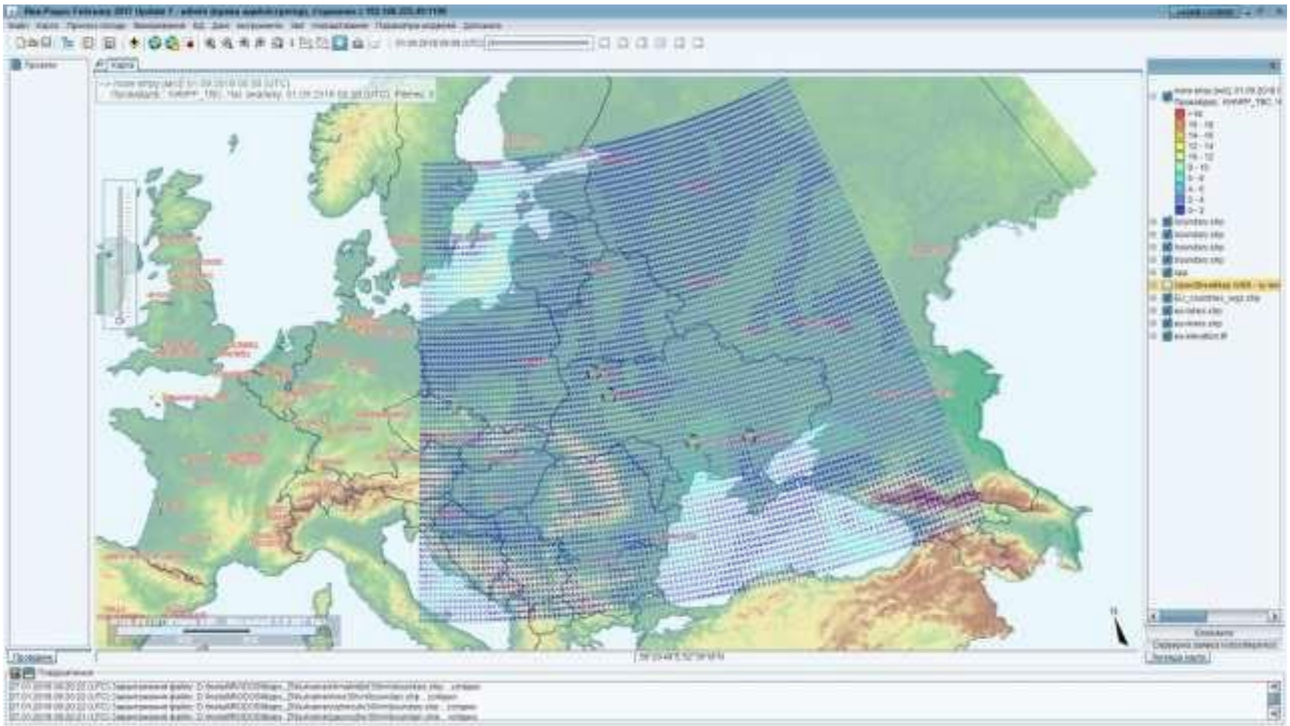
Modelling results on the transboundary transfer of the accidental releases at KhNPP

The modelling of radioactive substances transfer was made using the Decision Support System (DSS) JRODOS (version JRodosServerFebruary2017u1). The diffusion model – DIPCOT, a time period between particle releases is 3 seconds.

The forecasting meteorological data calculated by the Radiation Accidents Prediction Center of the State Emergency Service of Ukraine using the mesoscale forecasting model WRF for the period from 01 June till 31 October 2018, were used to assess the consequences of the transboundary transfer.



Picture 1 Area of the calculated meteorological parameters

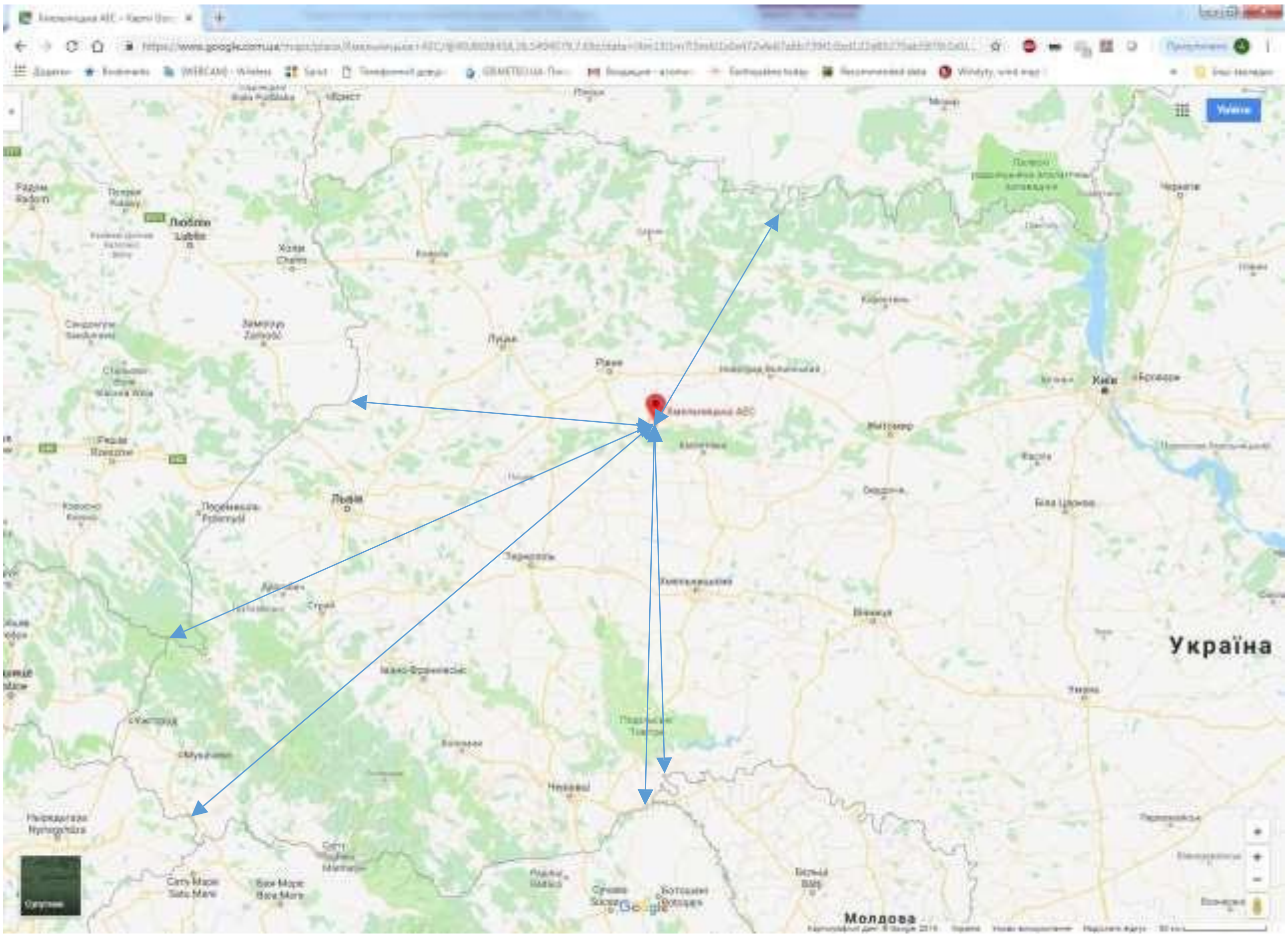
Activity of the release has been taken in accordance with a table 2.7 «Assessment of the transboundary transfer consequences under normal and emergency conditions» 43-814.203.004.ОЭ.13.14:

Nuclide	Release activity, Bq
I-131	8.792E+13
I-132	7.610E+13
I-133	2.052E+14
I-135	4.687E+13
Kr-85m	1.920E+14
Kr-85	1.170E+13
Xe-133	2.180E+15
Xe-135	4.670E+14
Sr-90	4.090E+10

Nuclide	Release activity, Bq
Zr-95	2.600E+10
Nb-95	8.880E+10
Ru-103	8.130E+11
Ru-106	8.040E+10
Cs-134	7.210E+11
Cs-137	4.480E+11
Ba-140	8.740E+11
Ce-144	6.120E+11

Distribution of iodine isotope by the fractions: 20.5% - molecular, 79.5% - organic.

