MINISTRY OF ENERGY OF THE REPUBLIC OF BELARUS

**BELNIPIENERGOPROM**
DESIGN SCIENTIFIC AND RESEARCH REPUBLICAN UNITARY ENTERPRISE

# VALIDATION OF INVESTMENTS IN THE NUCLEAR POWER PLANT CONSTRUCTION IN THE REPUBLIC OF BELARUS

## BOOK 11

## ENVIRONMENTAL IMPACT ASSESSMENT

**1588-ПЗ-ОИ4**

## PART 8

## EIA REPORT

# Part 8.2. Current condition of environment

## EXPLANATORY NOTE

**(06.07.2010 version)**

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# Contents

# 13 CHARACTERISTIC OF ENVIRONMENT

## 13 .1 Geological environment

### *13.1.1 General characteristic of geomorphologic peculiarities, geological and structural tectonic composition*

Geomorphologic conditions, geological and structural tectonic composition are characterized by certain differences within the limits of a particular part of the 30-km area. Structure of the geological medium of the NPP site differs from that of the 30-km area. So, the characteristics of the 30-km area in whole and the NPP site itself ere given below. Planimetric map–scheme of the 30-km area and the NPP site is shown in Figure 38.

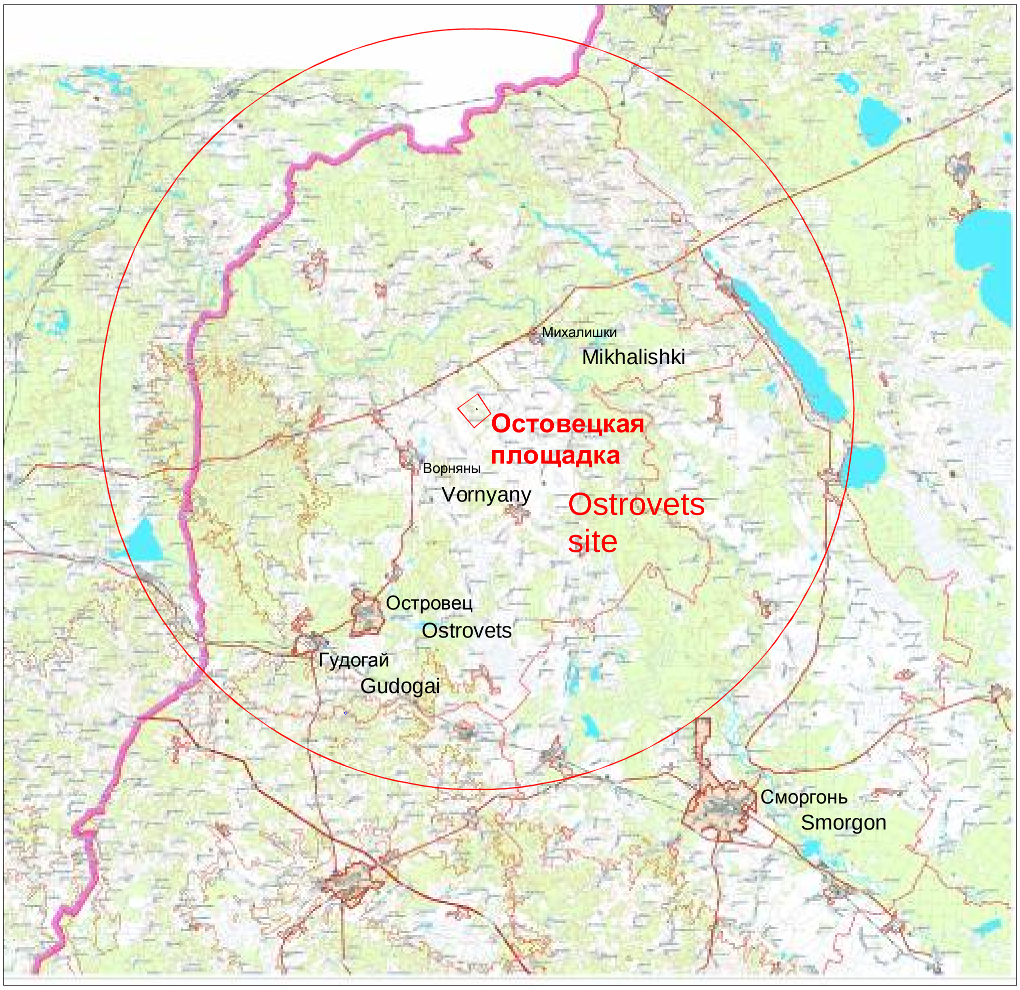



**Figure 38 – Situation map–scheme for the 30-km area and the NPP site**

#### *13.1.1.1 NPP 30-km area*

30-km safety area is characterized by the results of work performed by the Republican Unitary Enterprise «Belgeologiya» [62,63,64].

The main structural components of the surface are the Viliya valley, the flat-wavy Viliya plain situated at both sides of the valley and moraine elevation: Svir elevation on the North–East and Oshmyany elevation on the South–West.

Hydrographical network of the region is presented by a latitudinal area of the Viliya-river which crosses this region from the East to the West, as well as by small rivers which fall into the Viliya, namely, the Oshmyanka, the Gozovka and the stream Polpe to the left, the rivers Stracha and Sorochanka to the right.

The Viliya is the right tributary of the Neman, referring to the Baltic Sea basin. The middle course of the Viliya is situated within the expected working area. The river canal is wavy, the canal width is equal to 65-101 m, and the depth is equal to 1.22 м. The bottom is sandy, riffling. The bottom is encumbered by boulders in restricted river areas. The river stream mean velocity is equal to 0.3 m/sec. Absolute elevations for the low stage are changing from 120.4 m at the Oshmyanka-river outfall to 116.0 m at the Gozovka-river outfall. The river slope is equal to 3.6 m per 16 km. Two floodplains and two above the floodplain terraces are marked out in the Viliya-river valley. The river floodplain is developed at some areas, its width equaling no more than hundreds meters. In some cases the floodplain width reaches 600 m (the area located above the Mikhalishki village). The floodplain height above the water edge is equal to 0.2-3.5 m.

The first above the floodplain terrace is traced at both river banks in the form of narrow 100–200 m stripes alternating in an accord with the river bed curve (the terrace becomes apparent alternating at both banks). The width of the first above the floodplain terrace is increased repeatedly reaching 500–800 m in the vicinity of the inflow of the Stracha-river and the inflow of the Oshmyanka. Terrace step toward the river floodplain is well-marked. The step height is equal to 2.5 – 4 m, the step height is up to 5 m relative to the water edge.

The Oshmyanka is the left inflow of the Viliya of the first order. The Oshmyanka flows as a winding tape along the eastern edge of the 30-km area. Its valley is oriented almost strictly in the meridional direction along the moraine plane which is covered with fluvioglacial sediments in some areas. The riverbed within the area under discussion having the width of 15-20 m is everywhere accompanied with a narrow double-sided floodplain rising above the water edge up to the height of 0.5 – 2.5 м.

The Stracha is the right inflow of the Viliya. Only a small part of downstream of the Stracha falls into the 30-km area. The river stream canal is highly wavy; the canal width is equal to 8-15 m. The valley is clearly defined; it is formed by the double-sided floodplain 50 –150 m wide, the floodplain width reaches up to 600 m in the vicinity of the inflow of the Stracha to the Viliya.

*From the geology– tectonic point of view* the territory under study is situated in the middle part of its Baltic monocline, namely, between the Viliya buried prominence of the crystal foundation and the distant wing of the Baltic syneclise. The depth of the foundation burial (bedrock foundation) and the total value of the sedimentary cover change from 347 m near Smorgon to 536 m near the Lake Naroch. To the east of Oshmyany this value reaches 438 m.

Internal structure of the foundation is non-uniform; it is defined by its position within the junction area of large-scale structure formation areas of Belarusian– Baltic granulite belt, namely, the Ivye–Smorgon area to the east–south–east and the Oshmyany area to the north–west.

The boundary existing between the Oshmyany and Ivye– Smorgon areas is interzonal regional structure– formative deep fracture of the mantle (mantle - crust) laying of the Archean stage of the development of Baltic granulite belt. This fracture called Ostrovetsky separates two structure formation areas, wherein rocks of different origin and different material composition are developed in the areas.

In accordance with the course of the Ostrovets board fracture the West-Ostrovets fracture is traced in parallel to it at the distance of 2.5-5 km to the north–west.

Sediments of four structural–material complexes are found in composition of the sedimentary cover the studied region, namely, Verkhnedvinsk–lower Cambrian (late Baikal), lower Cambrian – lower Devon (Caledonian), middle Devonian–middle Triassic (Hercynian) and middle Triassic – Quaternary (Cimmerian – Alpine) complexes.

From the point of view of impact on the geological medium the upper part of the geological cross-section stacked by Quaternary sediments is of the greatest interest.

According to the geological survey data related to the territory under study as well as the data related to studying the cross– sections of the holes of different purposes the stratum of the Quaternary sediments changes from 60.6 m to 145 m. Being so, the minimal values of the stratum are observed within the Viliya valley that is within the lower marks of the day surface. The maximal values of the Quaternary sediment thickness are found on the finite– moraine elevations characterized by the highest relief levels, namely, the Oshmyany and Konstantinovo ridges.

In accordance with the accepted stratigraphical scale for the Quaternary (anthropogenic) sediments four sections are defined in the geological structure: lower, middle, upper and modern sections. In its turn, the Brest (pre-glacial), Narevskij glacial, Belovezhskij interglacial and Berezinskij glacial horizons (the last three horizons are often combined by the Belarusian superhorizon) are selected in the lower section. In the middle section the horizons Alexandrijskij interglacial and Pripyat glacial (with two subhorizons, namely, Dnieper and Sozh) are located. Muravinskij interglacial and Poozerskij glacial horizons are related to the upper section. The modern section is presented by the Holocene horizon.

*The Brest (pre-glacial) horizon* has an island structure. It is mainly formed from lacustrine sediments, least often from alluvial deposits. Thickness of these formations does not exceed 5 -10 m, the maximum thickness values are observed within the area of towns Oshmyany and Smorgon. The strata are mainly represented by thin clay sand layer and (to a lesser degree) clay and sand layers. These sediments do not appear on the day surface.

*The Narevskij glacial horizon* is formed by the stratum consisting of coarse layers clay sand, loam and clay coloured mainly with grey and green-gray colors. This is locally spread; it includes sand interlayers, segregations of chalk and Cainozoic rocks. The moraine thickness is generally equal to approximately 10-15 m; in some cases it exceeds 30 m. Fluvioglacial sand and coarse rocks, thin clay sand layers, as well as horizon ribbon clay have not remained on the whole territory. Thickness of these geological layers very seldom exceeds 10-15 m. All these rocks are present in the glacial dislocation structure. Narevskij horizon sediments are not found on the studied territory, but their occurrence is possible.

*The Belovezhskiy interglacial horizon* is formed by clay, thin clay sand and sand layers, mainly, of lacustrine and alluvial genesis. Peat swamp and highly humus rich rocks are found in isolated open-casts. These geological formations are relatively thin (generally 3-10 m), they are only developed in restricted areas; in many cases they are glaciogenic allocated and they do not play any important role in the composition of the anthropogenic sediments.

*The Berezinskiy glacial horizon* includes moraine and outwash; it is wide developed as compared with the Narevskiy horizon. The Berezinskiy glacial horizon is mainly presented in the southern part of the 30–km area. These sediments occur either on the more ancient (Quaternary) rocks or directly on ledge rocks. Thickness of the horizon does not exceed 5-25 m; it is equal to 3-15 m in the vicinity of the site. The stratum is not uniform; often it is of the two– or three–term composition type, it can include float stone clay sand or loam of different tints (gray or brown coloured substances with interlayers of anisomerous sand, thin clay sand and sand-gravel material).

*As a rule, the water and glacial deposits of the Berezinskiy horizon* in the form of anisomerous sand and lacustrine glacial clayey sediments underlays and covers the moraine, its thickness changes from several meters to 20-40 m. In many cases, such strata close down with similar accumulations of the Narevskiy or Dnieper glaciations; so, they create a non-segmented complex characterized by thickness of 100–120 m at glacial hollows and edge forms.

*The Alexandrijskiy interglacial horizon* is confidently defined by paleontological attributes, and it serves a marking reference. The horizon is formed by rocks of alluvial, lacustrine and marsh l genesis; to a lesser degree it is presented by clay sand and loam soil, gyttja, marl, diatomite, peat. Thickness of the layers changes from 2-5 m to 25 m. Within the 30–km area (hole No 6, Zhodishki village) layer thickness is equal to 12.2 m.

*The Dnieper glacial subhorizon* of the Pripyat glacial horizon is everywhere developed within the region under study. It is actually formed by glacial (moraine), outwash and periglaciological formations. Thickness of these layers is often up to 5-30 m, the maximum thickness is 43.4 m. The underlying rock rejects are often observed in the moraine. Thickness of the outwash accumulations presented together with moraine reaches several tens of meters.

*The Sozh glacial subhorizon* is widely spread as the Dniepr subhorizon. To the south from the Svir ridge the Sozh glacial subhorizon comes out on the day surface. In fact, the glacial drifts are particular well developed within the limits of the Oshmyany ridge. The thickness of moraine formed by red–white coarse clay sand and loam is mainly equal to 10-25 m. It reaches 84.1 m at Oshmyany elevation (the village Zhuprany). The fluvioglacial sand and clay underlay and overlap the moraine in many places, their thickness is equal from several meters to 20 m, and the mean value is 7 m.

*The Muravinskiy horizon.* The alluvial and marsh accumulations predominate within Muravinskij horizon. The Muravinskiy formation thickness is upon the average equal to 2 - 6 m reaching 18-20 m for several open-casts.

*The Poozerskiy horizon.* The boundary of the Poozerskiy glacier coincides with the south boundary of the Belarusian Poozerye. Within the area of placing the ice, the glacial and fluvioglacial sediments are accumulated; on other territory the periglaciological formations are observed. The mean horizon thickness is about 25 m; it enhances up to 60-70 m at erosion depressions within the region of the edge formations (the village Konstantinovo). Moraine consists of reddish-brown boulder clay sand, loam and clay (mean thickness is about 20 m). Within the limits of outwash plain the fluvioglacial sand thickness  changes from 10 m to 25 m. Limnoglaciologic formations (sand, thin clay sand and clay) have the thickness values of 10 -15 m and more. Within the non- glacial area the sediments of the first and second over– floodplain terraces (the thickness is varied from 1– 5 to several tens of meters) are attributed to the Poozerskiy horizon. These sediments are mainly presented by send, lacustrine– alluvial formations created in ancient lacustrine kettles, as well as by the locally developed lacustrine, atmogenic, outwash and other accumulations.

*The Holocene horizon* completes the Quaternary section. It includes the alluvial, lacustrine, boggy, outwash, atmogenic and other formations accumulated during the last 10 thousand years. The most remarkable (in respect of thickness and area of spreading) strata Holocene formations relate to alluvium which forms the river floodplain. The contemporary alluvium is represented by channel, floodplain and former riverbed fractions. Thickness of the alluvial accumulations reaches 15-18 m on large rivers and 5-10 m on small ones. Other genetic types of Holocene formations play a subordinate role within the range of the regions and they are characterized by a restricted spreading.

#### *13.1.1.2 NPP site*

Geological structure, hydro-geological and engineering–geological conditions for the 2x2 km NPP site are described in details in the report of the Republic Unitary Enterprise «Geoservice» [65].

The site is situated within the limits of the moraine plain with flattened relief at the Viliya watershed, between its left inflows, namely, the Oshmyanka and the Gozovka.

The Viliya (the right inflow of the Neman) rounds the site in 5-8 km from north-east, north and north – west. In the westward and eastward sectors the Gozovka and Oshmyanka rivers flow from the south to the north. The Gozovka flows into Viliya at the distance of 3-4 km in the north – west direction; the Oshmyanka flows into Viliya at the distance of 5-6 km to the east from the site.

The most elevated part of the site is the central one; it is spread from the south to the north. Absolute marks of the surface are 176-185 m at the extreme west and east parts, 160-175 m at the parts related to the watershed slopes. The slopes are gently sloping; maximum inclination is 2-30$^{o}$. Outside the site contour the surface of slopes is complicated by the drain hollows of the Gozovka and Viliya rivers flowing into the valleys. Within the east part of the site region the flat depression is observed, this is the hollow riverhead going out to the hollow of the stream Polpe (left inflow of the Viliya-river). The width of the hollow is 100-200 m, the hollow length (within the site limits) is equal to 600 - 700 m.

Rivers or streams do not directly intersect the site area.

From the stratigraphic point of view the geological complex (from bottom to top) is formed by the sediments of the water pumping upper Proterozoic, low and middle sections of the Cambrian, Ordovician, Silurian, middle section of the Devonian, low Neogene as well as by the Quaternary sediments. According to the preliminary geophysical investigation data the absolute marks for the top of crystal foundation are minus 340 – 410 m.

The typical geological section is shown in figure 39.

