10. METHODS FOR ANALYZING THE HYDROGEOLOGICAL CHARACTERISTICS OF THE AQUIFERS IN THE VICINITY OF THE CHORNOBYL NUCLEAR POWER PLANT USING INDICATORS

M. I. PANASIUK[1], I. O. KOVALENKO[1], N. V. SOSONNA[1], M. G. BUZYNNYI[2]

[1] Institute for Safety Problems of Nuclear Power Plants of the NAS of Ukraine, 36-a, Kirova st., Chornobyl, Kyiv. reg., 07270, Ukraine
[2] The Marzeev Institute of Public Health, 50, Popudrenko st., Kyiv, Ukraine

Abstract

An analysis of the radioactive contamination of groundwater (^{3}H, ^{90}Sr) at the industrial site of the Chornobyl Nuclear Power Plant was carried out. As a result of monitoring of the tritium volumetric activities and analysis of its distribution halos, the direction of groundwater movement near the 3rd and 4th units of the Chornobyl Nuclear Power Plant was estimated. To assess the filtration parameters, an indicator bromide-ion in the form of NaBr was introduced into the aquifer.

The mathematical modeling of migration of the unsorbed indication on the way of filtration flow of the first from the surface alluvial aquifer underground waters was completed. The imitation modeling was performed to justify the use of isotope or indicator methods to obtain reliable data on aquifer parameters, in particular, the permeability coefficient. Three-dimensional geo-filtration model was used and the verification of received predictive results with the results of the field observations was completed.

The Visual Modflow 2011.1 software package was used as a tool to determine the filtration parameters of the aquifer.

Keywords: ^{3}H, ^{90}Sr, mathematical model, groundwater, mass transfer indicator, bromide-ion, permeability coefficient, Shelter object.

10.1. Introduction

Determination of levels and formation mechanisms for groundwater contamination by ^{3}H, ^{90}Sr, uranium and transuranium element (TUE) at the industrial site of the Chornobyl nuclear power plant (ChNPP) was being conducted since 1996. In 2018–2020, this work was financed by the IAEA grant under the Coordinated Research Project CRP F33.0.22.

New Safe Confinement (NSC or Arch) (Figs. 10.1 and 10.2) was moved over the Shelter object in November 2016. Observation research of wells is still carried out, despite the fact that some of them got inside the Arch (see Fig. 10.1). Also, within the framework of monitoring of radioactive and chemical contamination sources of the environment are studied: water accumulations (block waters or unit – derived) inside the Shelter object, 4th Unit of the ChNPP, and into the aquiferous communications (see Fig. 10.2).

The objective of this work is to analyze the distribution of radioactive isotopes in groundwater and develop methods for assessing hydrogeological parameters. The assessment of hydrogeological parameters was carried out comparing the conditions of migration of isotopes and indicators in the aquifer and the results of mathematical modeling.

The complex methodology for assessing the parameters of aquifers consisted in mathematical modeling of the groundwater movement in such a way that the predicted results (concentrations, trajectories and propagation rates of indicators or radioactive isotopes) coincide with the data of actual field observations of propagation (Br^{-} or 3H) in the aquifer.

10.2. Site description

Industrial site of the ChNPP has a developed aquifer relevant to alluvial sands of the first above the floodplain terrace of the Pripyat river (see Fig. 10.2). The aquifer thickness ranges from 26 to 28 m.

The alluvial aquifer is underlain by a layer of impermeable marks, with a thickness of 6–8 m. The pressure flow underground water of Buchak aquifer is spread underneath.

After decommissioning of the cooling pond (2014–2015), the direction of groundwater movement changed from the North to the North-East. Discharge of radioactively contaminated groundwater occurs in the riverbed of the Pripyat river and in the residual lakes on the site of the former cooling pond (Fig. 10.3).

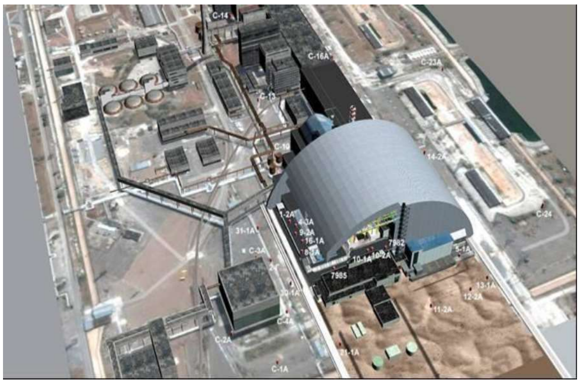

Fig. 10.1. Scheme of observation wells location and a view of the NSC

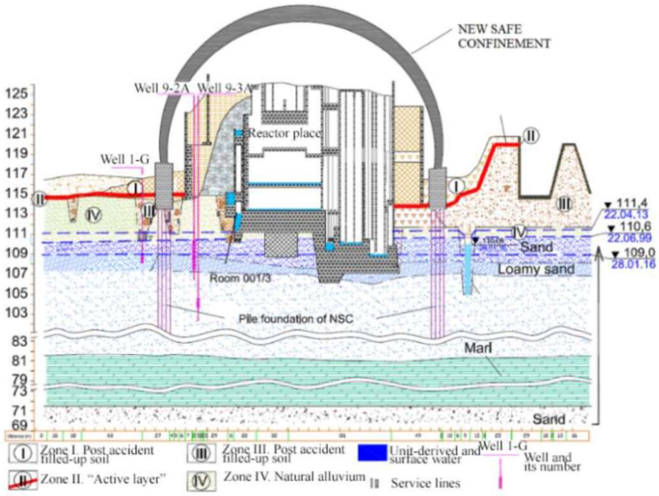

Fig. 10.2. Hydrogeological section of the Arch complex base – the Shelter Object

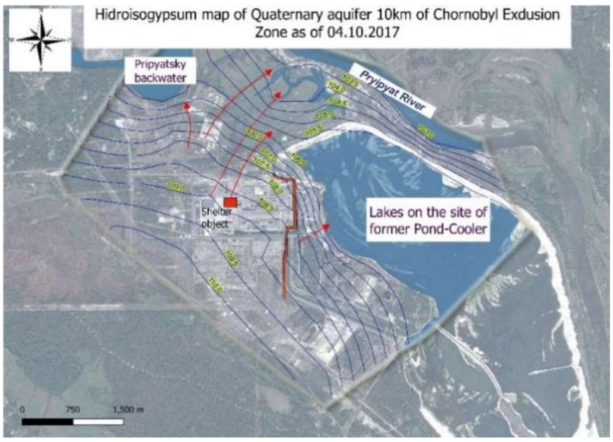

Fig. 10.3. Direction of groundwater flow (shown by arrows) after decommissioning of the cooling pond

A peculiarity of the anthropogenic and hydrogeological conditions for the SO site location is arrangement of 424 concrete piles of the Arch foundation, which overlap the aquifer by half of its power, and could have probable impact on change in the chemical composition of groundwater (see Fig. 10.2).