1 DISTANCE TO THE BORDERING COUNTRIES



Picture 2 The minimal distances from Khmelnitsky NPP to the bordering countries:

Country	Minimal distance, km
Belarus	150
Poland	180
Moldova	210
Rumania	230
Slovakia	320
Hungary	370
Russia	410

2 DETERMINATION OF THE CONSERVATIVE CALCULATION CONDITIONS

The influence assessment of the effective release height and release duration, as well as the age group specification for which a maximum dose is formed, must be carried out to determine the conservative conditions of a dose formation.

2.1 RELEASE HEIGHT

The calculations of the maximum annual effective doses received from cloud, by inhalation, ground deposition, secondary wind blowing and food consumption within the radiuses of 150, 180, 210, 230, 320, 370, 400 km, were carried out to determine the release height in terms of a maximum dose formation at the distances of 150 km and more from the release source.

Table 1 Dependence of a maximum effective dose (mSv) on a distance (km) for a 1-year- age group, release duration – 1 hour, starting date – 01.06.18, 00:00:

Release height, м	Distance from KhNPP, km						
	≥150	≥180	≥210	≥230	≥320	≥370	≥400
10	0.563	0.374	0.297	0.234	0.123	0.080	0.074
30	0.583	0.424	0.308	0.251	0.113	0.075	0.070
50	0.511	0.410	0.316	0.260	0.120	0.084	0.074
75	0.616	0.403	0.303	0.261	0.120	0.079	0.070
100	0.610	0.393	0.312	0.249	0.117	0.082	0.079
150	0.617	0.387	0.324	0.253	0.118	0.082	0.077
200	0.519	0.386	0.320	0.254	0.123	0.085	0.085
300	**0.661**	**0.406**	**0.328**	**0.275**	**0.118**	**0.090**	**0.086**
500	0.553	0.424	0.314	0.281	0.124	0.088	0.083
750	0.507	0.391	0.296	0.243	0.100	0.068	0.063
1000	0.174	0.174	0.168	0.167	0.084	0.062	0.050

As shown in Table 1, by the release under stable atmosphere stratification, the dose quantity related to the transboundary transfer distance barely depends on the effective release height.

Table 2 Dependence of a maximum effective dose (mSv) on a distance (km), for a 1-year- age group, release duration – 1 hour, starting date – 01.06.18, **12:00**:

Release height, м	Distance from KhNPP, km						
	≥150	≥180	≥210	≥230	≥320	≥370	≥400
10	0.463	0.352	0.223	0.188	0.114	0.114	0.110
30	0.460	0.330	0.210	0.184	0.117	0.117	0.089
50	0.467	0.334	0.213	0.202	0.114	0.114	0.106
75	0.468	0.323	0.216	0.188	0.114	0.112	0.107
100	0.467	0.322	0.222	0.190	0.114	0.114	0.099
150	0.431	0.301	0.213	0.183	0.116	0.108	0.108
200	0.495	0.351	0.212	0.212	0.116	0.112	0.108
300	0.493	0.324	0.227	0.180	0.115	0.115	0.087
500	0.451	0.326	0.208	0.195	0.112	0.112	0.088
750	0.454	0.338	0.220	0.184	0.112	0.112	0.106
1000	0.441	0.305	0.196	0.157	0.124	0.124	0.089

By a daytime release, the influence of the effective release height at a distance of the transboundary transfer is almost inconsiderable.

For calculation is used the effective release height of 300 m, which is a real one in respect of a heat cloud raise in the event of beyond design basis accident.

2.2 REALESE DURATION

Based on the calculation results of a reviewed accident («Severe accident management guidelines in the reactor facility and spent fuel storage pool (reactor facility condition – «power operation»), analytical justification by the severe accident management strategy at RNPP`s unit 4), the main quantity of radioactive substances will be releasing during 8 hours.

2.3 CRITICAL POPULATION GROUP

Table 3 Dependence of a maximum effective dose (mSv) on a distance (km) at the release height of 300 m, for the various age group, starting date – 01.06.18, 00:00:

Release duration, h	Distance from KhNPP, km						
	≥150	≥180	≥210	≥230	≥320	≥370	≥400
1-year-old children	**0.561**	**0.421**	**0.314**	**0.270**	**0.115**	**0.089**	**0.085**
5-year-old children	0.223	0.167	0.125	0.107	0.046	0.035	0.034
10-year-old children	0.131	0.099	0.074	0.063	0.027	0.021	0.020
15-year-old children	0.097	0.073	0.054	0.047	0.020	0.015	0.015
Adults	0.070	0.053	0.039	0.034	0.014	0.011	0.011

A 1-year-old children group is used for the conservative conditions of calculation.

3 CRITICAL WAYS OF RADIATION DOSE FORMATION

The calculation based on the meteorological conditions as on 01.06.18, 00:00, at the release height of 300 m, release duration – 1 hour, for the population group of 1-year-old children, was carried out to assess the ways of effective radiation dose formation.

Table 4 Dependence of an equivalent radiation dose (mSv) on a distance (km) at the release height of 300 m, for a 1-year-old children group, starting date – 01.06.18, 00:00:

Radiation source	Distance from KhNPP, km						
	≥150	≥180	≥210	≥230	≥320	≥370	≥400
Cloud	1.7E-04	9.8E-05	6.4E-05	5.0E-05	1.6E-05	1.0E-05	9.0E-06
Secondary wind blowing	3.0E-08	2.1E-08	1.6E-08	1.3E-08	5.3E-09	4.9E-09	4.9E-09
Inhalation	2.2E-03	1.6E-03	1.2E-03	1.0E-03	4.1E-04	3.1E-04	2.9E-04
Ground surface	2.0E-04	1.4E-04	1.1E-04	9.0E-05	3.5E-05	3.3E-05	3.3E-05
Skin	2.7E-05	1.9E-05	1.4E-05	1.1E-05	4.3E-06	3.2E-06	3.0E-06
	0.0026	0.0019	0.0014	0.0011	0.0005	0.0003	0.0003
Peroral way	**0.5580**	**0.4191**	**0.3129**	**0.2685**	**0.1149**	**0.0891**	**0.0848**
Effective dose	0.5606	0.4210	0.3143	0.2696	0.1154	0.0895	0.0851

More than 99% of dose is formed due to food consumption during the first year after the accident at a distance of the transboundary transfer.