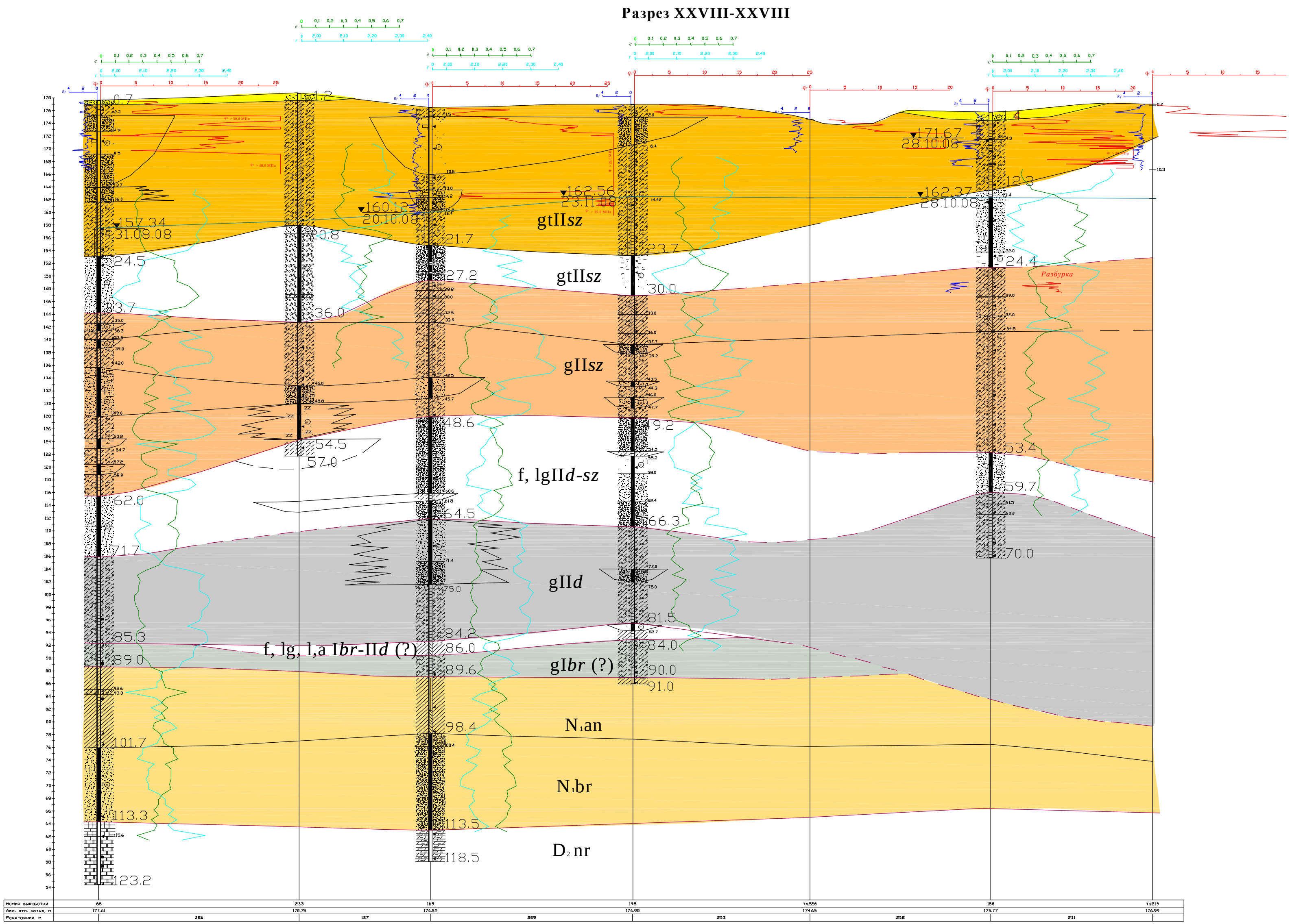
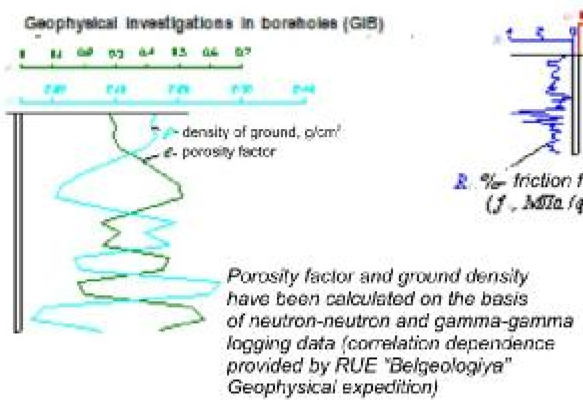
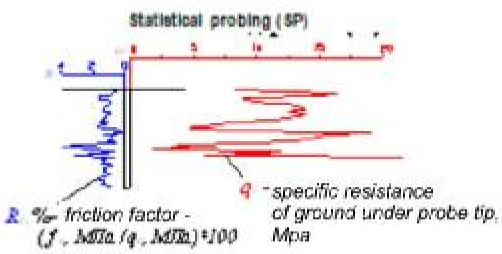



**Figure 39 – Geological profile accross the line XXVIII- XXVIII**

## Notation conventions

| | |
|---|---|
| gtII*sz* | Finitely–moraine sediments of Sozh horizon. Clay sand, dusty sand, fine sand, middle-sized sand. |
| gtII*sz* | Finitely–moraine sediments of Sozh horizon. Dusty sand, fine sand, middle-sized sand, gravel soil with lenses of clay sand. |
| gII*sz* | Moraine sediments of Sozh horizon. Clay sand, loam with lenses of sand, dusty sand, fine sand, gravel sand. |
| f, lgII*d-sz* | Fluvioglacial outwash sediments of Dnieper – Sozh horizon. Dusty sand, fine sand, middle-sized sand, gravel soil with lenses of clay sand. |
| gII*d* | Moraine sediments of Dnieper horizon. Clay sand with lenses of sand, dusty sand, fine sand. |
| f, lg, l, a I*br*-II*d* | Fluvioglacial outwash lacustrine alluvial sediments of Berezinskii – Dnieper horizon. Middle-sized sand, loam. |
| gI*br* | Moraine sediments of Berezinskii horizon. Clay sand. |
| $N_1$an | Sediments of Antopolskii horizon of the low Neogene. Loam. |
| $N_1$br | Sediments of Brinevskii horizon of the low Neogene. Dusty sand, fine sand, middle-sized sand, gravel soil with lenses of clay sand, loam. |
| $D_2$nr | Sediments of Narovskii horizon of the middle Devonian. Siltstones, marls with layers of dolomites. |



Thickness of the Quaternary sediments is equal to 71.7-102.8 m. The sediments are formed by three horizons of moraines (finite and main moraines of the Sozh horizon, moraine of the Dnieper horizon) divided by the strata of finite–moraine sand of fluvioglacial formations related to the Dnieper and Sozh horizons. The Berezinskaya moraine is separated from the Dnieper one by thin layers of clay sand, dusty clay sand, loam. Sometimes the layers include an addition of organic substance; they are notable for their lower values (20-40 Ohm) of the apparent resistance Кс as compared with the sediments of the Dnieper moraine (80-140 Ohm).

The finite–moraine sediments in the upper part are mainly present in the form of a clayey clay sand layer with non-uniform thickness; more seldom the loam with inclusion of gravel, pebbles up to 20-30 % as well as with inclusion of reddish-brown, brown sends with multiple layers and lenses (from dusty sand to middle-sized sand, often clay sand is found). The sand layer thickness changes from 0.5 -1.5 m to 10 m. In specific cases the clay sand occurring at the depth of 20-30 m forms uniform layer without large sand lenses.

The depth of burial for the clay sand bottom including the sand lenses is varied from 1,0 – 4,0 m to 29,2 – 34,5 m. Maximum depth for the clay sand bottom (about 15-20 m) is found at the central part of the site. The depth is outlined by the stripe directed from the south–east to the north–west; its value decreases in the south-west and north–east directions. In the east part the clay sand layer is completely blown out.

The clay stratum is stretched under by sand of different size; namely, from dusty to large size one. More seldom, the gravel sand with grey–yellow or dark– yellow colour occurs. Sand thickness varies in broad limits beginning with 1.8 – 4.3 m and ending with 27.3 – 31.5 m. Thickness increases in the south–west, east and north- east directions. In the east part of the site the sand is occurs from the surface layer.

The Sozh moraine (gIIsž) is formed by clay sand and loam. More seldom, brown or gray clay with inclusion of gravel and pebbles is observed. Loam and clay occur, as a rule, at upper part of the cross–section up to the depth of 25-40 m, they are revealed by layers with the thickness up to 2-10 m. Moraine clayey soils include thin (5 -10 mm) sand layers, as well as the lenses and layers of sands of size. Often, the clay sand with thickness from 1-2 to 6-8 m is found.

The depth of the main Sozh moraine roof is a very changeable value, it varies within the limits from 15.2 to 45.5 m; the absolute marks are equal to 128.95 – 159.62 m. Thickness of the stratum is equal to 3.1–38.3 m; the dominant thickness value is equal to 20-30 m. General descend of the roof and decrease of the moraine thickness is found in the south–west direction

At the depth of 36-69 m (the absolute mark is 109 -132 m) the Sozh moraine is understreched with fluvioglacial sediments of the Dnieper – Sozh horizons. The sediments are mainly formed by fluvioglacial yellow–gray or bright–gray sand (from dusty to gravelly sand; more seldom, the gravel and pebble soils are met). In the depth of sands the lacustrine– glacial clay sand and loam (coarse and dusty gray or blue–gray fractions) are occurred. They are mainly located in the south–east part of the site where the roof of the underlying Dnieper moraine is buried; they occur at the depth of 51-63 m. Thickness of the clay soil layers and lenses is equal to 1- 5 m.

General thickness of the fluvioglacial sediments changes from 1,8 – 4,8 m in the western part of the site to 23,9-26,4 m in the central and east parts.

The Dnieper moraine (gIId) is formed by clay sand and loam with inclusion of gravel and pebbles, as well as by brown–gray, bright–gray sand of different size with clay sand lenses and loam layers (the thickness is up 2-8 м). The roof is more stable as compared with the Sozh moraine; it is buried as a whole in the south–east direction. The roof is taped at depths of 49.5 – 78.5 m. The absolute marks are 99.7 – 118.61 m.

The thickness of the sediments in the south and central parts of the site is less than 20 m (11.3-19.6 m); in the north–west part it is mainly equal to 20-24 m. Absolute marks for the footing are 88-96 m at these areas. Moraine is buried in the north–east part filling the paleocut in the roof of the Neogene (absolute mark for the footing is 75-82 m); its thickness reaches 30,0-35,8 m.

The Sozh and Dnieper moraines have no breaks within the range of spreading; erosion "windows" are not revealed.

On the whole site area except north–east part (between the Sozh and Dnieper moraines at the depth of 72.0 m – the borehole No 52 and 87.4 m – the borehole No 53) the dusty blue–gray or gray clay sand and loam (often with addition of organic substance), dusty middle–sized sand which is conventionally referred to a non–partitioned complex of the low mid–Quaternary Berezina–Dnepr fluvioglacial, lacustrine and alluvial sediments (f,lg,l,aIbr-IId) (Belovezhskij interglacial period) are open. Absolute marks for the roof are 89.2 – 96.9 m. The thickness is equal to 0.6-1.1 – 5.8 m.

The Berezinskaya moraine (gIbr) is formed by gray or green–gray clay sand and with inclusion of gravel and pebbles, up to 5-10 %, having thin sand layers. They are open at the depth of 67.6 – 89.4 m under non–partitioned Berezina–Dnieper sediments or under the Dnieper moraine. In the latter case the boundary between the moraines are made conventionally based on the results of geophysical investigations (based on the value of apparent resistance). The absolute marks for the roof are 89.3 м (the borehole No 174) – 96.3 м. Thickness is equal to 2.8-6.0 m.

The Quaternary sediments are understretched by dusty gray or green–blue–gray loam, as well as by dark–brown or dark–gray clay. By taking into account the results of geophysical investigations the sediments are referred to Antopolskiy (N1an) horizon of low Neogene (Miocene). Loam includes addition of organic substance (from 1-2 % to 8 %). The inter-layer thickness for the peat soils (the content of the organic substance exceeding 10 %) is equal to 0,3-1,4 m.

The Antopolskiy horizon roof is rather flat (the depth is 79.4-96.0 m, the absolute elevation – 86,3-92.8 m), it only sags in the north–east part of the site (the depth – 82,0-102,8 m, the absolute mark – 75,7-81,6 m) forming a hollow stretched from south–east to north–west.

The thickness of the sediments is equal to 6,7 – 16,5 m; in the north–east direction the thickness is equal to 3,2 – 4,7 m.

Below the sediments of the Brinevskiy horizon of the low Neogene (N 1br) occur, namely, fine, dusty (very seldom, middle–sized) bright–gray or whitish sands which are uniform according to granulometric composition. Large–fragmental soils are found in the sand roof stratum with the aid of single boreholes. Loam lenses are met in sands at different depth (0.7-6.4 м). The total thickness of the sediments is equal to 9,1 – 14,5 m.

Neogene sands are understretched with sediments of Narovskiy horizon of mid–Devon (D2nr), namely, by siltstones and marls often interleaved with dense cracked dolomites with sublayers. The layers of clay and chalk are also met in marls. There are blue–green–gray sediments and speckled gray–brown siltstones. The penetrated bed thickness is 2,2-11,8 m.

The Devon roof depth is equal to 99,8 m (hole No 56) – 116.0 m (hole No 60); the absolute marks are equal to 62,7 m (hole No 162) – 66,4 m (hole No 195).

The hydrogeological conditions are characterized by practical absence of underground water up to the depth of 10 – 24,4 m within the main site area. The Quaternary sands (finite Sozh moraine, Dnieper–Sozh intermoraine and sand lenses in the main

Sozh, Dnieper and Berzina moraines) located below of this depth are fully water-saturated.

First from the surface water-bearing horizon of the Sozh finite–moraine sediments is pressured– non-pressured. Water–bearing soils, namely, sands of different size (from dusty to gravel sands). The level depth is equal to 8,4 – 24,4 m depending on the hypsometrical relief marks; the absolute marks are equal to 154,36 – 162,48 m. In the area wherein the foot of upper layer of moraine clay sand descends, the layers are characterized by hydraulic drop from 0,9-1,0 m down to 13,5-14,6 m. The horizon is drained by rivers; it feeds small streams of water in relation to drain hollow.

By the chemical content, waters are classified into fresh water and normal water; more seldom, alkaline and hydrocarbonate calcium-magnesium waters with mineralization of 224,24 – 442,46 mg/dm$^3$ are found. Total water hardness changes within the limits of 2,2-11,0 mg-equivalent/dm$^3$. Enhanced nitrate content (up to 74,0 mg/dm$^3$) is found. The content of other macro components is less than the maximum permissible concentration (MPC).

Underground waters are not aggressive relative to reinforcement of concrete constructions and to the concrete of the types $W_4$, $W_6$, $W_8$ (from the position of water permeability); in single cases, waters are weakly aggressive relative to the concrete of the type $W_4$.

Sporadically distributed waters coupled with widespread layers and sand lenses. These waters are formed due to infiltration of atmospheric precipitation and backwater from the water-bearing horizon of the Sozh finite- moraine sediments. They are found at different depths; but they are relatively seldom located at upper part of the cross–section at the depth of 3.6- 5.0 m (the absolute mark is equal to 155.77-173.01 m). More often these waters are met in the middle and lower parts (7-26 m), when theirs foot comes below the water-bearing horizon level.

Waters are not aggressive relative to the concrete of any types (from the position of water permeability) or they are weakly aggressive relative to the concrete of the type $W_4$.

Inter–moraine water-bearing complex of the Dnieper–Sozh horizons is of the force-feed type. Water– bearing soils are sands of different size and gravel soil. The piezometric head level is 19.6-29.6 m; the absolute marks are equal to 48,18 -154,72 m.

According to the chemical content, waters are classified as fresh waters, mainly hydrocarbonate calcium-magnesium waters with mineralization of 146.7–279.16 mg/dm$^3$ and soft waters. The total water hardness is equal to 1.2-2.4 mg-equivalent/dm$^3$. The content of the main macro components is less than the maximum permissible concentration (MPC) with an exception of nitrate content (up to 58.0 mg/dm$^3$).

Lenses of sands (dusty fine- middle- and large-sized as well as gravel sands) are founded in moraine clay sands and loams of the main Sozh, Dnieper and Berezina moraines at different depth. The thickness of sand layers is from 1-2 m to 6-8 m. In the course of future work the special hydrogeological boreholes (with pumping) will be drilled in direction of the largest lenses with the aim of determination of the head of water, piezometric level and qualitative evaluation of a possible hydrological connection with the inter– moraine water-bearing horizons.

Water-bearing horizons are isolated one. Moraines dividing these horizons are uniform within the spreading area. No «windows» of moraine washways or clayey sediments of the Antopolskij horizon of the Neogene have been revealed.

The thickness of soils creating the geological cross–section of the NPP site is divided into 27 engineering–geological elements. Theirs descriptions and physical–technical parameters are given in Table 47.

**Table 47 - Estimated soil parameters**

| No. | Soil | Soil density, *r*, g/cm$^3$ | Specific weight, *g*, kN/m$^3$ | Specific adhesion *S*, kPa | Angle of internal friction *j*, degree | Deformation module *E*, MPa | Accepted value $q_c$, MPa |
|---|---|---|---|---|---|---|---|
| *Finite-moraine sediments of Sozh horizon* (gtIIsž) | | | | | | | |
| 1 | Weak moraine clay sand (upper area) | 2,05 | 20,5 | 23 | 26 | 5 | ≤ 1 |
| 2 | Moraine clay sand of middle strength (upper area) | 2,10 | 21,0 | 27 | 27 | 10 | 2 |
| 3 | Moraine clay sand, strong (upper area) | 2,20 | 22,0 | 33 | 27 | 20 | 4 |
| 4 | Moraine clay sand, very strong | 2,20 | 22,0 | 40 | 29 | 40 and more | 8 |
| 2a | Moraine clay sand, middle strong | 2,20 | 22,0 | 33 | 27 | 20 | 4 |
| 5 | Dusty sand, middle strength | 1,69/2,01 | 16,9/10,1 | 3 | 29 | 14/10 | 4 |
| 6 | Dusty sand, strong | 1,79/2,07 | 17,9/10,7 | 5 | 33 | 25/20 | 10 |
| 7 | Fine sand, middle strength | 1,68/2,00 | 16,8/10,0 | 2 | 32 | 15 | 5 |
| 8 | Fine sand, strong | 1,78/2,06 | 17,8/10,6 | 4 | 36 | 30 and more | 25 |
| 9 | Sand of middle size, middle strength | 1,68/2,00 | 16,8/10,0 | 1 | 35 | 16 | 5 |
| 10 | Sand of middle size, strong | 1,78/2,06 | 17,8/10,6 | 2 | 38 | 35 and more | 25 |
| 11 | Sand of large size, gravel sand, strong | -/2,03 | -/10,3 | 1 | 41 | 40 and more | 25 |
| *Moraine sediments of Sozh horizon* (gIIsž) | | | | | | | |
| 12 | Weak moraine clay sand (upper area) | 2,25 | 22,5 | 23 | 26 | 5 | ≤ 1 |
| 13 | Moraine clay sand of middle strength (upper area) | 2,25 | 22,5 | 25 | 27 | 8 | 1,5 |
| 14 | Moraine clay sand, strong (qc= 3-5 MPa) | 2,27 | 22,7 | 32 | 27 | 18 | 3,5 |
| 15 | Moraine clay sand, strong (qc= 5-7 MPa) | 2,27 | 22,7 | 37 | 28 | 30 | 6 |
| 16 | Moraine clay sand, very strong | 2,30 | 23,0 | 40 | 29 | 40 and more | 8 |
| 17 | Loam, clay | 2,10 | 21,0 | 45 | 27 | 30 | 5 |
| *Fluvioglacial inter–moraine sediments* (f,lgIId-sž) | | | | | | | |
| 18 | Dusty sand | –/2,07 | –/10,7 | 5 | 39 | 20 | > 15 |
| 19 | Fine send | –/2,06 | –/10,6 | 4 | 36 | 30 and more | > 15 |

Table 47 (continued)

| No. | Soil | Soil density, *r*, g/cm$^3$ | Specific weight, *g*, kN/m$^3$ | Specific adhesion *S*, kPa | Angle of internal friction *j*, degree | Deformation module *E*, MPa | Accepted value $q_c$, MPa |
|---|---|---|---|---|---|---|---|
| 20 | Sand of middle size | $\frac{-}{2.06}$ | $\frac{-}{10.6}$ | 2 | 38 | 35 and more | > 15 |
| 21 | Coarse sand, gravel | $\frac{-}{2.03}$ | $\frac{-}{10.3}$ | 1 | 41 | 40 and more | > 15 |
| 22 | Coarse clay sand | 2.22 | 22.2 | 32 | 27 | 20 | ~ 4 |
| 23 | Dusty clay sand, loam | 2.15 | 21.5 | 56 | 13 | 15 | ~ 3 |
| *Moraine sediments of Dnieper horizon* (gIId) | | | | | | | |
| 25 | Moraine clay sand (soft) | 2.27 | 22.7 | 33 | 27 | 20 | 4 |
| 26 | Moraine clay sand (hard) | 2.27 | 22.7 | 38 | 28 | 30 | 5-6 |
| 27 | Dusty clay sand | 2.12 | 21.2 | 42 | 26 | 22 | 4 |

***Note***. For sands: the values of *r* above the line relate to the slightly wet condition, and the values under the line relate to the water-saturated one; the values of *g* above the line relate to the slightly wet condition, and the values under the line taken into account with the uplift action of water.

Conditions for the site foundation seem to be relatively favourable. There are possibilities for building the main structures on the soil foundation (this is the most economical version). Building conditions will be dry; several lenses of water-saturated sands in the moraine (water of sporadical spreading) can be drained using the surface unwatering in foundation pits.

Rocky ground has not been found up to the depth equal to two reactor diameters (110-120 m). Therefore, the most critical constructions will be rested on compressed clay or layered base.

Along with it, there are complicated factors:

– potentially, the site can be underflooded when technical leakage takes place;

– change of strength and deformation properties of soils during anthropogenic watering especially by waters with enhanced temperature and «unnatural» chemical content.