In Fig. 10.2, the accumulations of highly active water masses inside the premises of the destroyed fourth unit of the ChNPP so-called “block waters”, which are sources of radioactive contamination of groundwater are mapped with cyan color. In particular, block waters are a source of tritium entering the aquifer.

10.3. Materials and methods

The analysis of the distribution of radioactive isotopes in groundwater was carried out by taking water samples from observation wells. The activity of ^{3}H, ^{90}Sr, ^{137}Cs, U, $^{238,\ 239+240}Pu$, ^{241}Am and the concentration of the main ions are determined in groundwater samples in the laboratory.

The permeability coefficient of aquifers is one of the main parameters of soils, which significantly affects the accuracy of forecasts of changes in radio-hydrogeological conditions of the territory and the radiation situation in the environment. High accuracy of forecasts is the key to the effectiveness of management decisions on the non-proliferation or minimization of groundwater radionuclides spreading in the environment and protection of groundwater from pollution. A permeability coefficient, which is equal to 30 m/day for the entire thickness of the alluvial aquifer, at the territory of ChNPP, was determined in 2014, according to two pumping water from wells (Panasiuk M. I., 2014). However, the first unconfined aquifer consists of sandy layers, ranging from dusty to medium sized, from medium-sized to large ones with gravel and pebble inclusions and thus possibly having varying filtration properties.

Therefore, the determination of the permeability coefficients of individual sandy layers was proposed to be carried out using input of artificial tracer (bromide-ion as NaBr) or isotope (tritium) with the involvement of mathematical modeling of migration processes (Kovalenko I., 2020).

The essence of the method includes:

1) Preliminary mathematical modeling of the launch and propagation of an indicator (for example, sodium bromide) or an isotope (for example, tritium);
2) Preliminary modeling is performed for different values of the permeability coefficient;
3) Introduction of the indicator into the aquifer;
4) Observing the movement of the indicator with groundwater;
5) Mathematical modeling of the movement of the indicator with groundwater for different variants of the permeability coefficient;
6) The coefficient of permeability of sediments will correspond to the coefficient of permeability adopted in the model in variant, when the results of mathematical modeling coincided with observations of the movement of the indicator with groundwater.

A 3D geofiltration model created with Visual Modflow 2011.1 was used for modeling.

Thus, it is possible to determine the filtration parameters in individual intervals of the aquifer, in which the indicator migrates (Kovalenko I., 2020; Panasiuk M. I., Lytvyn I. A., 2017).

Sodium bromide is used as an indicator.

10.4. Results and discussion

10.4.1. Analysis of the distribution of radioactive isotopes in groundwater

10.4.1.1. Strontium-90

In recent years, in several observation wells located downstream the groundwater flow from the SO, there has been a significant increase in the content of ^{90}Sr by 200–500 times, as well as uranium and TUE by 2–12 times (Panasyuk M. I., Litvin I. A., 2017). In this, for individual wells, the concentration of ^{90}Sr increases to values 700–2,100 Bq/l. (Fig. 10.4).

According to our research, the mechanism for the formation of high volumetric activity of ^{90}Sr is associated with the formation of a highly alkaline medium in groundwater (Matrosov D., Shevchenko A., Nosovskyi A., Panasiuk M., 2018). Also, high volumetric activity of ^{90}Sr in groundwater is associated with high concentration of calcium–ion.

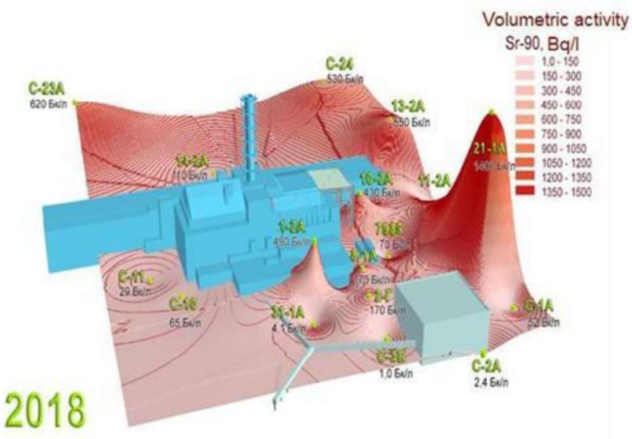

Fig. 10.4. Visualization of 3D model halo of distribution of ^{90}Sr volumetric activities in groundwater near the Shelter object complex

It is known from literary research that the degree of ^{90}Sr sorption from alkaline medium can reach 60–100%. But, according to our data it appears opposite. In the Fig. 10.5, the dynamics of the values of the pH (top graph) and the ^{90}Sr volumetric activity (bottom histogram) during the observation period of 1996–2017 is represented. On the graph, depending on the pH values, three periods marked with Roman numerals and different colors are identified. As can be seen from the Fig. 10.5 with pH values of the groundwaters mainly in the range of 7.5–8.5 (period I), ^{90}Sr volumetric activities in the underground waters are generally in the range of 6–8 Bq/l.

pH values of groundwater, mainly in the range of 8.5–9.5 (period II), the maximum plot of the distribution of ^{90}Sr volumetric activity is reduced to an interval of 2–4 Bq/l. However, at pH higher, basically, 9.5 (period III), the most frequent values of ^{90}Sr volumetric activity increases sharply to 40–60 Bq/l, with a maximum of 160–340 Bq/l.

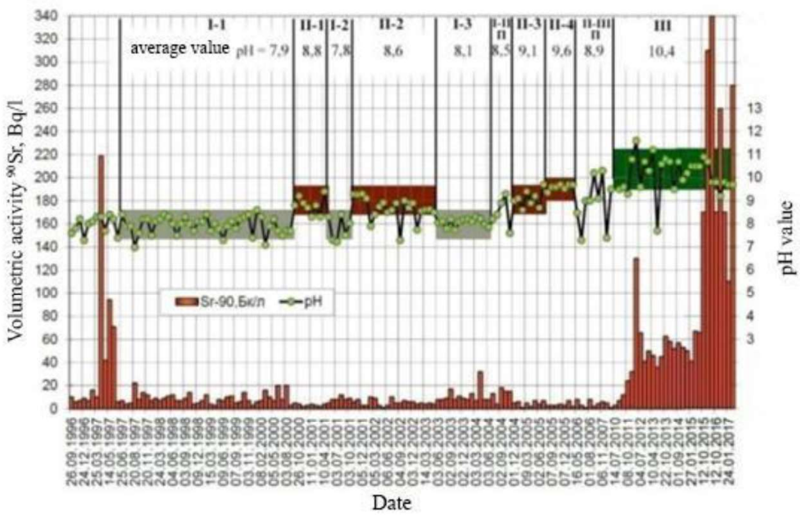

Fig. 10.5. Dynamics of pH values and ^{90}Sr volumetric activity in the samples of water obtained from 2-Г well. At the top are numbers of periods and subperiods and the average pH for each selected subperiod

The reason for reducing of ^{90}Sr concentrations at pH in the range of 8.5–9.5 (period II) is that, at pH 8.3–8.5 the hydrocarbonate ions in part turn into carbonate ions, which, in turn, form with the calcium and strontium ions insoluble compounds, that could fall out from the solution of groundwater into the precipitations.

