at end tool production and so far we have not had any end tool production in any of our systems. But this is something we are continuing to look at. We are continuing to measure this to see if that can be a problem. One thing which we probably need to look at some too is dissolved organic carbon and see are we getting an increase in dissolved organic carbon. And based on what we have done initially for the first few times, there is an increase in dissolved organic carbon load but this quickly decreases the background level or just about the background level in time.

Cyd Curtis
All right. The next question is Scott from Scott Tompkins. If the DO is so low coming out of the tile, have you looked at any impacts to downstream macro invertebrate communities?

<u>Richard Cooke</u>
This is one of the long-term studies which we want to look at. We have more or less two ditches. One where we have three bioreactors and another one where we have drainage systems with known bioreactors. We are looking at what happens along the stream profile. We want to look at the macro vertebrae; we want to look at what is happening in the sediments over time. But it doesn't seem as if there is a short term response but we are continuing to monitor this over a long time. And then we looked at how far downstream does it take -- what is the dissolved oxygen profile at different distances downstream from the bioreactor. In the short term, it does not seem to be much of a problem, but as I said we are continuing to look at that over time.

<u>Cyd Curtis</u>
Great. Well I am looking at the time and it's 10:58 so I want to shift gears real quick and just share if my computer will cooperate with me, it's not doing it right now. We have, as Richard mentioned, there is a drop box that I am trying to share with you but my screen is not switching. There we go.

>>Bioreactor Files Box and Acknowledgements Slide
So at the bottom of your screen you should see the URL for bioreactor files and beneath that there should be a button that you can click to go to that drop box. And if you are having any difficulty with that I've built a little redundancy in. If you stick around until the end of the meeting it will open up a URL, the window where the drop box is located so you can download this information.

So Dr. Cooke I would really like to thank you for your presentation and your time to answer everyone's questions. And I would like to remind everyone, our next webisode is April 24th again at 10:00 Central and it's about Indian Creek Watershed Community Supported Conservation. We are going to have Karen Scanlon from CTIC talking about that project. So thank you very much, everyone. And thank you, Dr. Cooke.

<u>Richard Cooke</u>
Thank you for the opportunity.