### *13.1.2 Analysis of existing and prospective negative endogenous and exogenous processes and phenomena*

#### *13.1.2.1 NPP 30-km safety area*

The territory under study is influenced by different natural and anthropogenic physical–geological processes. Depending on energy source all processes are divided into three classes: exogenous, endogenous and anthropogenic.

*Exogenous class*

Among this class the plain and line erosion of temporal water courses, erosion and accumulative activity of rivers, lacustrine accumulation and abrasion, as well as gravitational, atmogenic and biogenic processes prevail.

*Plain (dealluvial) washout* is the most widespread present geological process which intensity is mainly varied within the interval from 0 to 5 mm/year.

Trails are formed during the plain washout at the footing of slopes. Maximum thickness of the trails is more than 165 cm.

Dealluvial processes influence on the reconstruction of earth surface; it can assist to accumulation of harmful discharges at the footing of slopes and lead to a sedimentation of water bodies and watercourses.

*Erosion and accumulative activity of rivers*. Activity of constant line watercourses is the most active present physical–geological process. The result of this activity is the dense net of river valleys. Information about a size of the created forms and about a volume of alluvial sediments with the site area can be obtained by analysis of parameters of the largest valley of the Viliya. The valley banks are often bluffed along almost the whole length of the valley. The precipice height is mainly equal to 15-17 m. The valley width is up to 1-3 km; sometimes the valley is restricted by the distance of 0.4 km. It is marked out the floodplain with the height under the water surface in the river watercourse of 1-2 m and up to 4 over– floodplain terraces (4-5 m, 9-10, 12-14 and 15-20 m). The floodplain width is 200-800 m; the width of terraces is up to 0.3-0.5 м. The thickness of floodplain alluvium is up to 5-10 m. Taking into account valley parameters it is possible to evaluate that during Holocene period approximately $1{,}6 \cdot 10^9$ $m^3$ alluvium had been accumulated in the valley. The valley size for the rivers Naroch, Oshmyanka, Stracha and some other is rather small, but the sum effect of the geological activity of these rivers is approximately comparable with that of the river Viliya.

The coefficient of the relief horizontal partitioning can be used as an index of intensity of alluvial processes. The mean value for that index is approximately 0,4 $km/km^2$ (the main variation limits are from 0,3 to 0,7 $km/km^2$).

By analyzing the geological river activity it is important to track the results of a manifestation of floods and spates in theirs valleys. In other words, it is important to take into account such phases of the hydrological regimes when an abrupt rise of the water levels are take place. This leads to a flowage of floodplains, transfer and deposition of considerable volumes of alluvial sediments which can accumulate not only on low floodplain but also on higher hypsometrical levels. In the Viliya basin these elevations reach 3-5 m with the flow depth for that floodplain is equal to 0,5-1 m. When the flood is taken place, the territories laying in the vicinity of 1–3 km from the river watercourse are also underflooded, especially, within the areas of shallow watercourse entry.

*Line erosion of temporal watercourses*. In the area of a possible placing of the NPP, the process of this type is developed very well. As a result of action of the process the net of ravines, gullies and multiple rain canals has been created. The rain canal length is about tens of meters (up to 100 m), the depth is up to 1,0 m. The ravines are normally characterized by the length of hundreds meters (up to 1500 m), theirs depth is often varied within the interval of only 5-10 m, for some places up to 17-24 m. The gullies are characterized as larger objects: the length is up to 4-5-km, the depth is 20-30 m.

The line erosion is widely manifested in the Viliya (at inflow of the Oshmyanka-river, the villages Podvarishki, Voidatishki and other), Oshmyanka (at the town Oshmyany) basins and on the regions of a spreading of the edged glacial elevations between the villages Zharneli, Ignatsevo, Lipki, Kotlovka located in the south–west part of the area. The density of the forms is normally equal to 1-2.5 $unit/km^2$.

*Accumulation and abrasive action of water reservoirs* on the investigated territory plays remarkable role in a transformation of earth surface. The largest lake is Svir.

The lake Svir area is equal to about 22.28 $km^2$, the Svir length – 14.1 km, the width is up to 2.27 km, the depth is up to 8.7 m (mean value is 4.7 m). The lake banks are mainly low, the bottom is sandy up to the depth of 3-4 m; at greater depths the siliceous sapropel layer with the thickness of up to 5,6 m (mean value is 2,6 m) is located.

The other lakes are characterized by smaller dimensions. Accumulation of the sediments in a large volume (some of these sediments, sapropel, can be used for balneology or agricultural applications) takes also place in these lakes.

*Gravitational processes.* The shift of the sediments under influence of the gravitational forces depends of the ambient conditions. The slow movement of materials at slopes (creep) and processes going with a relatively high rate (landslides and taluses) are distinguished on the investigated region. The necessary condition for the start of these processes is the presence of relatively steep slopes (more than $2^o$ for the creep and about $5\text{-}20^o$ for the landslides and taluses).

The landslides and taluses are met practically along all length of the Viliya river valley, on slopes of the Naroch valley as well as on slopes of the rivers Oshmyanka and Gazovka. These processes are also revealed in many open-casts and some road earth cut. Generally, the volumes of shifting rocks are less than tens of cubic meters.

The creep is met on a rather greater area of the territory. Maximum rate of slow shifting of the material along the slopes is registered within the north–west and south–west parts of the region as well as on small areas at the villages Shakishki and Golginishki. The creep rate values of about 2 – 4 mm/year are recorded for above mentioned areas and for the north–east part of the region. For the rest part of the territory the rate is less than 2 mm/year. The creep is absent at flatten swampy surfaces.

*Eolian processes.* Wind is additional agent of the present material movement. Eolian activity becomes apparent in some extent on a whole territory of the region. Eolian factor begins to reveal starting from the material erosion stage. The erosion is divided into the daily (or local) erosion and the erosion in the form of so called dust storm. The daily erosion (when hundreds kilograms of soil per hectare is shifted every year) is taken place on the tilled lands.

The most remarkable results of the wind geological activity are the relief forms created of it. Small ridges and hills which linear dimension (length) are commonly less than 0,4 km, the height is less than 3-5 m is the typical forms for the region territory. Such forms are met in the valleys of the rivers Viliya, Naroch, Oshmyanka, Stracha and some others when they are presented as winnow embankments.

The dust storm is the extreme form of the eolian processes. During period of 1966-1993 years every weather station located on the investigated region territory (in the towns Vileika, Vologin, Dokshitsy, Oshmyany) has been registered from 1 to 6 dust storms. According to the calculations under an influence of these dust storms up to 3,5 metric tons of soil were removed from every hectare (approximately 0,2 ton/hour). On the base of that data Yu.A.Chizhikov attributes the sites of the Ostrovets on the stage of the regionalization of the Belarusian territory to the category of soils characterize by small or middle probabilities of an appearance of the extreme deflation phenomenon.

*Biogenic processes* also play definitive role in modeling the ground surface. In order to evaluate in full measure the geological effect of these processes it should be noted that besides of peat accumulation they determine the content of atmosphere and in large measure the content of hydrosphere. The content of atmosphere influences on the climate. In its turn, the climate peculiarities influences on parameters of the rock weathering process. Also, organic substance takes part in the material transportation with the transfer performed by means of mechanical action and by the processes involving dissolved and colloid forms.

On the region territory the biogenic processes led mainly to a formation of multiple peat swamps. The most large peat massives are located to the south of the lake Narotsh between the rivers Naroch, Viliya, Oshmyanka and Losh, to the west and south–west from the town Oshmyany. The peat layer thickness is mainly less than 4 – 5 m. A commercial peat excavation is performed on many sections.

*Endogenous processes*

Among this class of the physico–geological processes on the region territory the leading one are seismic processes, vertical and horizontal movement of the earth crust, processes specified direction and configuration of hydronet forms as well as formation of geophysical and geochemical anomalies.

The seismic activity is generally related with the fractures being active on up-to-date stage. On the greatest part of the territory a possible magnitude of the shakability is less than 5. But, there is the area located in the south–west part of the region (along the Oshmyany fracture) within the limit of which a possible magnitude of the shakability can reach 7. Earthquake with such magnitude value was registered for this area in 1908 year.

Everywhere on the territory under discussion the vertical movements of the earth crust are revealed. On a general background of the mean–year movement speed values of approximately minus 1 mm/year the local value can be varied from plus 1-2 to minus 1-2 mm/year. Within the areas which are active on up-to-date stage of the fracture development the speed amplitude reaches the value of 12-20 mm/year with the direction of the earth crust movement being changeable from year to year, but the mean year values are less than several millimeters.

Considerably less data ware collected on the territory under discussion for revealing the horizontal movements. Unfortunately, the instrumental studies for that type of the movement were performed only within the range ofary of the Volozin graben. For that area the measured graben movement speed along the Korelichi fault was as high as about 40 mm/year. But, the combined analysis of geomorphological, geological and tectonic data allow us to suggest that the horizontal shifts of the earth crust blocks go along a series of other fracture. In particular, it is likely to reveal the traces of such earth crust movement along the village lines Nestanishki – Bogdanishki, Sloboda – Tcheremishitsy near the village Markuny.

Available archive data related to modern vertical movements of the earth crust (СВДЗК) obtained for the period from 1913 till 1979 year allow us to conclude that within the Ostrovets site area the speed of modern earth crust movements is relatively small, it is approximately equal to V = - 0,1 mm/year (there is a tendency for slow down movement).

In accordance with the requirements of the document TKP 098-2007 [66] on the studied territory the geodesic works directed to determination of the modern movements of the earth crust are performed; these works will be finished in 2010 year before the beginning of the construction of the NPP.

*Anthropogenic processes*

Today the anthropogenic physical and geological processes on the territory of the site are a rather visible factor of transformation of the earth surface. Man armed by modern techniques creates a principally new relief forms and sediment types. This man activity effects on the flow of natural processes. Now, the anthropogenic relief (with ploughed field) is developed on area of no less than 1/3 of whole area of the territory. Without the contribution of the ploughed field the anthropogenic forms occupy about 2-5 % of the territory.

The roadway excavations and earthfills (theirs height and depth are about 7– 10 m with the sum length of hundreds kilometers), the terraced surfaces of the centers of population, the open pits (with the depth of 10 – 15 m) as well as the soil-reclamation canals, ponds, peat extraction fields an so on are the most characteristic forms created by the human. In addition to a direct influence on the earth surface the human initializes starting the series of natural geological process (landslips, screes, rock subsidences, deflation, linear and surface erosion and so on).

As a whole, a value of the earth surface anthropogenic transformation evaluated through the utilization of mean volume of the shifted substance (material) on the investigated area is varied from 40000-60000 $m^3/km^2$ to 600000-1000000 $m^3/km^2$ at the parts with the greatest anthropogenic development. The edged glacial formations along the roadways, river valleys and peat swamps as well as the areas in the vicinity of the centers of population were changed in a maximal extent. Often, the earth surface acquires the qualitatively new outline on those areas. Stability of these formations relative to action of the anthropogenic loads is decreased up 50 % level and less. This is an indicator of starting the irreversible change of natural complexes.

Summarizing the results of the carried out investigation of the peculiarities of the modern geological process demonstration on the territory under discussion it should be noted the following. It has been revealed no serious appearances of the modern geodynamics which could be considered as the unfavorable factors inhibited the building of the related engineering constructions.

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Summarizing the results of the carried out studies, the peculiarities of the modern geological process on the territory under discussion it should be noted the following. It has been revealed no serious appearances of the modern geodynamics which could be considered as the unfavorable factors preventing from the construction of the major engineering constructions.

*13.1.2.2 NPP site*

An appearance of the exogenous processes (landslides, karsts, erosive leakage, swamp formation and so on) does not been revealed.

However, there are conditions for development of surface underflooding on the site when the anthropogenic leakages or violation of the surface drainage take place. The underflooding is caused by an occurrence at the ground surface of the relatively seasoned moraine clay sands with the widespread sand layers and sand lenses. Sands are characterized by different granulometric content and filtering behavior. Spreading and thickness of the lenses are differed widely; the regularity in theirs appearance does not been ascertained. So, the underflooding can be localized on certain areas of the constructions or on the whole site.

The underflooding due to rise of the level of the first water-bearing horizon is little likelihood when the regime of the unloading bases for the rivers Viliya, Gozovka and Oshmyanka is not changed.

### *13.1.3 Seismic behavior analyses*

Seismic behavior analysis has been carried out by the Nature Management Institute of the National Academy of Sciences of the Republic of Belarus and the Geophysical Monitoring Center of the National Academy of Sciences of Belarus [67].

Seismic tool-empowered observations in the area of Ostrovets site are performed by the local network made up of 5 seismic stations (Telyaki, Litvyany, Ginkishki, Selishche, Porakity). Seismic activity has not been registered.

On the whole the area in question is typically low in seismic activity. However there have been rather powerful seismic events in the area. In 1908 according to the archives and literary sources a big earthquake took place in Ostrovets district with the epicenter being near the settlement of Gudogai. It measured 6-7 on the MSK-64 scale and the effects were substantial in magnitude. On October the 17th, 1987 a minor earthquake was registered. Its epicenter was located 10 km east of Ostrovets (forest zone, the Losha River). The magnitude of the earthquake was insubstantial. Seismic danger for the NPP site in close proximity is largely determined by the seismicity of Belarus's territory.

Depending on the depth and the radius of its effects the seismicity of the Vrancea zone is divided into the crust one (near the surface) when a relatively small area is affected and into that of 'undercrust' (with centers going deeper than the bottom of the earth's crust). The effects of the latter reach far away regions. The peculiar difference of the Carpathian earthquake effects on the territory of Belarus the Ostrovets site including is the stretching of the isoseismal lines north-east from the epicenter of an earthquake. These isoseismal lines are well represented by ellipses. There have been made an estimate of the earthquake intensity (EI) and an outside estimate of the intensity of an earthquake (OEI). The average distance from the Vrancea zone epicenters to Ostrovets site is 900 km. This value has been calculated according to the formulae of spherical geometry without taking into account the elliptical shape of the Earth which is quite acceptable for the estimates. The calculations were based on the least distance from the epicenter to the site. The Richter scale estimate of the OEI (frequency of occurrence 10 000 years) for the Ostrovets site amounted to IOEI=5. Relation between the estimates of EI and OEI has been used for the Richter scale estimate of EI. Normally the average value of the difference between the two estimates is one point. Therefore we accept the EI as IEI=4 points.

As comprehensive seismotectonic analysis was carried out potentially active structures were studied. Using such a comprehensive approach has been helpful in identifying PES zones, determining their characteristics, and estimating the level of potential danger including for the territory of the construction site. These are the nearest PES zones to the Ostrovetskaya site: Oshmyany seismogenic zone situated in 39 km south and Daugavpilss seismogenic zone located 67,5-km to the north. The estimate of seismic intensity from local PES zones has been carried out. It took into account seismotectonic potential which may be regarded as the $M_{max}$ estimate. It also took into account the hypocentral distance between PES zone and the site, as well as the depth of the source typical of this PES zone. With regard to Oshmyany PES zone (seismotectonic potential $M_{max}$ = 4,5; the depth of the source 5-km) the calculated value of the seismic magnitude comes down to I = 5 points the calculation being made with the use of the equation for a drop in seismic magnitude. As regards the Daugavpilsskaya PES zone (seismotectonic potential $M_{max}$ = 4,5; the depth of the source 8 km) the calculated value of the seismic magnitude amounts to I = 4 points the calculation being made with the use of the same equation.

Maximum earthquake magnitude which may be expected from the nearest PES zones is equal to 5 points (Oshmyany PES zone).

The level of the Carpathian earthquake magnitude also does not exceed five points for OEI. With regard to EI it does not exceed four points.

The general North Eurasia map of seismic risk zoning OSR-97-D with the scale of 1:10000000 is accepted as a reasonable foundation (TKP 45–3.02–108–2008) to evaluate the level of seismic danger, Belarus being represented in the map. The map is in keeping with the re-occurrence of seismic effect once in 10000 years on average (yearly average risk being $10^{-4}$) as well as the probability P=0.5% of the occurring and possibly exceeding during 50 years the seismic effect showed in the map in points of the MSK-64 scale. The map is meant for evaluating seismic danger in areas where atomic power stations, nuclear waste disposals, and other facilities of the utmost importance are situated.

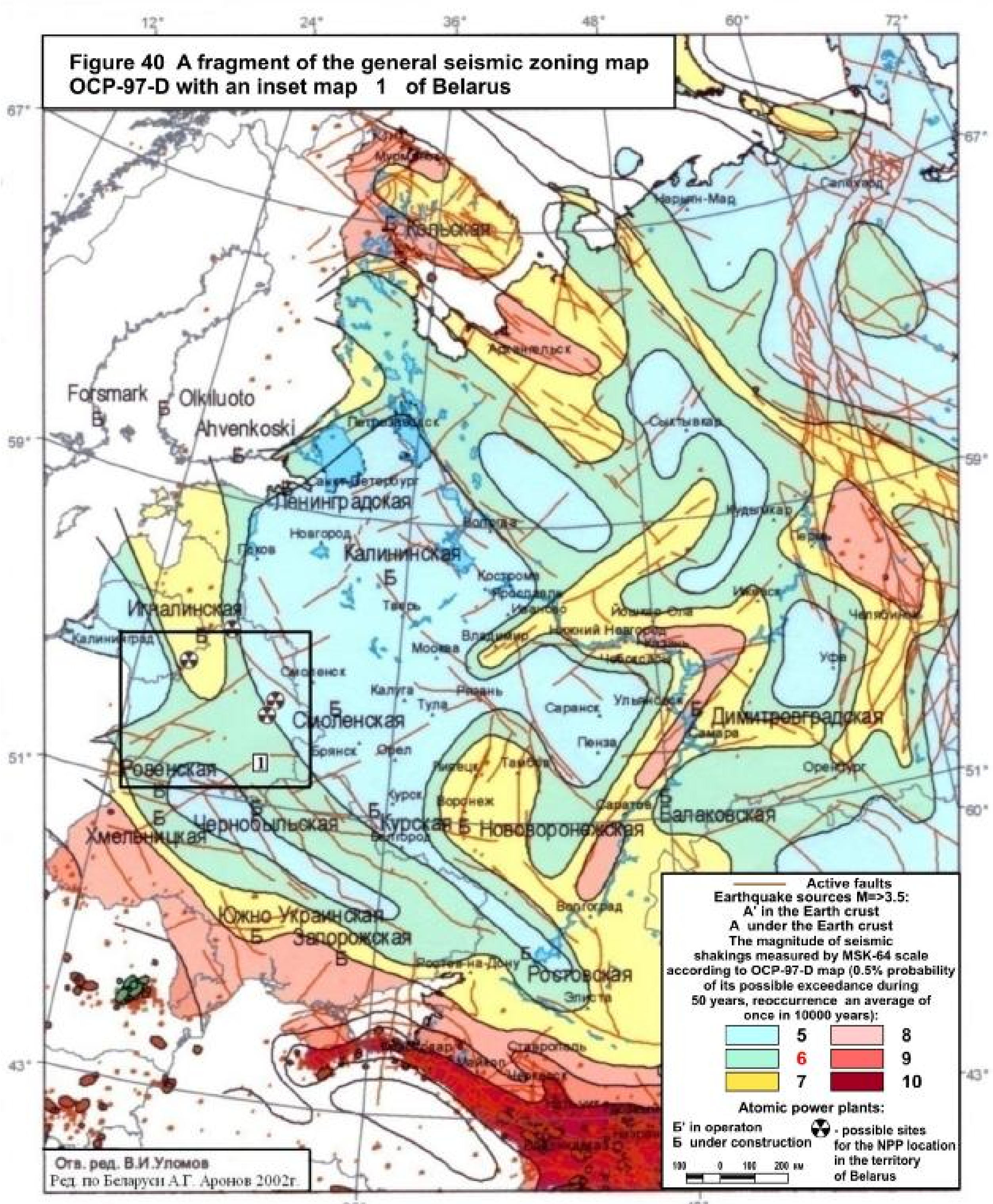



**Figure 40 – Map fragment of the seismic risk zoning OSR-97-D with insert (1) of the map of Belarus.**

According to the map OCP–97–D the territory of the Ostrovets site is in the seven point zone. Consequently the estimate that can be accepted based on this map must equal seven points on the MSK-64 scale. This estimate is in keeping with the OEI level. According to the established practice accepted in many regions the magnitude of EI is taken to be equal to the value of OEI minus one point.