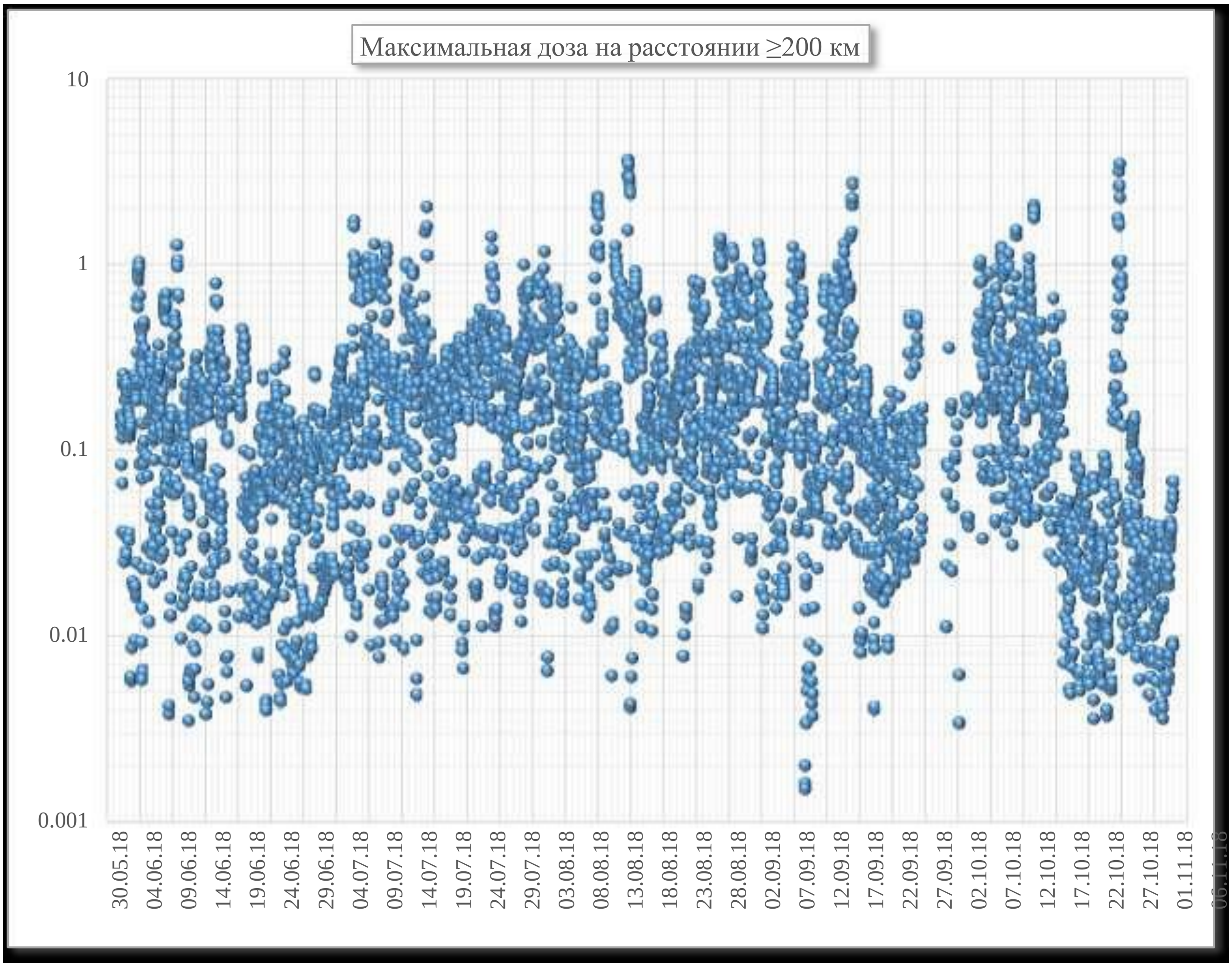
Table 5 Dependence of an equivalent radiation dose (mSv) on a distance (km) at the release height of 300 m, for a 1-year-old children group, starting date – 01.06.18, 00:00:

Radiation source	Distance from KhNPP, km						
	≥150	≥180	≥210	≥230	≥320	≥370	≥400
Isotopes of strontium	5.1E-05	3.9E-05	2.8E-05	2.4E-05	1.1E-05	8.3E-06	8.3E-06
Isotopes of caesium	1.4E-03	1.0E-03	7.8E-04	6.7E-04	2.9E-04	2.3E-04	2.1E-04
Isotopes of iodine	**0.559**	**0.420**	**0.313**	**0.269**	**0.115**	**0.089**	**0.085**
Effective dose	0.561	0.421	0.314	0.270	0.115	0.089	0.085

99% of the effective dose is formed during the first year after the accident due to food consumption, which consists of the iodine isotopes.

4 CALCULATION PERFORMANCE

About 4000 calculations were carried out to assess the transboundary influence of the releases at KhNPP, including the time of the releases during the period from 01.06.2018 по 08.11.2018. JRODOS StatisticOutput tool was used for these calculations. Total effective annual dose received through the all routes including digestive system for children at the age of 1 year has been used as the outcome. Picture 3 shows the calculation results in all release directions at a distance of 200 km and more from KhNPP.



Schedule 1 Maximum effective doses in all calculation directions, mSv

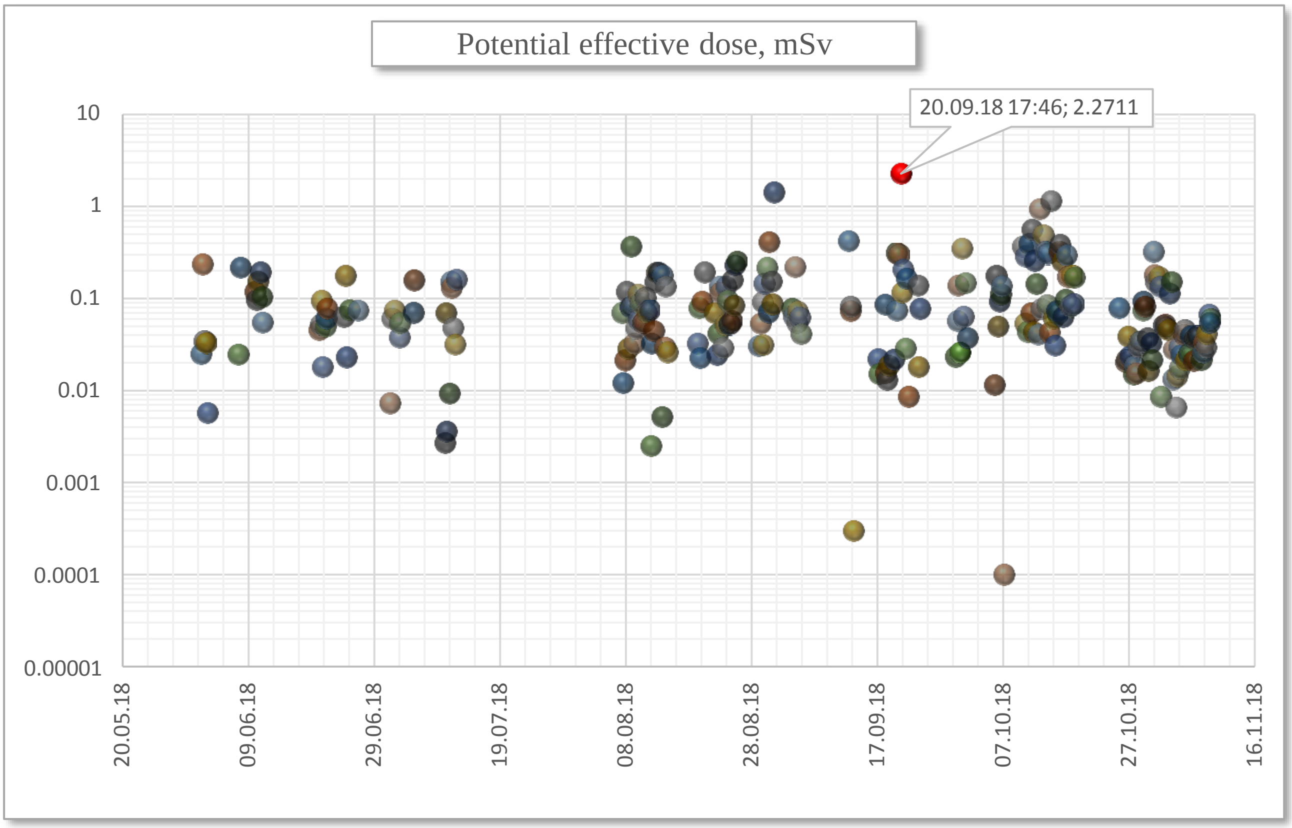
The selection of scenario on dispersion in the appropriate direction and the decorrelation of calculations were carried out to calculate the influence of the transboundary transfer on each country.

