Characterizing Point Source Phosphorus for the lower Boise River Total Maximum Daily Load and Aquatox Water Quality Modeling

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Version 2.1

Accurately characterizing point source phosphorus and communicating that description is a critically important step in the development of a total maximum daily load (TMDL) and the supporting water quality modeling. This is particularly critical for low phosphorus targets, which result in small wasteload allocations. Small wasteload allocations mean point sources must spend millions of dollars in facilities improvements to remove phosphorus. Accurate characterization is essential to demonstrating these expenditures will provide the intended benefit to the receiving water quality.

The importance of how to discuss and describe phosphorus during the TMDL development process, the associated modeling supporting the TMDL and in the final TMDL cannot be understated. Simply stating point sources were set at some concentration, say 100 μg/L for example, is not sufficient. Point source phosphorus must be characterized in much greater detail because nutrient removal treatment will not only reduce wastewater effluent concentration, but also alter phosphorus speciation and reduce bioavailability. This greater detail is important for multiple reasons, including:

- Promotes greater stakeholder communication and understanding of the phosphorus load and potential implications.
- Fosters communication between stakeholders and modelers in understanding stakeholder issues, conversion of model inputs and outputs, and scientific analysis into policy.
- Documents the effluent phosphorus characterizations under current conditions and after advanced nutrient removal treatment.
- Informs the final TMDL that in turn informs NPDES permit writers.

There are multiple elements to characterizing point source phosphorus and facilitating communication. A concise descriptive communication tool summarizing these elements is one method to maintain documentation of decisions, reminding stakeholders of those decisions, and readily accurately important information. One such communication tool that has been used in TMDL processes, for modeling, and in final TMDLs is a summary table that characterizes the spatial, temporal, flow, effluent phosphorus form, bioavailability, and other effluent o model translation, including:

- List point source facilities as identified for the TMDL.
  - o Identify point source locations and receiving waters. Note methodologies for representing point sources not on the main stem river.
- Identify seasonal variations in effluent concentrations.
- Identify point source facility flow.
- List effluent phosphorus concentrations for total phosphorus, total soluble phosphorus, and biological oxygen demand (suspended and dissolved detritus in Aquatox). Include conversion equations in footnotes.
- List the bioavailable fraction (fraction of phosphorus available in Aquatox).
- Identify translations between effluent concentration discharged at the facility and inputs to the water quality model.

A summary table characterizing point source phosphorus provides a means of tracking multiple elements. An example of how such a table may be structured is shown in Table 1. The basic framework of the table is structured similar to other point source tables in the draft TMDL. This table will be valuable not only during the TMDL process of evaluating alternative scenarios for phosphorus reduction and simulated changes in receiving water quality, but also for the final TMDL. It is important that the remaining inputs in the model scenario, such as nonpoint sources and groundwater, also be identified in this table.

Table 1. Characterization of Phosphorus for TMDL Scenario

Input	Flow (mgd)	Total Phosphorus[1] (mg/L)	Orthophosphate as P (mg/L)	CBOD5 (mg/L)	Chlorophyll a (mg/L)
Upstream background	2012-13 values	0.02	0.008	0.34	1.48
Boise River - Main stem					
Lander Street WWTF	15	Jan.-Apr 1.0 May-Sept. 0.3 Oct.-Dec. 0.5	Jan.-Apr 0.927 May-Sept. 0.228 Oct.-Dec. 0.427	5	n/a
West Boise WWTF	24				
Middleton WWTF	0.57				
Caldwell WWTF	7.9				
Tributaries					
Fifteenmile Creek and Meridian WWTF	2012-13 values + PS load	Min 0.070 Median 0.207 Max 0.224	Min 0.070 Median 0.186 Max 0.203	0.71	2012-13 values
Indian Creek and Nampa WWTF	2012-13 values + PS load	Min 0.154 Median 0.204 Max 0.207	Min 0.102 Median 0.153 Max 0.155	3.44	2012-13 values
All others	2012-13 values	0.07	Min 0.048 Median 0.056 Max 0.062	Min 0.11 Median 0.23 Max 0.77	Min 0.95 Median 1.47 Max 2.24
Groundwater and unmeasured	2012-13 values	0.07	0.07	n/a	n/a

[1]Total phosphorus = orthophosphate + 0.0144 * BOD + 0.007 * chlorophyll a.