The final estimate for the Ostrovets site (subsoil of category II) is to be as follows: the estimate of earthquake intensity value EI is 6 points; the outside estimate of earthquake intensity is 7 points. There are no seismotectonic factors disallowing the setting up of the NPP on the Ostrovets site.

To make an evaluation of the change in the intensity of seismic effects and to mark areas within the site that have different seismicity seismic microzoning is carried out.

## 13.2 Chemical and radioactive contamination

### *13.2.1 Surface Water*

#### *13.2.1.1 The Quality of Water according to Physical and Chemical Measurements*

The surface water monitoring is carried out in accordance with the Regulation on the procedure of surface water monitoring and the usage of its data as a part of the National Environment Monitoring System in the Republic of Belarus. The Regulation is approved by Decree No. 482 of the Cabinet of Ministers of the Republic of Belarus on April the $28^{th}$, 2004.

Fixed survey stations within the territory of Ostrovets District monitoring the quality of the surface water are situated on the river Oshmyanka (0,5-km a upper Velikiye Yatsyny) and the river Viliya (0,3 km north east to Bystritsa). The survey station on the river Oshmyanka was set up in 1956. Monitoring of river water quality waw carried out 7 times a year during basic phases of hydrological regime (the flow, the peak period and the ebb, minimum and maximum water flow during summer steady low-water season, in the fall before freeze-up, and during winter low-water season).

According to the Order of the Ministry of Natural Resources and Environmental Protection, No. 66 dated 17.03.2004 “On organization and carrying out of monitoring of surface water at the trans-border river stretches of the Republic of Belarus”, approved the list of survey stations at the trans-border stretches of the water bodies, parameters and frequency of monitoring, sampling and testing of hydrochemical samples taken at the trans-border stretch of the river Viliya (0,3 km north east to Bystritsa) shall be carried out 12 times a year, starting from April 1, 2004.

Survey stations of water ecosystem monitoring of the rivers Viliya and Oshmyanka are included in the State Register of the Survey Stations of the National Environment Monitoring System of the Republic of Belarus.

According to the results of hydrochemical surveying over the period of 2004-2007 the surface water of the river Oshmyanka was characterized by higher (408,7-417,6 $mg/dm^3$ in 2000-2001) and medium (358,1-400,0 $mg/dm^3$ in 2002-2007) mineralization. The mineralization during these years was largely due to $Ca^{2+}$ ions (59,6-71,8 $mg/dm^3$) and hydrocarbonates (235,1-260,5 $mg/dm^3$), Figure. 41.

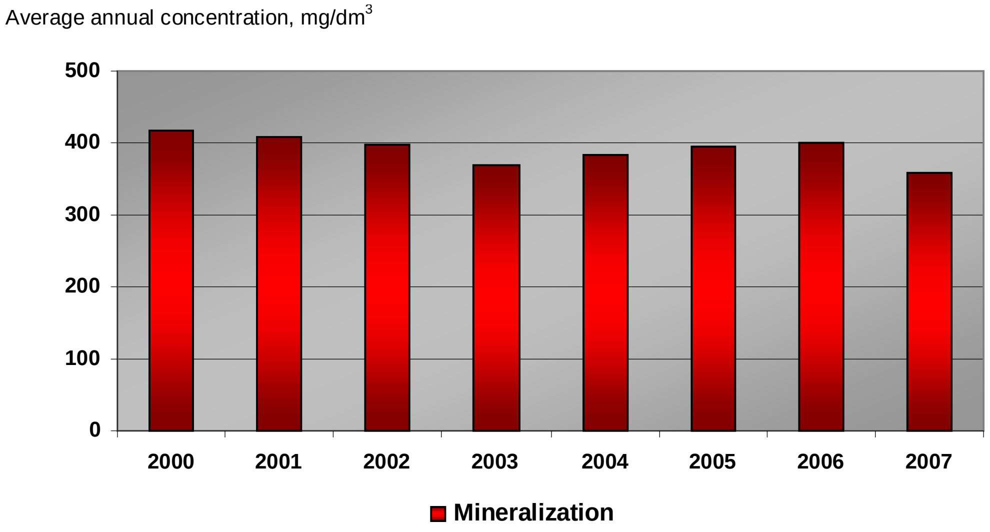



**Figure 41 – The dynamics of the annual average values of water mineralization in the river Oshmyanka upper Velikiye Yatsyny for the period of 2000-2007**

The dynamics of gas and thermal behavior of the stream flow proves the successfull functioning of the river water ecosystem over a long observation period. The annual average concentration of the dissolved oxygen varied from 8,79 $mgO_2/dm^3$ to 11,61 $mgO_2/dm^3$.

As a rule the level of organic matter in the river water was found to be within the range of naturally occurring values. The annual average $BOD_5$ values have been determined to be in the range of 1,42 $mgO_2/dm^3$ – 2,52 $mgO_2/dm^3$ (Figures 42, 43).

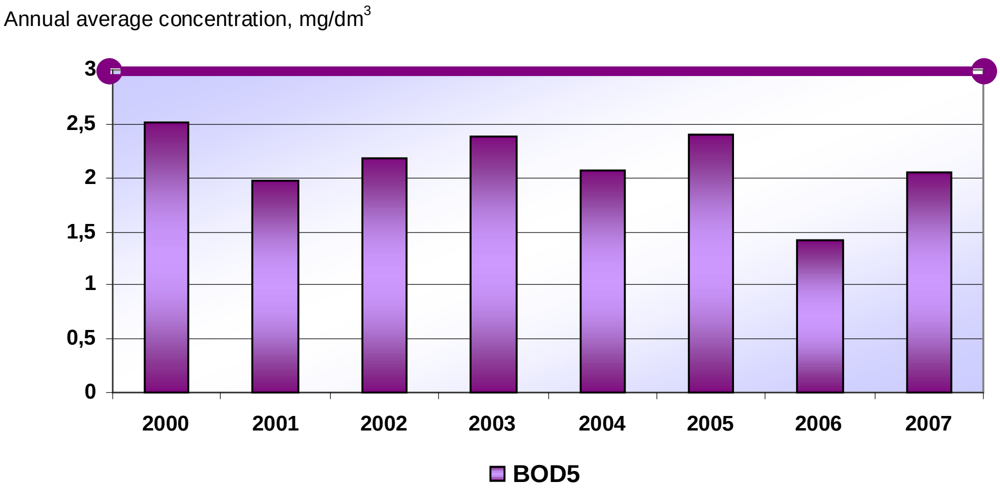



**Figure 42 – The dynamics of annual average concentration of unstable organic compounds (according to $BOD_5$) in the river Oshmyanka Upper Velikiye Yatsyny for the period of 2000-2007**

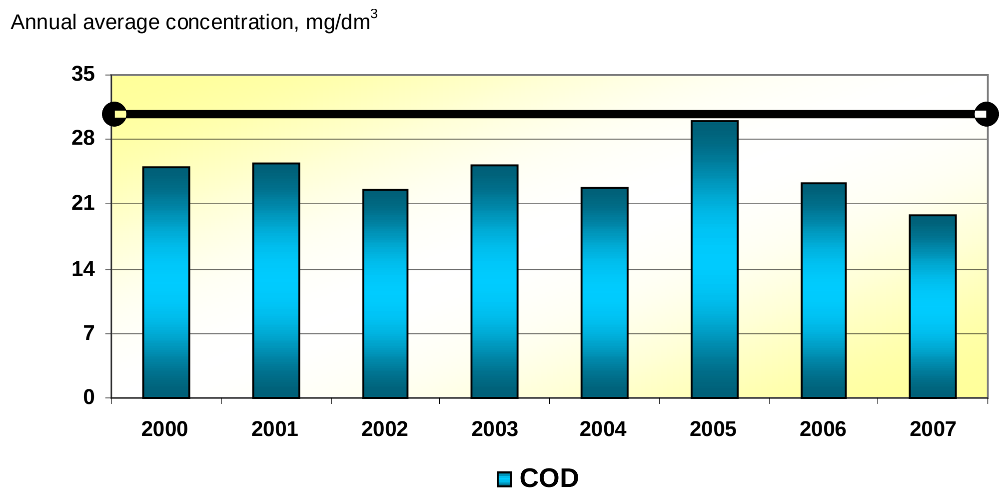



**Figure 43 – The dynamics of annual average concentration of organic substances (according to COD) in the river Oshmyanka upper Velikiye Yatsyny for the period of 2000-2007**

As for 2006 and 2007 the variability of $BOD_5$ and COD values prove a slight organic 'strain' on the river waters during all periods of observation.

Over the 2000-2004 ammonium nitrogen was a major biogenic 'stress' on the water ecosystems of the river Oshmyanka. Its annual average concentration was found to be 1,2-1,5 of MPC. Average concentrations of other forms of nitrogen (nitrate and nitrite) over this period were determined considerably below the MPC level. During 2006-2007 a higher concentration of ammonium nitrogen was found in certain water samples taken in a cold season (January – March). The dynamics nature of average ammonium nitrogen concentrations had also changed. Figure 44.

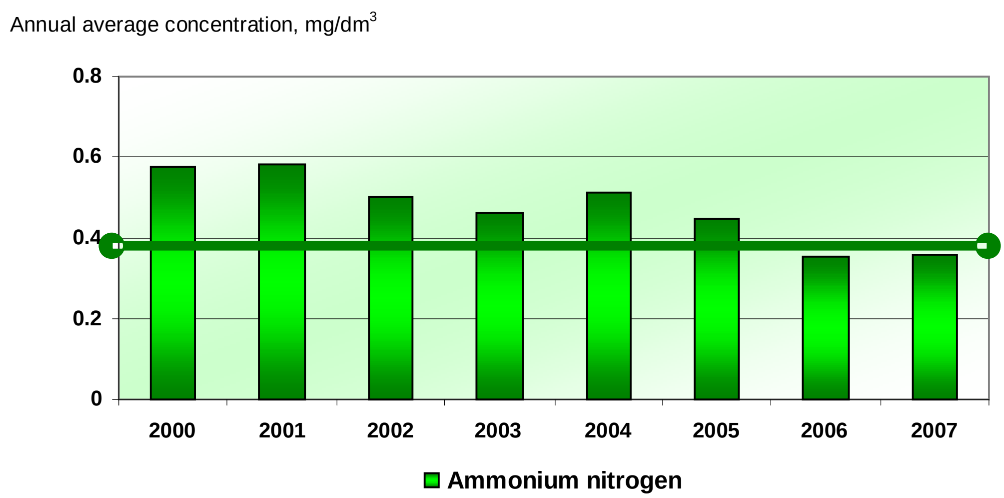



**Figure 44 – The dynamics of annual average ammonium nitrogen concentrations in the water of the river Oshmyanka upper Velikiye Yatsyny for the period of 2000-2007**

The annual average concentrations of phosphates of 0,2-0,3 of MPC as well as the analysis of the inorganic phosphorus annual cycle show the successful condition of the river's water ecosystem from the standpoint of the availability of one of the major elements of eutrophication of the environmental waters (Figures 45, 46).

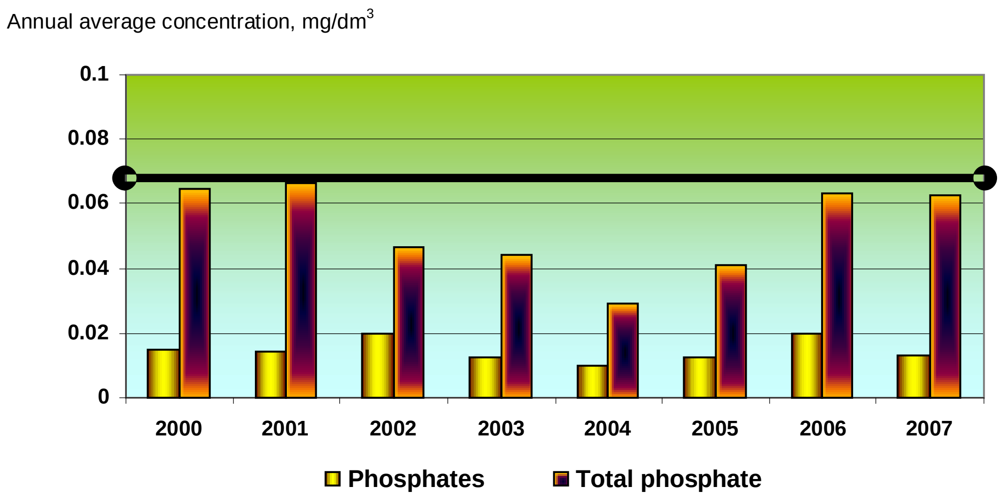



**Figure 45 – The dynamics of annual average inorganic phosphorus concentrations in the water of the river Oshmyanka upper Velikiye Yatsyny for the period of 2000-2007**

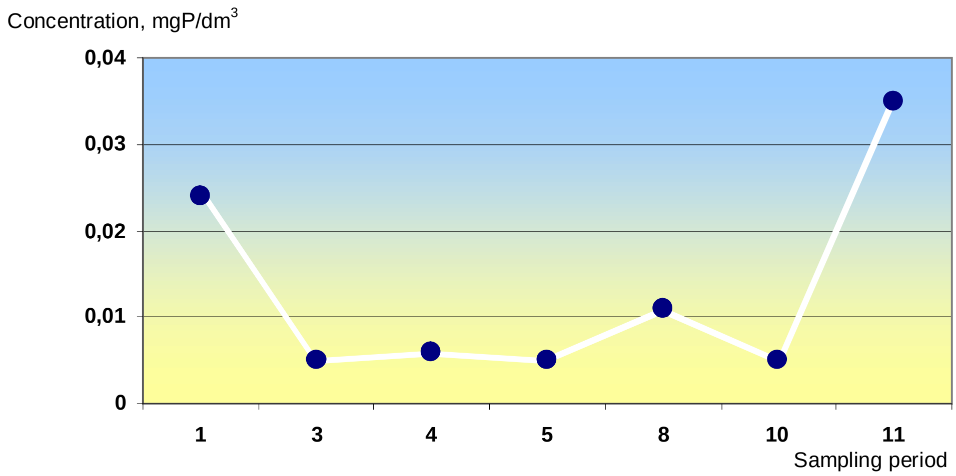



**Figure 46 – Annual distribution of inorganic phosphorus concentrations in the water of the river Oshmyanka River upper Velikiye Yatsyny in 2007**

Higher annual average concentrations of Total Ferrum (0,112-0,287 mg/dm$^3$), copper compounds (0,003-0,010 mg/dm$^3$) and manganese (0,016-0,077 mg/dm$^3$) stipulated for the river Oshmyanka are typical for practically all water bodies of the country. The annual average concentrations of Zinc compounds exceeded MPC 1,1-3,1-fold which is connected with the peculiarities of groundwater inflow and incoming of Zinc compounds from scattered (diffuse) sources of contamination. On the other hand the annual average concentrations of other metal – nickel – were found to be in the permissible range (Figure 47).

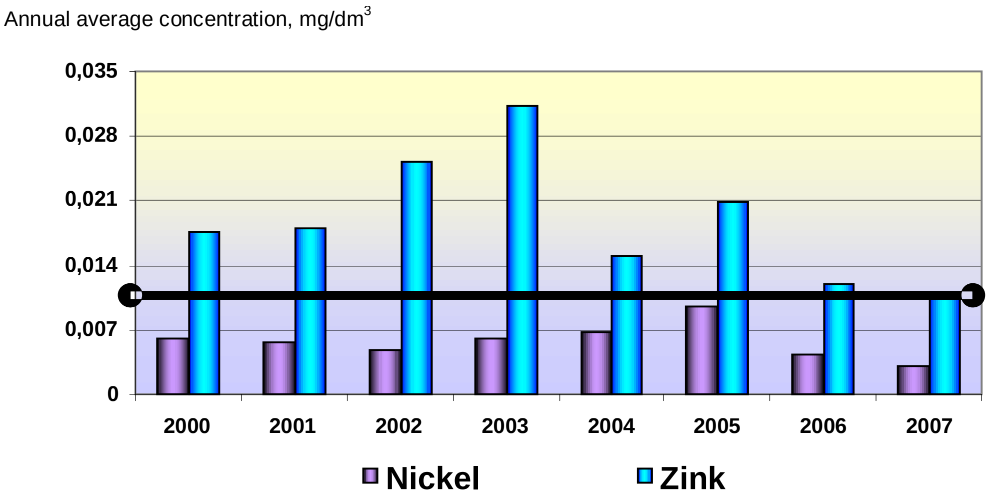



**Figure 47 – The dynamics of annual average concentrations of zinc and nickel compounds in the water of the river Oshmyanka upper Velikiye Yatsyny for the period of 2000-2007**

The concentrations of lead, cadmium, and synthetic surface–active substances continued to be low in a stable manner throughout the yearly observation period. During the period of 2000-2007 the tendency towards the contamination of the river Oshmyanka with oil products had not been reflected in a distinct way. The annual average concentrations of oil products of 1,0 of MPC and higher (2003-2006) are stipulated by the reoccurrence of samples with the concentrations exceeding the standard set during the year. The results of observations over 2007 allow one to state a decrease in anthropogenic stress on the stream flow (Figure 48).

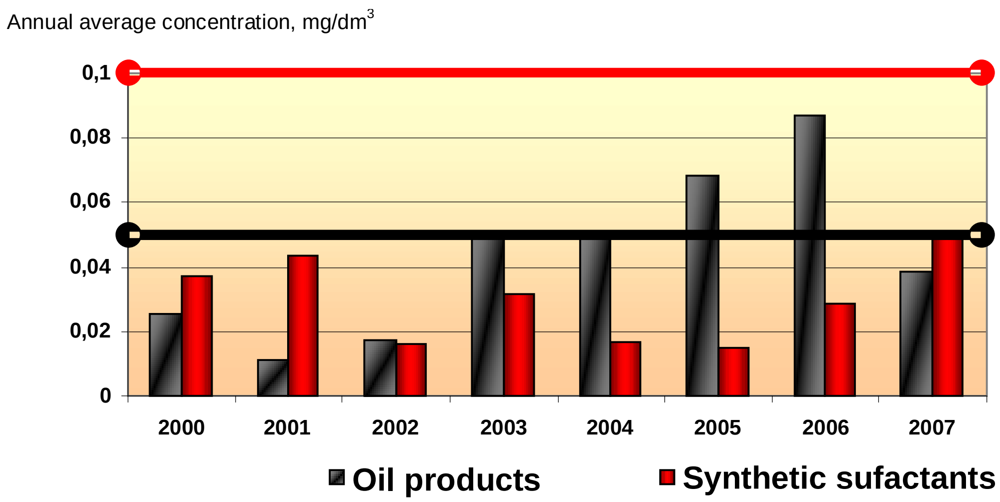



**Figure 48 – The dynamics of the annual average concentrations of oil products and synthetic surfactants in the water of the river Oshmyanka upper Velikiye Yatsyny for the period of 2000-2007**

The dynamics of the pollution index of the water in the river Oshmyanka is unstable. In 2007 according to the accepted evaluation standard the quality of water in the river corresponded to 'relatively pure' category – II (WPI=0,6) (Figure 49).

