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Water Treatment – Phosphorous Removal

Course Number: CH-02-216

PDH: 6

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Module 1: Nutrients and Water Quality Problems

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the impact of excessive nutrient loading on freshwater ecosystems and infrastructure.
- **Identify** the critical seasonal factors that make wastewater treatment plant (WWTP) discharges the primary source of phosphorus impairment.
- **Select** appropriate target effluent concentrations based on established waste load allocations in sensitive watersheds.

Executive Summary: Phosphorus is the primary limiting nutrient in freshwater systems; during dry summer months, treated wastewater becomes the dominant source of loading, necessitating advanced treatment to reach concentrations as low as 0.009 mg/l to prevent severe dissolved oxygen and pH swings that threaten aquatic life.

Nutrient Dynamics and System Impairment

Phosphorus and nitrogen are essential for aquatic growth, but an over-abundance over-stimulates algae and plant life, creating significant water quality degradation. In the Northwest United States alone, over **1,000 waterbodies** are listed as impaired under Clean Water Act §303(d) due to excessive nutrient loading.

Impacts of Nutrient Enrichment

- **Ecological Survival:** Impairments directly threaten the survival of key species, such as salmon.
- **Infrastructure and Safety:** Excessive nutrients compromise the safety of drinking water supplies.
- **Public Use:** Aesthetics of recreational areas are degraded, and navigation through rivers and lakes is often impeded by overgrowth.

Technical Fundamentals of Phosphorus Control

In most freshwater systems, phosphorus acts as the **limiting nutrient**. Therefore, productivity can be effectively controlled by restricting the mass of phosphorus entering the water column.

The "Critical" Summer Period

Many Northwest streams and lakes possess minimal capacity to assimilate phosphorus during the warm, dry summer months. During this window:

- **Metabolic Swings:** Excessive nutrients lead to large diurnal fluctuations in **pH** and **dissolved oxygen**.

- **Criteria Violations:** These swings frequently exceed state water quality criteria required to protect aquatic organisms across various life stages.

⚠ **Safety Constraint:** Current phosphorus entry levels in many watersheds exceed seasonal loading capacities; failure to reduce these levels prevents the resolution of documented water quality impairments.

Sources of Loading and Regulatory Requirements

The origin of phosphorus varies by watershed human activity. However, the relative impact of these sources changes seasonally:

- **Nonpoint Sources:** Contributions from agriculture or pet waste are often **minimal** in summer due to a lack of rainfall runoff.
- **Point Sources:** Discharges from treated wastewater become the **most significant source** of loading during critical summer months.

Waste Load Allocations (WLAs)

To address these issues, the EPA and state agencies now require dischargers to significantly reduce effluent phosphorus. Recent studies have established stringent targets:

- **Target Ranges:** 0.009 mg/l to 0.05 mg/l.
- **Requirement:** Achieving these levels necessitates the installation of additional **advanced treatment** beyond conventional secondary processes.

💡 **Design Tip:** When planning upgrades, engineers must balance water quality requirements with the need to increase plant capacity to accommodate rapid population growth.

Implementation Challenges

The implementation of water quality improvement plans, specifically **Total Maximum Daily Loads (TMDLs)**, is frequently delayed by several factors:

- **Resource Competition:** Public and private resources are limited and highly contested.
- **Technological Debate:** Arguments regarding the cost and availability of technologies capable of meeting "ultra-low" targets often slow progress.

🧮 **Calculation Note:** WLAs are calculated based on the specific assimilative capacity of the receiving waterbody during its most vulnerable seasonal period.



Checkpoint Quiz

1. Why is phosphorus control prioritized over nitrogen in Northwest freshwater systems?

- a) Nitrogen is toxic to salmon at all concentrations.
- b) Phosphorus is typically the limiting nutrient relative to biological needs.
- c) Nitrogen cannot be removed through tertiary filtration.
- d) Phosphorus loading only occurs from industrial sources.

Answer: (b). By limiting the nutrient in shortest supply, engineers can effectively control the over-stimulation of aquatic plant and algae growth.

2. During which period is treated wastewater discharge considered the most critical source of phosphorus loading?

- a) The wet winter season due to high influent flow.
- b) The spring runoff period when nonpoint sources are at their peak.
- c) The warm and dry summer months when runoff is minimal.
- d) Year-round, regardless of weather patterns.

Answer: (c). During dry months, the lack of rainfall means nonpoint source runoff is low, leaving constant wastewater discharges as the dominant contributor.

3. What is a primary technical indicator of nutrient-driven impairment in a stream?

- a) Constant pH levels throughout a 24-hour cycle.
- b) Large diurnal swings in dissolved oxygen and pH.
- c) Increased water velocity during summer months.
- d) A decrease in the total number of Idaho waterbodies on the 303(d) list.

Answer: (b). As excessive nutrients are metabolized by plants and algae, they cause fluctuations that can exceed state criteria for aquatic life protection.