As a result, a series of decorrelated quantities of the maximum doses received on the territory of the appropriate country at a different time of release beginning were carried out for each country. A time period between different releases has been chosen in the way that the correlation of the maximum doses received due to adjacent releases wouldn`t exceed 5 %. A time period was different for various countries and varied from 4 to 8 hours (as stated in the next sections).

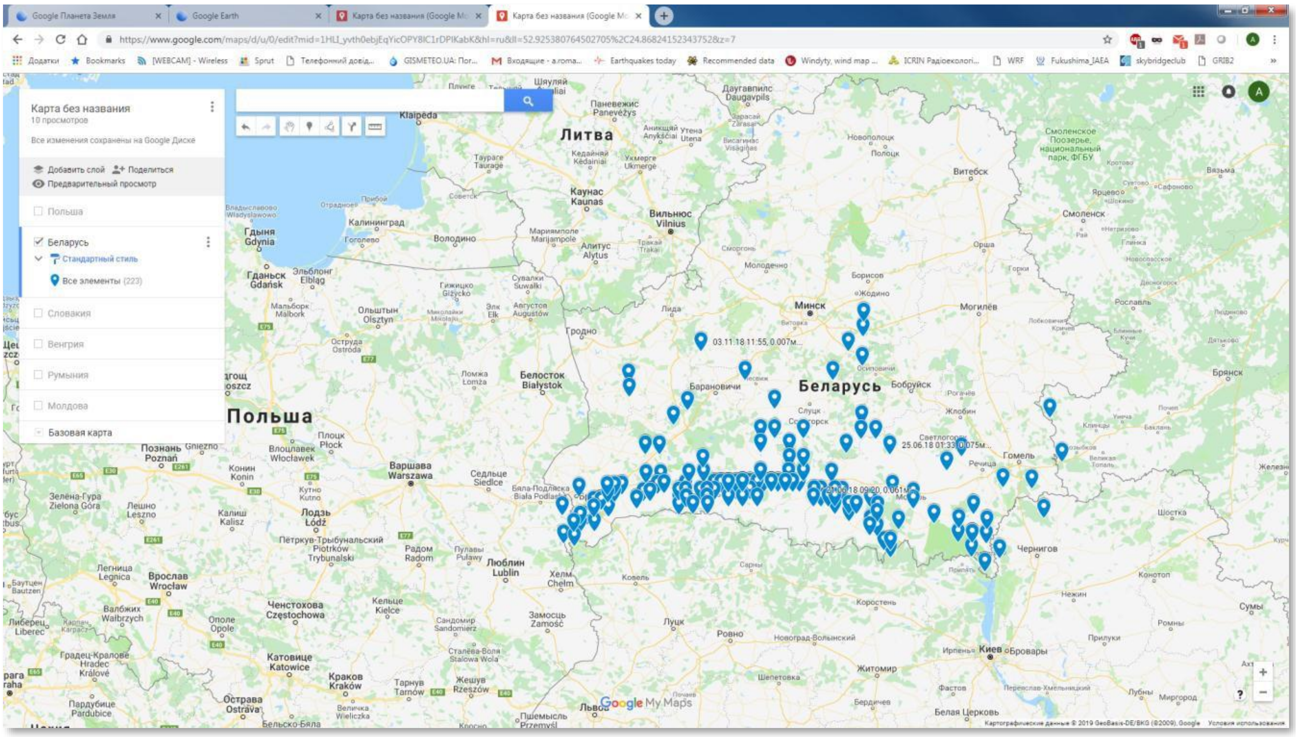
4.1 CALCULATION OF THE EFFECT OF TRANSBOUNDARY TRANSFER IN THE REPUBLIC OF BELARUS

To assess the impact of transboundary transport on the population of the Republic of Belarus, decorrelation was performed with an interval of 6 hours.

Total calculations	Minimum	Average	Maximum	Correlation
234	0.0001	0.1180	2.2711	0.0362



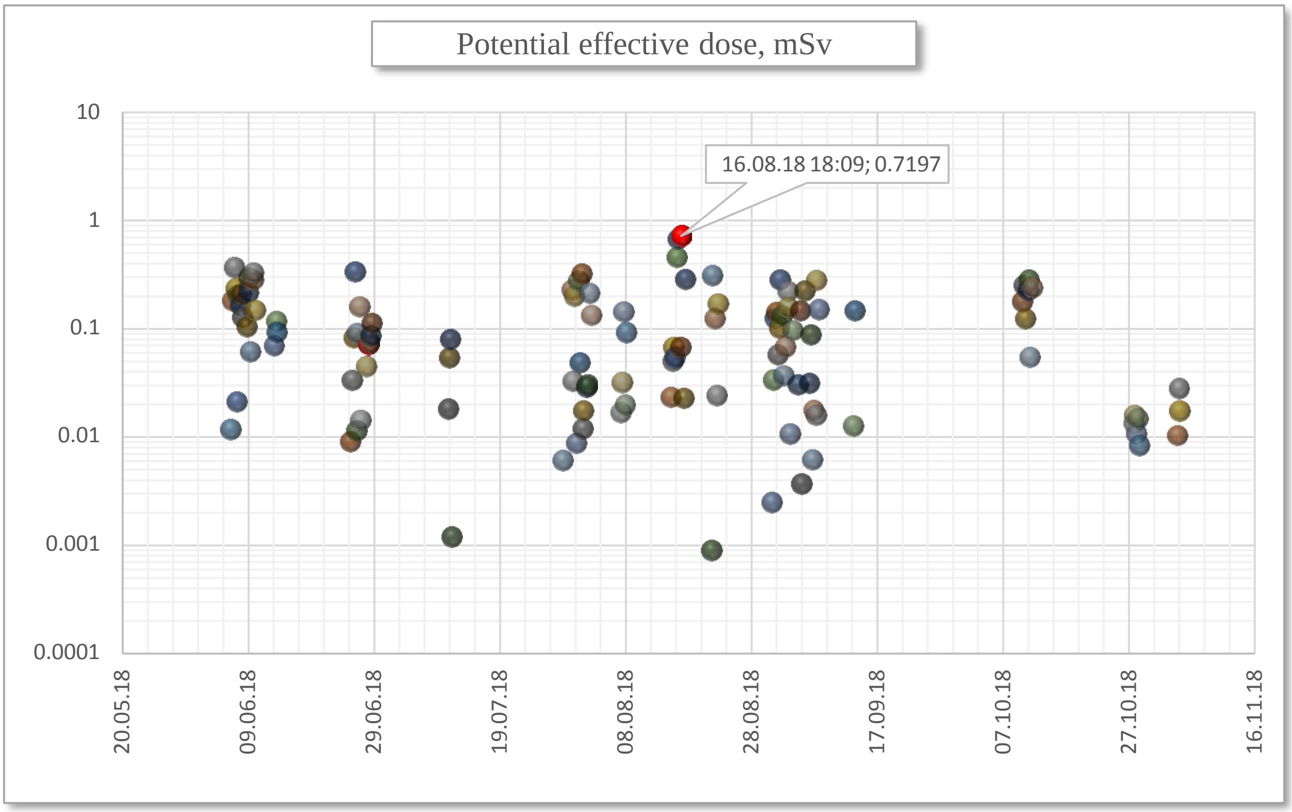
Schedule 2 The maximum effective dose, mSv



