Use of Drinking Water Treatment Residuals in Stormwater Infrastructure

KEY FINDINGS

- DWTRs effectively reduce phosphorus in stormwater. Field studies show up to 92% total phosphorus and 90% dissolved phosphorus removal in DWTR-amended bioretention systems.
- Amorphous Al and Fe oxides in DWTRs bind phosphorus quickly and resist phosphorus release, even under changing flow conditions.
- Hydraulic performance must be balanced with phosphorus removal. Optimal incorporation of DWTRs is 3-10% by volume mixed with sand to maintain desired flow.
- DWTRs support circularity, provide cost savings, and reduce landfill burdens.

Background

Contemporary stormwater infrastructure uses low-impact design strategies, such as bioretention cells and sand filters, to manage urban runoff and improve water quality. In developed areas with widespread impervious surfaces, such infrastructure helps reduce peak flows, mitigate erosion, protect downstream ecosystems, and filter pollutants from stormwater. However, the substrates, or granular media, used in these systems, such as sand, compost, and gravel, are not effective at removing dissolved phosphorus. Phosphorus (P) is a major contributor to harmful algal blooms and degraded water quality in lakes and rivers. Treatment solutions capable of retaining both dissolved and particulate P are needed. Enhancing stormwater treatment practices to address this challenge is essential for protecting aquatic ecosystems and enabling recreational activities such as swimming, fishing, and boating.

Drinking water treatment residuals (DWTRs), byproducts of municipal water treatment, are promising low-cost P-sorbing amendments that can improve P retention in stormwater infrastructure. Their use supports a more circular economy by repurposing waste materials while enhancing stormwater treatment performance.

What are DWTRs?

DWTRs are industrial byproducts collected from municipal drinking water treatment plants, typically sludge produced from coagulation (a chemical process that uses coagulants to aggregate suspended particles for removal). Coagulants such as aluminum sulfate (alum), polyaluminum chloride, and ferric chloride are most commonly used to remove impurities during drinking water treatment. The DWTRs remaining after the treatment process are often stockpiled and/or disposed of in landfills. However, DWTRs can contain high levels of aluminum (Al) and iron (Fe) that are in amorphous forms (i.e., lacking in defined structure) which makes them excellent candidates for use in P removal.

Benefits of DWTRs in Stormwater Infrastructure

- **Circular Solution:** DWTRs promote resource circularity by repurposing waste materials from drinking water treatment plants (Figure 1). An estimated 35-40 million tons are generated globally each year.[1] Often considered a waste product, DWTRs are widely available at low or no cost. Their reuse helps reduce the burden on landfills.[2]
- **Low Risk of Contaminants:** Studies have shown DWTRs can also remove heavy metals (e.g., arsenic, cadmium, zinc) from stormwater with low release risk.[3,4] Per- and polyfluoroalkyl substances (PFAS) concentrations in DWTRs have thus far been reported to typically be lower than in biosolids, composts, and many soils.[5]

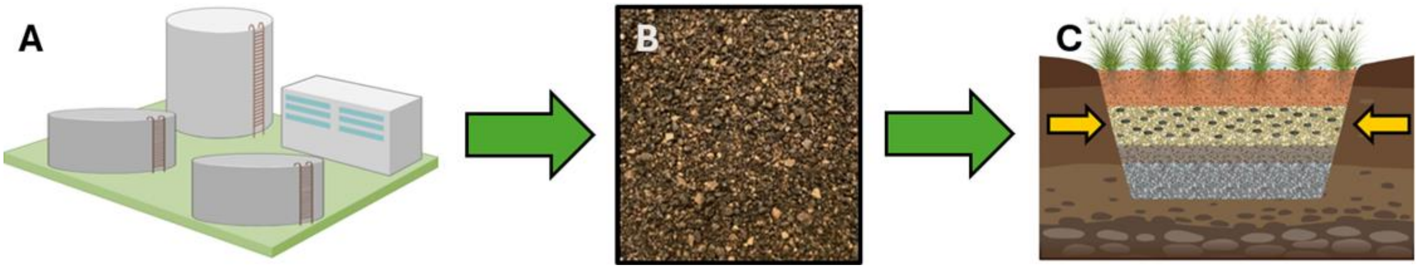

Figure 1. (A) Municipal drinking water treatment plants produce byproducts known as (B) drinking water treatment residuals (DWTRs);[5] (C) A bioretention cell constructed with layered media, including a DWTR-amended sand layer, demonstrating the beneficial reuse of DWTRs in stormwater treatment systems.

