UNIVERSITY of WASHINGTON
CIVIL & ENVIRONMENTAL ENGINEERING

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David Moore
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Washington State Department of Ecology
Water Quality Program - Eastern Regional Office

Dear David:

Thank you very much for your comments to our Spokane regional wastewater bioavailable phosphorus study final report. Below we have highlighted our responses in blue italics. We have also made the corresponding changes to our report.

General Points:

Probably the biggest point of confusion in our report is the proper interpretation of our %BAP values. We have thought of several different ways to get this point across, and have settled on the following explanation.

Consider that most studies have concluded the %BAP of the TP discharged from conventional secondary WWTPs is 80-90%. Then consider that most field studies have found that the TP in natural rivers, and agricultural and urban runoff is around 20-40% BAP. This suggests that if both sources of TP were treated equally, the true eutrophication potential of the WWTP effluents would be underestimated by a factor 2-3. That is, most regulators assume counting all P (as TP) is the most protective approach for receiving waters, when in fact the opposite is true. For example, if the folks in Spokane engaged in a nutrient trading scheme and counted the TP in the winter discharges from Hangman Creek as equivalent to those from the Spokane WWTP, they would likely be underestimating the mostly likely impact of the WWTP effluent by a factor 4 (i.e. I am guessing the %BAP for Hangman Creek during its high sediment/TP period is ca. 20%, whereas our data indicate the %BAP for the Spokane WWTP effluents during the winter is ca. 80%). It may seem most intuitive that counting all P as TP is the most conservative approach, but we argue precisely the opposite is actually the case. Similarly, our results suggest that once the advanced P removal processes are fully implemented at Spokane it is very likely that the %BAP of these effluents will be far lower than was previously the case. Putting an effluent with 50 µg/L TP with a very low %BAP should result in a very dramatic improvement in the WQ of Long Lake compared to the current situation (i.e. 500 µg/TP with a very high %BAP).

Below we have indicated your comments to our report in black font and our responses in blue italic font.

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Sincerely,

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General comments

- Request that any comments on this study by other Spokane River stakeholders (dischargers, environmental groups, tribes, etc.) be made available for public review.

Thanks for the suggestion! We will collect the comments made to this study as an appendix attached to the final report.

- Some treatment process information is provided in the report but to the extent possible, all information available on the operation of the treatment process (effluent flow rates, chemical dosage rates, unusual operating conditions, etc.) of the facilities should be included as well.

We have requested the information several times from the dischargers. The information presented in the report is all the information we have received in response.

- Have additional split samples been collected but not sent to UW for analysis? If so, the dischargers should provide these results (including other parameters in addition to phosphorus) for inclusion into the report. This data would provide a more complete overview of the effluent quality produced by the treatment systems.

We are unaware of any split samples that have not been sent to us. Further there is no mechanism by which we could compel anybody else to provide us data that was not collected and processed for our project.

Specific comments_

Page 3, second paragraph - Please explain significance of using KCI instead of K_2HPO_4. Is this a deviation from the standard methods?

The reason to replace K2HPO4 using KCl is to create a P-free media while also making sure there is enough K to support algal growth. This is necessary to create P-Starved algae prior to the start of the experiment.

Page 6, first paragraph - Please confirm that samples were shipped to UW within established holding times.

Yes, all the samples were shipped within 24hrs to UW lab for analysis.

Page 10, first paragraph - It is unclear what the significance of the sample variability divided by the square root of the number of replicates processed is. Is this a standard way of showing low analytical uncertainty?

This calculation shows the variability associated with the actual values we have reported. Because we have replicates for each analyte, the reported sample variability will always be less than the corresponding analytical error for these samples. For example, if we had a BAP estimate of 20 ± 4 ug/L with a sample size of four analyses, the actual uncertainly is less than ± 4 ug/L. The simplest way to think of this is to consider uncertainty about a mean estimate is also inversely proportional to the square root of the sample sized used to obtain the estimate of the mean. I.e. the SE of the mean = SD/sqrt(n).

Page 10, first paragraph - Identify which WWTP has the 17% variability.

It is for City of Coeur d'Alene the samples.

Page II, first paragraph - Is the high CV for the BAP samples problematic or is this just a statistical outcome? It seems that if the mean is low and the SD is also low, that's not a bad thing even if the CV is high. Should these instances be footnoted to the effect that these samples are not in fact problematic?