An example of a modeling scenario inputs summary table from a completed TMDL that demonstrates a similar process that was used in Idaho and EPA Region 10 is Table 3 of the Spokane River TMDL (Ecology 2010). The Spokane River summary table was organized differently than Table 1 but illustrates the elements necessary to characterize the conditions for the scenarios. The summary table has the various sources across the top of the table for the baseline, TMDL scenarios, and source assessment scenarios down the side (Ecology 2010). Extensive footnotes were required to provide additional definition and descriptions. Despite some of the challenges in the process, the Spokane River TMDL used both a modeling scenario inputs for TMDL technical analysis along with further descriptions in the text to facilitate the water quality modeling that resulted in an approved TMDL.

The multiple elements to characterizing point source phosphorus are further described in the following paragraphs. These descriptions include information about the element, why it is important, and how it may be addressed in scenarios evaluated using the water quality model.

Facilities and Location

Point source facilities identified for the TMDL should be listed. This facilitates ease of recognition of the flow and phosphorus characterization assigned for each facility. Facilities are located in different reaches along the main stem lower Boise River as well as on direct and indirect tributaries. Scenarios should be simulated with facilities set at different concentrations based on location within the watershed. Permits have been written with different concentrations based on location, trading may use ratios based on location, and the data show variability with locations; therefore, scenarios should be simulated to examine alternatives that consider the location of the facility.

Seasonal Variations

Point source facilities operate year-round. Additionally, some stakeholders have requested an analysis of water quality conditions year-round. The water quality model was setup to simulate 15 months. Scenarios should be simulated with facilities set at different concentrations depending upon the season since the seasonal phosphorus loads will have different impacts on the downstream water quality and seasonal variation in treatment levels will provide some benefits to the facilities. The continuous simulation water quality model is capable of simulating these seasonal variations.

Facility Flow

Point source facilities experience a range of flows, within the day, week, and year. Additionally, point source facilities are treating greater volumes of water with growth and conversion of areas with septic systems or other lesser forms of treatment in satellite systems, which increase the flows to nutrient removal facilities. Wastewater utilities plan for these flow changes within their facility plans. Project design flows should be used for the scenarios to characterize future conditions.

Phosphorus Forms or Speciation

The draft lower Boise River TMDL is for total phosphorus. Total phosphorus is compromised of various forms of phosphorus. These forms are used in the water quality model. If a scenario is intended to test effluent total phosphorus concentrations of some value, say 300 μg/L for example, then proper accounting of the forms of phosphorus in the model is necessary to accurately characterize effluent quality. For example, BOD may be set at zero, and the effluent concentration set as total phosphorus. Alternatively BOD may be set a value of greater then zero, in which case the fraction of phosphorus associated with BOD can be accounted for. In the lower Boise River final calibrated model the conversion factor for BOD to phosphorus is 0.0144 times the BOD. If the model is set with the input phosphorus as total soluble phosphorus, then the fraction from BOD and soluble should be added to together to represent the total phosphorus.

Initially when eutrophication issues were identified, the causes were generally associated with excess nutrients. As more was understood about the cause and effect relationships, nutrients were distinguished between nitrogen and phosphorus. Nitrogen was frequently measured as ammonia, nitrate, and/or total Kjeldahl nitrogen (TKN), and phosphorus as orthophosphate, which is an estimate of the soluble reactive phosphorus fraction. It was generally easy to discuss nutrients in these terms and consider nitrogen or phosphorus as soluble, organic, or total. As water quality goals continue to drive concentration endpoints lower, it becomes increasingly important to accurately communicate and discuss nitrogen and phosphorus at more refined levels of speciation. Utilities, regulatory agency staff, and water quality modelers are looking at nutrients in new ways and need to communicate and understand more explicitly how and what is analyzed and reported in datasets in order to more accurately simulate water quality conditions with models. Fostering communication necessitates standardized, clearly defined terminology to promote more effective communication around nutrient management issues by promoting clearly defined, standardized terminology for all stakeholders to use.