Phosphorus Removal Performance

Ament et al. (2021) used a multi-step laboratory study to determine the capacity of DWTRs collected from three New England drinking water facilities to retain P. Results from this initial study highlighted the high, but variable, P retention capacity of DWTRs, and demonstrated that mixing DWTRs with the sand layer of bioretention systems was superior to inserting a DWTR-only layer in terms of both P retention and hydraulics.[6] Second, Ament et al. (2022) tested the best design from the lab study in a field experiment, finding that DWTR-amended bioretention cells reduced total P by up to 92%, with excellent removal of dissolved P.[4] Third, Kubow et al. (2025) tested eleven DWTRs from the New England region, further demonstrating high, but variable, P removal in lab experiments, with less dense DWTRs having greater amorphous Al and Fe content performing best.[5] Fourth, Schambura et al. (in review) completed a field study of stormwater sand filters including 3-5% DWTRs by volume mixed into the sand. The DWTR-amended sand filters reduced P loads by 65-78%, including excellent performance at a site with runoff dominated by dissolved P.[7] Findings from these UVM studies build on past DWTR research.[3]

Key Design Considerations

Careful design and planning are important for gaining the maximum benefits from DWTRs. Some practical considerations include:

- **Choosing the right material:** DWTRs work best when they have a high content of amorphous metal oxides, large surface area, high porosity, and low bulk density.[3,5,6] In regions where PFAS or arsenic contamination are known problems, we recommend testing a facility's DWTRs prior to first use in stormwater treatment applications to assess risk.[5]
- **Balancing flow and treatment:** Incorporation of 3-10% DWTRs by volume into sand layers of stormwater infrastructure is recommended to optimize treatment performance while maintaining proper hydraulic flow.[6,7]
- **Thinking long-term:** DWTRs can likely continue to retain P for a few to several hundred years.[7] Longevity depends on the specific site conditions, the amount and form of P in runoff, DWTR characteristics, and overall design. More research is needed to verify long term field performance predicted based on lab studies.

References

[1] Krause, M., & Bronstein, K. 2024. Estimating national sludge generation and disposal from US drinking water and wastewater treatment plants. J. Clean. Prod., 453: 142121. https://doi.org/10.1016/j.jclepro.2024.142121.

[2] U.S. EPA. 2011. Drinking water treatment plant residuals management technical report: summary of residuals generation, treatment, and disposal at large community water systems. EPA 820-R-11-003. https://www.epa.gov/sites/default/files/2015-11/documents/dw-treatment-residuals-mgmt-tech-report-sept-2011.pdf. Accessed on: June 6, 2025.

[3] Ippolito, J. et al. 2011. Drinking Water Treatment Residuals: A Review of Recent Uses. J. Environ. Qual., 40: 1–12. https://doi.org/10.2134/jeq2010.0242.

[4] Ament, M. et al. 2022. Phosphorus Removal, Metals Dynamics, and Hydraulics in Stormwater Bioretention Systems Amended with Drinking Water Treatment Residuals. J. Sustainable Water Built Environ., 8(3): 04022003. https://doi.org/10.1061/jswbay.0000980.

[5] Kubow, M. et al. 2025. Phosphorus removal capacity, arsenic leaching, and PFAS content of drinking water treatment residuals with potential to enhance stormwater infrastructure in New England, USA. J. Sustainable Water Built Environ. In Press.

[6] Ament, M. et al. 2021. Balancing Hydraulic Control and Phosphorus Removal in Bioretention Media Amended with Drinking Water Treatment Residuals. ACS EST Water, 1(3): 688–697. https://doi.org/10.1021/acsestwater.0c00178.

[7] Schambura, M. et al. Phosphorus removal by two urban stormwater sand filters enhanced with alum-based drinking water treatment residuals. In Review.

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