Typification of Radioactive Contamination Conditions in Ground Water at the Semipalatinsk Test Site.

Ella Gorbunova

Institute for Dynamics of Geospheres, Russian Academy of Sciences, 38-1 Leninsky prosp., Moscow, Russia, E-mail: emgorbunova@mtu-net.ru

Abstract. For the first time the complex investigations on study of radioactive contamination in ground water at the underground nuclear explosion sites were carried out at the Semipalatinsk Test Site. Definition of the radioactive contamination aureoles of the basic water-bearing horizon located within the exogenous rocks fracturing area is based on the proper analysis of the experimental data on the biologically hazardous radionuclides content. Data on the current radionuclide activity in water-bearing horizon can be used for the retrospective analysis of the radioactive contamination of geological environment.

Introduction

One of the most important scientific and technical problems is the radiation environment monitoring on the areas of higher risk including the former test sites.

Complex scientific research on radioactive contamination study of water-bearing horizon referred to weathered fracturing zone of Paleozoic rocks occurring at the depth of 10 to 30 m within the radius of 0.2 to 2.3 km away from epicenter of underground nuclear explosion (UNE) at 1003 and 1388 sites were carried out in the framework of the project K-810 International Science and Technology Center at the Semipalatinsk Test Site (STS). The area selection depended on the level of site knowledge and type of UNEs. Findings of activities were used as the base data for typification of radioactive contamination conditions in ground water at the STS area.

17 years later after the camouflet UNE conduction in well 1388 the basic contamination in ground water was localized within cone of depression which has limited distribution in the central structural tectonic block (Fig.1). Piezometric surface within the radius of 0.5 km and far from UNE epicenter reached the initial

points. Basic ground water discharge carries out in the north-eastward in accordance with major flow direction (Fig.2).

Gamma-activity of bedrocks (Paleozoic) is changed in the near zone at the distance of up to 0.3 km (Fig.3). In the well 4075 which was drilled after the UNE conduction the displacement of the gamma-activity main peak was determined upwell by 10 m. Probably, that was connected with piezometric surface recovery. According to condition in 10/21/88 – the depth of occurrence is 40.7 m, according to condition in 03/01/04 – 16.1m.

Main source of radionuclide transfer into ground water is focused in fractured zone of fault occurrences, adjacent with zones of fracturing, related to chimney of UNE. The structural boundary reduction which is the partition between weathered, fractured and comparatively solid Paleozoic rocks runs up to 20 m, at the distance of 0.3 km away from UNE epicenter was traced (Fig.4).

Contour asymmetric stretched in the north-eastward is conditioned by massif anisotropy, general north-west spread, and occurrence of structural forms (folds) with well-defined dip plane of the rocks in the north-eastward.

Formation of additional source of radionuclide transfer into ground water was presumably caused by man-caused renovation of south fault system which served as a south boundary of the central structural tectonic block. Formation of zones of some fraction development at the level of UNE conduction contributed to radioactive inert gases distribution in tectonically weak zones.

Possibility of radionuclide transfer into ground water from surface is impossible. Data of gamma spectrometric measurements conducted at the height of 0.3 m

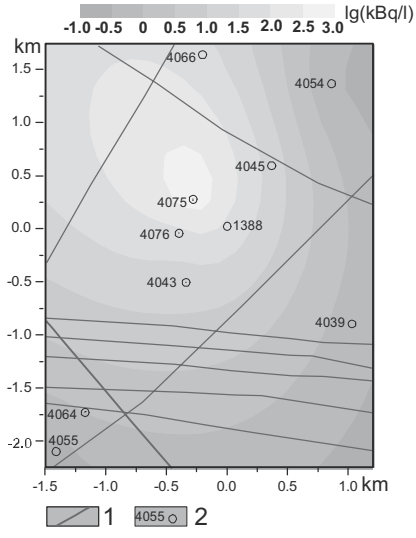

Fig. 1. Scheme of ^{3}H distribution (max.values, lg(kBq/l; 1 – fault; 2 – well and its number).

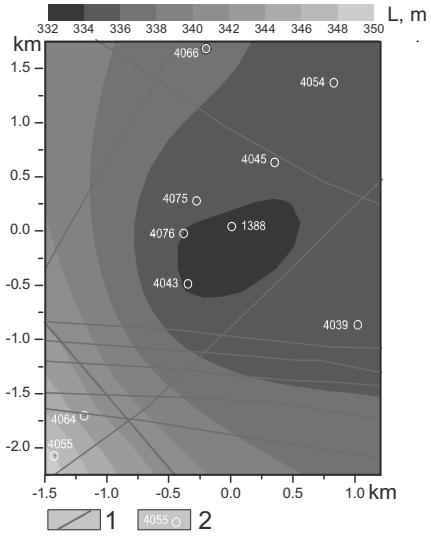

Fig. 2. Piezometric Surface (absolute point, m; as of 11/01/03; 1 – fault; 2 – well and its number).

and 1 m, and the results of soil sampling in the near-mouth area of the well 1388 indicate radioactive background within limits of allowable standards.