Wastewater nutrient management terms for phosphorus are shown in the Table 2. This table demonstrates the importance of the terminology especially between monitoring, modeling, and wastewater vocabulary. Recognizing these differences promotes more effective communication around nutrient management issues. The conventional operational categorization used to classify phosphorus has been examined (Li and Brett 2013). The conclusions indicate that this classical scheme can lead to misunderstandings and less effective water quality management decisions. Further, research has examined the changes in phosphorus forms as wastewater is treated through the treatment facility. An excellent description of the phosphorus forms and changes during the treatment processes is provided by Gu, et.al. (2011). The authors stress the importance of understanding the phosphorus removal mechanisms to understand the changes in phosphorus characteristics that occur in advanced treatment and in the final effluent discharged to the receiving water.

Table 2. Total Phosphorus Forms

<table>
<tr><td colspan="6">Total P (TP)</td></tr>
<tr><td colspan="3">Total Soluble P (TSP)</td><td colspan="3">Total Particulate P (TpP)</td></tr>
<tr><td>Phosphate</td><td colspan="2">Dissolved Organic Phosphorus Labile and Refractory</td><td>Particulate Organic Phosphate Labile</td><td>Particulate Organic Phosphate Refractory</td><td>Particulate Inorganic Phosphate</td></tr>
<tr><td rowspan="2">Soluble Reactive P (SRP)</td><td colspan="2">Soluble Non-reactive P (SNRP)</td><td rowspan="2">Particulate Reactive P (pRP)</td><td colspan="2">Particulate Non-reactive P (pNRP)</td></tr>
<tr><td>Soluble Acid Hydrolyzable P (SAHP)</td><td>Soluble Organic P (SOP)</td><td>Particulate Acid Hydrolyzable P (pAHP)</td><td>Particulate Organic P (pOP)</td></tr>
</table>

Recognizing the changes in phosphorus speciation, especially the reduction of SRP, is a fundamental aspect of advanced wastewater treatment. This speciation change is readily measureable with laboratory analysis of samples collected from locations throughout the treatment process using standard methods. A complete speciation study from a treatment plant is provided by Gu, et.al. (2011). This study provides an example of examining phosphorus speciation at different stages in the advanced treatment process, as shown in Figure 1 from Gu, et.al. (2011).

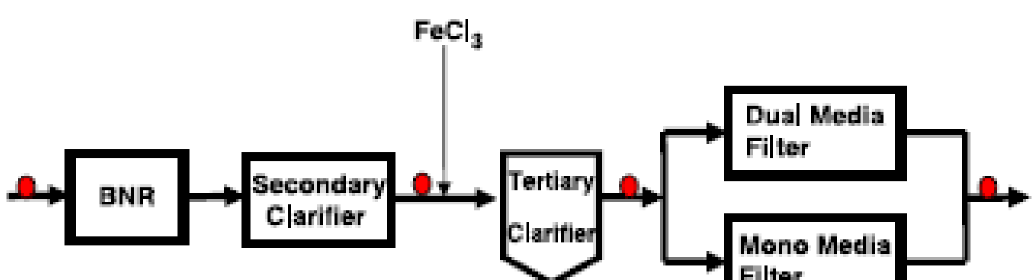

Figure 1. Flow schematic of secondary and tertiary treatment processes at WWTP-N (Dot points indicated the samples locations for phosphorus fractionation analysis (Gu, et.al. 2011).

The results of the study demonstrate the range of phosphorus speciation, changes, and reductions during the treatment process. "*Different level of treatment processes can effectively remove certain fractions of phosphorus. In this study, soluble reactive phosphorus was the fraction that was removed most effectively through both biological nutrient removal and chemical phosphorus removal processes. And as soluble reactive phosphorus is removed and total phosphorus concentration in the effluent is reduced, other fractions such as organic phosphorus and acid-hydrolysable phosphorus become relevant important to achieve lower phosphorus level. On the other hand, some of the refractory fraction remaining in final treated effluent might not be from original influent and they can be created by certain treatment process (e.g. particulate reactive phosphorus which is reacted by chemical phosphorus removal process, acid hydrolysable phosphorus can be produced by enhanced biological phosphorus removal process)"* (Gu, et.al. 2011). The changes in phosphorus through the treatment process for the study completed by Gu, et.al. (2011) is shown in Figure 2. As shown in Table 3, the effectiveness of different treatment units in removing different fractions of phosphorus was summarized by Gu et.al. (2011). Table 3 provides a general guideline for effluent speciation for secondary effluent (influent to biological nutrient removal), biological nutrient removal, chemical phosphorus removal, and mono/dual media effluent filtration.