Because CV is the result of dividing SD by the mean, a high CV for the low BAP samples is just a statistical result. Thus we pointed it out in the discussion to draw people's attention that it is not problematic. Beyond this, we don't think footnotes are warranted.

Page 13 - Please use the formal name of City of Spokane WWTP (Riverside Park Water Reclamation Facility (RPWRF)) to distinguish from other "Spokane WWTPs" throughout report

as per page 51.

Thanks for the suggestion! We have changed this in the report.

Page 13, first sentence - Please add "with current (secondary) treatment methods" at the end of the first sentence discussing RPWRF.

Thanks for the suggestion! We have put it in the report.

Page 13, second sentence - Do the pilot treatments come after the secondary clarifier? This is unclear as worded here.

Yes, the pilot plant receives the effluent from secondary wastewater treatment plant after the secondary clarifier.

Page 14, Figure 3 – Identify that the colored boxes represent where samples were taken. Please add similar, consistent diagrams for other facilities (particularly where samples are taken).

Thanks for the suggestion, we have changed the figures.

Page 18, 3rd paragraph - This section does not clearly answer the question posed as to whether TP can be used as a conservative measure of %BAP in this pilot study.

Though TP can be a conservative measure, TP will largely overestimate the BAP especially for final effluent samples with less than 20% BAP. We suggested using TRP rather than TP as a surrogate measure it is due to TRP not only provides a more conservative value but also it estimates a closer value to the BAP than TP.

Most phosphorus management plans focus on TP loading based on the assumption that accounting for all P forms is the most conservative approach. However, several studies suggest agricultural and urban runoff, and natural stream flows commonly have %BAP values in the 20-40% range (1, 2, 3) whereas secondary WWTP effluents have %BAP averaging 80-90% (4, this study). Therefore, comparing the eutrophication potential of these different sources without accounting for %BAP greatly underestimates the true risk associated with wastewater discharges (2). Further, our results show the effluents of alum-based tertiary P removal processes have %BAP of ≈ 10% which suggest that this P source is likely to promote eutrophication a factor two less than urban, agricultural and natural P sources and much less than conventional WWTP effluents. It is especially important to consider %BAP in nutrient trading schemes (5) where P sources with vastly different bioavailability may be treated equivalently based on the false assumption quantifying all nutrient sources as TP is the most protective approach for minimizing eutrophication.

(1) Ekholm, P.; Krogerus, K. Determining algal-available phosphorus of differing origin: routine phosphorus analyses versus algal assays. *Hydrobiologia* **2003**, 492, 29-42.

(2) Reynolds, C.S.; Davies, P.S. Sources and bioavailability of phosphorus fractions in freshwaters: a British perspective. *Biol. Rev.* **2001**, 76, 27-64.

(3) Ellison, M.E.; Brett, M.T. Particulate phosphorus bioavailability as a function of stream flow and land cover. Water Res. **2006**, 40, 1258-1268.
(4) Ekholm, P.; Krogerus, K. Bioavailability of phosphorus in purified municipal wastewaters. *Water Res*. **1998**, 32, 343-351.
(5) Paul, F. Fertile ground: nutrient trading's potential to cost-effectively improve water quality. World Resources Institute, Washington, DC, 2000.

Page 19, second paragraph – What are the units in this section? Are these numbers ratios?

The results are unitless BAP/TRP ratios.

Page 20, Figure 6 – Why is the BAP/TRP relationship presented as a ratio in this figure and not in a regression such as in Figure 5?

For the BAP/TRP ratio, the results in each effluent type have relative large standard deviations. So we didn't put it as a regression model as in Figure 5.

Page 20, second paragraph, 3rd sentence – What is meant by a "sustainability perspective?" Depending on the expertise of the reviewing staff, sustainability perspective has been interpreted differently. One reviewer suggests checking with Prof. Dave Stensel to provide extra clarity and perspective to the statement. Alternately section 9.3 of the USEPA Nutrient Control Design Manual, August 2010 could be consulted.

