Clean-up Levels for Recovery of a ^{137}Cs Contaminated Site in the Slovak Republic

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The 19 km long banks of the Bohunice NPP waste water recipient (Manivier canal (0.3 m3/s) and Dudváh River (0.8 m3/s)) has been identified as contaminated by 137Cs as a result of two accidents on the CO2 cooled and heavy water moderated NPP-A1 unit in 1976 and 1977. Until 1992, NPP waste water had been derived through a 5 km-long canal to the Dudváh River (Qa=1.8 m3/s) conjucting with the Váh River (150 m3/s) after 13 km downstream at 90 km from Váh's mouth into the Danube River. Between 1976 and 1978, when both accidents happened, construction of a flood control project on Dudváh River had just been being implemented in the length of 8 km upstream of its mouth. In the next upstream part of the River with about 5 km long river section, affected by NPP, the flood control conditions are insufficient and has, hitherto, caused permanent concern of the public.

The contamination of banks and its significance was discovered in 1991 in connection with preparation of a flood control project implementation. As a result, the flood control project implementation was stopped. In 1992 a bank restoration project including shallow burial of removed soil was initiated by the nuclear Power Plant (NPP) who was considered as responsible for the site contamination. A cleanup level of 1 Bq/g 137Cs was given ad hoc by the authority. The contaminated soil disposal was designed as a subsurface concrete structure with planned capacity 5 000 m3 inside the NPP area. This area was considered to be as the most acceptable disposal site for the nearby public.

Radiological characterization of the contaminated banks. Detailed radiological survey done between 1992 and 1994 shows that the top ^{137}Cs soil contamination on the banks widely varies from background level to about 20 kBq/kg (3.8 MBq/m^2) the Dudváh River and reaches 250 kBq/kg for some limited spotty-contaminated sections on the Manivier canal banks. The average ^{137}Cs activity concentration on the lower part of banks reaches 6.3 kBq/kg

in the top 10 cm soil layer. The overall contaminated area in the site with ^{137}Cs exceeding 1Bq/g, selected as a preliminary working limit by the authority, has been identified as about 67,000 m^2 and the volume of soil to be removed at this clearance level about 13 000 m^3.

Re-consideration of the restoration project. In view of above new monitoring results, it became clear that the 1 Bq/g of ^{137}Cs level in soil is too-low for use as justified cleanup criteria. The restoration project showed to be necessary to being re-considered with emphasis on the complexity of proposed restoration project, e.g. large area monitoring in NPP surroundings, analysis of proper bank restoration techniques (removing, clean covering, trenching, fencing) including disposal of the removed soil and siting of designed disposal structure relating to concerned public. As typical feature of these efforts, clear legislation in the field has hitherto absent. There is why a primary demand to develop some principles for evaluation of the justified scale of cleanup measures including appropriate cleanup criteria development showed out to be as of first priority in order to achieve confidence and authorization of the re-considered restoration project. This demand was realized in a tight cooperation with competent hygiene authorities and experts.

Two techniques belonging to more cost-consuming techniques have been selected for contaminated banks cleanup measures: a) the standard removing/disposal of top soil layer for the steep and un-engineered banks and b) mechanical dilution/fixation of contaminated top soil by clean soil cover for the flat contaminated terraces areas. The clean cover technique sufficiently reduces the anticipated radiation risk, however, its price is about 10-time lower comparing to the standard removing/disposal technique.

Criterial dose assessments and cleanup level developments: The contaminated banks are accessible for 16,000 residents living in a 3.5 km wide strip alongside the river. Selected exposure pathway scenarios with authorised parameters were applied for characterization dose assessments and development of proper cleanup criteria (see Tab.1). Apart from external exposure pathway, also, ingestion pathways using transfer factors for goats milk and meat (for loamy soil according to the reference [1]) were also part of the made dose assessments. It was agreed by the authority that exceeding of the derived cleanup levels only justifies implementation of more cost-consuming restoration techniques.

A stay scenario for the evaluation of actual risk on the banks (300 h of fishing in sitting position) and a residential scenario for use of relocated contaminated soil for housing were selected for evaluation of potential risk from the use of contaminated soil. So, according to these conditions, the effective dose from a stay on a bank did not exceed (in 1993) 0.35

mSv/a, although, the potential risk from the use of contaminated soil reached higher levels of effective dose to up to about 2 to 3 mSv/a. The annual collective dose from the stay on the banks was estimated as low, maximally, on the level of about 100 - 200 man mSv, accordingly to not too-intense use of the banks.