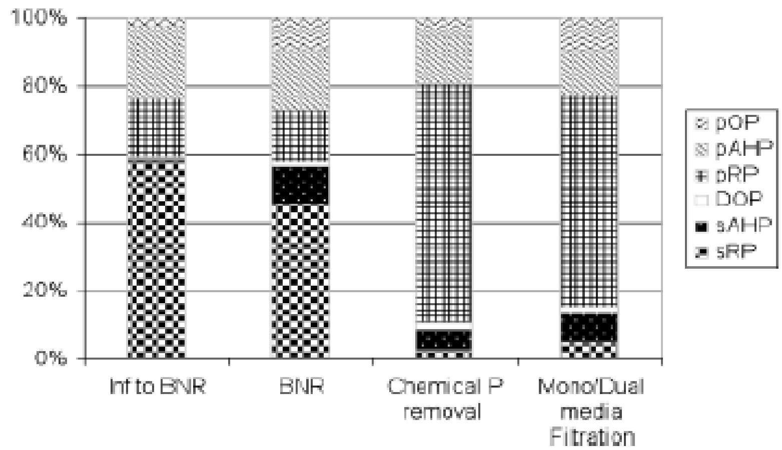

Figure 2. Distribution of total phosphorus in various influent and effluents at WWTP-N (Gu, et.al. 2011). Abbreviations are: particulate organic phosphorus (pOP), particulate acid hydrolysable phosphorus (pAHP), particulate reactive phosphorus (pRP), dissolved organic phosphorus (DOP), soluble acid hydrolysable phosphorus (sAHP), and soluble reactive phosphorus (sRP).

Table 3. Efficacy (percentage removal) of different treatment for removing various fractions of phosphorus in the biological nutrient removal influent (Gu, et.al. 2011)

	TP	sTP	pTP	tAHP	sAHP	pAHP	tRP	sRP	pRP	tOP	DOP	pOP
BNR	94	94	94	92	40	95	95	95	94	79	83	75
Chemical P removal	24	86	-66	54	56	37	7	96	-255	44	0	56
Mono/Dual media Filtration	59	42	62	50	45	64	63	20	64	35	60	26
Total	98	99	96	98	86	99	98	100	93	92	93	92

Total phosphorus (TP), soluble total phosphorus (sTP), particulate total phosphorus (pTP), total acid hydrolysable phosphorus (tAHP), soluble acid hydrolysable phosphorus (tAHP), particulatel acid hydrolysable phosphorus (tAHP), total reactive phosphorus (tRP), soluble reactive phosphorus (tRP), particulate reactive phosphorus (tRP), total organic phosphorus (tOP), dissolved organic phosphorus (DOP), particulate organic phosphorus (pOP).

The findings by Gu, et.al. (2011) are applicable to the treatment facilities in the lower Boise River watershed. These provide general guidance for effluent speciation and soluble reactive phosphorus content of effluent from the range of treatment processes that are likely to be of primary consideration by the point source discharges to the Boise River and its tributaries. Additional information about the changes to phosphorus by various treatment processes has been researched (Li and Brett 2012). The findings indicated that there was "*a significant difference between the processes with chemical addition (alum or ferric) and the biological processes without chemical addition*" (Li and Brett 2012). This information is useful as treatment facilities in the lower Boise River select approaches to treatment process upgrades for phosphorus removal. Additionally, the speciation change in reducing soluble reactive phosphorus will be very important for categorizing effluent as advanced nutrient removal is implemented by the treatment facilities and the changes to the Boise River.

Nutrient Species Implications for Treatment Performance and Water Quality Impacts

An evaluation of the performance of full-scale and pilot-scale wastewater treatment nutrient removal processes has shown that the processes are able to remove some nutrient species quickly while other recalcitrant nutrient species remain (Neethling and Stensel 2013). Nutrient species that are readily removed by biological and chemical treatment processes includes ammonia, nitrate, nitrite, and phosphate. More complex molecules and soluble organic species react slower and, in some cases, too slow to show measurable reductions in treatment plants. In some cases, the refractory nutrients increase in concentration.

