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Kinetics of ^{3}H, ^{90}Sr and ^{137}Cs content changes in hydrosphere in the Vltava River system (Czech Republic)

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ABSTRACT

The paper presents results and interpretation of long-term monitoring of occurrence and behaviour of radioisotopes ^{3}H, ^{90}Sr, and ^{137}Cs in the vicinity of the Temelín Nuclear Power Plant. ^{3}H, ^{90}Sr, and ^{137}Cs originate predominantly from residual contamination due to atmospheric nuclear weapons tests and the Chernobyl disaster in the last century. Monitoring of radionuclides comprised surface waters, river sediments, aquatic plants, and fish. This enables an up-to-date appraisal of the Temelín Nuclear Power Plant impact on the hydrosphere in all indicators at standard power plant operation, as well as at critical situations. The time and spatial variability of these radionuclide concentrations were monitored in the hydrosphere at in- and out-flow of the Orlík Water Reservoir. The basic evaluated radioecological characteristics can be used in assessing the long-term kinetics of decline and behaviour of radionuclides and their potential release into the environment. A very slow decline in ^{3}H concentration at unaffected sites was observed. At sites downstream from the power plant the ^{3}H concentrations were significantly higher, an evident impact of the power plant operation. A decline in ^{90}Sr and ^{137}Cs concentrations was observed in all the monitored indicators. Also, the characteristic effective and ecological half-lives were evaluated.

1. Introduction

The usual operation of a nuclear power plant is associated with production of different radionuclides that can be released into the environment in very low concentrations. Operation of such facility is obviously accompanied with high requirements to keep radiation protection (Corner et al., 2011). Moreover, the past accidents at nuclear facilities had unquestionable impacts on environment: Fukushima accident (Konoplev et al., 2016), Chernobyl accident (Smith and Beresford, 2005) and accidents in the Southern Urals (Soyfer, 2002).

Anthropogenic radionuclides in the territory of South Bohemia (Czech Republic) have been studied by T.G.M. Water research institute (TGM WRI) long because of the Temelín Nuclear Power Plant (Temelín NPP). Main technical parameters of the Temelín NPP are mentioned in Table 1. Pilot operation of the first reactor was launched in June 2002 and of the second one in April 2003. Since May 2003, the Temelín NPP has been in full operation. The plant releases its waste water into the Vltava River. The Orlík Water Reservoir, located on the Vltava River downstream of the waste water outflow, is presumed to play a major role in the radionuclides behaviour in the hydrosphere and its outflow from assessed area (Fig. 1).

Usually, the wastewater from a NPP is discharged into a big river, e.g. as in (Pujol and Sanchez-Cabeza, 2000), however the wastewater from the Temelín NPP is discharged into a relatively small watercourse (see Table 2). Regarding the expected climate change impacts in the Czech Republic including the hydrological drought (e.g. Potop et al., 2012), the radionuclide activity concentrations has potential to increase due to lower dilution in the Vltava River affected directly by the Temelín NPP (Fig. 1).

Anthropogenic radionuclides have been observed in the environment since atmospheric tests of nuclear weapons and following the accident at the Chernobyl nuclear reactor in the last century. During the atmospheric tests of nuclear weapons 186.10^{3} PBq ^{3}H, 622 PBq ^{90}Sr and 948 PBq ^{137}Cs was released (UNSCEAR, 2000). The estimated amount of released radionuclides during the Chernobyl disaster is 10 PBq ^{90}Sr and 85 PBq ^{137}Cs (UNSCEAR, 2000). According to Atlas (1998), the average surface deposition of ^{137}Cs due to Chernobyl disaster in the Czech Republic was 7.6 kBq/m^{2}.

Estimates of the amount of ^{137}Cs deposited on the territory of the Czech Republic are based predominantly on investigations carried out in June 1986 by the Centre of Radiation Hygiene of the Institute of Hygiene and Epidemiology (IHE CRH, 1987). These investigations were

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Table 1
Main technical parameters for the Temelín NPP (ČEZ, 2017).

Number of reactor blocks	2
Installed output	2 × 1055 MW
Reactor	pressurised water, VVER 1000
Year of commissioning	2002
Radioactive discharges into the Vltava River	
Limit of ^{3}H	66 TBq/y
Annual average ^{3}H discharges[a]	51 TBq/y
Limit of other activation and fission products (AaFP)	1 GBq/y
Annual average discharges AaFP[a]	0.116 GBq/y

[a] Average in 2008–2016 when the ^{3}H and other AaFP amount released from the Temelín NPP were stabilized.

Table 2
Characteristics of sampling sites.