According to prediction modeling data of radionuclide migration in ground water conducted at the site 1388 the aureole of radioactive contamination in ground water along the radioactive tracer which extends in accordance with filtration characteristics of underground flow can be determined at the site border 3 km away from epicenter, only 150 years later after UNE conduction.

On October 1965, conduction of UN excavating explosion for civil purposes at the well 1003 was accompanied with base wave formation extending in the zone of 600 m in diameter and dust column of 120 m in diameter (Izrayl et al. 1970). Ground radioactive contamination within the radius of 75 m away from epicenter is determined by initial ground ejection out of crater. Primary trace of radioactive contamination of day surface stretched in the north-eastward formed due to fall-out.

Presence of spots of ground radioactive contamination within the studied area determined at the bulk zone of ejected grounds along axis of radioactive trace and at the distance of 0.2 – 0.4 km in south-east of the explosion epicenter was confirmed in accordance with radiometric observations in 1999.

Nonuniform tectonic structure of the Site is shown in variability of paleorelief observed on upper part of rocks. The allocation of experimental and observant wells to buried slope of paleovalley determines the nature of water-bearing horizon developed in zone of jointing of Paleozoic rocks as confined-unconfined one. The general unloading of the ground water carried out in the north-east direction (Fig.5).

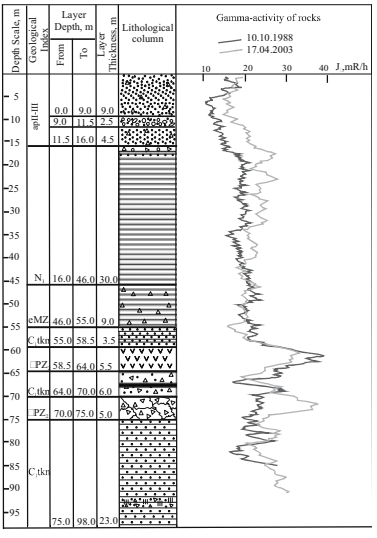

Fig. 3. Results of well 4075 radiometry.

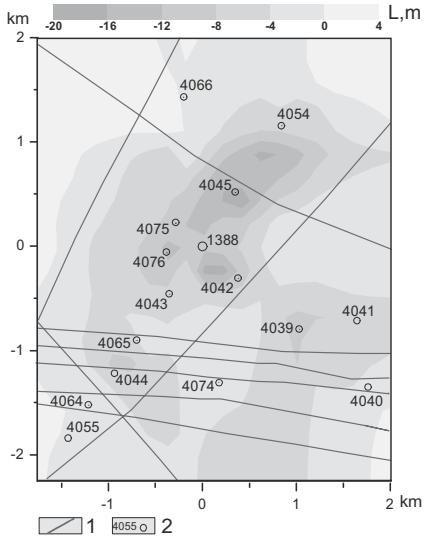

Fig. 4. Change in Depth of Occurrence of Structural Boundary (m; 1 – fault; 2 – well and its number).

Within the site of the well 1003 location the irregular radioactive contamination in ground water was revealed 40 years late after UNE conduction. Main aureole of ^{3}H maximal concentration was referred to the effected zone of sub latitudinal fault, probably, man-made renewed during UNE (Fig.6). Hence, conduction UN excavating explosion resulted in not only formation of radioactive spot traced on the surface, but in massif radioactive contamination at the level of UNE conduction.

Revealed regularities of current radioactive contamination distribution in ground water within the selected studied areas were used for method elaboration of radiation probing of the STS area. During the period of 1965-1989, 131 UNEs of camouflet type with range of yields from 0.001 to 150 kt and 2 UN excavating explosions at 1003 and 1004 wells were carried out at STS (Table 1). These explosions resulted in radioactive products release into the atmosphere in aerosol and gas phases with formation of craters on the surface.

The part of UNEs of incomplete camouflet type was accompanied by insignificant outflow of radioactive inert gases (RIG). There were determined 7 incidents of with non-standard situations which are characterized by early head outflow of RIG in the atmosphere (Adushkin 2000).

The fulfilled research activities on radiation monitoring of the STS area allowed to determine and delineate the radiation contamination traces which are due to low atmospheric and aboveground explosions (Shkol'nik et al. 2003). Formation of local radioactive spots is due to UNEs of excavating type and with non-standard situations. Increased dose rates of gamma radiation were traced at the sites of experimental wells they are characterized by early RIG outflow.

