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Phosphorus retention in constructed wetlands enhanced by zeolite- and clinopyroxene-dominated lava sand

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Constructed wetlands (CWs) are engineered systems for treating wastewater by sequestering nutrients and contaminants. Our aim was to assess the main phosphorus (P) binding states in operating CWs to assess P saturation and indications on P recycling potential of filter materials, which might be necessary under future peak P scenarios. The investigated vertical flow CWs (operation time up to 16) are based on either fluviatile (Fluv) sand or zeolite- (Ze-LS) and clinopyroxene (Cl-LS)-dominated lava sand. Organic and inorganic P accumulated in all CWs independent of filter materials and showed a considerable increase with operation time. Concentrations of P decreased sharply with depth in the Fluv-CWs compared to only a slight decrease in the lava sand CWs, with P concentrations of deeper horizons approximating the relatively P enriched original lava sand substrates. Orthophosphate was the dominant pool in all CWs, while the sum of organic fractions ranged between 11% and 33%. Sequential extraction indicated that P was mainly associated with Fe and Al (hydr)oxides for Fluv-CWs and Ze-LS-CWs, while Ca and Mg bound mineral phosphates dominated in Cl-LS-CWs. Oxalate extractions pointed to a clear dominance of P fractions associated with poorly crystalline Fe- and Al-(oxy)hydroxides. Solution 31P NMR analyses revealed that inositol hexakisphosphates were a major pool of organic P in surface layers of CWs, which increased with operation time. With a maximum of 0.5% P content, filter sands do not appear to be a suitable fertilizer for direct application to agricultural fields. The dominance of inorganic, poorly crystalline P species point to potentially high desorption capacity which might be investigated further, to assess recycling potential of P or usage of filter materials as soil amendments with relatively high plant available P. The latter might become feasible and economically attractive under future P scarcity. Simultaneously, P saturation indexes (DPS) did not indicate an imminent P saturation of filters, since P accumulation was not restricted by binding to Al and Fe minerals.
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