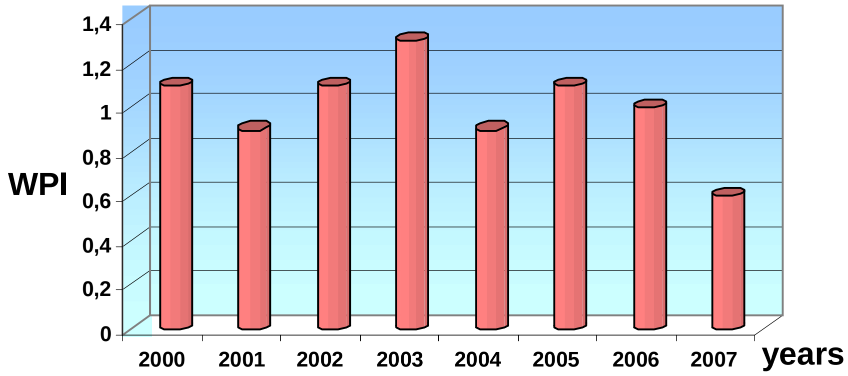



**Figure 49 – The dynamics of the water pollution index (WPI) of the river Oshmyanka upper Velikiye Yatsyny for the period of 2000-2007**

During observation period of 2004 – 2007 the transborder waters of the river Viliya at the settlement Bystritsa are to be marked by higher concentration of Total Ferrum (0,309-0,405 mg/dm$^3$), copper compounds (0,001-0,004 mg/dm$^3$), manganese (0,002-0,007 mg/dm$^3$) which is typical for not only the majority of transborder survey stations but also for most water bodies of the Republic of Belarus. The annual average concentrations of other metals – zinc and nickel – were found to be in the range that is significantly lower than MPC. Moreover, there is a strong tendency towards further decrease in the annual average concentrations of these elements (Figure 50).

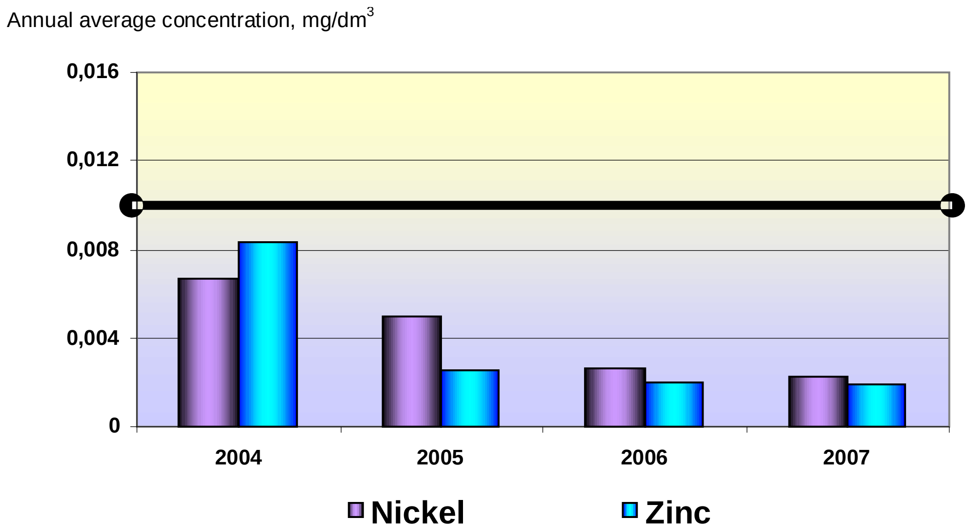



**Figure 50 – The dynamics of annual average concentrations of zinc and nickel compounds in the water of the river Viliya at the settlement Bystritsa for the period of 2004-2007**

The analysis of hydrochemical data concerning the concentrations of oil products and synthetic surfactants proves the absence of contamination across this river stretch by major contaminants.

Figure 51 shows the dynamics of the annual average concentrations of oil products and synthetic surfactants in the water of the river Viliya for period of 2004-2007.

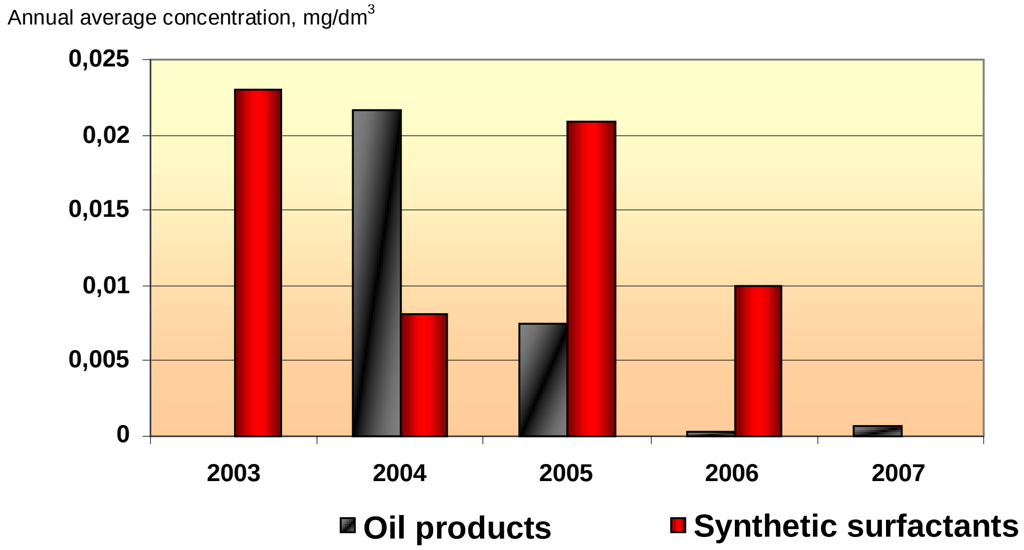



**Figure 51 – The dynamics of annual average concentrations of oil products and synthetic surfactants in the water of the river Viliya for the period of 2004-2007**

There remained components of basic salt composition against the regional background. The data of the monitoring observations characterizes the Viliya waters at settlement Bystritsa as those of medium mineralization (234,0-287,4 mg/dm$^3$) with the absolute dominance of cations $Ca^{2+}$ and hydrocarbonates in the salt composition (Figure 52).

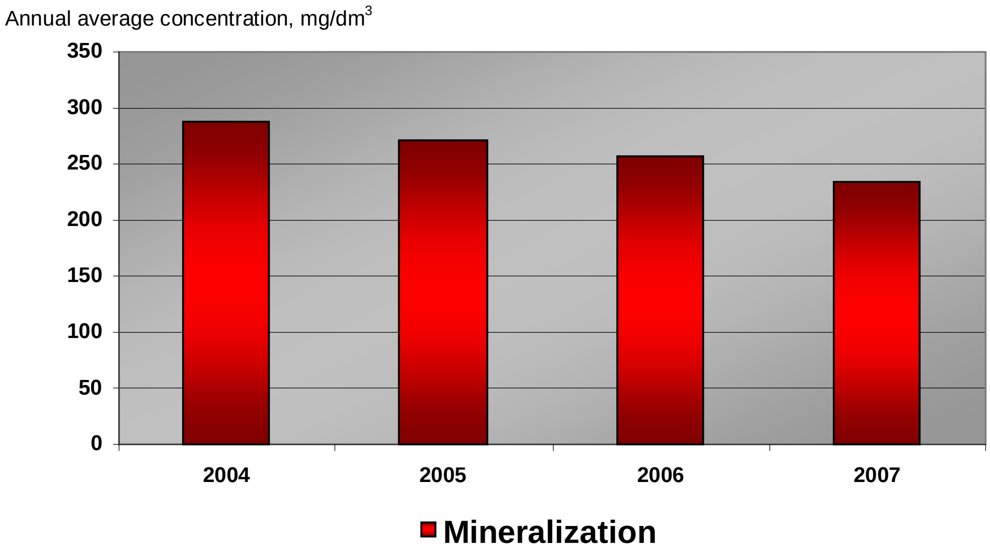



**Figure 52 – The dynamics of annual average values of water mineralization of the river Viliya at the settlement Bystritsa for the period of 2004-2007**

Despite the fact that the annual average dichromate values ($COD_{Cr}$) reflecting the general level of organic stress on the stream flow remained in the range of medium values (17,7-23,6 $mgO_2/dm^3$), $BOD_5$ values proving the content of easily oxidizable organic matter were found to be 1,0-1,2 of MPC (Figures 53, 54).

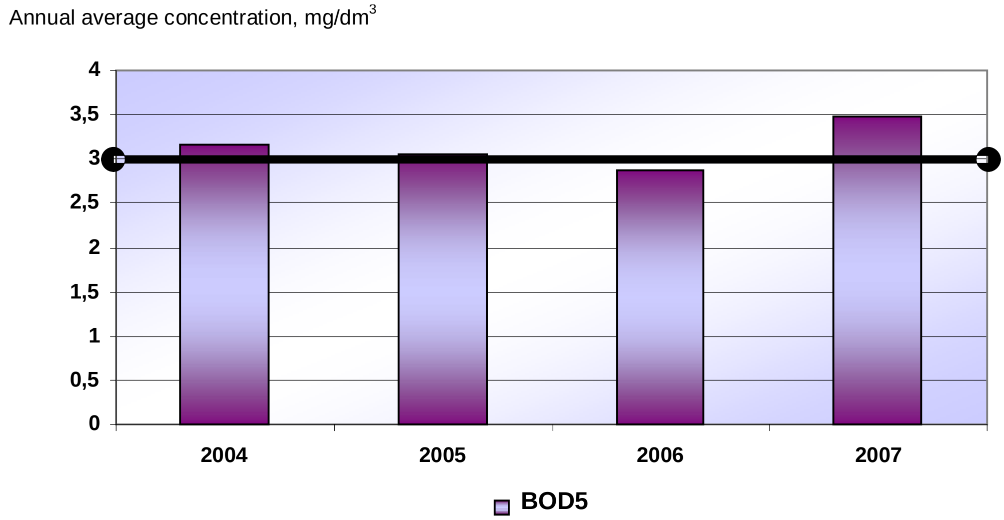



**Figure 53 – The dynamics of annual average concentrations of easily oxidizable organic compounds (according to $BOD_5$) in the water of the river Viliya at the settlement Bystritsa for the period of 2004-2007**

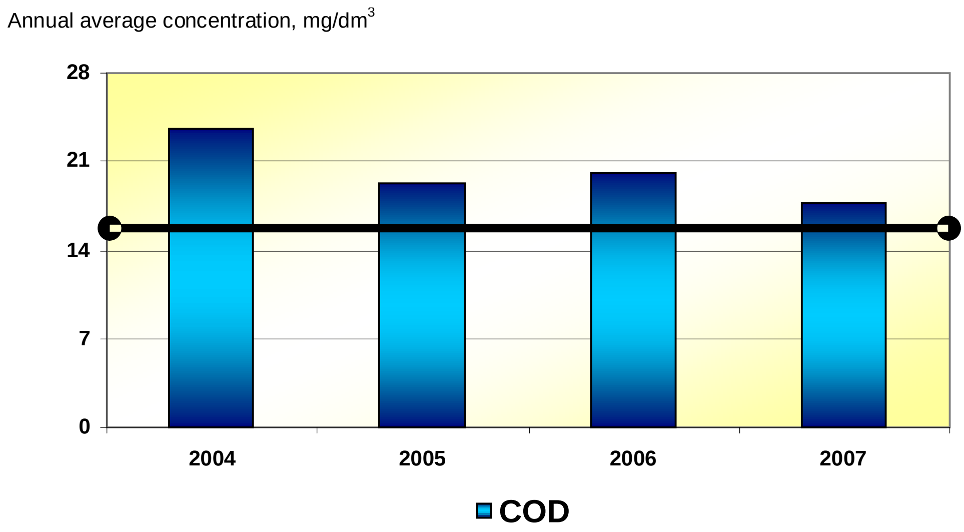



**Figure 54 – The dynamics of annual average concentrations of organic compounds ($COD_{Cr}$) in the water of the river Viliya at the settlement Bystritsa for the period of 2004-2007**

The analysis of the hydrochemical behavior of nitrogen and phosphorus compounds proves the successful state of the water ecosystem (Figures 55, 56). However, from the standpoint of protecting the rivers from eutrophication the annual average concentrations of nitrate nitrogen and inorganic phosphorus exceeded the environmentally permissible value of 0,5 $mgN/dm^3$ for nitrate nitrogen and 0,030 $mgP/dm^3$ for inorganic phosphorus.

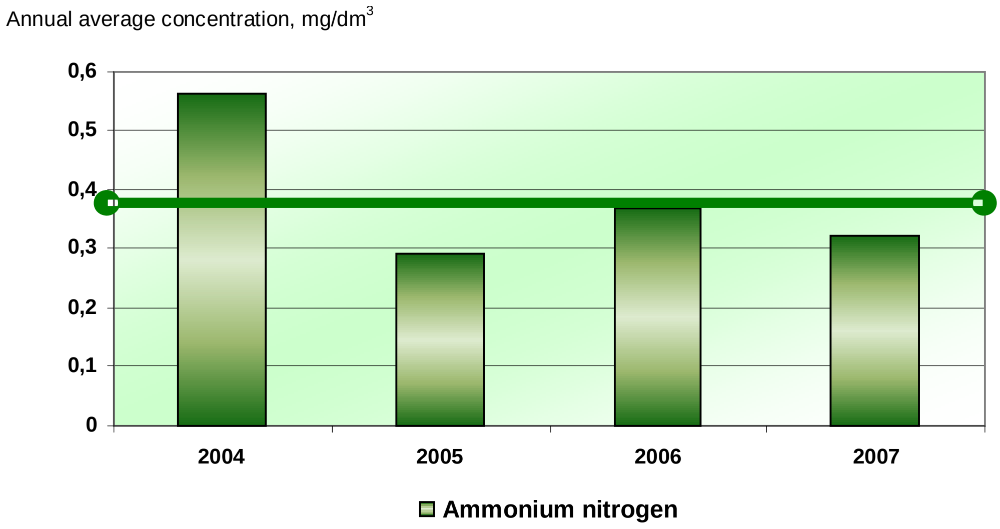



**Figure 55 - The dynamics of annual average concentrations of ammonium nitrogen in the water of the river Viliya at the settlement Bystritsa for the period of 2004-2007**

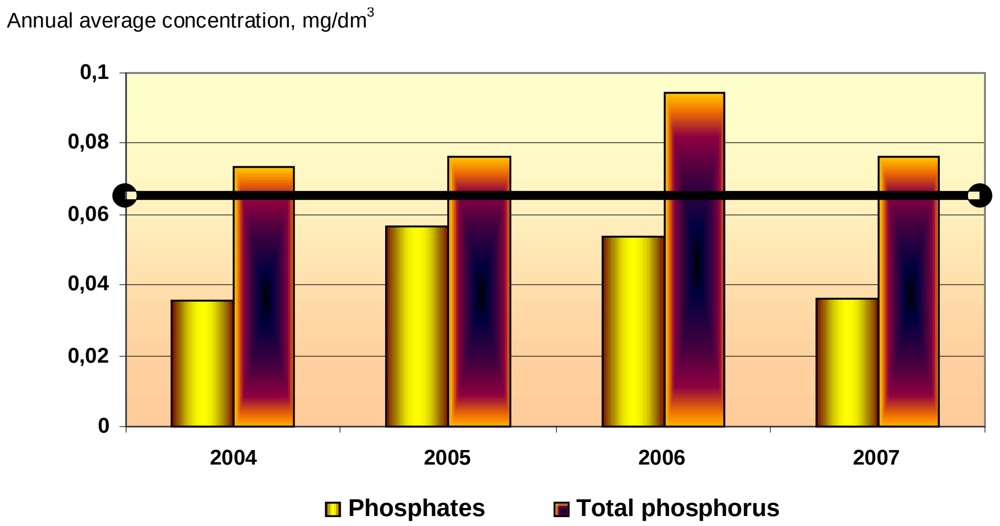



**Figure 56 – The dynamics of annual average concentrations of inorganic and total phosphorus in the water of the river Viliya at the settlement Bystritsa for the period of 2004-2007**

Figure 57 shows the dynamics of the water pollution index (WPI) of the river Viliya at the settlement Bystritsa for the period of 2004-2007.

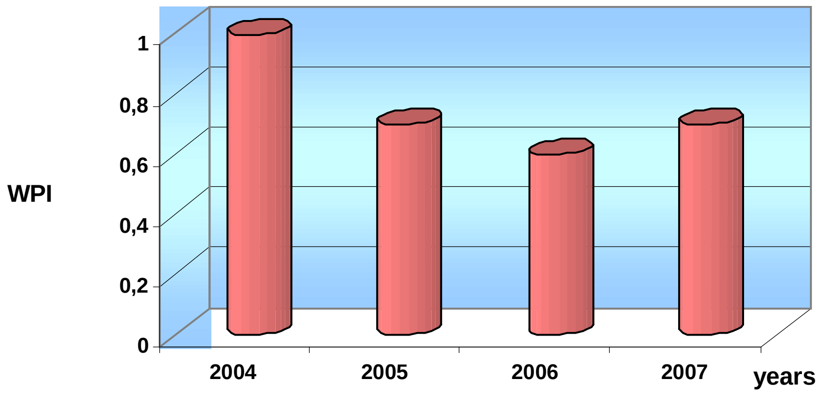



**Figure 57 – The dynamics of the water pollution index (WPI) of the river Viliya at the settlement Bystritsa for the period of 2004-2007**

According to the accepted evaluation standard the quality of the water of the river Viliya was characterized by ‘relatively pure’ category (WPI=0,6-1,0).

*13.2.1.2 Field Study Data*

During the field studies carried out in 2008 – 2009 at the water bodies within the 30-km area of the Belarusian NPP, water sample were taken from the following water bodies: the Viliya at Mikhalishki settlement (within the borders of the settlement), the Gozovka at Goza settlement (1,0 km upper the settlement), the Losha at Gervyaty settlement (2,0 km upper the settlement), the Oshmyanka at the Velikiye Yatsyny settlement (2,0 km upper the settlement) (Figure 58).


The Gozovka (Goza)


The Losha (Gervyaty)

**Figure 58 – Photos of the Gozovka and Losha where the samples were taken**

'First day analysis’ measurements were taken at all water bodies in regard to biogenic substances and the major ions of salt composition as well as in regard to ‘prioritized’ organic substances, trace elements (heavy-metal ions) and major contaminants. The temperature test, evalution of dissolved oxygen, pH, as well as the conservation of the samples and measuring of $BOD_5$ were all carried out at the place of sampling. The determining of other hydrochemical parameters was performed in the laboratories of water chemistry and physico-chemical measurements of RCRCEM State Enterprise, which meet the criteria of the Belarussian accreditation system and have been accredited in regard to independence and technical examination in accordance with the STB ISO/MEK 17025.

The results of the hydrochemical analysis of water samples are shown in Table 48. Careful consideration of the table data proves that according to the 'first day analysis' results all rivers have slightly alkaline water (the value being pH 7,82 – 8,28). The lowest and the highest dissolved oxygen content value are the following: minimum 8,50 $mgO_2/dm^3$ (the Gozovka at Goza settlement) and maximal 10,48 $mgO_2/dm^3$ (the Oshmyanka at Velikiye Yatsyny settlement), the oxygen saturation being 111 %. According to the water pollution assessment (MPC), the dissolved oxygen content during summer season in the water bodies should be not less than 6 $mgO_2/dm^3$. Carbon dioxide content values were found to be in the range of 7,9 – 14,1 $mg/dm^3$ while there was no carbon dioxide to be found at the sample taken in the Losha at Gervyaty settlement and the Viliya at Mikhalishki settlement. That is typical for the summer season end when plant life is rampant in the water bodies.