Module 2: Evaluation Considerations and Summary of Observations

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the selection criteria and performance metrics used by the EPA to characterize advanced phosphorus removal.
- **Analyze** the comparative effectiveness of different filtration and biological nutrient removal (BNR) technologies across varying plant capacities.
- **Assess** the economic implications of advanced water treatment by reviewing residential sewer fee structures.

Executive Summary: Advanced wastewater treatment (AWT) using multi-stage filtration and chemical addition can consistently reduce effluent phosphorus to near-limit-of-detection levels (0.01 mg/l), while the integration of Enhanced Biological Nutrient Removal (EBNR) serves as a critical optimization step to reduce chemical costs and improve overall effluent quality.

Project Selection and Monitoring Protocols

The WWTPs in this evaluation were selected based on documented phosphorus removal effectiveness over several years. EPA included a diverse range of treatment technologies and facility sizes to provide a broad technical overview.

Characterizing Performance

Performance is defined by discharge monitoring data required under the **National Pollutant Discharge Elimination System (NPDES)**.

- **Methodology:** Monitoring follows EPA-approved analytical methods and quality control.
- **Long-term Trends:** Performance is expressed via the average and range of reported monthly concentrations.
- **Operational Buffer:** Actual effluent quality may be significantly better than reported, as many facilities are not currently required to optimize for their absolute best possible removal.

Summary of Observations: Performance Data

The following table summarizes the technology, capacity, and performance of the 23 evaluated facilities.



Water Treatment – Phosphorous Removal

EPA REGION 10

Facility Name and Location	NPDES Permit Number	Capacity	Advanced Phosphorus Treatment Technology	NPDES Permit Limitation for Phosphorus	*Average Effluent Phosphorus Concentration	Range of Monthly Average Phosphorus Concentrations	Monthly Residential Sewer Rate
Sand Creek WWRP Aurora, CO	CO0026611	5 mgd	BNR, filtration	None	0.1 to 0.2 mg/l	N/A	\$2.38 + \$4.50 / 1,000 gal used
Breckenridge S.D., Iowa Hill WWRP, CO	CO0045420	1.5 mgd	BNR, chemical addition, tertiary settlers and filtration	0.5 mg/l daily max & 225 lbs/year	0.055 mg/l	0.017 to 0.13 mg/l	\$19
Breckenridge S.D., Farmers Korner WWTP, CO	CO0021539	3 mgd	BNR, chemical addition, tertiary settlers and filtration	0.5 mg/l daily max & 225 lbs/year	0.007 mg/l	0.002 to 0.036 mg/l	\$19
Summit County Snake River WWTP, CO	CO0029955	2.6 mgd	BNR, chemical addition, tertiary settlers and filtration	0.5 mg/l daily max & 340 lbs/year	0.015 mg/l	<0.01 to 0.04 mg/l	\$36
Pinery WWRF Parker, CO	CO0041092	2 mgd	BNR, chemical addition, two- stage filtration	0.05 mg/l & 304 lbs/year	0.029 mg/l	0.021 to 0.074 mg/l	\$18
Clean Water Services, Rock Creek WWTP, OR	OR0029777	39 mgd	Chemical addition, filtration	0.1 mg/l (monthly median limitation)	0.07 mg/l	0.04 to 0.09 mg/l	\$16.07 + \$1.11/ccf
Clean Water Services, Durham WWTP, OR	OR0028118	24 mgd	BNR, chemical addition, filtration	0.11 mg/l (monthly median limitation)	0.07 mg/l	0.05 to 0.1 mg/l	\$16.07 + \$1.11/ccf
Stamford WWTP Stamford, NY	NY0021555	0.5 mgd	Chemical addition, two-stage filtration	0.2 mg/l	<0.011 mg/l	<0.005 to < 0.06 mg/l	\$10**
Walton WWTP Walton, NY	NY0027154	1.55 mgd	Chemical addition, two-stage filtration	0.2 mg/l	<0.01 mg/l	<0.005 to <0.06 mg/l	\$10**
Milford WWTP Milford, MA	MA0100579	4.8 mgd	Multi-point chemical addition, filtration	0.2 mg/l	0.07 mg/l	0.04 to 0.16 mg/l	\$27.50
Alexandria Sanitation Authority AWWTP, Alexandria, VA	VA0025160	54 mgd	BNR, Multi-point chemical addition, tertiary settling and filtration	0.18 mg/l	0.065 mg/l	0.04 to 0.1 mg/l	\$4.17 + \$4.49 / 1,000 gal used
Upper Occoquan Sewerage Authority WWTP, VA	VA0024988	42 mgd	Chemical (high lime) and tertiary filtration	0.10 mg/l	<0.088 mg/l	0.023 to <0.282 mg/l	\$3.03 to \$4.09/1,000 g
Fairfax County, Noman Cole WWTP, VA	VA0025364	67 mgd	BNR, chemical addition, tertiary clarification and filtration	0.18 mg/l	<0.061 mg/l	<0.02 to <0.13 mg/l	\$3.28/1,000 g



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