

DETERMINATION OF THE MASS TRANSFER PARAMETERS FROM FIELD TEST RESULTS ON SARATOV SITE

Prozorov L.B., Gousskov A.V., Speshilov S.L., Korneva S.A.

Mos NPO “Radon”, Moscow

7th Rostovsky Lane 2/14, Moscow, 119121, Russia

E-mail: Radonlev@pol.ru

ABSTRACT

The paper reports about determination of mass transfer parameters from field experiments, fulfilled as a part of comprehensive researchers that have been carrying out in the Saratov disposal site, for collecting actual data in purpose of long-term safety prediction. The tests embraced sampling the real contaminated solutions from closed vaults, pouring indicator solutions into a dug hole, studying rocks underlying the dug hole bottom, estimation of filtration characteristics and sorption parameters of the layer and, after laboratory study, pouring contaminated solutions in natural conditions with following sampling contaminated rocks and inspecting lateral and vertical spreading.

BACKGROUND.

There are 15 regional disposal facilities of “Radon” system besides MosNPO “Radon” created in the beginning of sixties in Russia. It is their function to collect, transport, treat and dispose radioactive wastes, generated in industry, medicine and science.

On purpose to obtain important information for likely radionuclide migration prediction, to analyze the geological medium as a factor of radiation contamination constraint and to develop and verify safety assessment approach for current and new repositories in the “Radon” facilities the complex of researches for evaluation of geological and ecological safety of LLW/ILW isolation in specific geological-and-hydrogeological conditions was projected by specialists of Scientific and Research Center of Geology-and Ecology and Rehabilitation of MosNPO “Radon”. The complex includes:

Stage 1. Exploratory wells drilling;

Stage 2. Monitoring drilling for radiation and hydro-geological control of surrounding rock;

Stage 3. Obtaining of filtration properties of surrounding rock in natural conditions;

Stage 4. Contaminated water analysis (chemical and radionuclide);

Stage 5. Laboratory study of real radioactive solution interaction with containing rock in static conditions and in dynamics (on filtration or diffusion models);

Stage 6. Field experiments for geological barrier protective properties clarification;

Stage 7. Safety assessment prediction.

All these stages differ for different sites depending on geological and hydro-geological conditions, storage construction and available data.

Since 1996 “Radon” specialists have been carrying out the comprehensive researchers on the Saratov site.

The Saratov disposal facility does storage of solid and liquid radioactive wastes of low and intermediate level (LILW) and spent sealed sources from Belgorod, Voronezh, Kursk, Lipetsk, Orel, Penza, Saratov and Tambov regions.

The Saratov disposal facility was built according to •P-4891 type design and has been operating since 1964. At present the facility includes:

- 5 closed filled exposed trenches;
- 1 spent source storage;
- 1 reservoir for liquid radioactive waste disposal (empty);
- 3 filled and closed vaults with solid radioactive wastes;
- 1 active solid waste storage

FIELD EXPERIMENTS.

One of the important parts of the radioactive waste disposal safety assessment is the consideration of a number of likely pathways associated with natural groundwater, human intrusion, disruptive events and others factors. Geological medium has significant interest in point of radionuclide transport through hosting rocks in subsurface groundwater and for long-term safety assessment of the disposal sites it is necessary to receive as more details in geology, hydrogeology and geochemistry of the underlying strata as it is possible and profitable.

In the framework of the researchers on stage 3 and on stage 6 field experiments were fulfilled for determination of migration parameters in-situ after exploratory drilling, preliminary modeling and after lab studies accordingly. The tests embraced sampling the real contaminated solutions from closed vaults, pouring indicator solutions into dug hole, studying rocks underlying the dug hole bottom, estimation of filtration characteristics and sorption parameters of the layer and, after laboratory study, pouring contaminated solutions in natural conditions with following sampling contaminated rocks and inspecting lateral and vertical spreading.

All tests were fulfilled on the depths of vault bottom location.

At stage 3 the pouring tests were carried out in accordance with Russian standard GOST 23278-78. In a dug hole with size 1,5 x 1,4 m and with depth 0,93 m sump with diameter 0,6 m and depth 0,29 m was made (fig.1).