BOD (biochemical oxygen demand) serves as the quantitive assessment of easily oxidizable organic substances showing the oxygen quantity used for the biochemical oxydizing of organic substances over a period of time (5 days). The highest biochemical oxygen demand ($BOD_5$) value was found in the Viliya within the borders of Mikhalishki settlement– 5,93 $mgO_2/dm^3$ (about 2 of MPC) which proves that there is a higher content of easily oxidizable organic substance in the water.

Organic carbon is indicative of the aggregate content of organic substance in the water. The simplest and the most widespread way to determine the content of organic substance is the method of determining the water oxidizability by the oxygen quantity used for oxidizing (oxidizer $K_2Cr_2O_7$). As for the rivers studied the maximum dichromate value of 31,6 $mgO_2/dm^3$ is found in the Viliya within the borders of Mikhalishki settlement while the minimum one of 16.3 $mgO_2/dm^3$ in the Oshmyanka 0,5-km Upper Velikiye Yatsyny settlement.

**Table 48 – Results of the hydrochemical analysis of water samples**

| Name of element | The Gozovka, Goza | The Losha, Gervyaty | The Viliya, Mikhalishki | The Oshmyanka, Velikiye Yatsyny | MPC |
|---|---|---|---|---|---|
| Date of sampling | 02.09 | 02.09 | 02.09 | 03.09 | |
| Time | 14.20 | 17.45 | 19.00 | 14.15 | |
| Temperature | 12,5 | 15,8 | 16,7 | 17,6 | |
| pH | 7,84 | 8,15 | 8,28 | 7,82 | 6,5-8,5 |
| Oxygen, $mg/dm^3$ | 8,50 | 10,17 | 10,45 | 10,48 | <6,0 |
| Carbon dioxide, $mg/dm^3$ | 14,1 | 0 | 0 | 7,9 | |
| $BOD_5$, $mg/dm^3$ | 2,79 | 2,67 | 5,93 | 3,14 | 3,0 |
| % oxygen saturation | 82 | 106 | 111 | 108 | |
| Colour grade | 19 | 13 | 30 | 20 | |
| COD, $mgO/dm^3$ | 19,8 | 17,8 | 31,6 | 16,3 | |

Table 48 (continued)

| Name of element | The Gozovka, Goza | The Losha, Gervyaty | The Viliya, Mikhalishki | The Oshmyanka, Velikiye Yatsyny | MPC |
|---|---|---|---|---|---|
| Ammonium Nitrogen, mgN/$dm^3$ | 0,41 | 0,34 | 0,39 | 0,26 | 0,39 |
| Nitrate Nitrogen, mgN/$dm^3$ | 0,48 | 0,24 | 0,007 | 0,10 | 9,03 |
| Nitrite Nitrogen, mgN/$dm^3$ | 0,007 | 0,008 | <0,005 | 0,007 | 0,024 |
| Phosphates, mgP/$dm^3$ | 0,019 | 0,015 | 0,014 | 0,015 | 0,066 |
| Total phosphorus, mgP/$dm^3$ | 0,024 | 0,023 | 0,024 | 0,032 | 0,200 |
| Total Ferrum, mg/$dm^3$ | 0,17 | 0,08 | 0,05 | 0,17 | 0,10 |
| Silicon, mg/$dm^3$ | 2,7 | 2,3 | 2,7 | 3,2 | 10,0 |
| Hydro carbonate, mg/$dm^3$ | 228,8 | 237,3 | 226,9 | 265,4 | |
| Total water hardness, mg-eq/$dm^3$ | 4,40 | 4,22 | 4,18 | 4,90 | <7,0 |
| Sulphates, mg/$dm^3$ | 15,0 | 16,7 | 18,4 | 27,4 | 100,0 |
| Chlorides, mg/$dm^3$ | 28,7 | 17,0 | 25,8 | 14,1 | 300,0 |
| Calcium, mg/$dm^3$ | 62,3 | 53,1 | 55,5 | 55,1 | 180,0 |
| Magnesium, mg/$dm^3$ | 15,7 | 19,1 | 19,1 | 26,1 | 40,0 |
| Solids content, mg/$dm^3$ | 324,8 | 283,2 | 264,8 | | |
| Oil products, mg/$dm^3$ | 0,06 | 0,03 | 0,03 | 0,03 | 0,05 |
| Phenols, mg/$dm^3$ | 0,004 | 0,003 | 0,003 | 0,002 | |
| Total Chrome, mg/$dm^3$ | 0,002 | 0,001 | 0,001 | 0,001 | 0,005 |
| Synthetic Surfactant, mg/$dm^3$ | 0,024 | 0,024 | 0,041 | 0,028 | |
| Suspended solids, mg/$dm^3$ | <5,0 | <5,0 | 8,0 | 5,0 | Увел. на 0,25 |
| Transparency, cm | 49 | 49 | 25 | 49 | |
| Electrical conductivity cm/cm | 0,000445 | 0,000460 | 0,000411 | 0,000489 | |

Nitrogen, silicon, phosphorus and ferrum compounds belong to a group of biogenic substances. Ammonium, nitrite, and nitrate ions that are interconnected and can turn into one another belong to inorganic nitrogen compounds.

The highest ammonium nitrogen content values were found in the following rivers: the Gozovka (1,0 km Upper Goza) – 0,41 mgN/$dm^3$ and the Viliya (within the borders of Mikhalishki) – 0,39 mgN/$dm^3$ (over 1 of MPC). Nitrate and nitrite nitrogen content in the rivers studied was not found to be above of MPC.

Phosphorus in the river water is present in the form of inorganic as well as organic compounds. Phosphorus compounds content in the river water is usually in the tenths of a milligram/liter while higher concentrations of phosphorus are indicative of the water contamination since phosphorus compounds belong to the decomposition products of the compound organic substances. The inorganic phosphorus content in the river water under study is 0,014 – 0,019 mgP/dm$^3$ while the total phosphorus content (both organic and inorganic) is in the range of 0,023 to 0,032 mgP/dm$^3$ which does not exceed the acceptable values of MPC.

Ferrum compounds come into the river water with groundwater inflow, industrial as well as agricultural waste waters, and as a result of the chemical erosion of earth material. Maximum values as to the Total Ferrum content – 0,17 mg/dm$^3$ (over 1,0 of MPC) - were found in the following rivers: the Gozovka at Goza and the Oshmyanka at Velikiye Yatsyny.

Based on the results of the analysis of basic salt composition ions the rivers under study belong to the rivers with small and medium mineralization, the highest value (according to solids content) being 324,8 mg/dm$^3$. The total water hardness value of the rivers is not high while the maximum value is 4,90 mg-eq/dm$^3$ (the Oshmyanka at Velikiye Yatsyny). Ampng the major ions (macro-components) the ones that dominate are hydrocarbonate and calcium ions.

The following trace elements were found in the rivers under study: copper, zinc, nickel, lead, cadmium, and manganese.

Among the major pollutants the following were found in the river water: oil products in the Goza 1,0 km Upper Gozovka – 0,06 mg/dm$^3$ (over 1 of MPC), aggregate phenols yielded values that are in the range of 0,002 – 0,004 mg/dm$^3$. Neither synthetic surfactants (SS) nor total chrome content in the rivers under study were found to be above MPC norms.

Nothing was registered as for other parameters and elements found in the water bodies of the Ostrovets site that would rise above MPC.

### *13.2.2 Radiation situation*

Radiation monitoring is carried out in the Republic of Belarus in accordance with the following regulatory legal acts:

- Regulation on the procedure of radiation monitoring and usage of its data as a part of the National Environment Monitoring System in the Republic of Belarus. The Regulation is approved by Decree No. 576 of the Cabinet of Ministers of the Republic of Belarus on May 17$^{th}$, 2004.
- Instruction on procedure of radiation monitoring by bodies subordinated to the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus, approved by Resolution of the Ministry of Natural Resources of the Republic of Belarus, No. 98 dated November 11$^{th}$, 2008.

### *13.2.3 Surface water and bottom sediments*

During the field studies in 2008 – 2009 surface water and bottom sediments samples were taken in the river Viliya – settlement Mikhalishki (within the settlement), settlement Bystritsa (near the road bridge), settlement Muzhily, on the river Gozovka – settlement Goza (1.0 km upper the settlement), on the river Losha – rural settlement Gerviaty (2,0 km upper the settlement), on the river Oshmyanka – settlement Velikiye Yatsyny (0,5-km upper the settlement), on the river Polpe – settlement Valeikuny, on the river Stracha – settlement Olkhovka, and also in the reservoir near settlement Olkhovka.

Results of determination of radioactive nuclides content in surface water samples are shown in Table 49.

**Table 49 – Determination of radioactive nuclides in surface water samples taken from the studied water bodies in Ostrovets District, Grodno Region. Date of sampling: 02.09.2008**

| Sampling point | Volumetric activity, Bq/l | |
|---|---|---|
| | $^{137}Cs$ | $^{90}Sr$ |
| river Gozovka (settl. Goza) | 0,006±0,001 | 0,008±0,002 |
| river Losha (settl. Gerviaty) | 0,007±0,001 | 0,007±0,002 |
| river Viliya (settl. Mikhalishki) | 0,007±0,001 | 0,010±0,002 |
| river Oshmyanka (settl. Velikiye Yatsyny) | 0,006±0,001 | 0,009±0,002 |

Bottom sediments samples were taken during the field studies; results of determination of radioactive nuclides in bottom sediments samples are shown in Table 50.

**Table 50 – Determination of radioactive nuclides in bottom sediments samples**

| Place of sampling, date of sampling | Sampling point | Weight, kg | Specific activity, Bq/kg | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $^{40}K$ | $^{238}U$ | $^{232}Th$ | $^{226}Ra$ | $^{137}Cs$ | $^{90}Sr$ |
| r. Gozovka (settl. Goza) 03.09.2008 | T.1 | 0,600 | 424±17 | 4,4±0,4 | 21,0±1,9 | 13,1±1,2 | 1,5±0,2 | 1,9±0,8 |
| | T.2 | 0,789 | 421±16 | 4,8±0,4 | 15,4±1,3 | 11,9±0,9 | 2,05± | 1,3±0,6 |
| | T.3 | 1,062 | 411±15 | 6,8±0,3 | 19±1,9 | 12,9±1,2 | 1,9±0,2 | 1,1±0,5 |
| r. Losha (settl. Gerviaty) 03.09.2008 | T.1 | 1,467 | 375±18 | 7,5±0,6 | 9,3±0,8 | 6,8±0,6 | 0,6±0,1 | 0,8±0,4 |
| | T.2 | 1,215 | 373±19 | 5,8±0,5 | 12,3±1,4 | 7,9±0,7 | 1,2±0,1 | 1,1±0,5 |
| | T.3 | 0,965 | 393±19 | 8,5±0,6 | 10,3±0,9 | 7,7±0,7 | 0,9±0,1 | 0,6±0,2 |
| r. Viliya (settl. Mikhalishki) 03.09.2008 | T.1 | 1,376 | 386±16 | 7,6±0,6 | 16,5±1,8 | 10,6±1,1 | 1,7±0,2 | 1,3±0,6 |
| | T.2 | 1,129 | 420±16 | 4,8±0,4 | 15,4±1,3 | 10,6±0,9 | 4,7±0,3 | 1,0±0,5 |
| | T.3 | 0,988 | 394±15 | 7,6±0,6 | 12,8±1,0 | 10,9±0,8 | 2,6±0,2 | 1,7±0,7 |
| r. Viliya (settl. Bystritsa) 06.05.2009 | T.1 | 1,639 | 451±110 | | 15,9±4,1 | 10,4±2,7 | 3,0±0,8 | |
| | T.2 | 1,204 | 320±46 | | 12,8±2,4 | 6,6±1,3 | 5,0±1,0 | |
| | T.3 | 0,774 | 360±18 | | 11,1±0,5 | 7,3±0,4 | 5,5±0,4 | |
| | T.4 | 0,578 | 431±21 | | 14,5±0,6 | 9,1±0,4 | 6,7±0,4 | |
| r. Viliya (settl. Muzhily) 06.05.2009 | T.1 | 0,633 | 355±28 | | 15,7±1,4 | 9,1±0,8 | 5,4±0,6 | |
| | T.2 | 1,425 | 338±82 | | 10,5±2,5 | 7,6±1,8 | 5,5±1,3 | |
| | T.3 | 1,184 | 328±47 | | 9,8±1,5 | 6,7±1,7 | 7,2±1,2 | |
| | T.4 | 1,120 | 334±84 | | 12,8±3,4 | 7,9±2,1 | 7,9±1,9 | |

Table 50 (continued)

| Place of sampling, date of sampling | Sampling point | Weight, kg | Specific activity, Bq/kg | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $^{40}$K | $^{238}$U | $^{232}$Th | $^{226}$Ra | $^{137}$Cs | $^{90}$Sr |
| r. Stracha – (settl. Olkhovka) 06.05.2009 | T.1 | 1,000 | 328±47 | | 9,8±1,5 | 6,7±1,7 | 2,6±0,7 | |
| | T.2 | 0,700 | 282±12 | | 15,9±0,2 | 7,9±0,4 | 1,1±0,2 | |
| | T.3 | 0,650 | 316±16 | | 12,8±0,6 | 7,4±0,4 | 1,2±0,2 | |
| | T.4 | 0,668 | 335±28 | | 8,8±1,1 | 7,9±0,8 | 1,0±0,4 | |
| Olkhovskoye reservoir (settl. Olkhovka) 06.05.2009 | T.1 | 0,774 | 487±24 | | 15,4±0,7 | 10,0±0,5 | 0,7±0,1 | |
| | T.2 | 1,440 | 414±100 | | 13,9±3,7 | 9,7±2,5 | 1,2±0,3 | |
| | T.3 | 1,458 | 373±82 | | 9,8±2,4 | 6,69±1,5 | 1,2±0,3 | |
| | T.4 | 1,773 | 394±85 | | 9,9±2,4 | 7,2±1,7 | 0,4±0,1 | |

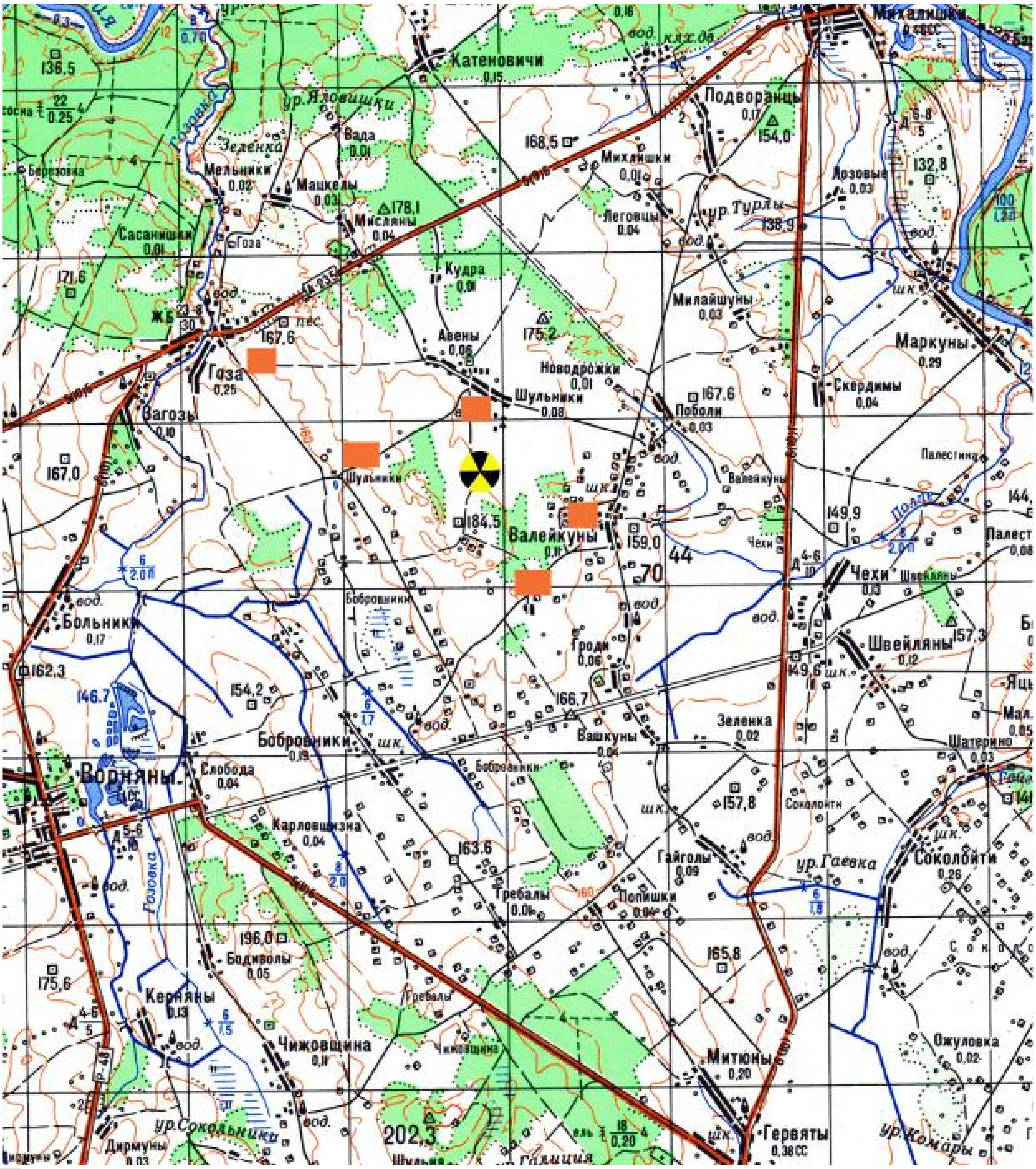
As you can see in Table 50 the levels of the anthropogenic radioactive nuclides in bottom sediments of the examined rivers are close to global fallout level. Specific activity levels of natural radioactive nuclides in the samples of bottom sediments correspond to mean activity levels of these radioactive nuclides which are typical for soddy podzolic and podzolic soil.

### *13.2.4 Soil*

Assessment of radiation situation and technogenic pollution was made within the area of settlements Goza, Aveny, Valeikuny in Ostrovets District, Grodno region during the field studies in 2008-2009 (figure 59) and also on the territory of the planned site of NPP construction. Figure 60 shows sketch map of benchmark sites (BS) where soil samples were taken.

BS No. 1 settl. Goza BS No. 2 settl. Aveny

**Figure 59 – Photo of the territory of the benchmark sites, on which the field studies were made**




BS

**Figure 60 – Sketch map of benchmark sites location**

The selected sites were selected on the open territory; there were no dwellings and other buildings, no areas covered by asphalt. Square of the area is 200 m x 200 m.

Soil samples were taken from the benchmark sited by envelope method. Gamma-radiation intensity (INT) was measured at the height of 1 m and 2-3 cm from soil level ath the sampling points.

Radiation dosimeters DBG-06T, MKS-1117 with measurement range from 0,10 to 99,99 μSv/hour, and relative measurement error of not more than 20 % were used for

INT measurement. Sampling equipment of 200 mm height, 40 mm diameter was used for soil sampling.

On each BS soil profile was cut for assessment of spatial redistribution of radioactive nuclides in vertical profile of soil.

*13.2.4.1 Technogenic pollution*

Whereas there are no big highways and industrial production within the Belarusian NPP site area, fixed stations for examination of chemical polluting agents and heavy metals content in soil are absent. Ecological state of soil was assessed by results of field studies.

Analysis of soil samples for content of chemical polluting agents was made in laboratory of soil pollution monitoring and laboratory of physical and chemical measurements of the RCREM, State Enterprise.

The soil samples taken were dried under room temperature until they became air-dry, then they were meshed in big porcelain mortar and filtered (mesh size – 1 mm). By quartering method an average sample was taken from this filtered sample.