A similar pattern is traced through wells 4-Г (Fig. 10.6), 1-2A, 1-1A, and others.

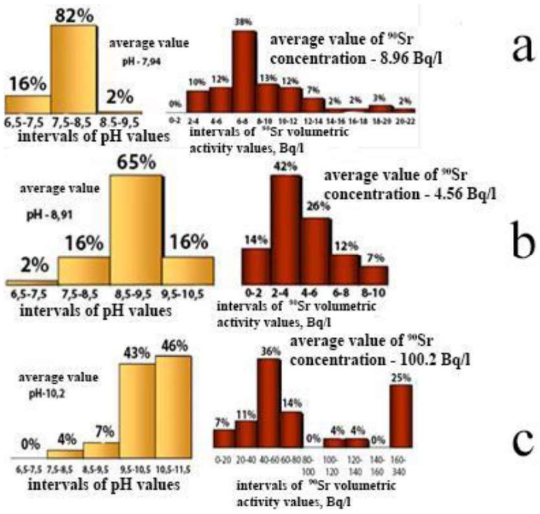

Fig. 10.6. Distribution of pH values and ^{90}Sr volumetric activity for selected 3 periods:
a – period I; b – period II; c – period III

As can be seen from Fig. 10.7, in well 4-Г, at pH values in the range of 7.5–8.5 (period I), volumetric activity of ^{90}Sr in groundwater mainly is in the range of 20–35 Bq/l. At pH in the range of 8.5–9.5 (period II) ^{90}Sr volumetric activity decreases to an interval of 1–2 Bq/l. When pH values reach values higher than 9.5, values of volumetric activity ^{90}Sr increases to 300–400 Bq/l, with a maximum of 650–680 Bq/l (Kovalenko I. O., Panasiuk M. I., Skorbun A. D. et al.).

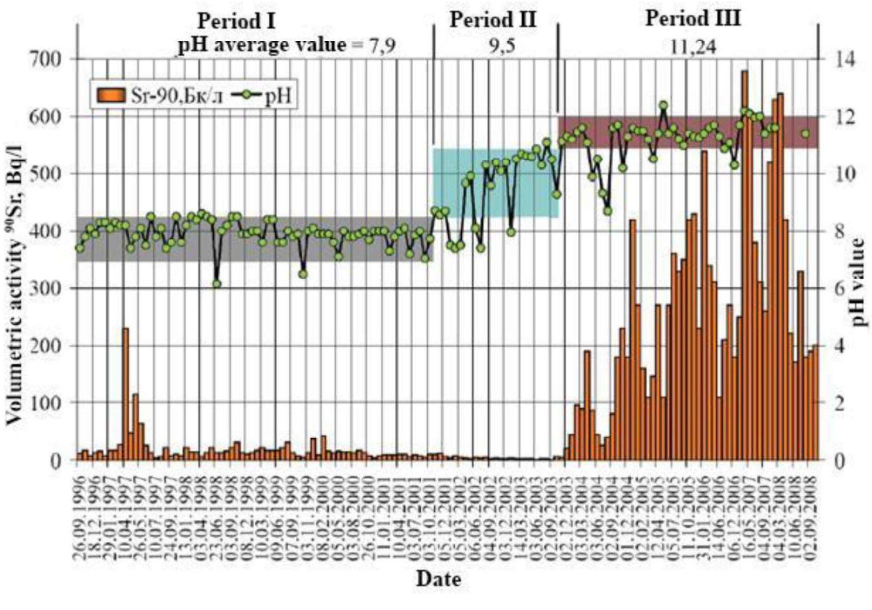

Fig. 10.7. Dynamics of pH values and volumetric activity ^{90}Sr in the samples of water from 4-Г well.
Numbers of periods are at the top

As shown in (Panasiuk M. I., 2014 ; Kovalenko I., 2020; Panasiuk M. I. et al., 2017; Matrosov D. et al., 2018), according to the research of the phase differentiation of ^{90}Sr in samples of groundwater from the well 4-Г (Fig. 10.8) for the period III in comparison with the periods I and II, growth of ^{90}Sr volumetric activity is characteristic in the ion-dispersed (soluble) form from 53–54 to 91–98% of the total volumetric activity of ^{90}Sr in the sample.

Decrease portions of ^{90}Sr in coarse-dispersed phase from 38–41% (periods I-II) to 1–8% and colloidal phase from 9.5% (periods I-II) to 0.6–0.7% (period III) unambiguously points to process of desorption of radioactive strontium from the surface of particles of sandy soils of the alluvial aquifer.

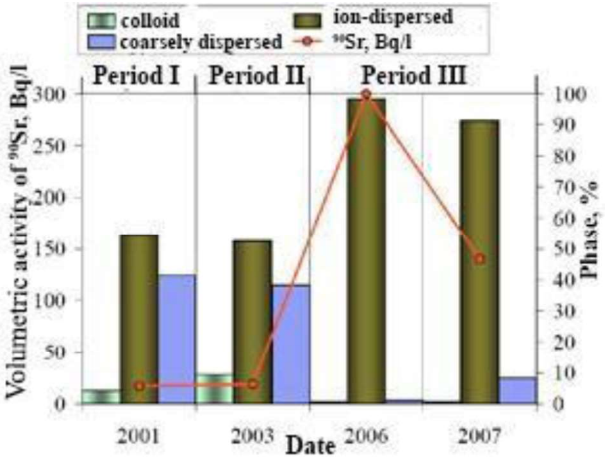

Fig. 10.8. Phase distribution of ^{90}Sr in samples of groundwater from a well 4-Г

Thus, obviously, with the high pH-value (9.5–12.5) ^{90}Sr forms complex compounds, which are poorly absorbed by sandy soil of the alluvial aquifer.

High pH-values are formed because of a contact between the groundwater and concrete bases of constructions. In case of pH-value increase up to 9.5–10 through concrete corrosion of the piles foundation of the NSC (see Fig. 2), that blocks a part of the aquifer, it is possible to register considerable growth in volumetric activity of ^{90}Sr, U and TUE.

Nevertheless, the fact of ^{90}Sr volumetric activity decreases with pH-value of the groundwater in the range of 8.5–9.5 (II period) seems to suggest that artificial sustaining in the aquifer of these pH-values can slow the spread of ^{90}Sr by flow of the groundwater beyond the industrial site of the ChNPP.