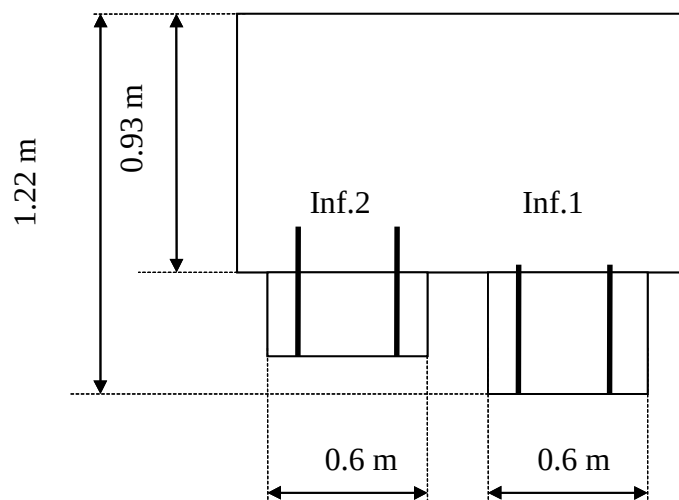


Figure 1. Schematic section of the dug hole and the sumps for the filtration tests

In the seepage gage (infiltrometer) •1 ($\varnothing=30,35$ cm; $h=22,0$ cm) pouring of water, colored with black ink, was carried out with free recession of level. The black ink «Raduga» was repeatedly applied earlier and in the present experiment was used as elementary non-sorbed indicator for visual supervision. Water was filled in up to initial 15 cm. Time of the filling - 0,33 minutes. Up to the same level not-colored water was being filled simultaneously in the sump into the external part of the infiltrometer. Further measuring dropdown were carried out and time from the beginning of the filling was fixed. The level of water in the external ring was lowered practically simultaneously with the internal one. At supervision it was necessary, that a lot of measuring points will ensure higher accuracy at filtration parameter definition for the underlying rocks. The results of the measurements are given in the table 1 and in figure 2.

Table 1

Dropdown measurements during water filling in the infiltrometer 1

•	Dropdown (•m)	Time (min)	•	Dropdown (•m)	Time (min)
1	pouring	0,33	9	9,1	90
2	3,0	18	10	9,9	100
3	4,3	30	11	10,0	102
4	5,0	36	12	10,4	110
5	6,4	54	13	11,2	118
6	7,3	66	14	14,3	163
7	8,2	72	15	15,0	169
8	8,7	80			

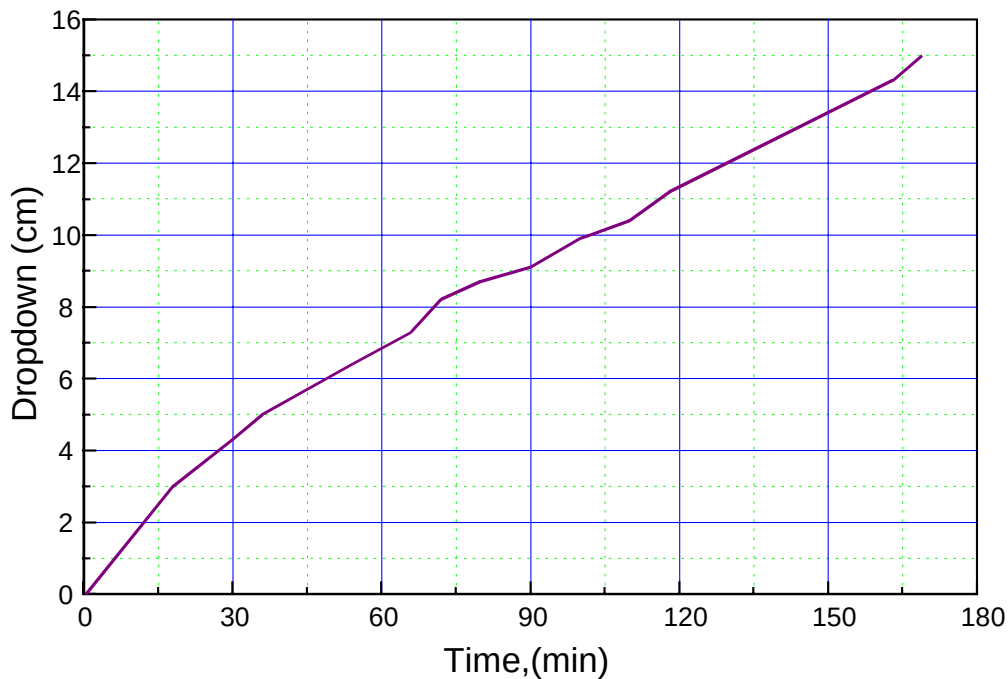


Fig.2 Dynamic of water level dropdown in the infiltrometer 1

One exploratory well, drilled on the 1 stage at 4,5 m from the dug hole had showed loamy sand occurring directly under the infiltrometer bottom on the same level as the vault bottom. Their average filtration features were determined as results of the sump pouring, that were approximated with 17 standard functions in dependense on time. For complete sample good approximation (the correlation 0.99) was received on linear function:

$$H=13.370128-0.081417t$$

The experiment on the field determination of the filtration properties of the aeration zone might also be considered as test of migration of one neutral component - ink. For convection transfer that is accompanied with hydraulic dispersion, decisions of one-dimensional mass transfer are known. To obtain hydroulic conductivity other test was carried out on the same place: after water saturation of the ground solutions were poured through two infiltrometers, set concentrically. Colored water was discharged into the internal infiltrometer and clear water – into the external one. The test was lasting while the filtration rate had become constant.

So, as a result of the pouring series following filtration parameters of the hosting rocks were determined in the interval from 1.3 up to 3.1 m:

- Hydraulic conductivity $k= 0.5-0.9$ m/day;
- Water saturation defficiency $\mu = 0.33-0.55$;
- Dispersion coefficient $D=0.00078-0.00379$ m²/day;
- Porosity $n=0.47-0.69$.

During the stage real contaminated solutions, formed inside the vault, were sampled for further studying. In the lab conditions such tests as chemical and radiological analyzes, definition of sorption capacity properties of the loam sands and distribution coefficient in static and dynamic conditions, physical mass transfer modeling through filtration column were carried out in accordance with Russian standards and techniques.

Taking into account sorption rate factor $\alpha=0.496 \text{ h}^{-1}$, obtained in the lab conditions with allowance for dispersion, it is possible to estimate maximal penetration depth of contaminated solutions with ^{137}Cs as 27.5 cm

On the stage 6 in the same place new series of experiments of aeration zone rock interaction with radioactive solutions were executed. The dug hole was escalated to 110x270 cm in size and dredged up to 164 cm in relation to closed vault site.

Contaminated solutions for this experiment were taken from vault 2, as well as for laboratory study. Its chemical and radionuclide analysis was determined on stage 4 (table 2).

Table 2.

Chemical and radionuclide analysis of real solutions (mg/l)

HCO_3^-	NO_3^-	SO_4^{2-}	K^+	Mg^{2+}	Ca^{2+}	pH	^{226}Ra	^{60}Co	^{232}Th	^{137}Cs
96.1	3.7	7.5	100.0	16.8	16.0	7.65	13.1	41	-	8407.5

The tests were carried out under the same circuit, as in 1996: at first, water filling was made, after in order to prevent lateral spreading solutions were poured through two seepage gages (infiltrimeters), set concentrically. Radioactive solution was discharged into the internal seepage gage with 19.44 cm in diameter, into the external one with diameter 30.35 clean water from water supply well was discharged. Water level in the gages was hold the same. All tests were carried out with equal gradient $J=1.2$. At whole the radioactive solutions with special activity up to 7360 Bq/l had water column height of 1, 2 and 3 meters, or, in recalculation on volume, 29.68 l, 59.36 l and 89.04 l. Directly after every pouring opening of the layer under the infiltrimeter bottom was carried out also as , sampling of rocks and lateral spreading of the pollution. The results of three experiments are presented in the table 3.

Table 3.
Field test results

	Test 1	Test 2	Test 3
Liquid pole height in whole, m	1	2	3
Solution activity, Bq/l	6800	6600	6100
Volume of the solutions, l	29,681265	59,362529	89,043794
Summary activity, Bq	201832,60	391792,69	543167,14
Average depth of sampling, m	Soil activity on ^{137}Cs , (Bq/kg)		
0,01	--	161200	223400
0,015	77530	--	--
0,035	--	59900	86000
0,04	47500	--	--
0,065	--	--	69650
0,075	3180	10200	--
0,095	--	--	14320
0,125	2640	1740	--
0,13	--	--	2070
0,175	760	760	850

The processing of the results was carried out for each experiment and it included selection of empirical dependence of specific concentration of the loam sand from depth.