Chemical analysis for heavy metals content was made in accordance with Temporary guidelines for soil pollution control. Part 1.- M., 1983. Termination of analysis was made using atomic absorption spectrophotometer AAS - 3.

Content of sulphate in soil was detected using spectrophotometer SF-46 according to method described in the same guidelines.

Soil pH was determined by potentiometric method on the grounds of GOST 26423-85 Soils. Methods of Detection of Electric Conductivity, PH and Dissolved Solids in Water Extract.

Oil product analysis was made by means of gravimetric procedure according to method described in Guidelines for hygienic regulation of chemical substances in soil.

Nitrate detection in soil was made according to GOST 25951-66 Soils. Nitrate Detection by Ionometric Technique.

Detection of heavy metals in soil was made by means of atomic absorption spectrophotometer with electrothermal atomizer NovAA-400 «Analyst Jena», German Democratic Republic, working range: (190-860), detection limit of Ni – 0.3 µg/l, Pb – 0,08 µg/l, Cu – 0,19 µg/l, Mn – 0,014 µg/l, Cd – 0,007 µg/l, Zn – 0,003 µg/l. Measurement error is 5 %.

Measurement results of chemical polluting agents and heavy metals content are shown in Tables 51 and 52.

**Table 51 – Content of chemical polluting agents in BS soil samples**

| BS No | Sampling point No | pH | Sulphates mg/kg | Nitrates mg/kg | Oil products, mg/kg |
|---|---|---|---|---|---|
| *BS No 1 Goza* | 1 | 6,85 | 11,3 | 3,5 | <5,0 |
| | 2 | 7,13 | 20,7 | 2,8 | 10,0 |
| | 3 | 6,85 | 16,0 | 3,1 | 10,0 |
| | 4 | 7,15 | 16,0 | 3,0 | 13,3 |
| | 5 | 7,01 | 20,7 | 3,6 | 10,0 |
| *BS No 2 Aveny* | 1 | 6,81 | 26,9 | 4,9 | 6,7 |
| | 2 | 7,00 | 23,8 | 4,9 | 13,3 |
| | 3 | 7,12 | 26,9 | 5,1 | 10,0 |
| | 4 | 6,96 | 31,7 | 12,9 | 16,7 |
| | 5 | 6,52 | 37,9 | 9,6 | 6,7 |

Table 51(continued)

| BS No | Sampling point No | pH | Sulphates mg/kg | Nitrates mg/kg | Oil products, mg/kg |
|---|---|---|---|---|---|
| *BS No 3 Valeikuny* | 1 | 6,92 | 30,1 | 12,9 | <5,0 |
| | 2 | 6,88 | 22,2 | 8,1 | <5,0 |
| | 3 | 7,10 | 31,7 | 9,1 | <5,0 |
| | 4 | 6,51 | 22,2 | 25,1 | 10,0 |
| | 5 | 6,80 | 53,6 | 4,5 | 20,0 |
| MPC* | | | 160 | 130 | 50 |

** MPC – Maximum permissible concentration of chemical polluting agents*

**Table 52 – Content of heavy metals in soil samples taken at the benchmark sites (BS) within the 30-km area**

| BS No | Sampling point No | Cadmium mg/kg | Zinc, mg/kg | Lead, mg/kg | Copper, mg/kg | Nickel, mg/kg | Manganese, mg/kg |
|---|---|---|---|---|---|---|---|
| *BS No 1 Goza* | 1 | 0,07 | 12,7 | 6,8 | 1,0 | 4,1 | 57,2 |
| | 2 | 0,13 | 11,7 | 9,1 | 1,1 | 4,1 | 54 |
| | 3 | 0,1 | 16,7 | 6,8 | 2,0 | 8,5 | 199 |
| | 4 | 0,18 | 14,6 | 8,5 | 1,5 | 5,4 | 64 |
| | 5 | 0,08 | 13,7 | 7,2 | 1,4 | 4,6 | 103 |
| *BS No 2 Aveny* | 1 | 0,14 | 21,1 | 7,6 | 1,6 | 5,6 | 358 |
| | 2 | 0,14 | 22,7 | 8,7 | 1,7 | 5,9 | 585 |
| | 3 | 0,14 | 24,4 | 8,0 | 1,6 | 5,0 | 423 |
| | 4 | 0,13 | 24,8 | 9,1 | 8,2 | 1,4 | 718 |
| | 5 | 0,17 | 21,5 | 8,7 | 1,6 | 5,3 | 629 |
| *BS No 3 Valeikuny* | 1 | 0,14 | 21,1 | 6,0 | 1,8 | 5,9 | 285 |
| | 2 | 0,12 | 19,4 | 5,8 | 1,6 | 5,4 | 305 |
| | 3 | 0,12 | 21,0 | 7,5 | 1,6 | 5,7 | 326 |
| | 4 | 0,19 | 22,4 | 8,0 | 2,0 | 5,9 | 356 |
| | 5 | 0,15 | 21,9 | 7,2 | 1,9 | 6,6 | 368 |
| Variation range | | 0,07-0,19 | 11,7-24,8 | 5,8-9,1 | 1,0-8,2 | 1,4-8,5 | 54-718 |
| MPC * | | 2,0 | 220 | 32,0 | 132 | 80 | 1500 |

** MPC – Maximum permissible concentration of chemical polluting agents for each case, when pH > 5*

It is clearly described in Tables 51 and 52 that content of chemical polluting agents and heavy metals in the soil samples taken do not exceed maximum permissible values.

### *13.2.4.2 Radioactive contamination*

There are no fixed stations for observance of radioactive soil contamination within the 30-km-area of the Belarusian NPP because this territory hasn't almost been sufferd as a result of the accident at the Chernobyl NPP, however there are results of surveys on environmental contamination of all territory of the Republic of Belarus in data base of the Republican Center of Radiation Control and Environment Monitoring (RCRCEM) made during first years after the accident at the Chernobyl NPP, including data on radioactive contamination of soil in 252 settlements situated within the 30-km area. In 243 settlements the average contamination density with $^{137}$Cs amounts to less than

0,1 Ci/sq.km (3,7 kBq/sq.m), in 9 settlements the average contamination density with $^{137}$Cs is within 0,1 – 0,28 Cu/sq.km (3,7 – 10,4 7 kBq/sq.m).

In soil samples taken in 122 settlements, the radioactive nuclides $^{90}$Sr identified, in 46 settlementsm the isotopes of plutonium were identified.

Measurement of gamma-emitting radioactive nuclides content and detection of $^{90}$Sr in soil samples taken during field studies was made in radiation analytic department of the RCRCEM, State Enterprise.

Content of $^{238}$U was detected according to Measurements Techniques. MH 1497–2001 This is a method of uranium detection in soil and aerosol filter which determines radiochemical and radiometric procedures used in the course of detection of alpha-emitting radioactive nuclides of uranium by radiochemical method and is applied for soil samples, bottom samples, bottom sediments samples, vegetation samples and aerosol filters.

Minimum detected activity of uranium radioactive nuclides amounts to 0.005 Bq/sample if counting efficiency of alpha-particles is 30 %, time of measurements is less than 20 000 s and the least permissible uranium radioactive yield is 20 %. Minimum detected activity of uranium radioactive nuclides at radioactive yield of 60 % is 0,002 Bq/sample.

This method gives an opportunity to analyze samples with specific activity for $^{238}$U not less than 0,1 Bq/kg. During analysis of samples with specific activity of less than 0,1 Bq/kg made with the help of this method, permissible error limits in detection of $^{238}$U activity are not more than 40 % and acceptable probability is 0,95.

Radiation intensity levels at the height of 1 m from soil level are within 0,10 – 0,17 µSv/hour. Results of detection of $^{137}$Cs and natural radioactive nuclides in soil samples, taken at the BS, are shown in Table 53.

**Table 53 – Results of detection of radioactive nuclides in soil samples taken at the BS**

| Sampling point No | Contamination density, kBq/m$^2$ | | | | | |
|---|---|---|---|---|---|---|
| | $^{40}$K | $^{232}$Th | $^{226}$Ra | $^{238}$U | $^{137}$Cs | $^{90}$Sr |
| *BS No. 1 Goza, year 2008* | | | | | | |
| 1 | 160 ± 6 | 7,4 ± 0,6 | 5,1 ± 0,4 | 2,3± 0,2 | 1,5 ± 0,1 | 0,47± 0,2 |
| 2 | 158 ± 6 | 6,5 ± 0,6 | 4,8 ± 0,5 | 3,6± 0,3 | 1,8 ± 0,1 | 0,35± 0,2 |
| 3 | 184 ± 7 | 9,2 ± 0,7 | 6,0 ± 0,5 | 3,8± 0,3 | 1,5 ± 0,1 | 0,18± 0,2 |
| 4 | 142 ± 6 | 5,7 ± 0,6 | 4,4 ± 0,4 | 2,4± 0,2 | 1,3 ± 0,1 | 0,22± 0,2 |
| 5 | 196 ± 8 | 8,4 ± 0,7 | 6,2 ± 0,5 | 3,8± 0,3 | 1,0 ± 0,1 | 0,23± 0,2 |
| average | 168 | 7,4 | 5,3 | 3,2 | 1,4 | 0,29 |
| *BS No. 2 Aveny, year 2008* | | | | | | |
| 1 | 192 ± 10 | 6,6 ± 0,7 | 4,9 ± 1,2 | 2,6± 0,2 | 1,4 ± 0,1 | 0,49±0,2 |
| 2 | 155 ± 8 | 5,4 ± 0,4 | 4,1 ± 0,3 | 3,1± 0,2 | 1,3 ± 0,1 | 0,19±0,2 |
| 3 | 152 ± 7 | 5,3 ± 0,4 | 3,9 ± 0,3 | 2,3± 0,2 | 1,5 ± 0,1 | 0,26±0,2 |
| 4 | 172 ± 9 | 6,3 ± 0,6 | 4,1 ± 0,4 | 2,5± 0,2 | 1,8 ± 0,1 | 0,20±0,2 |
| 5 | 181 ± 9 | 7,6 ± 0,6 | 5,4 ± 0,4 | 3,4± 0,3 | 2,1 ± 0,1 | 0,95±0,2 |
| average | 170 | 6,2 | 4,5 | 2,8 | 1,6 | 0,42 |
| *BS No. 3 Valeikuny, year 2008* | | | | | | |
| 1 | 153 ± 8 | 5,6 ± 0,5 | 3,5 ± 0,3 | 2,2± 0,2 | 0,8 ± 0,1 | 0,68±0,2 |
| 2 | 154 ± 8 | 5,5 ± 0,5 | 3,8 ± 0,3 | 2,3± 0,2 | 0,6 ± 0,1 | 0,54±0,2 |
| 3 | 160 ± 8 | 6,2 ± 0,5 | 4,1 ± 0,3 | 2,6± 0,2 | 1,5 ± 0,1 | 0,46±0,2 |
| 4 | 156 ± 8 | 5,6 ± 0,5 | 3,7 ± 0,3 | 3,3± 0,3 | 1,6 ± 0,1 | 0,64±0,2 |
| 5 | 161 ± 8 | 6,2 ± 0,5 | 4,1 ± 0,3 | 3,5± 0,3 | 1,2 ± 0,1 | 0,23±0,2 |
| average | 157 | 5,8 | 3,8 | 2,8 | 1,1 | 0,51 |

Table 53 (continued)

| Sampling point No | Contamination density. kBq/sq.m | | | | | |
|---|---|---|---|---|---|---|
| | $^{40}K$ | $^{232}Th$ | $^{226}Ra$ | $^{238}U$ | $^{137}Cs$ | $^{90}Sr$ |
| | | | | | | |
| *BS No. 4 Rudnishki, year 2009* | | | | | | |
| 1 | 176 ± 41 | 7,9 ± 1,9 | 5,8 ± 1,4 | 2,7± 0,2 | 2,0 ± 0,5 | 0,22±0,2 |
| 2 | 180 ± 25 | 7,0 ± 1,2 | 4,6 ± 0,7 | 2,1± 0,2 | 1,4 ± 0,3 | 0,21±0,2 |
| 3 | 166 ± 37 | 5,8 ± 1,4 | 4,1 ± 1,0 | 2,6± 0,2 | 1,7 ± 0,4 | 0,22±0,2 |
| 4 | 175 ± 42 | 6,6 ± 1,6 | 5,1 ± 1,2 | 3,2± 0,2 | 1,9 ± 0,4 | 0,53±0,2 |
| 5 | 132 ± 29 | 4,5 ± 1,1 | 3,1 ± 0,7 | 2,9± 0,3 | 2,6 ± 0,6 | 0,29±0,2 |
| average | 166 | 6,4 | 4,5 | 2,7 | 1,9 | 0,29 |
| *BS No. 5 Shulniki, year 2009* | | | | | | |
| 1 | 159 ± 37 | 6,7 ± 1,5 | 4,7 ± 1,1 | 2,8± 0,3 | 2,1 ± 0,5 | 0,55±0,2 |
| 2 | 162 ± 8 | 5,4 ± 0,5 | 3.8 ± 0,4 | 2,4± 0,2 | 1,5 ± 0,1 | 0,34±0,2 |
| 3 | 187 ± 47 | 6,8 ± 1,7 | 4,5 ± 1,1 | 2,2± 0,2 | 0,7 ± 0,2 | 0,41±0,2 |
| 4 | 154 ± 34 | 5,2 ± 1,2 | 3,8 ± 0,9 | 3,3± 0,3 | 3,7 ± 0,9 | 0,76±0,2 |
| 5 | 181 ± 9 | 6,4 ± 1,4 | 4,1 ± 0,3 | 3,1± 0,3 | 1,3 ± 0,1 | 0,43±0,2 |
| average | 169 | 6,1 | 4,2 | 2,8 | 1,9 | 0,50 |

Content of $^{238,239,240}Pu$ in soil samples taken at the benchmark sites is in the range of 0,026 – 0,074 kBq/sq.m (0,0007 – 0,002 Ci/sq.km).

15 soil samples were taken on the territory of the NPP planned construction site. Scheme of location of sampling points is shown in Figure 61.

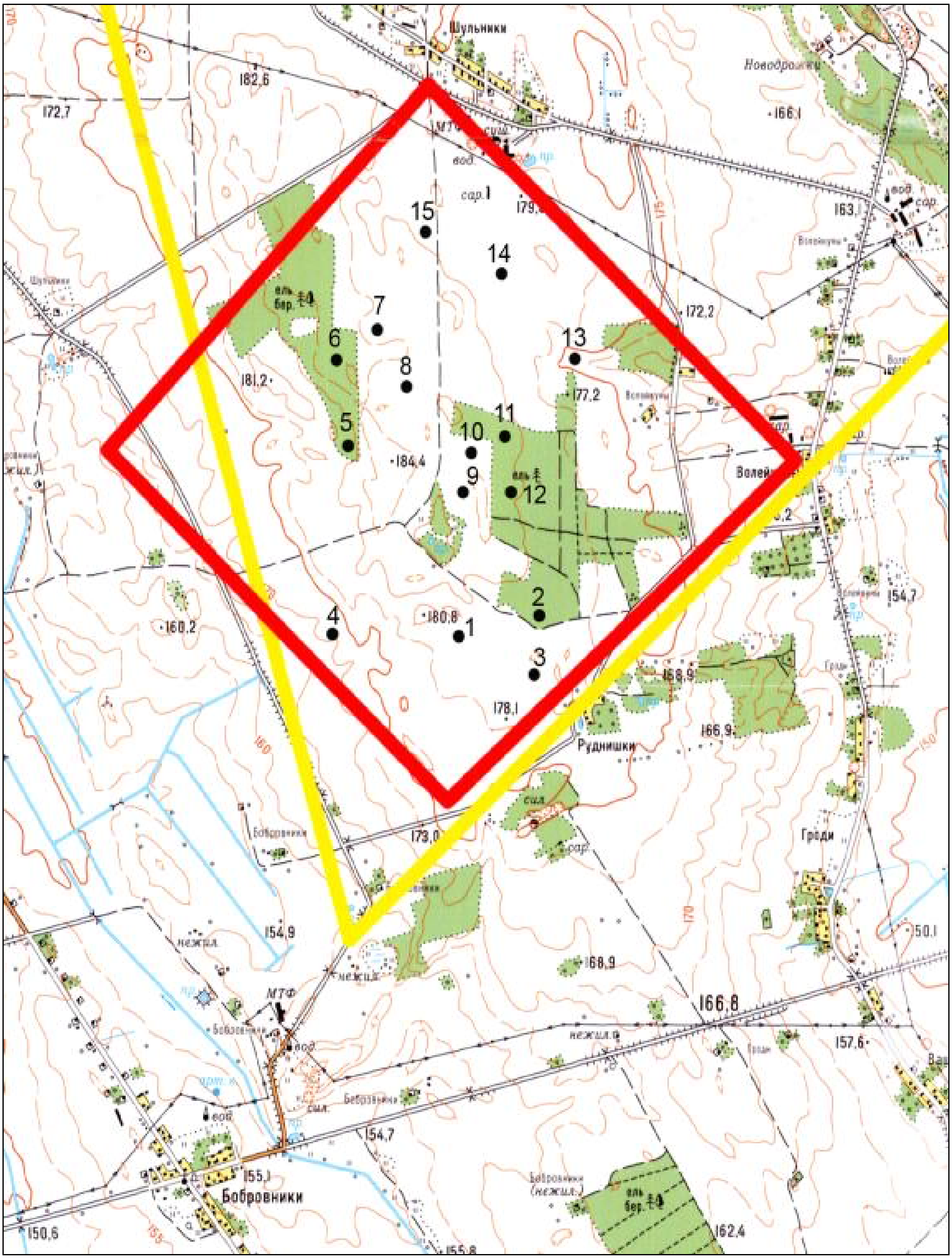



**Figure 61 – Scheme of location of sampling points on the territory of the Belarusian NPP planned construction site**

Results of gamma-emitting radioactive nuclides detection in soil samples taken are shown in Table 54.

**Table 54 - Results of detection of gamma-emitting radioactive nuclides in soil samples taken at the planned construction site of the Belarusian NPP**

| Sampling point No. | Contamination density, kBq/sq.m | | | | | |
|---|---|---|---|---|---|---|
| | $^{40}$K | $^{232}$Th | $^{226}$Ra | $^{238}$U | $^{137}$Cs | $^{90}$Sr |
| 1 | 185 ± 7 | 7,4 ± 0,6 | 5,0 ± 0,4 | 2,9± 0,3 | 1,8 ± 0,1 | 0,37± 0,2 |
| 2 | 158 ± 6 | 6,3 ± 1,2 | 3,7 ± 0,7 | 2,2± 0,2 | 2,2 ± 0,3 | 0,25± 0,2 |
| 3 | 162 ± 36 | 7,3 ± 1,7 | 5,0 ± 1,2 | 3,7± 0,3 | 1,9 ± 0,3 | 0,19± 0,2 |
| 4 | 174 ± 44 | 6,7 ± 1,7 | 4,3 ± 1,1 | 2,8± 0,3 | 1,2 ± 0,3 | 0,24± 0,2 |
| 5 | 142 ± 11 | 6,0 ± 0,9 | 3,6 ± 0,6 | 3,6± 0,3 | 1,0 ± 0,1 | 0,23± 0,2 |
| 6 | 160 ± 8 | 6,3 ± 0,5 | 4,5 ± 0,4 | 2,4± 0,2 | 1,9 ± 0,1 | 0,37± 0,2 |
| 7 | 173 ± 14 | 6,5 ± 0,6 | 4,3 ± 1,0 | 3,5± 0,3 | 1,1 ± 0,2 | 0,33± 0,2 |
| 8 | 191 ± 27 | 7,0 ± 1,2 | 5,1 ± 0,9 | 3,7± 0,3 | 2,2 ± 0,5 | 0,19± 0,2 |
| 9 | 180 ± 40 | 6,3 ± 1,5 | 4,1 ± 1,0 | 2,6± 0,2 | 1,3 ± 0,1 | 0,24± 0,2 |
| 10 | 177 ± 25 | 6,5 ± 1,0 | 4,1 ± 0,7 | 3,6± 0,3 | 1,7 ± 0,4 | 0,21± 0,2 |
| 11 | 141 ± 7 | 5,3 ± 0,4 | 3,8 ± 0,3 | 2,3± 0,2 | 2,5 ± 0,2 | 0,37± 0,2 |
| 12 | 154 ± 6 | 7,2 ± 0,6 | 3,9 ± 0,3 | 3,3± 0,3 | 1,8 ± 0,1 | 0,31± 0,2 |
| 13 | 204 ± 45 | 6,5 ± 1,5 | 4,7 ± 1,1 | 3,8± 0,3 | 1,6 ± 0,4 | 0,17± 0,2 |
| 14 | 203 ± 51 | 8,4 ± 2,1 | 5,8 ± 1,4 | 2,4± 0,2 | 1,8 ± 0,5 | 0,24± 0,2 |
| 15 | 189 ± 9 | 7,1 ± 0,6 | 4,0± 0,5 | 3,7± 0,3 | 1,5 ± 0,1 | 0,29± 0,2 |
| average | 173 | 6,7 | 4,4 | 3,1 | 1,7 | |

Levels of soil radioactive contamination at the site almost conform to global fallout observed before the accident of the Chernobyl NPP.