Perhaps we should not be pontificating in this report, but we think it should be noted that by using very resource and energy intensive technologies to remove P to extremely low levels secondary environmental impacts will accrue (e.g. the energy costs to produce, transport and dispose of alum). For example, our results suggest the first alum dose within secondary treatment will remove 22 µg TP/mg Alum, the second dose in the tertiary process removes 4 µg TP/mg Alum, and the final dose the pilot plant removes 0.4 µg TP/mg Alum. At some point somebody should consider the collective environmental impact of the final Alum dose (in for example greenhouse gas units) against the likely benefit (in terms of higher DO concentrations in Long Lake). As environmental engineers and scientists we would be considering this problem broadly.

Page 21, second paragraph – Please refer to appropriate figure (Figure 5?) for the statement in the first sentence. It's unclear where this statement comes from since there is no statement that TP overestimates BAP elsewhere in the results section. Are the authors saying that TP, which is used in permitting, is assumed to be 100% bioavailable in wastewater treatment permits and that this is an overestimation? That would be a correct statement but BAP is a fraction of TP so TP is always going to be an "overestimate" of BAP.

We have put Figure 5 after that sentence. The statement about the TP greatly overestimated BAP at high treatment level comes from the data shown in Figure 5 and Table 3 that final effluent only

have around 20% BAP. In another words, TP is almost 4 times BAP. It is true that TP is always going to overestimate BAP since BAP is a portion of TP. However, we put this statement in the beginning of discussion to point out TP will largely overestimate BAP while TRP will provide a more realistic estimate with an average BAP/TRP at 0.44. So it is possible to use TRP as a conservative measure of the eutrophication potential of the wastewater effluent.

Page 21, second paragraph – Figure 5 shows there's some relationship between TP and BAP but this section puts those findings aside and moves on to TRP and BAP ratios without explaining why TP and BAP relationships can't be used.

As we explained for previous question, using TP to estimate the eutrophication potential will be problematic since it showed much higher value than BAP (4 times higher than BAP for final alum treated effluents).

Page 22, first paragraph, last sentence – Define "protracted" as it relates to the reference cited.

Protracted means long term biological activity in sediment or digenesis by chemicals or materials.

Page 24 – It would be easier on the reader if you present the layout of the WWTP pilot treatment and where samples were collected first as you did for the City of Spokane samples. This section starts right off with results with no context or explanation of the treatment technology. Carry suggestion through for remaining sections.

Thanks for the suggestion! We will reorganize our report.

Page 26, first paragraph – Why were some samples composited and others were grabs? Could spikes be missed or muted by either approach?

Most of the samples were composited. Only when there was miscommunication between the facility and the people in charge of sampling, grabs samples were sent for analysis.

Page 29, second paragraph – It is unclear how the BAP outliers are caused by mean BAP values approaching the analytical limits for the bioassay by looking at the values in Table 4c. In short, this last sentence doesn't make sense without further explanation. Is the quantitation limit several times the detection limit for the BAP test as it is for most wet chemistry tests?

The outliers in this statement mean the CV outliers not BAP outliers. When the mean BAP is low (for instance, <5µg/L) and the SD is normal. CV is going to be much higher than other high BAP samples and shows as an outlier.

Page 30, Figure 13 – Missing legend symbol for %BAP.

Thanks for the suggestion; we have put the symbol in.

Page 30, third paragraph – Please verify whether first sentence is correct ("Prior to any treatment…"). Figure 7 shows that there is at least primary treatment prior to the treatment plant influent. Did you mean before the tertiary treatment for P removal?

Yes, it meant before any tertiary treatment for P removal. It has been changed to "Prior to any treatment in pilot plant".

Page 32 – Please highlight difference in pilot influent samples at Post Falls compared to City of Spokane and Coeur d' Alene samples. Post Falls influent is true, raw influent and not post treatment into a pilot facility. This should be mentioned in the opening paragraphs for the Post Falls chapter.

Thanks for the suggestion. It has been pointed out that it is not a pilot plant in the report.

Page 37, second sentence – Typo, strike word "that" following "one set of effluent samples (LLE)…"

Thanks for the suggestion, we have changed the word.

Page 37, first paragraph, last sentence – Replace word "located" with "taken(?)"

Thanks for the suggestion. We have changed the word.

Page 37, Figure 18 – Clarify whether there is any treatment prior to influent sample or, if like Post Falls, the influent sample is raw sewage and the effluent samples are following existing treatment, not pilot (small scale) treatment technology. This point needs to be made very clear for facilities where raw effluent is tested because we are essentially looking at "scaled up" existing technology BAP removal performance at these two facilities (notwithstanding the outliers and low sample size).