10.4.1.2. Tritium

Tritium as a "natural" indicator was used to estimate conditions for entering "unit-derived waters" into groundwater (Fig. 10.9 and 10.10). It is also used within this research. Tritium is detected in considerable amount only in "unit-derived waters". The content of high concentrations of tritium downstream from the Shelter object indicates for sure the locations of radioactive contamination of groundwater resulted by entering of contaminated waters and the leakage of the Shelter object.

After the moving of the Arch in November 2016, the access of precipitation to the destroyed ChNPP 4th unit was stopped. This led to the fact that the flow of water containing high concentrations of radionuclides from the destroyed unit to the environment was stopped. That's why tritium concentrations in groundwater samples decreased from 900–1,100 to 30–50 Bq/l (Fig. 10.11 – 10.14). Also, in full accordance with the change in the direction of movement of groundwater from north to northeast, the direction of the halation of tritium distribution has changed. In the C-10 well, which is located in the northeast direction from the destroyed 4th unit, at the end of 2018, an increase in the volumetric activity of tritium from 2 to 30 Bq/l was recorded (see Fig. 10.12, Table 10.1).

Fig. 10.13 shows that well 9-3A recorded an increase in the volumetric activity of tritium from 17.1 Bq/l in 2018 to 235.7 Bq/l in 2020 (Table 10.1). Groundwater flow direction of the halation of tritium distribution did not change in 2020 as compared to 2018.

Thus, the use of the isotope method made it possible to determine the conditions (sources) of radioactive contamination of groundwater, the direction and speed of groundwater movement.

The change in the direction of movement of groundwater led to a change in the direction of impact of the Shelter object on radioactive and chemical contamination of groundwater. To control new ways of spreading pollutants, it was necessary to change the system of observation boreholes.

The locations of the new boreholes were selected taking into account the results of the analysis of changes in the halo of tritium migration, and mathematical modeling of the spread of radioactive contamination under unit 4. Observation boreholes location installed along the path of the proposed new pathways for pollutants. New clusters C-10K, C-11K, and C-19K (Figs. 10.15) consist of three wells, the filter intervals in which are installed in the upper, middle, and lower parts of the aquifer.

Table 10.1. Volumetric activity of tritium in samples from observation wells in the vicinity of the ChNPPUnit 4

Well No.	Sampling Dates/Concentration ^{3}H, Bq/l			
	24-25.04.2018, 09.06.2018	08-11.10.2018	05-25.06.2019	14-16.07.2020
1-2A	3,1	3,1	10	-
1-3A	38,7	2,3	12, 7	12,5
1-4A	5,8	4	6	5,2
16-1A	4,4	0.8	-	-
16-2A	36,5	22.6	-	21
31-1A	5,4	4	2	3,1
4-2Г	10,4	2.8	10	-
4-3A	54,2	53.2	20	21,7
8-1A	2,7	-	3,9	-
9-2A	2	2.7	5.4	-
9-3A	32,6	17.1	-	235,7
C-10	2,1	30,6	1,4	9,2

In the upper part of the aquifer in 2020–2021 in samples from new wells C-11A and C-19A increased concentrations of ^{3}H (9.9–83.3 Bq/l) were observed (see Fig. 10.14). This indicates that the change in the direction of groundwater movement in 2014–2015 led to a change in the direction of movement of radionuclides with groundwater. However, the existing network of wells did not control the spread of radionuclides under the SO due to the lack of observation points in the area between wells C-10 and 31-1A (see Fig. 10.1). Therefore, new well clusters were drilled in this area.

The relatively high concentrations of ^{3}H (see Fig. 10.14) in water samples from new wells indicate the correct choice of location and design of new observation wells.

10.4.2. Hydrochemical conditions

Hydrochemical investigations are carried out to determine the levels and conditions of aquifer pollution, to determine the areas of influence of chemical pollutants sources into groundwater as well as formation mechanisms of high radionuclide concentrations. As it is known and as mentioned above, the chemical composition of groundwater can have a significant impact on the migration capacity of radionuclides.

10.4.2.1. Impact of the Shelter object on groundwater chemistry

The SO is a significant source of nitrates (NO_3^-) (Fig. 10.16), nitrites (NO_2^-), ions Na^+ and K^+ in groundwater, and as a result, there is an increase of mineralization in the process of groundwater flowing under the complex NSC–SO. If we take into account that the composition of saw suppressing solution, which is fed into the middle of the SO, includes nitroxide hydolinium, then there is nothing remarkable in such distribution of nitrates. According to the data of mass-spectrometric analyses, the underground waters also contain gadolinium.

The study of the effect of the SO is performed by comparing the chemical composition of groundwater samples from wells (13-3A, 5-1A, 14-2A, C-24) that are located upstream (before the SO) and downstream (behind the SO) of the groundwater flow.

Observation well blocks (1-2A and 1-3A, 4-2G and 4-3A, 8-1A and 1-4A, 9-2A and 9-3A 16-1A and 16-2A) are located downstream of groundwater, i.e., north and northeast of the SO (see Fig. 10.1). According to these wells observe changes in the chemical composition of water that flows out of the Unit 4 (SO) and compare with the results of chemical analyses of water samples from wells, which are located in front of the SO.

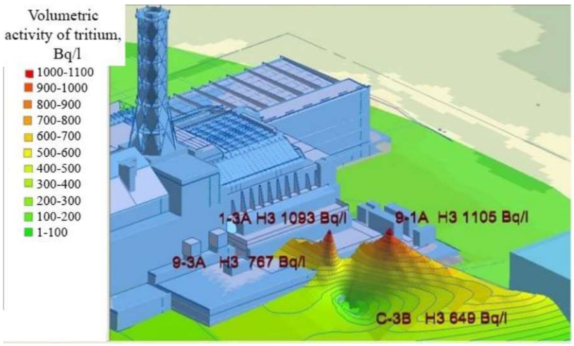

Fig. 10.9. Area of tritium distribution into the groundwater in the vicinity of the ChNPP Unit 4 in 2008

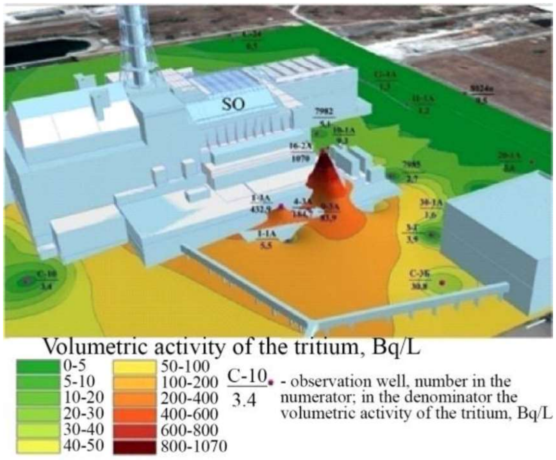

Fig. 10.10. Area of tritium distribution into the groundwater in the vicinity of the ChNPP Unit 4 in 2013