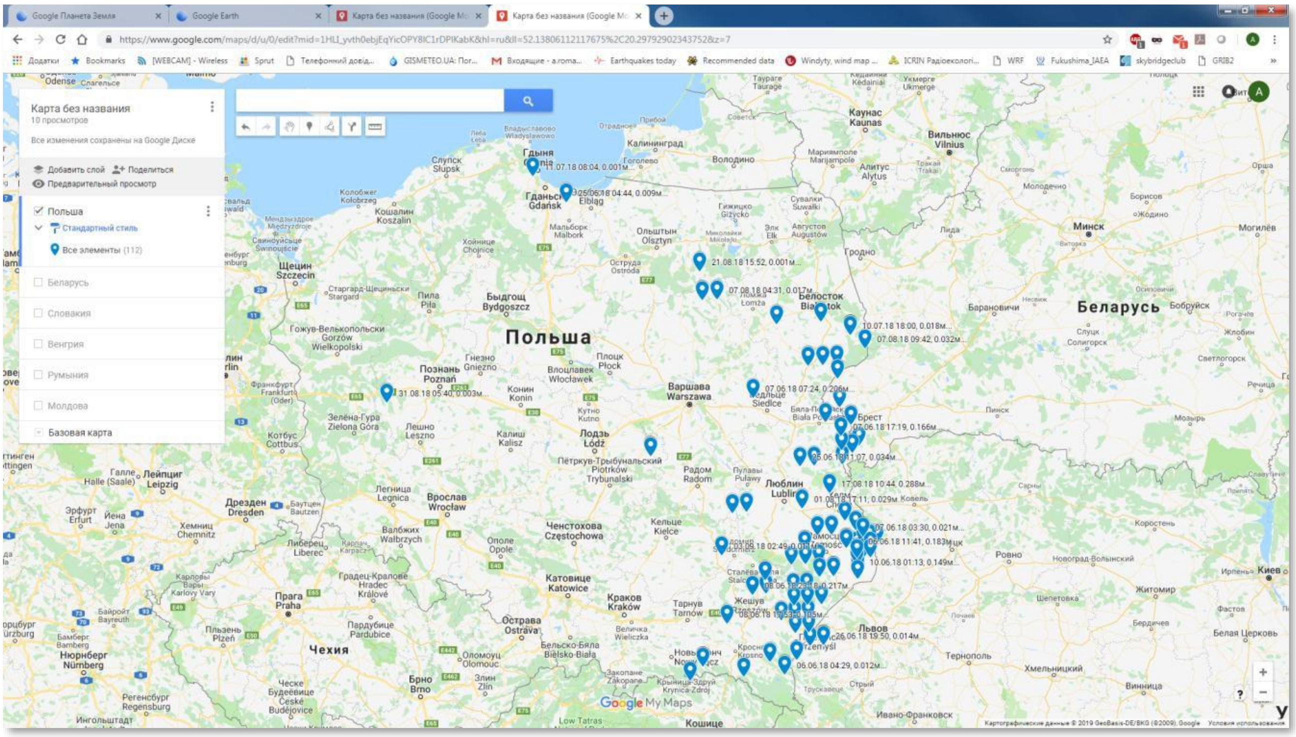
Picture 3 Location of effective dose maxima

4.2 CALCULATION OF THE EFFECT OF TRANSBOUNDARY TRANSFER IN THE REPUBLIC OF POLAND To assess the impact of transboundary transport on the population of the Republic of Poland, decorrelation was performed with an interval of 6 hours.

Total calculations	Minimum	Average	Maximum	Correlation
112	0.0009	0.1204	0.7197	0.0451