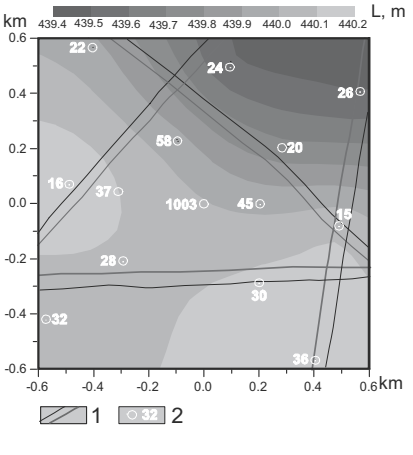

Fig. 5. Piezometric Surface (absolute point, m; as of 02/01/03; 1 – zone of dynamic effect of the fault; 2 – well and its number).

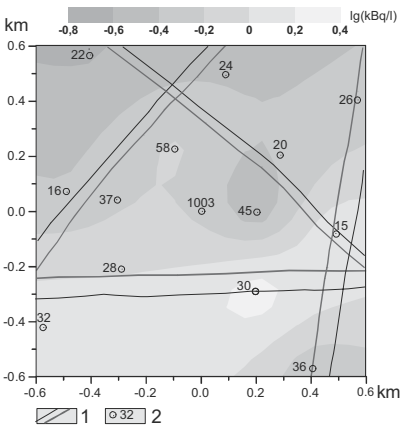

Fig. 6. Scheme of ^{3}H distribution (max.values, lg (kBq/l; 1 - zone of dynamic effect of the fault; 2 – well and its number).

Specific of radionuclide distribution in natural landscapes within the area of radioactive trace and their accumulation at higher areas of small hills determines the conditions of possible local contamination of surface and ground water due to initial primary fallout of aerosols and as the result of following washing-off, transfer and infiltration of radioactive particles from soil surface.

Areas of ground water discharge into surface watercourses at the places of steadfast confining layer absence stand as the second contamination centers of primary water-bearing horizon from the surface. Therefore, when typification of conditions of radioactive contamination in ground water it is necessary to provide scheme-mapping of regional confining layer spread at the STS area.

Besides radionuclide migration from "surface", there is risk of radioactive contamination from "low parts" at the areas of UNE conduction. The breaking-down moment of the cavity determined in many respects the nature of radioactive contamination in all zones of man-made fracturing. A number of radionuclides (volatile, having gas predecessors, and tritium) which were not fixed in melt in full released out of cavity and dispersed within zone of man-made fracturing (Izrayl and Stukin 2000). Formation of aureole of radioactive contamination in ground water is due to gradual impoverishment of the center that contains long-living radionuclides.

The local zones with man-made disturbed regime in ground water associated with general change in geological environment were determined for the areas of UNE conduction (Gorbunova 2003). Formation of cones of depression within the radius of 0.3 - 0.5 km away from epicenter was evidence of establishment of hydraulical connections between water-bearing horizon referred to weathered roof of host rocks and to zones of man-made fracturing which are enriched with RIG.

Accordingly, definition of the sites with man-made disturbed regime of ground water in accordance with archival and current data will allow to determine existence of potential sources of concealed radionuclide migration from zones of man-made fracturing. The tracing of counter spread of post explosive deformations on the day surface by different methods (reconnaissance observation of UNE epicenters, results of remote probing) serves as indirect corroboration of massif irreversible deformation at depth.

During UNE conduction of incomplete camouflet type and with non-standard

Table 1.

Group №	Quantity of UNEs	Time of RNG discharge	UNE depth $m/kt^{1/3}$	Complete gas content in rocks, %	Remark
1	30	10 sec - 20min	70 - 960	4.5 - 18	RIG discharge outside pipe of well
2	40 30 10	25 - 60min 1 - 5h 5 - 25h	88 - 236	2.6 - 14.4	Late discharge of RIG in the epicenter
3	23	-	96 - 225	4 - 12	RIG discharge was absent

situations associated with head inflow of RNG the possibility of radioactively contaminated in ground water of the epicenter zone is high. The sites of well flowing during UNE conduction was special hazard since during the first seconds and hours of pressure excessive outbreak the transfer of active radioactive product into water-bearing bed was possible, accordingly.

The special activities on radionuclide migration study at the determined areas were not carried out. But results of sampling of the nearest wells determine the high radionuclide content. Particularly, in the unused well 1419 located at the distance of 1.5 km south-east of well 1069 where was ejection of casing pips and driving complex, the tritium concentration was more than 1000 kBk/l (Logachev et al. 2002).