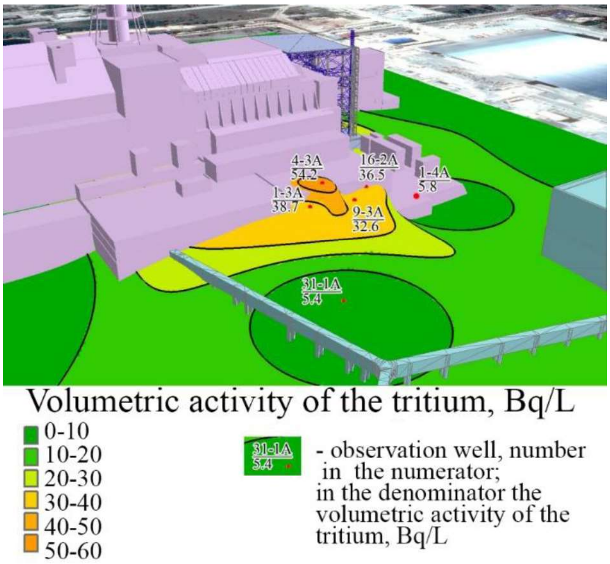

Fig. 10.11. Area of tritium distribution into the groundwater in the vicinity of the ChNPP Unit 4 in the first half of 2018

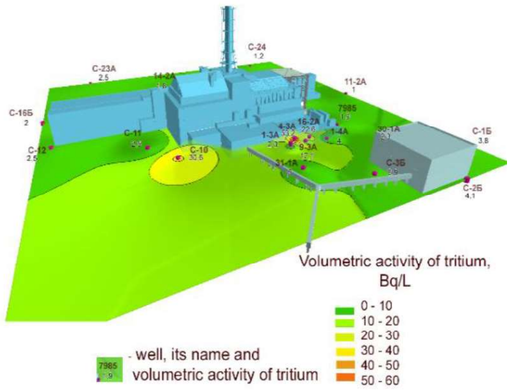

Fig. 10.12. Area of tritium distribution into the groundwater in the vicinity of the ChNPP Unit 4 in the second half of 2018

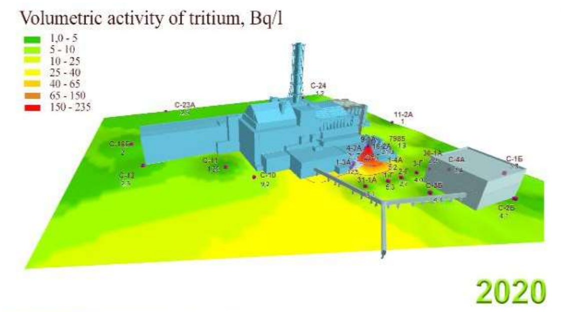

Fig. 10.13. Area of tritium distribution into the groundwater in the vicinity of the ChNPP Unit 4 in the second half of 2020

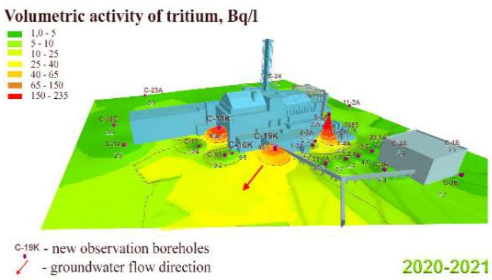

Fig. 10.14. The area of distribution of tritium to groundwater in the area of the ChNPP Unit 4 in 2020–2021, taking into account the results obtained for the new wells C-10K, C-11K, and C-19K

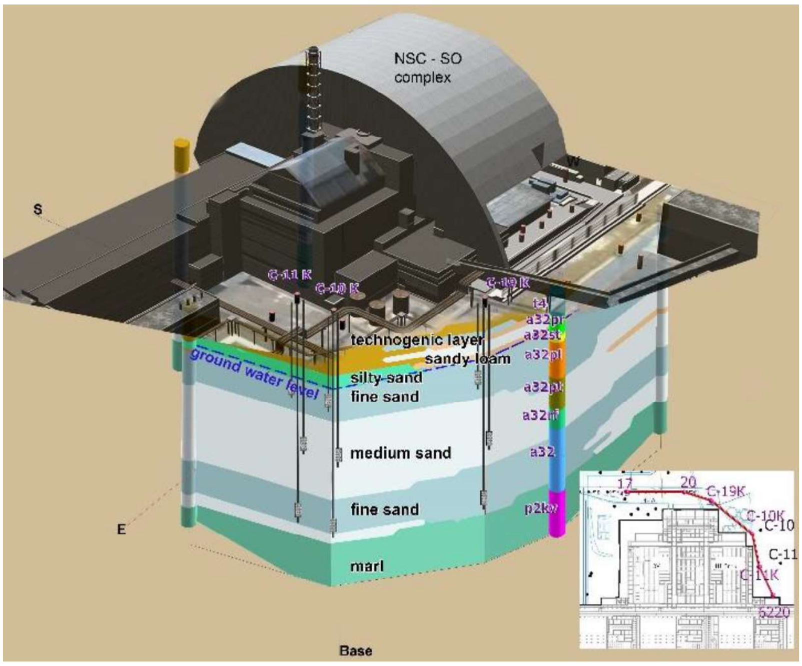

Fig. 10.15. Section and mutual placement of new observation wells, structures of the NSC – SO complex and Unit 3 of the ChNPP