Long term and short term data were evaluated to establish the expected best reliable nutrient removal performance of full-scale wastewater treatment plants (Neethling and Stensel 2013). Neethling and Stensel present treatment present Technology Performance Statistics (TPS) for 22 phosphorus removal processes for 7 phosphorus species, including total phosphorus (TP) and soluble reactive phosphorus (SRP). Results indicate orthophosphate and particulate phosphorus is readily removed, but that soluble non-reactive phosphorus (SNRP) and soluble organic phosphorus remains recalcitrant. The same recalcitrant species also appear to be degraded relatively slowly in bioassays, and contain an effluent nutrient fraction that is not available for algal growth. Expected reliable performance from tertiary processes for soluble reactive phosphorus (SRP) and SNRP may have effluent concentrations in the range of 5 to 15 ug/L and 15 to 25 ug/L, respectively. Different soluble phosphorus species will be used at different rates by algae in surface waters and water quality models can be modified to reflect their behavior and kinetics.

Bioavailability

The extension of the understanding of the changes in phosphorus speciation that occur in advanced treatment is recognition that bioavailability is also changed and reduced with advanced treatment. The term “bioavailable” is used in this discussion although the terminology is changing and rather than using soluble nonreactive phosphorus that is non-bioavailable, the most current industry terminology being adopted is “slowly bioavailable.” Terminology aside, bioavailable means readily available for uptake by algae including periphyton, for which targets were established for the lower Boise River. If the phosphorus is not bioavailable, then it is not contributing to the growth of excessive periphyton. Research and monitoring data have shown that as treatment facilities remove phosphorus to lower concentrations, much of the remaining phosphorus in the effluent discharged to the receiving water is not bioavailable, or is only slowly bioavailable. Further reductions in effluent phosphorus to still lower concentrations may not benefit the water quality of the receiving water because the remaining fractions are not bioavailable.

Wastewater treatment facilities that produce effluent with extremely low phosphorus concentrations may remove bioavailable phosphorus and the remaining phosphorus that is discharged may not be bioavailable. Recent testing of phosphorus speciation in other communities in the region suggests that the soluble, nonreactive phosphorus concentration in municipal wastewater treating to low effluent phosphorus concentrations is between 0.010 mg/L and 0.015 mg/L.

Management of a river system by reducing phosphorus discharged from wastewater treatment facilities should consider the amount of the total phosphorus that is biologically available to support algae and bacteria growth. Bioavailable phosphorus is the component of total phosphorus which supports the growth of algae or other organisms. While the measurement of bioavailable phosphorus is more recent research, the goal of managing the speciation of phosphorus causing river impairment is fundamental.

Much of the recent research has been performed for treatment facilities in the Spokane River watershed in response to the low phosphorus allocations in a dissolved oxygen TMDL (Ecology 2010). Research included examining the bioavailable phosphorus in samples from the Spokane River, six treatment facilities and three pilot plants (Li and Brett 2011). The findings indicate that when advanced nutrient removal processes are added to a treatment facility that the characteristics of the discharged phosphorus are very different than from conventional treatment. The authors encourage this consideration in management decisions for controlling eutrophication in the context of over-treating resulting in secondary environmental impacts such as excess chemical and energy consumption and solid waste generation (Li and Brett 2011). The authors further advocate a combined approach in considering total phosphorus and bioavailable phosphorus in watershed management. While secondary treatment reduces the total phosphorus, bioavailable phosphorus is still high, potential 80 to 90 percent. However, when advanced nutrient removal processes are added, the bioavailable phosphorus drops to approximately 10 percent. Recent data on nonpoint sources indicate that bioavailable phosphorus is in the 20 to 40 percent range, and exceeds the fraction of bioavailable phosphorus remaining in point source discharges following advanced treatment, illustrating that nonpoint sources may have a much greater impact on eutrophication. Not only is this consideration an important factor in allocating phosphorus loads across the watershed, but this also has important implications for watershed management to achieve the overall water quality goals. For example, the authors point out “*It is especially important to consider the percent bioavailable phosphorus in nutrient trading schemes where phosphorus sources with vastly different bioavailability may be treated equivalently based on the false assumption quantifying all nutrient sources as total phosphorus is the most protective approach for minimizing eutrophication*” (Li and Brett 2011).

