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Groundwater and surface water interaction in flow-through gravel pit lakes.

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Gravel pits are excavated in aquifers to fulfill the need for construction materials. Flow-through lakes form when the gravel pits are below the water table and fill with groundwater. In certain areas there are more than 60 of these lakes close together and their presence changes the drainage patterns and water- and hydrochemical budgets of a watershed. In flow-through gravel pit lakes, groundwater mixes with surface water and interacts with the atmosphere; outflow occurs only via groundwater. The lifespan of gravel pit lakes may be up to thousands of years as their depth to surface ratio is typically large and sedimentation rates are low. We have studied two gravel pit lake systems, a fluvial freshwater system in the Netherlands and a coastal brackish lake system in Italy. One Dutch gravel pit lake studied in detail is in part artificially replenished with Meuse River water for drinking water production that occurs downstream of the lake by water pumps. The Italian gravel pit lakes are fed by brackish groundwater that is a mix of freshwater from precipitation, Apennine Rivers and brackish (Holocene) Adriatic Sea water. Here, the drainage system of the low lying land enhances groundwater flow into the lake. Surface water evaporation is larger in temperate and Mediterranean climates than the actual evapotranspiration of pre-existing grassland and forests. The lakes, therefore, cause a loss of freshwater. The creation of water surfaces allows algae and other flora and fauna to develop. In general, water becomes gradually enriched in certain chemical constituents on its way through the hydrological cycle, especially as groundwater due to water-rock interactions. When groundwater ex-filtrates into gravel pit lakes, the natural flow of solutes towards the sea is interrupted. Hydrochemical analysis of ground- and surface waters, as well as chemical analysis of lake bottom sediments and stable H and O isotope data, show that gravel pit lake water is characterized (among others) by a higher pH, O_2 and alkalinity and lower dissolved metal and certain trace concentrations than natural lakes and groundwater. In both settings, groundwater rich in dissolved elements (e.g. Al, As, Fe, Mn, Ni and PO43) flows into the gravel pit lakes where the pH and DO are high, which enhances the (co)precipitation of Fe, Mn and Al oxides that include trace elements. Metal concentrations in the Dutch lake's bottom sediments have increased over a 10 year period. Redox reactions caused by water table lowering and farmland fertilization upstream from the lake explain the metals mobilization and subsequent transport with groundwater towards the lakes. The gravel pit lakes, especially if there are many close together, influence so the cycle of water metals, nutrients as well as other trace elements of a watershed by incorporating them into biomass and bottom sediments or creating an environment where they can remain in concentrated solution.