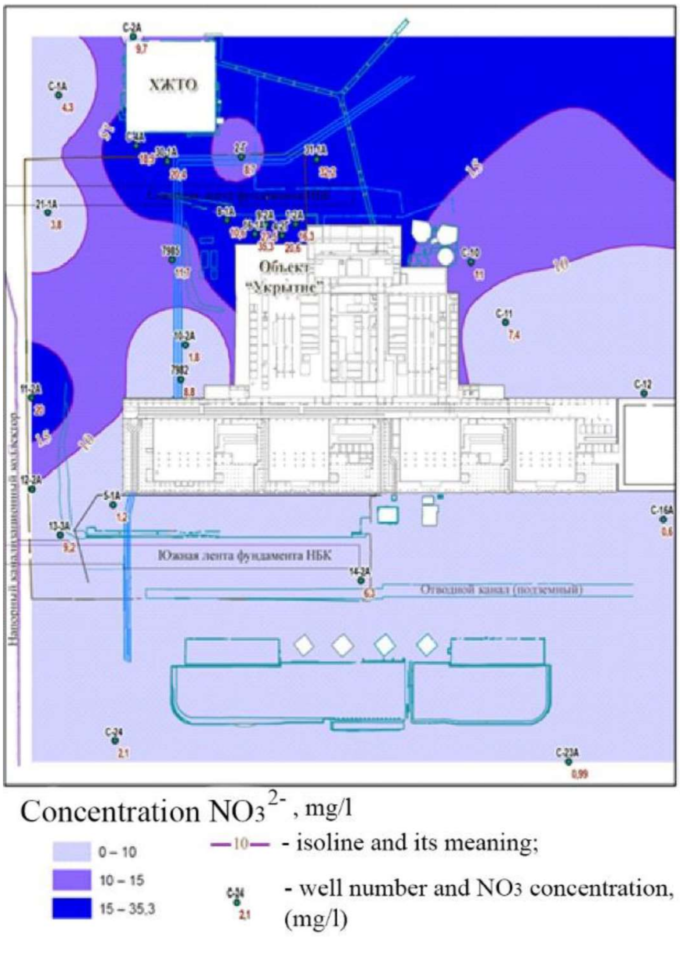

Fig. 10.16. Distribution of nitrate-ion (NO_3^-) concentrations in groundwater

10.4.2.2. Analysis of changes in the chemical composition of groundwater by means of Piper and Durov diagrams

The analysis of Piper and Durov diagrams (Fig. 10.17) shows that in the chemical composition of underground water that passed the filtration process under the NSC-SO the concentration of sodium and potassium ions increases and the volume of calcium ions decreases. Also, the impact of the NSC-SO complex is manifested in the increase of pH value to the strongly alkaline medium too.

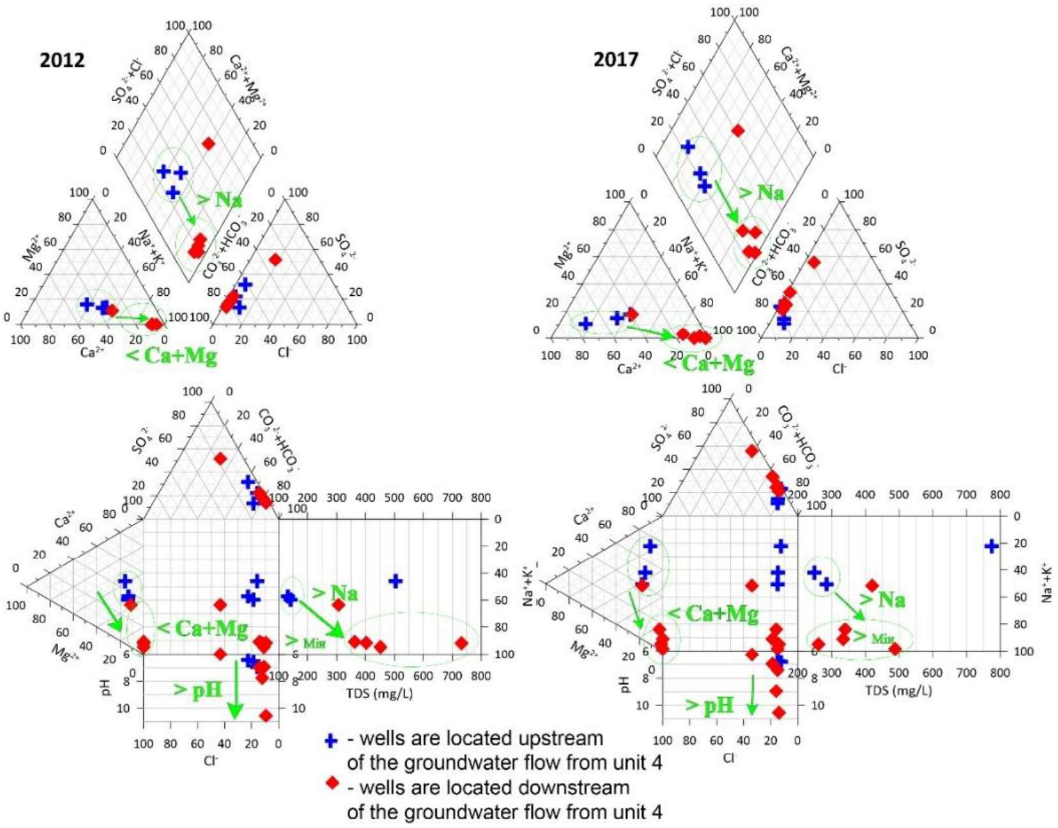

Fig. 10.17. Chemical composition of groundwater in the observation wells located upstream of the groundwater flow from the NSC-SO complex and downstream of it

10.5. Developing methods for assessing hydrogeological parameters

10.5.1. Conditions for introducing the indicator into groundwater to determine the parameters of aquifers

Within the framework of this project, activities for determination of input places and kinds of tracer were carried out as following: conducting measurements of groundwater levels on observation wells; water table contour mapping for determination of general groundwater movement direction; analysis of observation wells location**;** analysis of depths and structures of observation wells; sampling of groundwater and determining the background concentrations content of various supposed tracers (tritium, bromide ions, chlorine ions) in it; selection of indicator material; sampling of groundwater and determining in it the background concentration of tracer; selection of observation wells located in the same line of stream of groundwater flow for tracer input and for monitoring of its spreading.

As a result of the preparatory work, a bromide ion was chosen and used as a tracer. For the injection and observation of its spreading there were selected wells 16-1A and 9-3A located in the same line of stream of groundwater flow.

On May 24, 2018 the bromine-ion indicator was injected into the well 16-1A (Fig. 10.18).

A sharp increase in the concentration of bromide-ion in observation well 9-3A occurred 20 months after its introduction into well 16-1A (Fig. 10.19).