These findings further support an adaptive management approach for reducing phosphorus (primarily bioavailable phosphorus) from all sources throughout the watershed.

Subsequent investigations examined whether some other potentially unaccounted for factors caused the prior findings to suggest less bioavailable phosphorus than reality. Factors that were examined included nutrient limitation and toxicity inhibition (Li and Brett 2014). The additional studies show that these factors cause weak or no impacts on the conclusions about the amount of bioavailable phosphorus. Furthermore, the data show that representing phosphorus with a single constant rate decay coefficient is an oversimplification of the process (Li and Brett 2014). A realistic representation categorizes phosphorus into three groups, readily bioavailable, slowly bioavailable, and recalcitrant. While the selected water quality model, such as Aquatox, may not directly support this full categorization, representing the different uptake rates may be accomplish with a combination of external accounting methods and use of the available model inputs and coefficients.

More recently, bioassay studies funded by the Washington Department of Ecology and Spokane River wastewater utilities, conducted by researchers at the University of Washington, have found little bioavailable phosphorus remains after advanced treatment. Bioassays have been conducted on samples taken from advanced phosphorus removal pilot facilities operating at the City of Spokane's Riverside Park wastewater facility, City of Coeur d'Alene Low Phosphorus Pilot Facility, and the Hayden Water Reclamation Facility. Researchers are analyzing the influent and effluent of the pilot facility for total phosphorus removal. Subsequent analyses are used to quantify the bioavailable phosphorus percentage in each sample. The influent concentrations to the advanced tertiary filtration steps were around 0.500 mg/L TP with effluent concentrations of approximately 0.020 mg/L TP. The remaining bioavailable phosphorus in the influent to the advanced pilot treatment facility (effluent of the conventional treatment plant) was around 70 percent and decreased to less than 10 percent in the final effluent. When considering the phosphorus that is available for plant and animal uptake, the pilot facility is achieving 99.6 percent removal. The majority of the effluent phosphorus is non-reactive and does not support algal growth.

Idaho References for Effluent Phosphorus Speciation

Effluent monitoring data from Idaho wastewater facilities provides information to guide considerations of effluent speciation associated with various types and levels of advanced phosphorus removal processes. The City of Coeur d'Alene has more than a 20 year history of chemical precipitation for phosphorus removal at the City's full scale facility discharging to the Spokane River. The City of Pocatello has had a long practice of biological phosphorus removal for discharge to the Portneuf River. Limit of technology treatment with dual sand filtration and microfiltration membranes has been investigated in detail in pilot testing in Coeur d'Alene with effluent phosphorus targets of less than 0.050 mg/L. Monitoring data for these facilities is readily available for reference and is summarized here to provide a guideline on how effluent phosphorus speciation will be changed in future discharges to the Lower Boise River.

Five effluent samples from each of the three limit of technology pilot systems that were evaluated at the City of Coeur d'Alene Low Phosphorus Demonstration Pilot Facility were sent to the University of Washington between April and July 2011 for effluent speciation and bioavailability analysis. These samples were analyzed for total phosphorus and then filtered to determine the soluble and particulate phosphorus fractions. The average effluent concentrations by species for each of the technologies are summarized in Table 4.

Table 4. Coeur d'Alene Pilot Facility Phosphorus Speciation and Bioavailability – Average Effluent Concentrations by Species (n=5, mg/L)

Phosphorus Species	Dual-Stage Sand Media Filter with Ferric	Tertiary Membrane Filtration (TMF) with Alum	Membrane Bioreactor (MBR) Biological Phosphorus Removal (no coagulant)
Soluble Reactive	0.003	0.006	0.023
Soluble Nonreactive	0.01	0.007	0.020
Particulate	0.007	0	0.001
Total Phosphorus	0.020	0.013	0.044
Bioavailable Fraction	15%	46%	52%

Ten recent effluent samples from the Pocatello biological phosphorus removal facility were collected between June 4 and June 17 2013. These samples were analyzed for total phosphorus and then filtered to determine the soluble and particulate fractions. The effluent concentrations by species are summarized in Table 5. This provides an example from Idaho of biological nutrient removal and how speciation is changed resulting in a reduced fraction of soluble reactive phosphorus. This example provides a representation of expected effluent characteristics after biological nutrient removal.