For all three tests the empirical dependence looks like:

$$N = A_1 e^{-\frac{x - A_2}{A_3}}, \quad (1)$$

where: N - specific activity of ^{137}Cs in rock,

A_1 , A_2 , A_3 - parameters of the experiments.

The further works provide search of dependences of these parameters from other characteristics of experiments.

These field tests may be considered as physical modeling of emergency scenario.

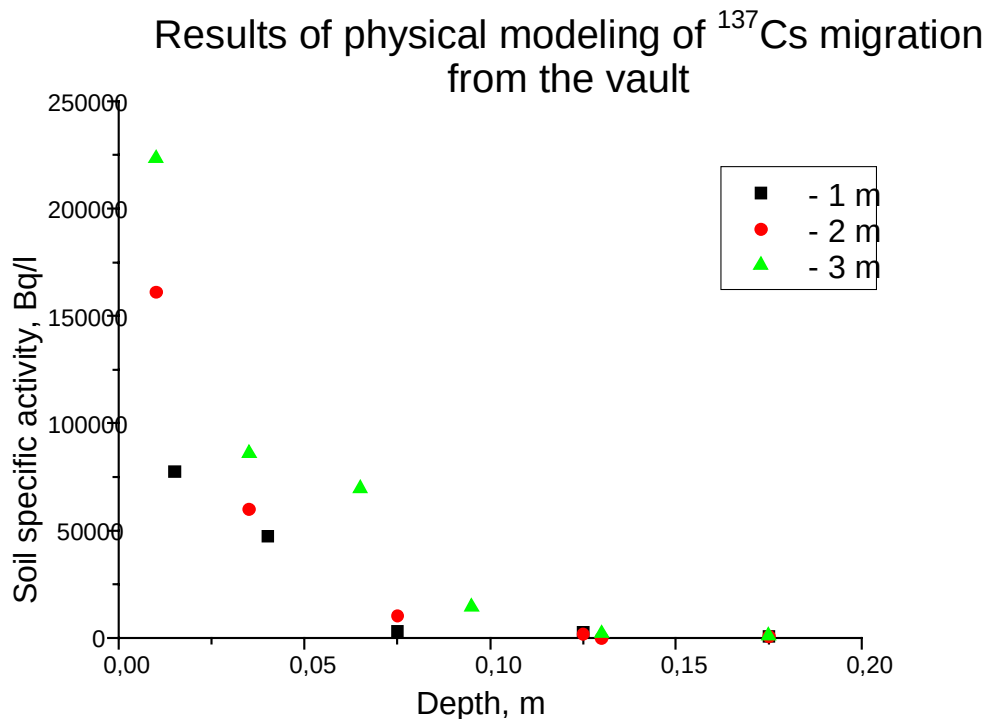


Fig.3. Results of physical modeling of ^{137}Cs migration from the vault

Taking into account, that valid height of the vaults does not exceed three meters and, accordingly, height of the liquid, accumulated there, can not exceed this size, it is possible to consider these field tests as physical modeling of an emergency scenario, which in contradistinction to laboratory experiments, takes into account macroporosity and real variability of aeration zone rocks.

As it is visible from figure 3, in practice independently on time, volume of the sent solutions and sent activity, the depth of pollution of the hosting rocks remains practically constant and does not exceed 15-17 cm. This fact approves hypothesis, founded on stage 5, that interaction of this contaminated water and real host rock may be considered as unlimited absorption.

OUTCOMES

Summarizing the results of the field investigations, it is possible to get the following outcomes:

The field tests allowed specifying filtration parameters of the hosting loamy sands on the depths of vault bottom placement (1.22-2.0 m):

- Hydraulic conductivity $k=0.69$ m/day,
- active porosity $n=0.53$ (in view of the large heterogeneity and macroporosity structure),
- dispersion factor $D=0.00206$ m²/day;

In conditions of low concentration of ^{137}Cs in the solutions it is possible to consider ^{137}Cs sorption by the loam sand as irreversible, and sorption capacity of the soil as unlimited. The ^{137}Cs absorption process may be described by the equation,

$$\frac{\partial N}{\partial t} = \alpha C$$

for which sorption rate factor due of the field test results is $a=19.303 \text{ day}^{-1}$ or 0.804 h^{-1} ;

For approximate calculations the way of natural cleansing of real contaminated solutions in the unbroken soil may be determined as 0.32-0.37 of the solution pole height for water with ^{137}Cs specific activity on 7360 Bq/l.