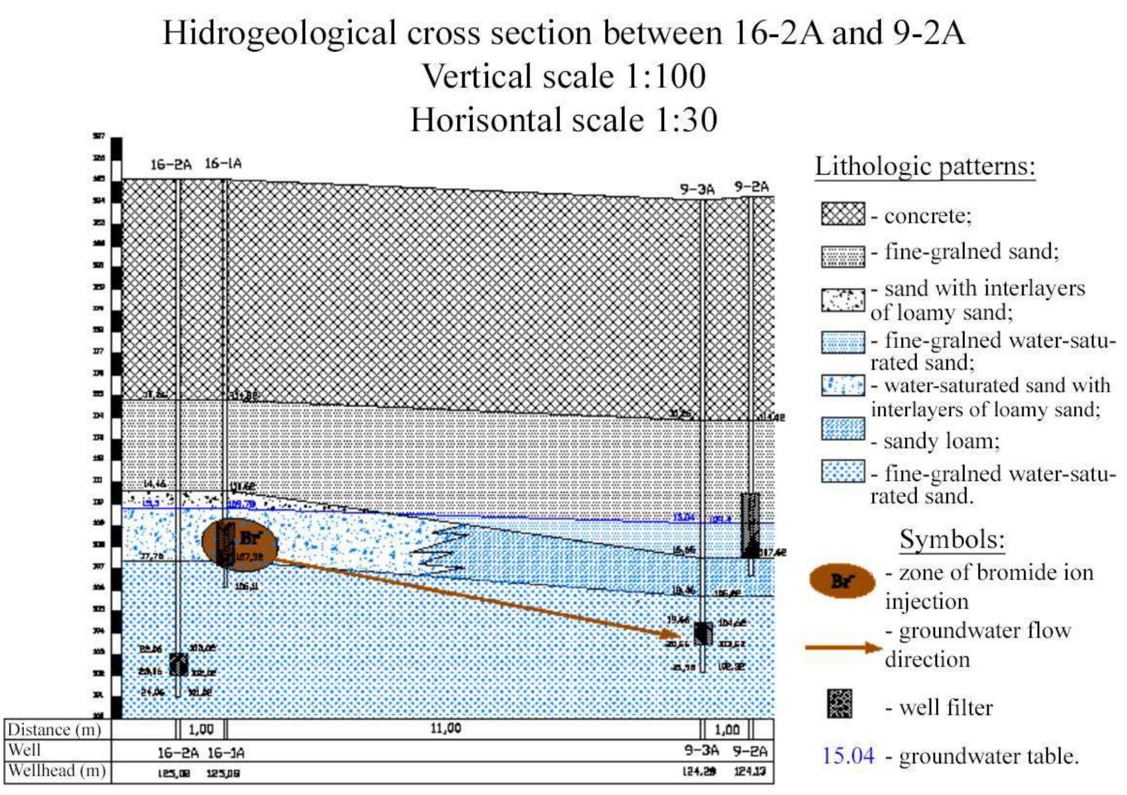

Fig. 10.18. Hydrogeological cross section between 16-2A and 9-2A. Input of sodium bromide (NaBr) tracer into the well 16-1A

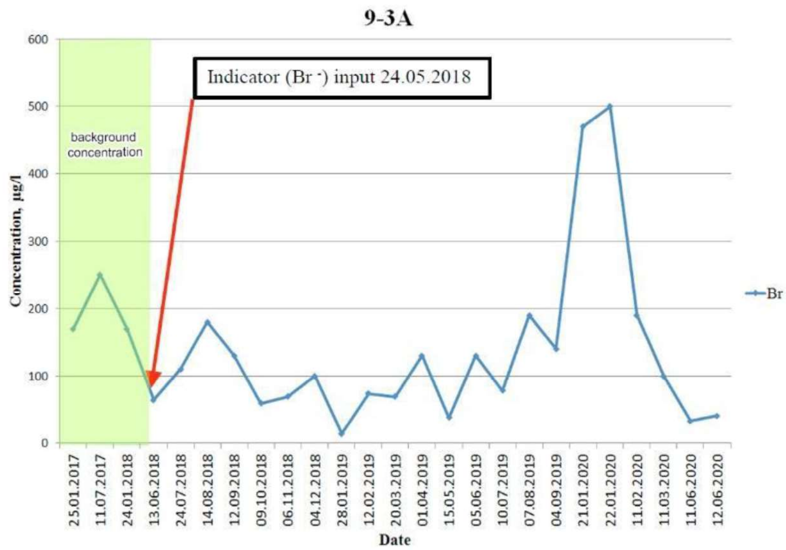

Fig. 10.19. The dynamics of the indicator concentration (Br-) in samples from the observation well 9-3A

Thus, the indicator experiment was successfully completed. And the next step is mathematical modeling of this indicator experiment.

10.5.2. Mathematical modeling

The filtration and capacity parameters of the aquifers were selected after mathematical modeling of the indicator spread so that the predicted results (concentrations, trajectories and propagation rates of indicators) coincide with the data of actual observations.

For the simulation, a three-dimensional geofiltration model was created using Visual Modflow 2011.1 and used (Panasiuk M. I., 2014; Kovalenko I., 2020).

Simulation mathematical modeling in Visual Modflow 2011.1 is aimed at obtaining the prognosed trajectory of bromide ion movement in groundwater on slice between wells 16-1A and 9-3A. These wells are located near the walls of the Shelter object on the first ledge of the cascade wall. Now they are located under the Arch.

We used to create earlier three-dimentional finite-difference model of the ChNPP site and 30 km territory around it and supllemented with a new data.

To develop the model, the investigated area is divided by the system of planes into elementary, interconnected, blocks and all filtration hydrodynamic parameters belong to the center of such a block, called the computational node.

This model covers a rectangular territory approximately 8 km long and 13 km wide (Figs. 10.20 and 10.21). In total, the model consists of three layers, which are divided into 412 columns and 301 rows. It includes data of aquifers, aquitards, permeability coefficients, etc.

Model reproduces a three-layer filtration region, which consists of two aquifers - the upper unconfined and the lower confined, separated by a weakly permeable layer in the filtration plan.

Visual Modflow 2011.1 lets you simulate, among other things, the movement of indicators in groundwater, and what has been used (N. I. Panasyuk et al., 2012; N. I. Panasyuk et al., 2011).

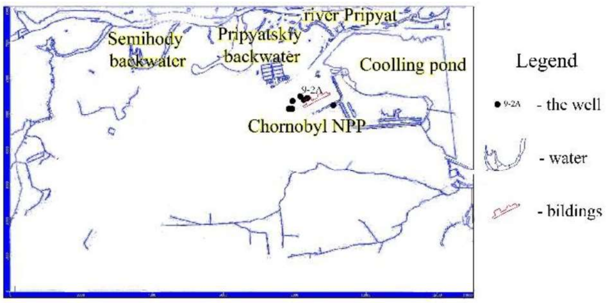

Fig. 10.20. General view of the mathematical model of the 30 km territory adjacent to the ChNPP

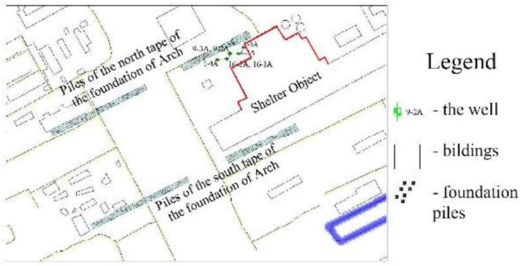

Fig. 10.21. Fragment of a mathematical model, used in experiment with tracking of bromide-ion moving

Sodium bromide was chosen as an indicator for the experiment. We selected 16-1A and 9-3A wells, located in a single line of groundwater flow, for modeling distribution of the bromide-ion.

According to the results of real observation time for indicator, passing from wells 16-1A to wells 9-3A is 20 months.

As a comparison, we simulated the movement of indicators with a filtration coefficient of 30 m/day and simulated situations, in which the results more closely match the actual data obtained from our indicator experiment.

The model contains the permeability coefficient of the entire thickness of the alluvial aquifer - 30 m/day. Figs. 10.22 and 10.23 show the simulated trajectory of the tracer from well 16-1A towards well 9-3A. The arrows indicate the direction of travel, and the steps between the arrows are 30 days. Considering the possible modeling error, we can say that the indicator will reach well 9-3A in 2–2.5 months with a filtration coefficient of 30 m/day.

The next step in modeling was the option, in which the indicator will reach well 9-3A in 20 months.