Concerning the low collective doses, it was recognized that the benefit from the planned bank restoration is mainly indirect consisting in allowing the implementation of necessary flood control project. In this context, moving of large amount of the contaminated soil from the river banks, and its free release into the environment during a flood control project implementation (and so its possible use for housing) poses the most serious potential risks for the nearby population. Respective cleanup criteria were derived on the basis of the recovery approach of the ICRP [1], accepted by the authority. According to this both the actual dose and potential risk to a critical individuals from the contaminated banks must not exceed 1 mSv/a.

Average ^{137}Cs contamination level in the top (10 cm) bank soil, AL_{50} = 7.1 Bq/g continuously over 80 m long sections, corresponds to the above critical potential dose constraint requirement. In addition, ^{137}Cs activity concentrations $AL_{.3}$ = 25 Bq/g for isolated spots was proposed for the spotty contaminated sections of canal banks.

According to the authorized principles, clean soil cover is sufficient to be applied over 9,500 m^2 of contaminated flat area [3]. On the spotty contaminated canal section, only the isolated spots of contamination is proposed to be removed. So, the resulting volume of soil to be removed from the steep banks and safely buried in a disposal concrete structure inside the Bohunice NPP area equals to about 1,100 m^3.

The derived criteria are in good relation, also, with the results of the volume distribution of the activity concentration analysis. Cleanup measures, even, for a small part of the contaminated area on the banks (contamination above of 7 $Bq.g^{-1}$) would lead to significant improvement in remediation of the contaminated banks.

Other crucial aspects influencing the final restoration project were identified as follow: a.) anxiety of the nearby population about the planned subsurface disposal facility for removed soil, b.) limited disposal capacity inside the NPP area and c.) willingness of the Bohunice NPP to pay and support to the bank restoration project implemetation.

Present conditions for implementation of planned bank restoration. Even at the mentioned wishing political conditions, the developed restoration project has not till been implemented.

It was mainly caused by problems with siting and disagreement of land-cataster owner with placement of the planned disposal facility inside the NPP area.

Meantime, during the past ten year in Slovakia, the social and political conditions have crucially changed (privatization, more democracy, change in finance allocation priorities). Moreover, a general concept for handling with contaminated soil inside the Bohunice NPP area is being now under development within the current decommissioning efforts in the site. It tends to avoid moving and re-disposal of large volume of contaminated soil as it is considered as very expensive. All these changes crucially influence the cost side of the optimization equation for the contaminated bank remediation. Therefore one can expect that the developed cleanup levels including the scale of burial of the removed contaminated soil from the banks will be newly re-considered as soon as the final decision on the necessity of the bank remediation will be made. Probably, the flood control project implementation on the un-engineered part of the Dudváh banks will be the new starting point for addressing again the remediation at least of the concerned contaminated banks.

Tab. 1 Dose factors (DF) and derived inetrvention levels (DIL=1/DF) for selected criterial scenarios relating to 1Bq/g of ^{137}Cs in soils

Scenario	Geometry factor, g*	t_{exp}, h/y	Ingestion pathway**	Ingestion dose rel.unit***	Dose factor DF mSv/y	DIL(1mSv / y) Bq/g
Stay on banks	0.54 x1.4	300	mi+me	0.4	0.035	28.6
Stay on field	0.67	500	ve+po	1	0.078	12.8
Use of soil 50m3	0.39	1950	ve+po+mi+me	1.2	0.14	7.1
Use of soil 200m3	0.67	2000	ve+po+mi+me	1.2	0.21	4.8

** - g = (used dose rate/Bq.g-1)/(0,118 mSv.h-1/Bq.g-1), is a geometry factor against a half-definite source,*

*** - we – vegetable, po – potato, mi – milk, me – meat*

**** - unit for ingestion was chosen as 0,04 mSv/y corresponding to consumption of 110 kg potato, 55 kg root and 55 kg fruit vegetables grown in contaminated soils with 1 Bq/g of ^{137}Cs and $^{90}Sr/^{137}Cs$=0.02*

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