Thanks for the suggestion! We will emphases in our report the Post Falls is a full scale treatment plant receiving raw sewage and not pilot treatment plant.

Page 40, third paragraph – Please describe what is meant by "quality of P in effluent." Is this describing the composition of P species?

Yes, it changed the composition of P species and reduced the portion of P can be bioavailable, such as inorganic P. Thus, the Phosphorus in the effluent becomes less bioavailable to algal.

Page 41 – Until more information becomes available from HARSB, it doesn't seem useful to include any further report on this facility beyond the first paragraph. Suggest deleting rest of chapter after introduction on this page.

Thanks for the advice! However, the author feels it is necessary to report all the data and provide

suggestive interpretation of the data. Though there is only one set of sample for Blue Water effluent, the extremely low TP concentration (32 µg/L) in that sample compared to regular effluent (2250 µg/L) is interesting. Clearly, more samples are needed to draw any firm conclusions. However, it is also important to report these preliminary results and suggest there were some similar trends shown in the result as other plants, such as high removal efficiency of Blue Water technology and decrease of %BAP in the effluent.

Page 45 – Suggest preceding the term "classic algal growth bioassay" with "as determined in this study using the…" to clarify that this study in fact uses the classic growth bioassay.

Thanks for the suggestion! We have put the term in our report.

Page 45, second sentence – Clarify the type of particles being described; algae, sediment, other? Always precede term "particles" with "algae" to avoid confusion in this section please.

The Coulter Counter analysis only quantifies the particles. But we can tell whether the particles in the samples are algae or not by looking at the size distribution. So the size distribution shown in the "expected" figure has a normal distribution with an average size of 4 µm. However, the size distribution in IEP effluent after adding algae and cultured for 14 days indicated there were particles other than algae in these samples.

Page 45, Figure 26 – Is the "expected" size distribution graph the typical pattern observed from other WWTPs in this study? In other words, this is an expected distribution for what? Wastewater effluent, streams, lakes, etc?

Yes, the "expected" size distribution graph is the typical pattern observed for all the samples (wastewater influent, effluent, Spokane River, etc.) except the Inland Empire Paper effluent sample.

Page 46, first paragraph This paragraph needs a heading to reflect the conjecturing into low BAP from IEP being presented. Suggest "Potential Causes of Low BAP" as the heading or something similar.

Thanks for the suggestion! We have put a heading in our report.

Page 46, second paragraph, second sentence add "pilot" between "advance" and "tertiary."

Thanks for the suggestion! We have added the word in.

Page 46, second paragraph Ecology agrees that IEP's installation of a pilot plant is a "proactive commitment" but why is this term is missing for the other treatment plants that have also installed tertiary pilot systems in advance of the TMDL?

We used the term for "proactive commitment" for IEP treatment plant is because this term is used in the description of their pilot plant and we didn't see this term is used in the information provided from other plants. If that is the same case for other pilot plant, we can add the term in the description of the treatment process for other pilot plant.

Page 46, second paragraph - It would be helpful to have a treatment diagram for IEPs treatment system as the report has for the other treatment systems.

Thanks for the suggestion! We have put a simplified diagram for IEP treatment process.

Page 47, second paragraph - What are the potential shortcomings of only having one influent sample? One sample doesn't seem to be enough to characterize the quality.

At the beginning of the study, we were more focused on the analysis of the effluents from IEP treatment process. Only effluents were collected for the P analyse. After the several batches of bioassay analysis for the effluent samples, it turned out there were some issues with algal growth in the effluent samples as we discussed in the report. So we decided to analyse the influent as well to test if there was a growth inhibition issue associated with the influent samples as well. Only one influent sample was sent to our lab towards the end of the study. It is clear that one sample is not sufficient to draw any statistical conclusions. However, it is also important to present the data and show there is high BAP in the influent to start with. These limited also suggest growth inhibition is probably not the reason why algae grow poorly in the final IEP effluents.

Page 47, third paragraph Last sentence is awkwardly worded. Please revise to something like "Our initial results suggest this effluent may be a poor substrate for..."

Thanks for the suggestion! We have edited our report as suggested.

Page 48, first sentence Same comment as regarding the one influent sample. It really needs to be highlighted that there is only one influent sample to consider; more so than just saying "if one merely considers the result for the one influent sample..." The report makes much of the fact that there are few samples for the other facilities but make little of the same situation for the influent at IEP.