Schedule 3 The maximum effective dose, mSv

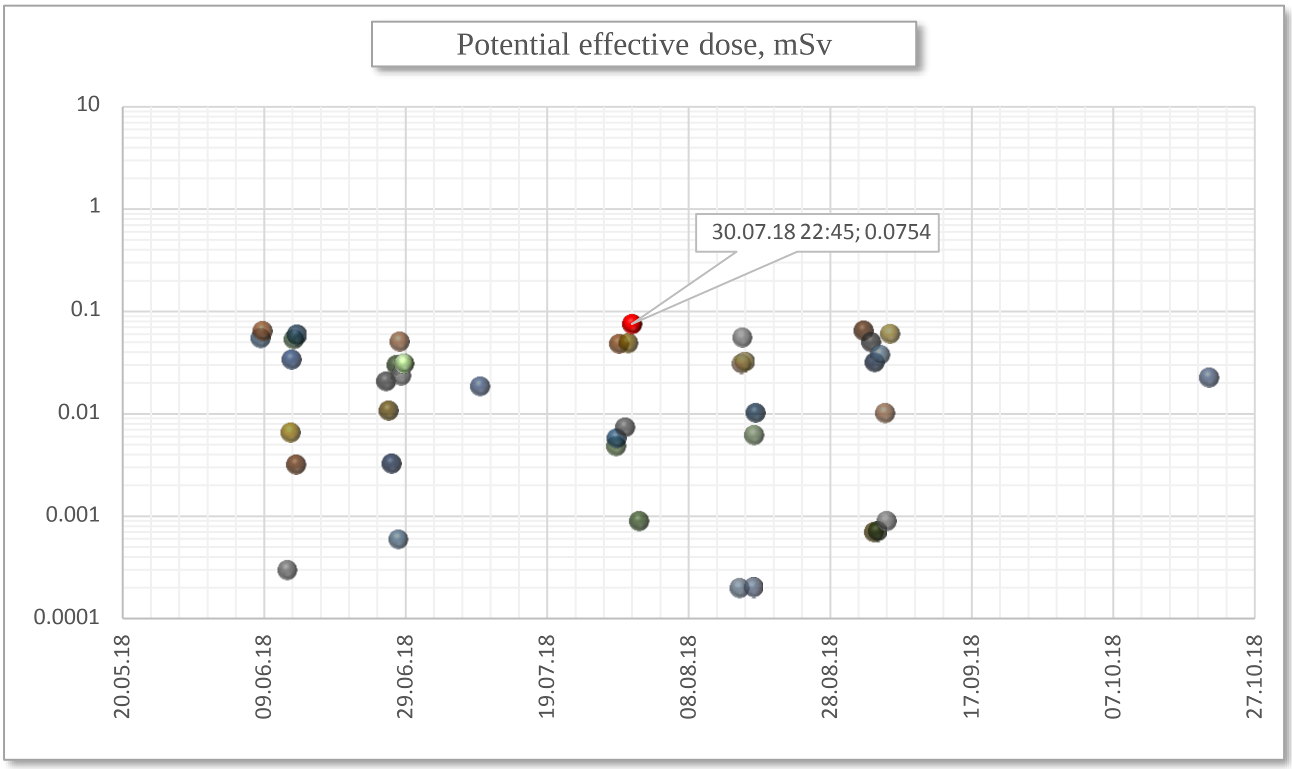


Picture 4 Location of effective dose maxima

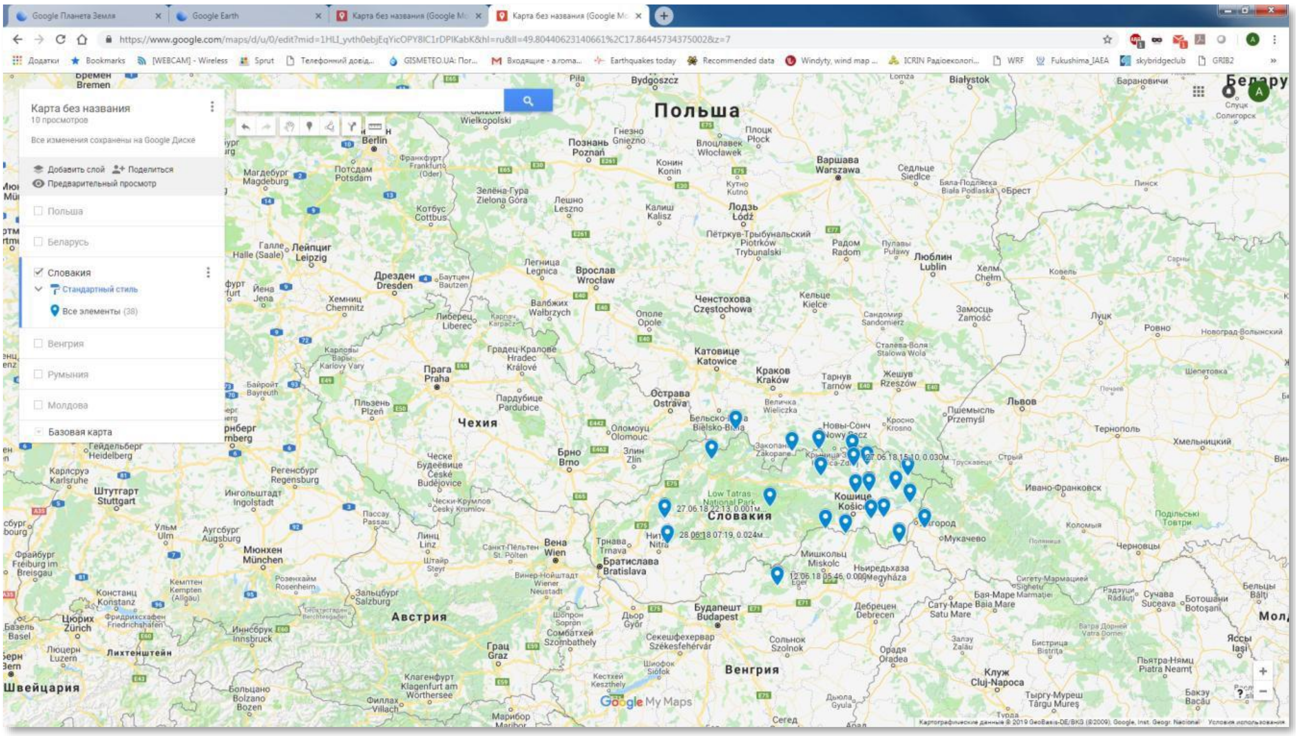
4.3 CALCULATION OF THE EFFECT OF TRANSBOUNDARY MOVEMENT ON SLOVAK REPUBLIC

To assess the impact of transboundary transport on the population of the Slovak Republic, decorrelation was performed with an interval of 6 hours.

Total calculations	Minimum	Average	Maximum	Correlation
41	0.0002	0.0258	0.0754	-0.0410



Schedule 4 The maximum effective dose, mSv

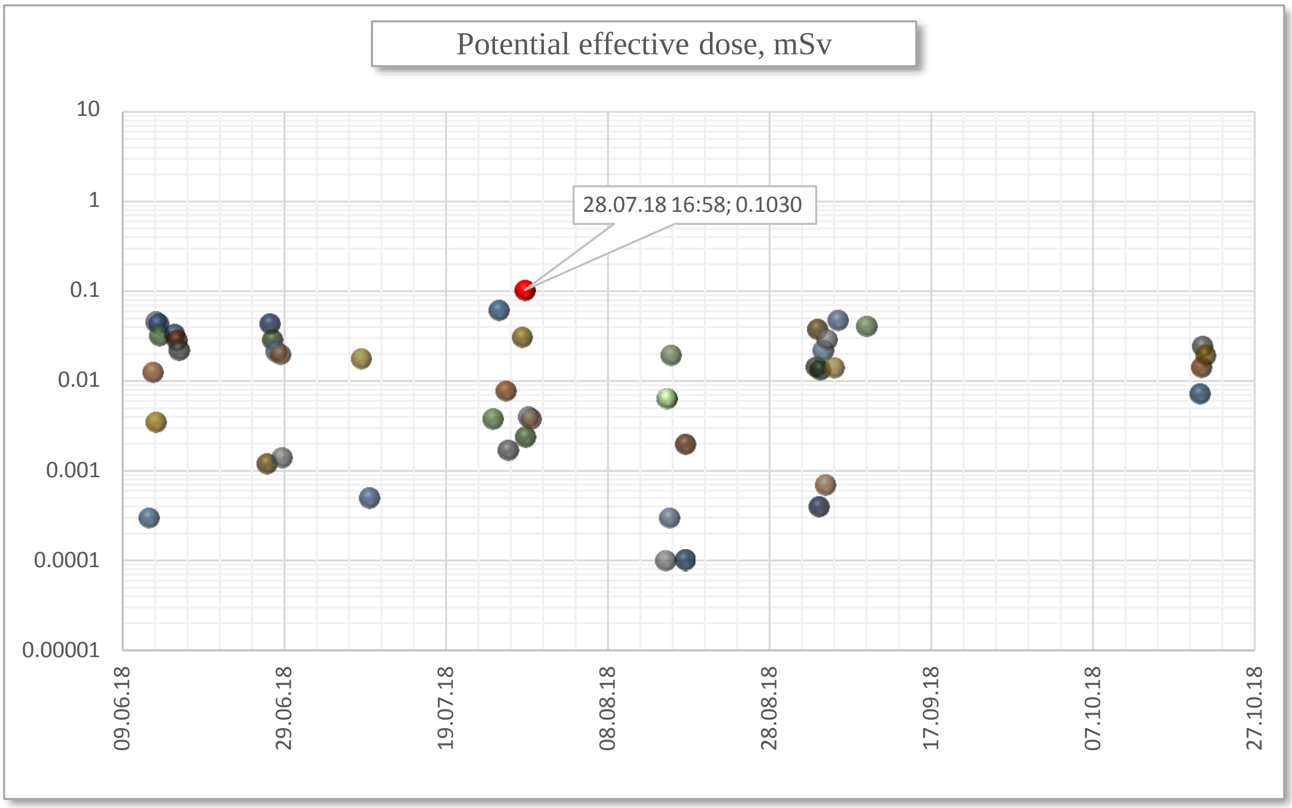


Picture 5 Location of effective dose maxima

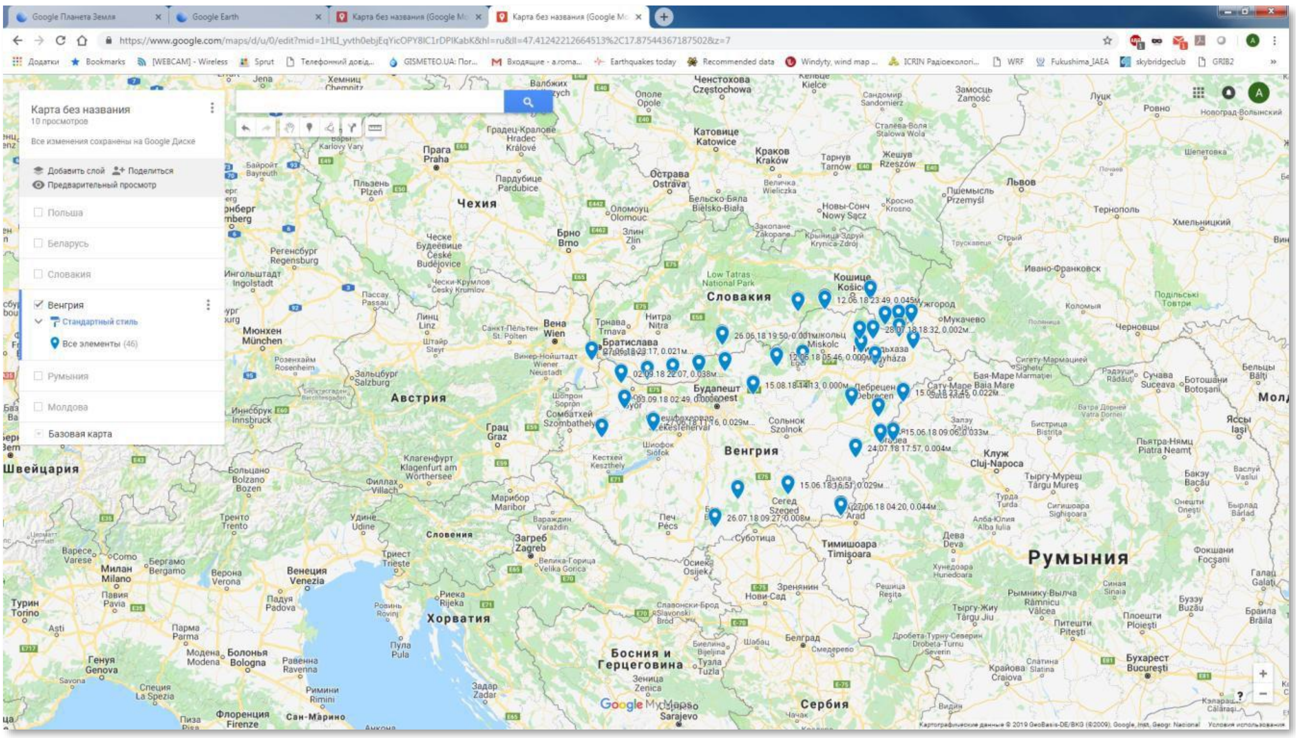
4.4 CALCULATION OF THE EFFECT OF TRANSBOUNDARY TRANSFER ON HUNGARY

To assess the impact of transboundary transport on the population of Hungary, decorrelation was performed with an interval of 6 hours.