	Q_a	TSS	K	Ca
	m^3/s	mg/l	mg/l	mg/l
Vltava Hluboká	30.0			
Vltava Hněvkovice	30.6	9.4 ± 3.7	3.6 ± 1.0	16.2 ± 5.3
Lužnice Koloděje	23.6	24.8 ± 8.5	7.0 ± 2.3	26.6 ± 6.4
Otava Topělec	23.3	11.5 ± 8.8	3.9 ± 1.3	19.1 ± 4.2
Vltava Solenice	84.3	3.9 ± 1.8	4.2 ± 1.2	21.0 ± 4.4
Vltava Štěchovice	85.6			
Vltava Prague Podolí	143			
Vltava Zelčín	152			
Elbe Hřensko	319			

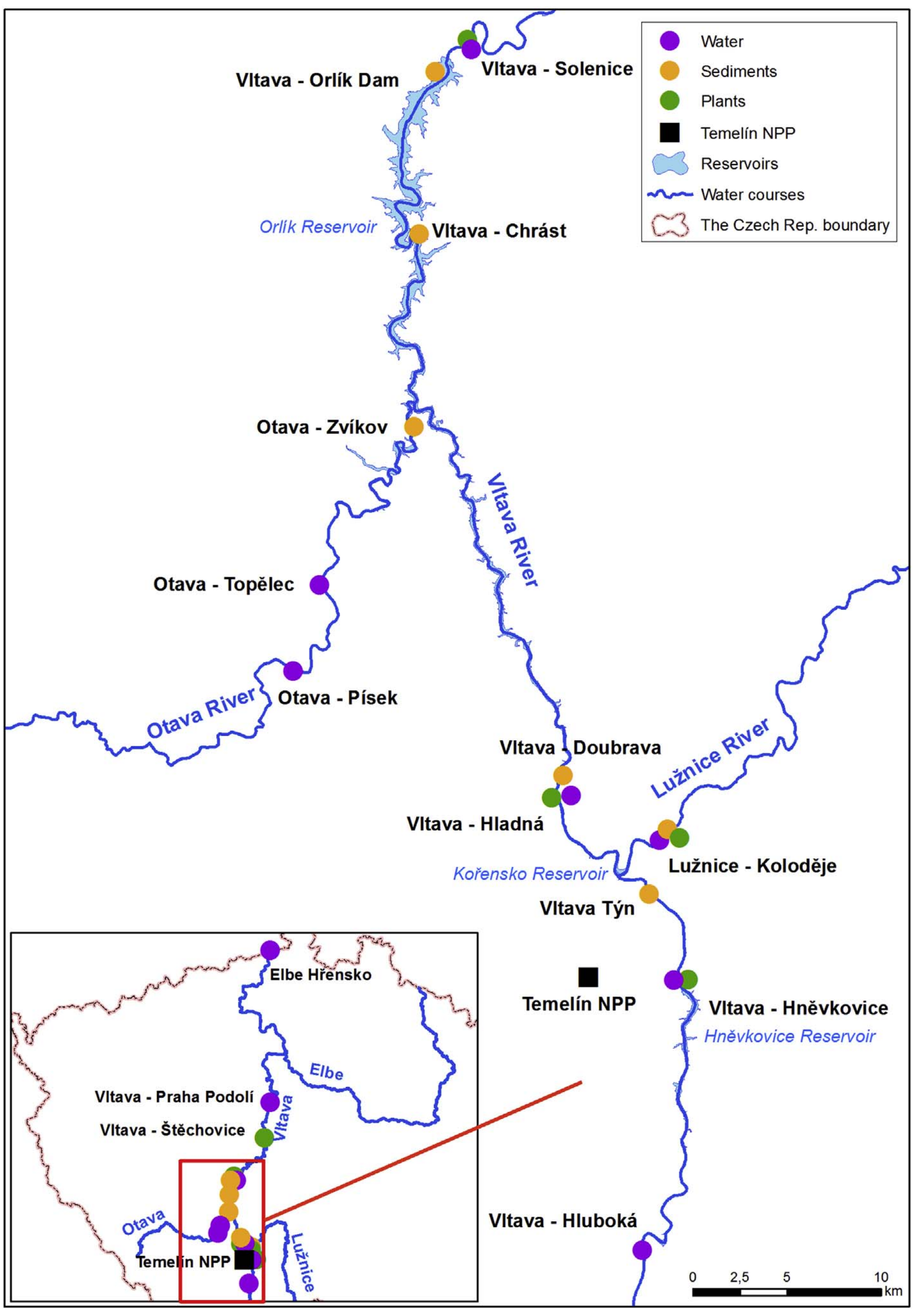

Fig. 1. Map of the sampling sites.

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