Thanks for the suggestion! We will emphasis this in our report.

Page 49, third paragraph Typo, replace "like" with "likely."

Thanks for the suggestion! We have changed the word.

Page 49, third paragraph Same comment as for Page 46, last paragraph; this section needs a heading to clearly show authors speculation, discussion and conclusions as to what the likely causes of low BAP are in IEP effluent.

Thanks for the suggestion! We have put a heading in our report.

Page 51 - Please provide intro sentence as to why samples were collected from the river and lake; what was the objective for this part of the study (take from the QAPP)? In general, the report should have a consistent organization in all chapters, i.e., intro, sampling, results, conclusions.

Thanks for the suggestion! We will put the intro in our report for Spokane River samples.

Page 51, first paragraph The correct term for the City of Spokane WWTP is introduced here but needs to be introduced at the beginning of the report and use the same term throughout the rest of the report.

Thanks for the suggestion! We have changed the name of the City of Spokane WWTP throughout the report.

Page 51, first paragraph Please provide exact locations of where Spokane River samples were taken. From which bridge, outfall, etc.

From the sampling information provided, the samples were collected at river downstream of Nine Mile Falls Dam.

Page 51, last sentence From where did the "upstream" concerns come from? What were the concerns (DO, algae, other)? How is upstream defined? Why was stateline chosen and not some other upstream location from Lake Spokane and the RPWRF (there are three other discharges between stateline and RPWRF)? Stateline was not a location from the QAPP. This needs to be clearly defined as to what the concern was, why this location was chosen and why it was sampled.

Fairly late in our project, Jim Ross in Environmental Protection Agency suggested we include upstream sample for the Spokane River. He suggested that we collect water samples upstream either at the Cd'A lake outlet or stateline to see if the result was different than the samples collected downstream. Because this request was made late in the project, only one upstream sample at stateline was collected on the way of sampling.

Page 52, first paragraph Could there be another explanation for the high BAP in winter other than cessation of alum from the RPWRF? What about lake turnover or other seasonal factors that affect nutrient cycling? This should at least be acknowledged and discussed.

Thanks for the suggestion! We have put one sentence in to mention there might be other seasonal factors contribute to this difference between winter and summer samples.

Page 52, second paragraph Regarding the statement "the algae bioassays indicated that most of the phosphorus was unavailable to algae," an alternative explanation is that the most readily bioavailable phosphorus was already used by algae and macrophytes in the river.

With the possible exception of the pools behind upstream dams, the water in the Spokane River is shallow enough that the entire water column is euphotic. Trying to determine what percentage of phosphorus still in the water column is bioavailable is uncertain under the best of conditions. In lake Spokane, taking composite samples from the euphotic zone, the interflow zone and the hypolimnion give SRP/TP ratios of 16%, 82% and 86% respectively. This is not due to actual differences in the bio-availability of the phosphorus, rather the fact that a portion of the available phosphorus has already been taken up by algae or macrophytes.

Yes, the author agrees with this statement. We also have one sentence in discussion section mentioning the low P concentration in Spokane River sample "could also be due to most of the bioavailable phosphorus already having been used up by algae or other plants before our river samples were collected."

Page 53, third paragraph - There should be a discussion about the fact that at the stateline, the river is a losing reach to groundwater and you also have Post Falls dam upstream, which can act as a sink for algae and phosphorus before it hits stateline. These factors should be considered in the evaluation of this one sample. The report should also mention that Ecology has a long data record for this and numerous other sites throughout the river, which provide a much better characterization of water quality than this one sample.

Thanks for the suggestion! We have added paragraph to discuss this issue and suggest Ecology has a better dataset to characterize the water quality.

Page 54, first paragraph Please define "raw sample." Is this unfiltered river water?

The raw sample means the unfiltered and undiluted river water. All the wastewater influent and some effluent samples have high P concentration and need to be diluted to an appropriate P concentration range with P-free medium. The Spokane River sample has low P concentration (≈ 30µg/L), so we didn't dilute these samples for BAP analysis.

Page 56 Typo, "Executive" Summary. This should be at the beginning of the report.

Thanks for the suggestion! We have changed the word.

Page 57, first paragraph, last sentence Replace "very hard" with "impossible."

Thanks for the suggestion! We have changed the word.