Total calculations	Minimum	Average	Maximum	Correlation
46	0.0001	0.0191	0.1030	-0.00002



Schedule 5 The maximum effective dose, mSv

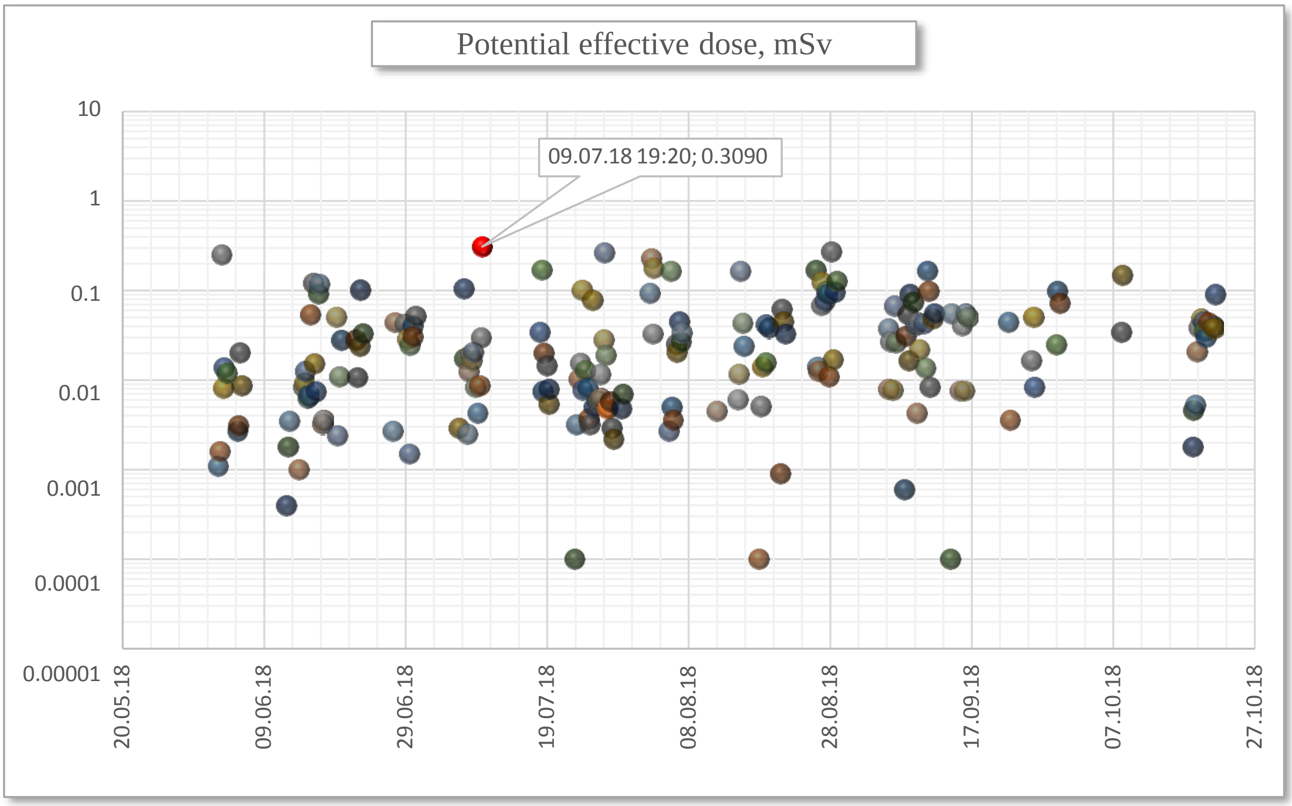


Picture 6 Location of effective dose maxima

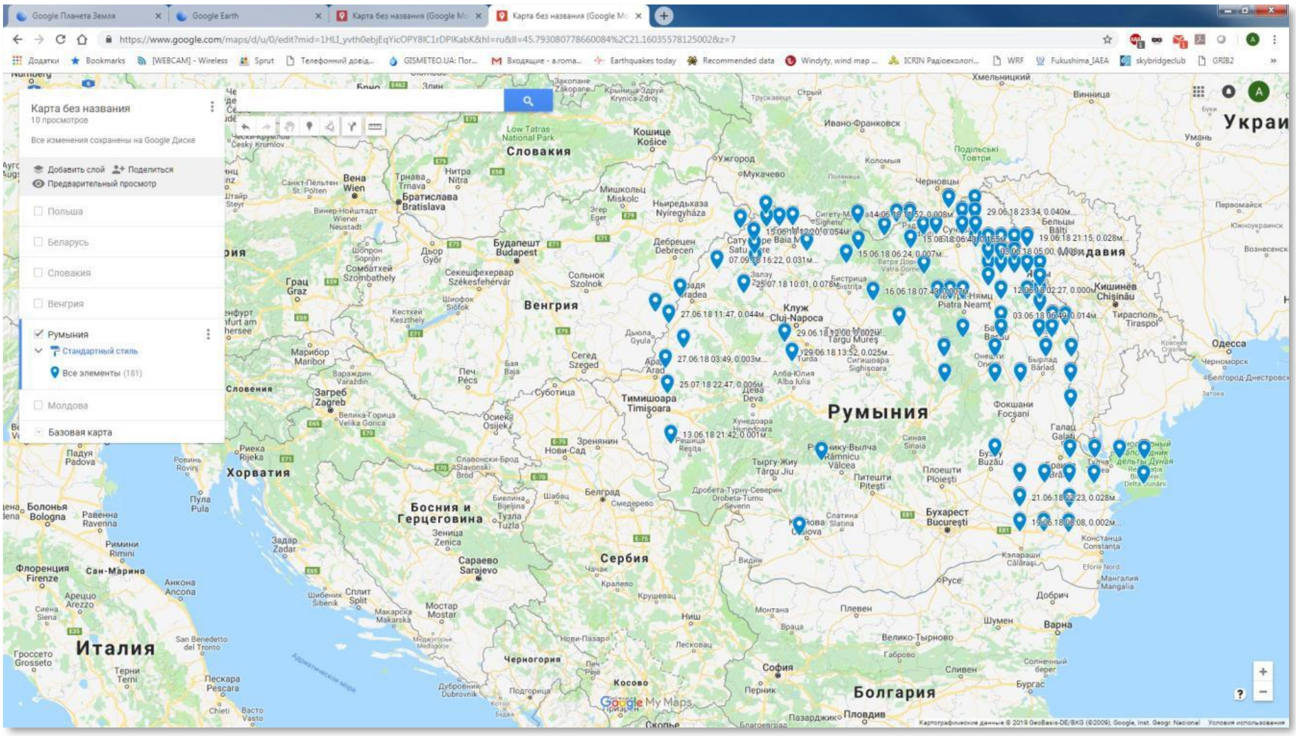
4.5 CALCULATION OF THE EFFECT OF TRANSBOUNDARY TRANSFER IN ROMANIA

To assess the impact of transboundary transport on the population of Romania, decorrelation was performed at intervals of 8 hours.

