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Water budgets of Italian and Dutch gravel pit lakes: a study using a fen as a natural evaporation pan, stable isotopes and conservative tracer modeling.

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Gravel pits are excavated in aquifers to fulfill the need for construction materials. Flow-through lakes form where the gravel pits are below the water table and fill with groundwater. Their presence changes the drainage patterns, water- and hydrochemical budgets of a watershed. We have studied the water budget of two gravel pit lakes systems using stable H and O isotopes of water as well as conservative tracer (Cl) modeling. The Dutch gravel pit lakes are a fluvial fresh water system of 70 lakes along the Meuse River and the Italian gravel pit lakes are a brackish system along the Adriatic coast. Surface water evaporation from the gravel pit lakes is larger than the actual evapotranspiration of the grass land and forests that were replaced. The ratio of evaporation to total flow into the Dutch lakes was determined by using a Fen as a natural evaporation pan: the isotope content of the Tuspeel Fen, filled with rain water and sampled in a dry and warm summer period (August 2012), is representative for the limiting isotopic enrichment under local hydro meteorological conditions. The Local Evaporation line (LEL) was determined δ2 H = 4.20 δ 18O - 14.10 (R^2 = 0.99) and the ratio of total inflow to evaporation for three gravel pit lakes were calculated to be 22.6 for the De Lange Vlieter lake used for drinking water production, 11.3 for the Boschmolen Lake and 8.9 for the Anna's Beemd lake showing that groundwater flow is much larger than evaporation.
The Italian gravel pit lakes are characterized by high salinity (TDS = 4.6-12.3 g L-1). Stable isotope data show that these latter gravel pit lakes are fed by groundwater, which is a mix between fresh Apennine River water and brackish (Holocene) Adriatic Sea water. The local evaporation line is determined: δ2H = 5.02 δ18O - 10.49. The ratio of total inflow to evaporation is 5. Conservative tracer modeling indicates that the chloride concentration in the Italian gravel pit lakes stabilizes after a short period of rapid increase, because water leaving the lake via groundwater flow, driven by the drainage system, removes part of the Cl that accumulates in the lake due to evapo-concentration. Under climate change, rising sea levels and continuing land subsidence as well as increasing precipitation would increase the need for drainage which would enhance groundwater flow through the lake. The resulting steady-state Cl concentration of the lakes could become less than the current Cl concentration. This effect would be larger than increasing evapo- concentration. Both gravel pit lake systems have a large flux of groundwater into and out of the lakes driven by evaporation and (artificial) drainage with important consequences for the water- and hydrochemical budgets of the whole watershed and in particular on freshwater quantity and groundwater salinity.