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Diurnal patterns and removal of selected elements in two Norwegian wastewater treatment plants with primary treatment

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Discharges from wastewater treatment plants (WWTPs) are a source for pollutants to the environment. Here we studied influent patterns and removal of selected elements in two full-scale WWTPs, Ladehammeren (LARA) and Høvringen (HØRA) in Trondheim, Norway. Both WWTPs have significant industrial loading contributions (up to 40% in LARA), employ preliminary and primary treatment steps, including chemically aided flocculation ($ClFeO_4S$/polyamine in LARA, polyacrylamide in HØRA), and discharge directly into Trondheimsfjord. In a 7 day sampling campaign, 24 h composite samples of influent and effluent wastewater, as well as sludge samples, were taken to determine influent concentrations and removal of Al, P, S, Cr, Fe, Ni, Cu, Zn, As, Cd and Pd. To study release patterns and gain information about potential sources, diurnal variations of elemental concentrations were determined and modelled in 8 h composite samples of raw influent wastewater from morning, evening and night discharges.

Element concentrations in 24 h composite influent samples were highest for S>P and Al and lowest for Cd<As<Cr and Pd. Concentrations of Al, P, Cr, Cu and Cd were higher in HØRA than LARA, with Fe loadings being approximately double. Removal efficiencies varied between the analysed elements, and were highest for Al (86%), P (74%) and Cu (57%) in LARA, which utilises both inorganic and organic flocculants. In contrast, removal rates were below <50% for P, Cu and S in HØRA. However, in LARA, concentrations of Fe, Ni and S were significantly higher in the treated effluent compared to the raw influent, deriving from the use of inorganic flocculant. This was also reflected in Fe and S concentrations in treated sludge.

Elemental concentrations in 8 h composite samples mostly followed general diurnal discharge patterns, with higher concentrations in mornings and evenings and lower concentrations at night. In HØRA, concentrations of most elements further correlated well with total suspended solid concentrations (TSS), with the strongest correlations observed for P, S and Cu (R^2>0.9). Correlations with TSS were less pronounced in LARA, and were weakest for Pb, Fe and Cu (R^2<0.6), which can be potentially attributed to the higher industrial loading contributions in LARA. Enrichment factors were high for P>Cu>Zn>Cd>As, and were still above 10 for Cr and Ni in biosolids, indicating anthropogenic sources for these elements. Several elements also occurred as nano- and micron-sized particles.