Total calculations	Minimum	Average	Maximum	Correlation
185	0.0001	0.0404	0.3090	0.00041



Schedule 6 Maximum effective doses, mSv

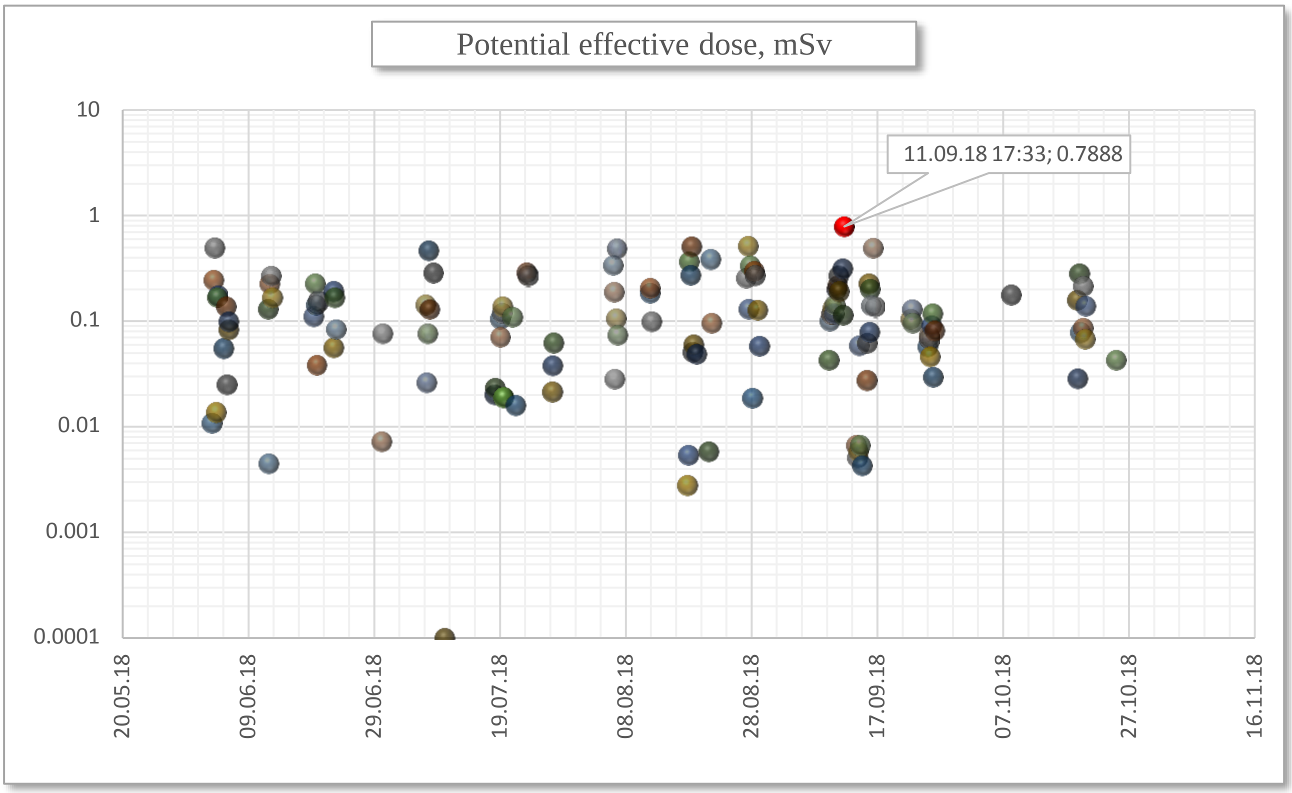


Picture 7 The location of the effective dose maxima

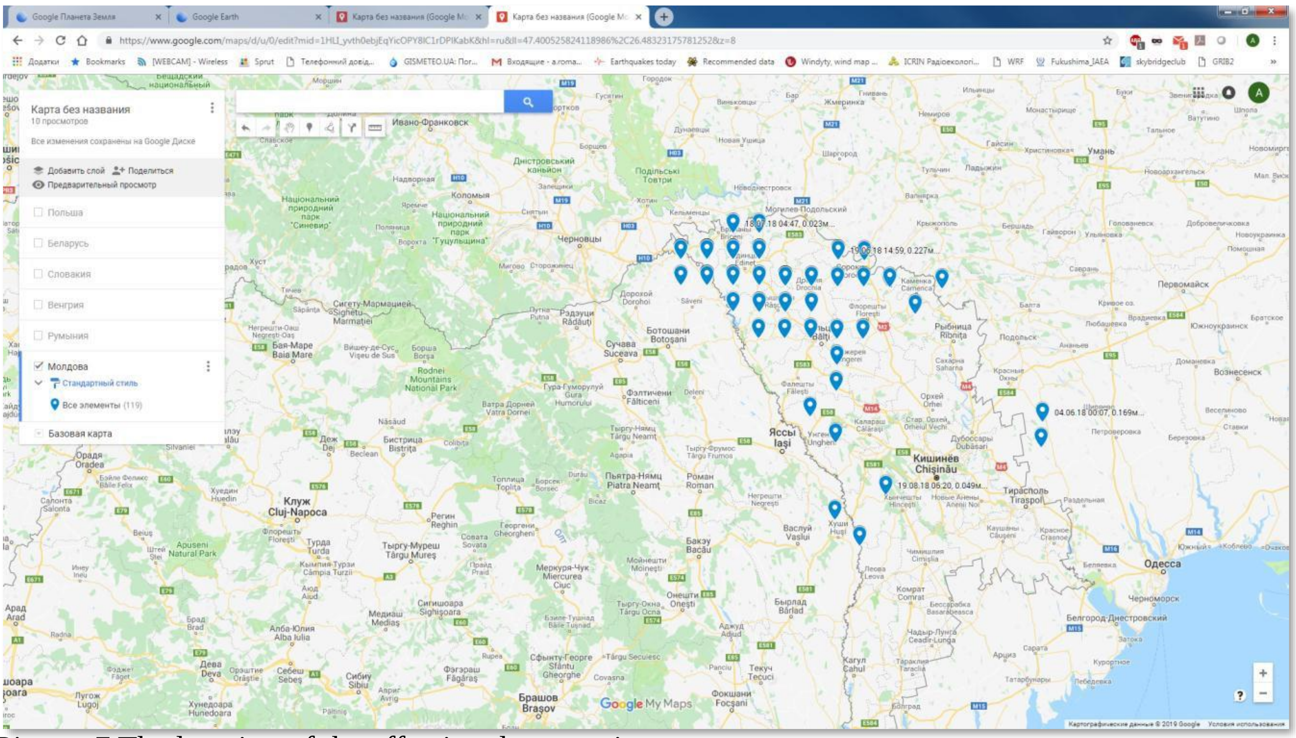
4.6 CALCULATION OF THE EFFECT OF TRANSBOUNDARY MOVEMENT ON THE REPUBLIC OF MOLDOVA

To assess the impact of transboundary transport on the population of the Republic of Moldova, decorrelation was performed at 4-hour intervals.

Total calculations	Minimum	Average	Maximum	Correlation
126	0.0001	0.1418	0.7888	0.01996



Schedule 6 Maximum effective doses, mSv



Picture 7 The location of the effective dose maxima

5 EFFECT OF TRANSBOUNDARY TRANSFER IN AUSTRIA

The minimum distance from the Khmelnitsky NPP to the Austrian border is 730 kilometers. Taking into account the calculations performed in the previous sections, it can be argued that the accidents at KhNPP power units No. 3.4 will not exceed the annual dose rate at the border with Austria in excess of 1 mSv with a large margin.