Probably, the ground water exposed to radioactive contamination as well as site of well location where coal-bed fire was determined. So, 15 years later after the UNE conduction the epicentral zone failure with formation of explosion crater 115 m in diameter and depth of 30 m occurred in the well "Glubokaya" in April, 1992 (Logachev et al. 2002). Consequently, the sites of UNE conduction of incomplete camouflet type and with non-standard situations should be referred to the objects of higher risk.

Special emphasis should be given to assessment of man-made activation on effected zones of faults connected with UNE. Tracing of fault main systems of defined in accordance with archival geologic-geophysical data should be confirmed by the results of remote probing. It is recommended to use computer-aided system of satellite images LESSA allowing to specify the structure and nature of effected zones of faults as well as to contour the allocation area of post explosive deformations on the day surface connected with UNE (Gorbunova and Ivanchenko 2004).

Any man-made load onto man-made changed massif especially at the level of depths which correspond to hypsometric position of UNE hypocenter is peculiar trigger for massif "simplification" (topology) due to formation of additional fracturing and renew of present. Particularly, conduction of whole series of non-nuclear experimental and calibration explosions to destruct 13 unused wells up to depth of 10 m and over the range of 50 – 580 m with charge of yield up to 50 – 100 kg, 2 t and 25 t were recorded by all seismic stations in 1997 - 1998 (Shkol'nik et al. 2003). Then, formed craters were covered up with earth and leveled to initial state.

The openworking coal field Karazhir in the central part of STS is connected with treat of possible contaminated ground water involving into areas of cone of depression developing due to drainage activities as well as with probable accidents – failure of pit wall by blowout of hydrocarbon gases. It should be noted UNEs were conducted to the south and south-east of the pit. Dominant direction of regional fault is the north-west.

During radioecological assessment of the STS condition it is necessary to provide area cadastre making up with criterion elaboration on vulnerability of ground water upon the following gradations: unprotected, weakly protected and conditionally protected. The protectability of ground water radioactive contamination from "surface" means the interception of water-bearing horizon by low-penetrating (waterproof) sediments which impede penetration of radionuclides

from surface into ground water. Reliability of radionuclide preservation out of "bottom" guarantees hydraulical connection absence between water-bearing horizon and zones of man-made fracturing. For the mapping of natural protectability of STS area it is necessary to counter the zones of mechanical effect of UNE. The block massif structure should be taken into account during the engineering-geological characteristic of the area.

The hydrogeological analysis of the situation should be carried out in accordance with condition study of distribution and filtration features of water-bearing filtration. The special emphasis should be given to the sites of natural and man-made discharge of ground water. To the last ones relate the areas of established hydraulic connection between artificial reservoirs formed during the UN excavating explosions and non-standard situations as well as the zones of split-off effects are characterized by alteration of watered rock parameters (increase, reduction of thickness, penetrability) under the UNE impact. The zones of massif irreversible deformations which include bands of man-made fracturing enriched by RNG are potential radionuclide sources.

Further elaboration of general conception of typification of radioactive contamination conditions in ground water will serve as base of radioecological assessment of situation at the STS area.

References

Adushkin VV (2000) Effect of geological factors on radioactive product distribution during underground nuclear explosions - Radioactivity during nuclear explosions and accidents. Proceedings of the International Conference. Moscow April, 24-26 2000. St. Petersburg: Hydrometeoizdat Volume 1: 585—593

Gorbunova EM (2003) Formation peculiarities of man-caused disturbed regime in ground water. The third All-Russian Scientific Conference "Physical problems in ecology" (Ecological physics). Reports, №11 M, MSU: 70—78

Gorbunova EM, Ivanchenko GN (2004) Study of Geological Structure Around Boreholes at the Semipalatinsk Test Site Using Computer-Aided Interpretation of Satellite Images. International Conference on Monitoring of Nuclear Tests and Their Consequences. NNC Bulletin. Kurchatov, NNC: 76—81

Izrayl YuA et al. (1970) Radioactive contamination of natural environment during underground nuclear explosions and prediction methods. Leningrad, Hydrometeoizdat: 68

Izrayl YuA, Stukin ED (2000) Phenomenology of ground water contamination after underground nuclear explosion - Radioactivity during nuclear explosions and accidents. Proceedings of the International Conference. Moscow April, 24-26 2000. St. Petersburg: Hydrometeoizdat, Volume 1: 616—623

Logachev VA (2002) Nuclear tests in USSR: Current radioecological condition of the sites. M, IzdAt: 652

Shkol'nik VS et al. (2003) The Semipalatinsk Test Site (creation, activity, conversion). Almaty: 344