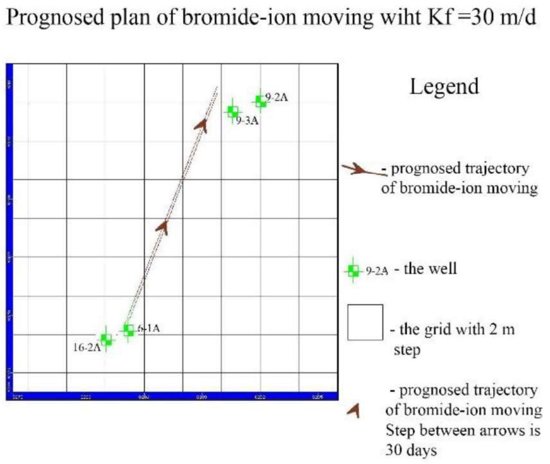

Fig. 10.22. Estimated trajectory of sodium bromide (NaBr) movement, injected into the well 16-1A with K_f = 30 m/day

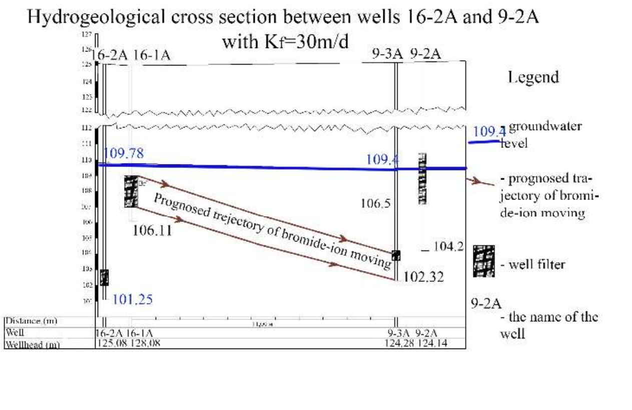

Fig. 10.23. Estimated motion trajectory profile of sodium bromide (NaBr), injected into the well 16-1A at K_f = 30 m/day

The results of the indicator experiment modeling (Figs. 10.24 and 10.25) showed that the permeability coefficient in the upper layer of the aquifer is 1.8 m/day. Difference between the filtration coefficient of the whole layer is 30 m/day, and 1.8 m/day for the upper layer of the aquifer indicates the filtration heterogeneity of soil layers that are part of the aquifer. The heterogeneity of the layers is manifested in different filtration rates. The actual velocity of groundwater movement throughout the entire thickness (K_f = 30 m/day) is 55 m/year. And in the upper part of the aquifer (K_f = 1.8 m/day), the actual flow rate of groundwater is about 6 m/year.

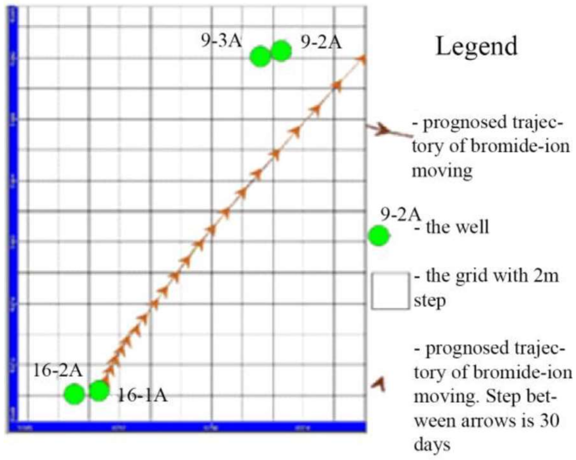

Fig. 10.24. Estimated trajectory of sodium bromide (NaBr) movement, injected into the well 16-1A with K_f = 1.8 m/day

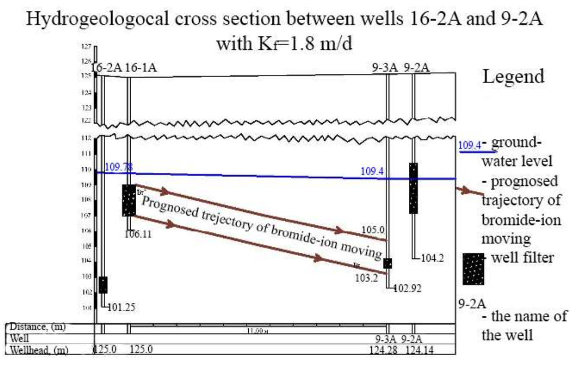

Fig. 10.25. Estimated motion trajectory profile of sodium bromide (NaBr), injected into the well 16-1A with K_f = 1.8 m/day

10.6 . Conclusion

Analysis of the distributions of the volumetric activities of ^{90}Sr in groundwater samples from observation wells confirmed the previously identified new mechanism for the formation of its high migration capacity in a highly alkaline environment at pH above 9.5. At pH above 9.5, the volumetric activity of ^{90}Sr in samples from observation wells increases 200–500 times to values of 400–700 Bq/l due to a decrease in the sorption capacity of soils and the entry of ^{90}Sr into groundwater during its desorption from the surface of particles composing the aquifer.

Studies of the distribution of tritium in groundwater made it possible to apply the isotope method to clarify the hydrogeological parameters near the 4th Unit of the ChNPP. These parameters include the conditions for the entry of radioactive contamination from sources into the aquifer, the direction and speed of groundwater movement, and hence the further spread of radionuclides in the environment. After the withdrawal of the cooling pond from operation in 2014–2015. The halo of tritium distribution in groundwater changed from north to north-east in full accordance with the predicted change in the direction of groundwater movement. The sliding of the Arch over the Shelter object in November 2016 led to the fact that atmospheric water stopped flowing into the 4th unit of the ChNPP. As a result, the flow of water containing high concentrations of radionuclides from the destroyed unit to the aquifer stopped. At the same time, the concentration of tritium in groundwater samples decreased from 900–1,100 to 30–50 Bq/l.

To assess the impact of the Arch – SO complex on the chemical pollution of groundwater, samples were taken and the concentration of the main ions (Na^+, K^+, Mg^{2+}, $Ca^{2+,}$ Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}) in them was determined. An analysis of the Pfeiffer and Durov diagrams shows that in the chemical composition of groundwater that has passed the filtration process under the NSC – SO complex, the concentration of sodium and potassium ions significantly increases and the amount of calcium ions decreases. Also, the influence of the NSC-SO complex is manifested in an increase of the groundwater pH to 11–12, which corresponds to a strongly alkaline environment.

To assess the filtration parameters of individual layers of the aquifer, an indicator method is proposed using mathematical modeling of the conditions of its distribution with groundwater. The possibility of its application in real field conditions has been demonstrated. As a result of applying the above mentioned methodology, the filtration coefficient of the upper part of the aquifer was determined to be 1.8 m/day. Whereas, the filtration coefficient of the entire stratum of the aquifer was 30 m/day.

Due to the new data obtained on the hydrogeological conditions of the aquifer, the location of some observation wells was moved to make the observation system and the goals and objectives of radiohydroecological monitoring coinciding.

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