Table 5. Effluent Phosphorus Speciation from Pocatello, ID Biological Phosphorus Removal (BPR) Process (No Coagulant, No Effluent Filtration)

Date	Total Phosphorus	Filtered Total Phosphorus	Filtered Ortho Phosphorus
6/4/2013	0.20	0.162	0.051
6/5/2013	0.20	0.165	0.044
6/6/2013	0.21	0.165	0.048
6/7/2013	0.23	0.190	0.046
6/10/2013	0.30	0.192	0.045
6/11/2013	0.29	0.195	0.054
6/12/2013	0.28	0.193	0.043
6/13/2013	0.32	0.185	0.047
6/14/2013	0.30	0.230	0.044
6/17/2013	0.24	0.182	0.040
Average	**0.257**	**0.186**	**0.046**
Percentage of Total Phosphorus		**72.3%**	**18%**

Effluent monitoring data from the City of Coeur d'Alene chemical phosphorus removal facility from May of 2014 is summarized in Table 6. This provides an example from Idaho of chemical phosphorus removal and how speciation is changed resulting in a reduced fraction of soluble reactive phosphorus. This example provides a representation of expected effluent characteristics after chemical phosphorus removal.

Table 6. Effluent Phosphorus Speciation from Coeur d'Alene, ID Chemical (Alum) Phosphorus Removal Process (No Effluent Filtration)

Date	Total Phosphorus	Ortho- Phosphate	Soluble Phosphorus
5/1/14	0.52	--	--
5/4/14	0.51	0.36	0.23
5/6/14	0.45	--	--
5/8/14	0.50	--	--
5/11/14	0.56	0.44	0.29
5/13/14	0.49	--	--
5/15/14	0.40	--	--
5/18/14	0.38	--	--
5/20/14	0.40	0.28	0.20
5/21/14	0.38	--	--
5/26/14	0.32	0.20	0.14
5/27/14	0.35	--	--
5/29/14	0.34	--	--
Average	**0.43**	**0.32**	**0.22**
Percentage of Total Phosphorus		**74.3%**	**49.9%**

Conclusions and Recommendations

Full scale operating experience in Idaho phosphorus removal facilities illustrates the change in speciation that occur in advanced treatment using chemical precipitation and biological phosphorus removal at the Coeur d'Alene and Pocatello wastewater facilities. The Spokane River bioavailability studies Phase I and Phase II are examples of changes in effluent speciation and bioavailability in effluent from treatment processes. While some processes evaluated in these studies may not be appropriate or considered for implementation at treatment facilities in the lower Boise River watershed, many are applicable and representative of the type of processes point sources in the watershed may select and use. The effluent concentrations are on the low end of those currently being considered for the lower Boise River. The middle or higher end of effluent concentrations being considered is similar to the effluent concentrations from full scale facilities in Coeur d'Alene and Pocatello. These serve as examples of the change in phosphorus as it is processed through the advanced treatment facility. Recognition of these changes to phosphorus in the future effluent from these facilities is important to setting allocations in the TMDL to achieve the intended water quality goals.

Accurately characterizing point source phosphorus characteristics and communicating that description is a critically important step in the development of a TMDL and the supporting water quality modeling. Much of the knowledge about phosphorus speciation and bioavailability, the ability to analyze the fractions in the laboratory, the changes throughout the treatment process, and the impacts to the receiving water are well documented. These should not be overlooked in the phosphorus TMDL development. Diligence in assessing future management scenarios necessitates representing the changes in effluent speciation expected for those advanced treatment scenarios for point sources based on the approach each individual wastewater utility plans to deploy for advanced treatment. This can best be accomplished by having each individual utility provide their future effluent characterization, as the example of the Spokane River TMDL future effluent characterizations illustrates. This can also be accomplished by having other stakeholder groups identify their expected source characterizations. It is should not be expected that the soluble reactive phosphorus in the future effluent will be as high as in existing effluent or equal to the total phosphorus. Understanding the characteristics of phosphorus as part of the overall management plan is both critical to economic decisions and environmental impacts.

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