ABSTRACT

Kinghorn Loch is a small lake of area 11.3 ha and maximum depth 12.8 m, situated in Fife Region of Scotland. From 1947-1983 the loch was polluted by leachate from Red Mud disposal. Red Mud is a waste product of the alumina dressing industry. The leachate consisted of a highly alkaline solution of sodium hydroxide and carbonate and contained high levels of dissolved aluminium, arsenic, vanadium and sulphate.

Initially the loch became nutrient enriched (mainly orthophosphate) but by 1961 the pH bagan to increase significantly so that by 1983 it exceeded a mean of pH 10.1, and levels of dissolved arsenic and vanadium were the highest of any watercourse in the U.K. During this time 0.5 m of red/red-brown fine mud accumulated, at a rate which by 1983 was in excess of 25 mm yr^{-1} (1.5 kg m^{-2} yr^{-1}). Aluminium in the leachate reacted with high levels of native silicon and magnesium to produce authigenic clay minerals. At near-neutral pH these proved to be high in silicon but by 1983 magnesium was dominant. The progression from high-Si to high-Mg seems to have been continuous and does not suggest the formation of discrete mineral phases. By 1983 authigenic clay minerals represented 24% of sediment mass, while organic material, generated by prolonged and severe phytoplankton blooms, accounted for 16% and detrital inputs 12%. Calcite, precipitated from the native water, made up 48% of the sediment. Experimental procedures found that calcite production was essentially abiotic and proceeded by second order kinetics. Precipitation of clay minerals was independant of calcite production and calcite did

not incorporate significant quantities of organic matter.

The high organic input, combined with hematite (washed-in as Red Mud solids), caused highly reducing conditions within the sediment, but the red colour indicated Fe(III) dominance, while interstitial sulphate was not fully reduced. In some cores a grey zone occured immediately above the native sediment and this indicated extensive pyrite formation. However, despite the high level of sulphate in the loch water, the lack of extensive sulphate reduction led to low sulphur levels in the polluted profile. The interstitial water was found to be chemically active, with high levels of dissolved iron, calcium, magnesium, aluminium and arsenic occuring.

The leachate was diverted from the loch in 1983 and the water quality recovered quickly. By 1984 the pH had returned to a natural pH 8. However by 1985 arsenic levels in the water remained substantially elevated (30-50 ug l^{-1}) and although sediment core profiles were found to be much less reducing, interstitial water chemistry was active, and dissolved arsenic levels exceeded 1 mg l^{-1}, which was passed to the body of the loch.

A thermodynamic model was developed to determine the chemical speciation of mixed waters and to calculate the degree and character of mineral deposition. However, due to the lack of available kinetic data, application of the model was limited.

Benthic populations were extremely restricted in 1983 but although greatly increased in numbers by 1985, no diversification had occured. Plankton and benthic invertebrates (in 1985) did not concentrate arsenic.

The high authigenic content of the sediments provides a unique opportunity for the further study of clay mineral formation over a very short time span, and allows a consideration of pH dependance of such processes.