Aquatic transport behaviour of cobalt deduced from nuclear reactor derived ^{60}Co

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Introduction

Swiss nuclear power plants discharge, since their installation in the early seventies, radionuclides, among them ^{60}Co in low abundance with their waste waters. These discharges represent excellent objects to study the fate of ^{60}Co after their release into the aquatic environment. The list of parameters is long and requires an interdisciplinary approach. There are parameters controlling adsorption of ^{60}Co by suspended particles of biologic, chemical and detrital origin, parameters controlling the sedimentation and resuspension of particles, parameters controlling the decomposition of biologic matter and redissolution of chemical precipitants, and parameters controlling the ionic speciation of ^{60}Co in solution.

We present first results from three different aquatic environments along the course of the river Aare in Switzerland: (1) in the 18 km section between the nuclear reactor Mühleberg, located 13 km WNW of Bern and Lake Biel, (2) within Lake Biel and (3) the 7 km section between the nuclear reactor Beznau and the Aare/Rhine confluence. These sections have different aquatic physical specifications and different types and concentrations of suspended particles. All sections have most significant annual variations, particularly regarding the importance of biological particles. In the Aare upstream of Lake Biel detrital silicates are mostly dominant due to natural erosion upstream. In the lake their dominance decreases with distance to the Aare delta. Within the lake, plankton and chemical precipitates play the major role. Further downstream, due to natural filtration by the lake, plankton continues being the most important suspended particle. These differences allow therefore to study the parameters listed above to some point independently.

Waste water discharges from both nuclear reactors are on a weekly to by-weekly basis, total activities per discharge are several million Bequerel of ^{60}Co. We measure ^{60}Co by γ-spectrometry in untreated and filtered water samples, and in particles of different grain-size obtained by in situ filtration and continuous flow centrifuging.

Results

^{60}Co adsorbs to both inorganic and organic phases. The adsorption dependence on grain-size and mineralogy, observed in laboratory experiments, has been confirmed in the field. Deposition of radionuclides in small reservoirs of hydroelectric plants, found all along the course of the Aare river, is small because here mainly particles in the sand and silt grain-size fraction (unefficient adsorbers) are deposited. Biological debris should decompose readily in river sections due to oxygen abundance. Riverine particle adsorption of ^{60}Co is slow. 30 minutes after discharge less than 1% is adsorbed to particles > 1 mm. Even after 2 days of waste water/particle contact adsorption equilibrium has not been reached. ^{60}Co in the waste water is in part particular ($\sim$20% > 0.45 mm) and in part in solution. The part in solution is entirely cationic. After 30 min. contact with the Aare water 50% of ^{60}Co is found to be anionic. We interpret this by complexation with organic ligands.

The behaviour of ^{60}Co in Lake Biel is controlled by aquatic physical and biological parameters. During the summer the biological factor reaches a maximum, while the lake has a stable stratification. Under this condition the Aare entrains into the epilimnion (controlled by temperature) and water residence time can be as low as 5 days (based on theoretical considerations and a tracer experiment). During the winter period total mixing takes place, the water residence time goes up, and the biological factor is reduced. This striking seasonal variation can be seen in sediment cores. Comparison of the monthly discharge of the nuclear reactor with sediment content indicates that during the summer period a significantly lower portion of ^{60}Co enters the sediments than during the winter period.