Levels of natural radioactive nuclides activity in the samples taken correspond to the levels of average activity of these radioactive nuclides typical for soddy-podzolic and podzolic soil.

***13.2.5 Soil generalization according to the intensity of radioactive nuclides migration in typical soil within the 30-km area of the Belarusian NPP***

Capacity of radioactive nuclides to redistribute among ecological system components mostly depends on their physical-chemical condition and migration capacity in soil. It is the most important element of biosphere which defines radioactive nuclides inflow to natural water, vegetation, atmospheric boundary layer and, finally to human body. Condition and behavior of radioactive nuclides in soil considerably influences on radio-ecological situation of the region as a whole.

Geological structure of Belarus is determined by its location in the Western part of the Russian plain, where 2 structural stages are presented in geological column – crystalline basement and sedimentary cover. Wide complex of ice, lake, alluvial, wind and boggy deposits enter in anthropogenic sediments rock mass structure. In methodological composition of anthropogenic sediments the following rocks predominate:

– morainic loam soil and sand clay;
– fluvioglacial and alluvial sands;
– glaciolacustrine sands, loam soil and clay soil.

The mentioned circumstances determine complexity and variety of soil of the Republic of Belarus.

### *13.2.5.1 Soil generalization according to migration intensity of $^{137}Cs$*

Whereas soil solutions play determining part in chemical elements mass transfer, including radioactive nuclides, a distribution coefficient $K_d$ in 'solid phase – vapor solution' system was used as one more parameter characterizing migration capacity of $^{137}Cs$ in soil medium.

Coefficient of interphase distribution of $^{137}Cs^{+}$ is an extent of sorption capacity in relation to radioactive nuclide. The higher distribution coefficient $K_d$ is, the less capacity of $^{137}Cs$ of turning from solid phase into soil solution becomes, and the less its mobility in the soil becomes.

Based on the results of evaluation of interphase distribution coefficient $^{137}Cs$ in 'solid phase – vapor solution' system, mineral and organic soil was differentiated in groups by migration capacity of radioactive cesium (Table 55).

**Table 55 – Differentiation of soil by mobility of $^{137}Cs$**

| Group | Soil | Mobility $^{137}Cs$ | Kd value, l/kg |
|---|---|---|---|
| | *Non-organic soil* | | |
| I | Soddy-podzolic friable sandy | Relatively high | < 1000 |
| II | Soddy-podzolic sandy loam | Medium | 1000 - 3000 |
| III | Flood plain sod sandy loam | Low | 3000 - 7000 |
| IV | Soddy-podzolic loam clay | Very low | > 7000 |
| | *Organic soil* | | |
| I | Highly organic peat-bog (RH ≥ 95 %), acid and very acid ($pH_{KCl}$ <5) | Relatively high | < 1000 |
| II | Boggy and peaty (RH = 14-60 %), slightly acid and close to neutral ($pH_{KCl}$ 6-7) | Medium | 1000 - 3000 |
| III | Peaty (RH = 30-60 %), close to neutral ($pH_{KCl}$ 6-7) | Low | 3000 - 7000 |
| IV | Boggy and peat-bog (RH up to 80 %), slightly acid, close to neutral and mildly alkaline ($pH_{KCl}$ 5-8) | Very low | > 7000 |

The defined generality of radioactive nuclides migration and also Soil map of the Belarusian SSR with a scale of 1:600 000 (year 1977) was considered as a basis while carrying out soil generalization within the 30-km area of the Belarusian NPP.

All soil series seen within the 30-km area of the Belarusian NPP were classified by characteristic of $^{137}Cs$ migration intensity. Results of generalization are shown in Table 56 and in Figure 62.

**Table 56 – Soil classification based on migration intensity of $^{137}Cs$**

| Group | Soil type number | Mobility $^{137}Cs$ | Colour on the map |
|---|---|---|---|
| I | 42; 43 | low | |
| II | 4; 6; 7; 11; 12; 13; 19; 32; 40; 47; 48 | moderate | |
| III | 27; 28; 14; 15; 16 | increased | |
| IV | 44; 46 | high | |

| Подвижность цезия-137 | $^{137}$Cesium mobility |
|---|---|
| низкая | Low |
| умеренная | Moderate |
| повышенная | Increased |
| высокая | High |

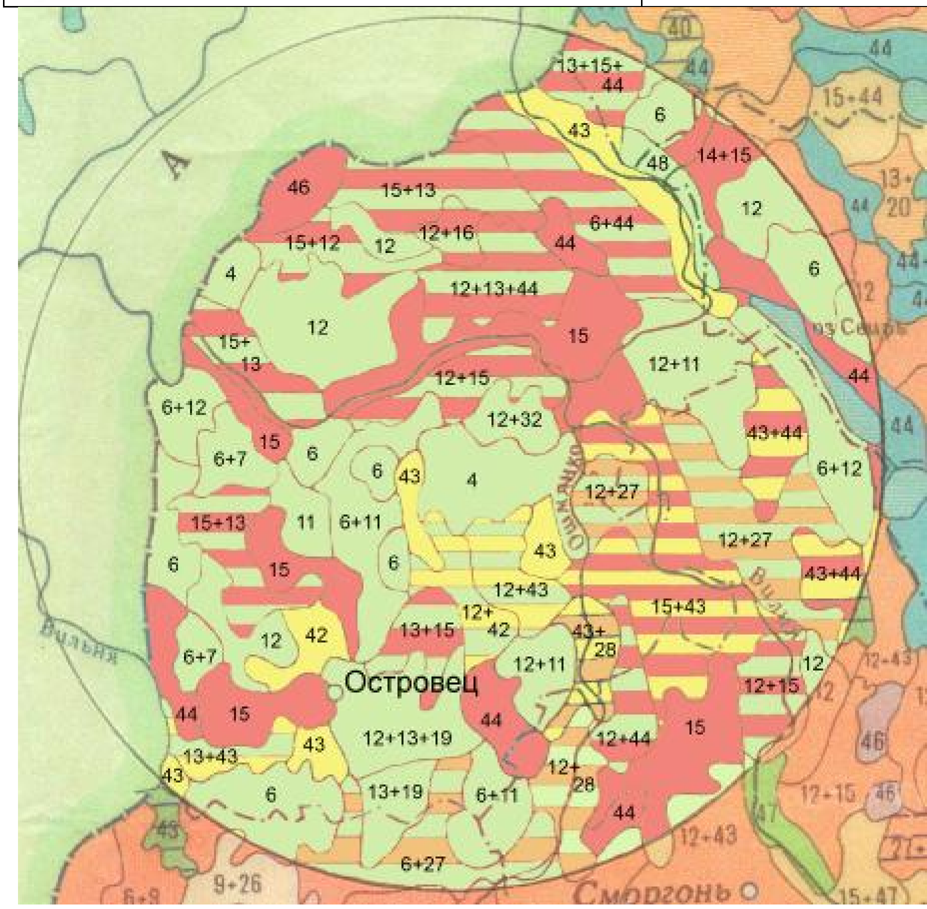



**Figure 62 – Generalization of soil by vertical migration intensity of $^{137}Cs$ within the 30-km area of the Belarusian NPP**

It is clearly described in Figure 62 that within the 30-km area of the NPP planned construction site, about 10 % of the territory is occupied by soil with low migration level of $^{137}Cs$, more than 60 % of the territory is occupied by soil with moderate migration capacity of this radioactive nuclide, 4,4 % - is occupied by soil with increased migration capacity, and 25,2 % of the territory is occupied by soil where high migration capacity of $^{137}Cs$ is observed.

Therefore more than 70 % of the territory of the 30-km area is occupied by soil where mobility of $^{137}Cs$ is low and moderate. This is a positive factor for assessment of site from the point of view of NPP location. The territory of the site of the Belarusian NPP itself is mostly occupied by soil with moderate migration capacity of $^{137}Cs$.

*13.2.5.2 Generalization of soil by migration intensity of $^{90}Sr$*

On the basis of real data in relation to $^{90}Sr$ distribution over vertical soil profiles a migration parameters of $^{90}Sr$ in various types of soil was defined, i.e. coefficient of quasidiffusion ($D_k$) in accordance with Konstantinov-Kovalenko quasidiffusion model of radioactive nuclides migration and effective velocity of coordinate movement of average weighted quantity of $^{90}Sr$ [68-70].

Differentiation of soil taken from fixed control stations by migration capacity of $^{90}Sr$ in accordance with effective velocity of coordinate deepening of the average weighted quantity of radioactive nuclide (V, cm/year) is shown in Table 57.

**Table 57 – Differentiation of soil by migration intensity of $^{90}Sr$ in accordance with movement velocity of coordinate of its average weighted quantity**

| Group | Soil | Migration intensity of $^{90}Sr$ | $V_D$, cm/year |
|---|---|---|---|
| I | – waterlogged peat-bog;<br>– soddy-podzolic friable sandy | high | more than 1.5 |
| II | – soddy-podzolic gleyic and gley (overmoisturized);<br>– soddy-gley (overmoistened) | increased | 1.0–1.5 |
| III | – automorphous soddy-podzolic of various grading (sandy, sandy loam, loamy soil, clay);<br>– semihydromorphic (temporary overmoistened) soddy-podzolic , sod and alluvial sod | moderate | 0.5–1.0 |
| IV | – meliorated boggy and peaty-like | low | less than 0.5 |

Differences between migration intensity of $^{90}Sr$ in various types of soil are determined by different physical and chemical condition of radioactive nuclide in soils, which differ by grading, content and mineral and organic composition, acidity, moisture-holding capacity, moisture conditions.

Based on the results of interphase distribution coefficient of $^{90}Sr$ in 'solid phase – vapor solution' system evaluation, for soil samples of various types and analysis of available data, soil was classified by migration capacity of radioactive nuclide. The defined soil groups and corresponding value of interphase distribution coefficients of $^{90}Sr$ ($K_d$) are shown in Table 58.

It is obvious from the available data that in most of organic soil in condition of full water saturation, a quantity of $^{90}Sr$ in interstitial water (1,0–3,2 %) exceeds the corresponding amount of radioactive nuclide in interstitial water of soddy-podzolic soil (0,6–0,9 %). This could occur because organic soil samples have more high moisture-holding capacity, which could achieve 500 % and more, while moisture-holding capacity of mineral soil samples do not exceed 85 %.

**Table 58 - lassification of soil by migration intensity of $^{90}Sr$ in accordance with coefficient value $K_d$**

| Group | Soil | Migration capacity of $^{90}Sr$ | $K_{d}$, |
|---|---|---|---|
| A | Soddy-podzolic friable sandy | high | ≤ 50 |
| B | Soddy-podzolic sandy loam<br>Alluvial sod | moderate | > 60–80 |
| C | Meliorated boggy and peat-like, slightly acid and close to neutral | low | 90–200 |
| D | Highly organic peat-bog soil | very low | ≥ 500 |

While classifying the soil within the 30-km area of the Belarusian NPP by migration intensity process of $^{90}Sr$, the following data were used:

– data on vertical migration of radioactive nuclide in soil of various types, contaminated with products of Chernobyl accident [68-70];

– results of $^{90}Sr$ distribution between interstitial moisture and solid phase of soil, being fully saturated along with the balanced distribution of radioactive nuclide in 'solid phase – interstitial soil solution' system [71-75];

– peculiarities of soil sorption complex and soil medium which influence on physical and chemical condition and migration of $^{90}Sr$ in soil.

Taking into consideration the influence of various factors, generalization of soil by migration intensity of $^{90}Sr$ was carried out, results are shown in Table 59 and Figure 63.

**Table 59 – Classification of soil within the 30-km area of the Belarusian NPP by migration intensity of $^{90}Sr$**

| Soil type number | Mobility of $^{90}Sr$ | Colour on the map |
|---|---|---|
| No | low | |
| 4; 6; 7; 11–15; 19 | moderate | (light green) |
| 27; 28; 32; 40; 42; 43; 47 | increased | (orange) |
| 16; 44; 46; 48 | high | (red) |

It is clearly described in Figure 63, that most of the territory of the 30-km area (85,4 % of the area of the Belarusian territory) is occupied by soil for which moderate mobility of $^{90}Sr$ is typical.

Surface of soil with increased mobility of $^{90}Sr$ is 9,4 %, and soil with high mobility of radioactive nuclide is 5,2 % of the Belarusian territory within the 30-km area of the Belarusian NPP.

The soil map shows that the examined territory is almost free from soil with low mobility of $^{90}Sr$.

| | |
|---|---|
| Подвижность стронция-90 | Mobility of strontium-90 |
| умеренная | Moderate |
| повышенная | Increased |
| высокая | High |

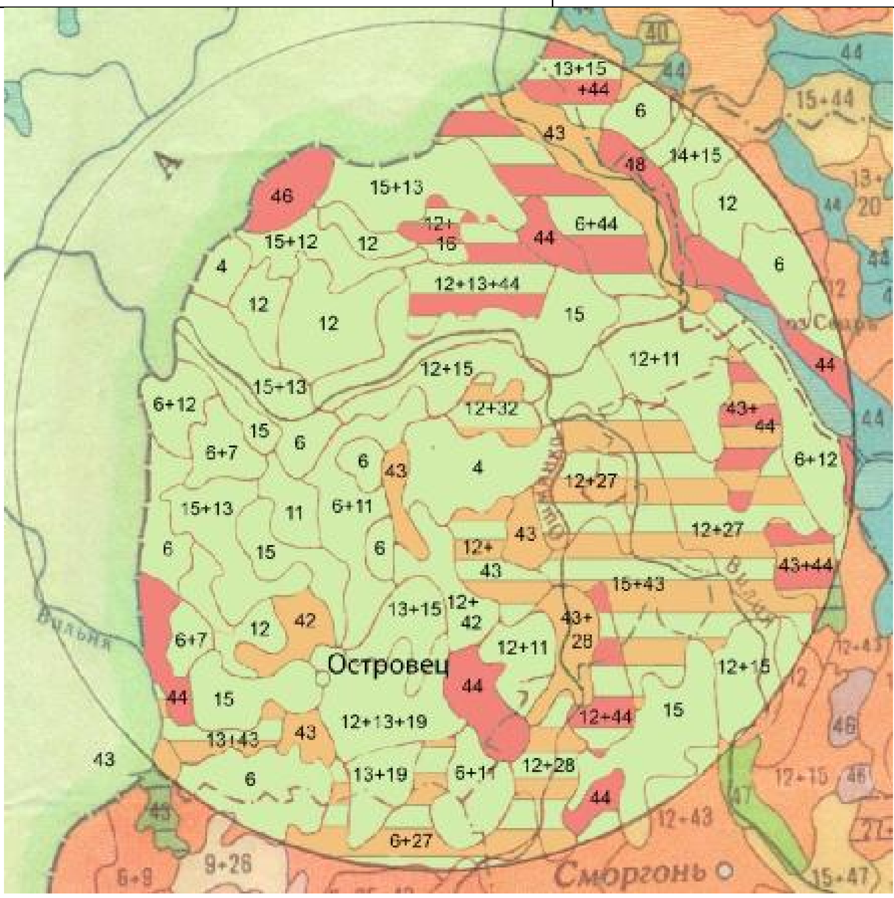



**Figure 63 - Generalization of soil within the 30-km area of the Belarusian NPP by migration intensity of $^{90}Sr$.**

Thus the most territory of the 30-km area of the planned construction site of the Belarusian NPP is occupied by soil with moderate mobility of $^{90}Sr$. This factor is a positive factor while assessment of site availability for location of radiation-dangerous object.

### *13.2.6 The Atmosphere*

#### *13.2.6.1 Chemical contamination*

Atmosphere monitoring in the Republic of Belarus is made in accordance with the following regulatory legal acts:

- Regulation on the procedure of the atmosphere monitoring and usage of its data as a part of the National Environment Monitoring System in the Republic of Belarus. The Regulation is approved by Decree No. 482 of the Cabinet of Ministers of the Republic of Belarus on April 28th, 2004.
- Instruction on procedure of the atmosphere monitoring, approved by Resolution of the Ministry of Natural Resources of the Republic of Belarus, No. 70 dated August 7th, 2004.

Whereas the atmosphere is not monitored within the site of the Belarusian NPP, the following approximate background concentration of contaminating agents in the atmosphere (maximum concentrations from single ones, values of which are exceeded in 5 % of cases):

- solid particles – 0,53 MPC;
- sulfur dioxide – 0,03 MPC;
- carbon oxide – 0,40 MPC;
- nitrogen dioxide – 0,18 MPC.

**Table 60 - Values of maximum permissible concentration of contaminating agent in the atmosphere**

| Agent | Formula | MPC value, µg/m$^3$ | | |
|---|---|---|---|---|
| | | max single | daily average | annual average |
| Solid particles | | 300,0 | 150,0 | 100 |
| Sulfur dioxide | $SO_2$ | 500,0 | 200,0 | 50,0 |
| Carbon oxide | CO | 5000,0 | 3000,0 | 500,0 |
| Nitrogen dioxide | $NO_2$ | 250,0 | 100,0 | 40,0 |

#### *13.2.6.2 Radiation situation*

The atmosphere radiation monitoring was carried out in five settlements within the 30-km area of the Belarusian NPP: Oshmyany, Lyntupy, Naroch, Vileika, Volozhin. Here is radiation monitoring stations where gamma-radiation intensity (INT) is measured every day.

Results of radiation monitoring show that during the period of 2003 – 2008 average annual INT in survey points was within: Oshmyany, Grodno region 0,10 – 0.11 µSv/hour, settlement Lyntupy, Vitebsk region – 0,10 – 0.12 µSv/hour, health resort Naroch, Vitebsk region – 0,10 – 0,11 µSv/hour, Vileika, Minsk region – 0,10 – 0,11 µSv/hour, Volozhin, Minsk region– 0,10 – 0,12 µSv/hour, and this correspond with long-term steady-state values.

In survey points Lyntupy (~55-km from the NPP site) and Naroch (~60 km from the NPP site) sampling of natural fallout from surface level of atmosphere was made by means of horizontal lipped boards. Sampling is made every day and total beta activity is measured in samples, and content of gamma-emitting radioactive nuclides is measured in combined monthly samples.

Time history of total beta-activity content in samples of radioactive fallouts from surface level of the atmosphere, taken in survey points in Lyntupy and Naroch is shown in Figure 64.

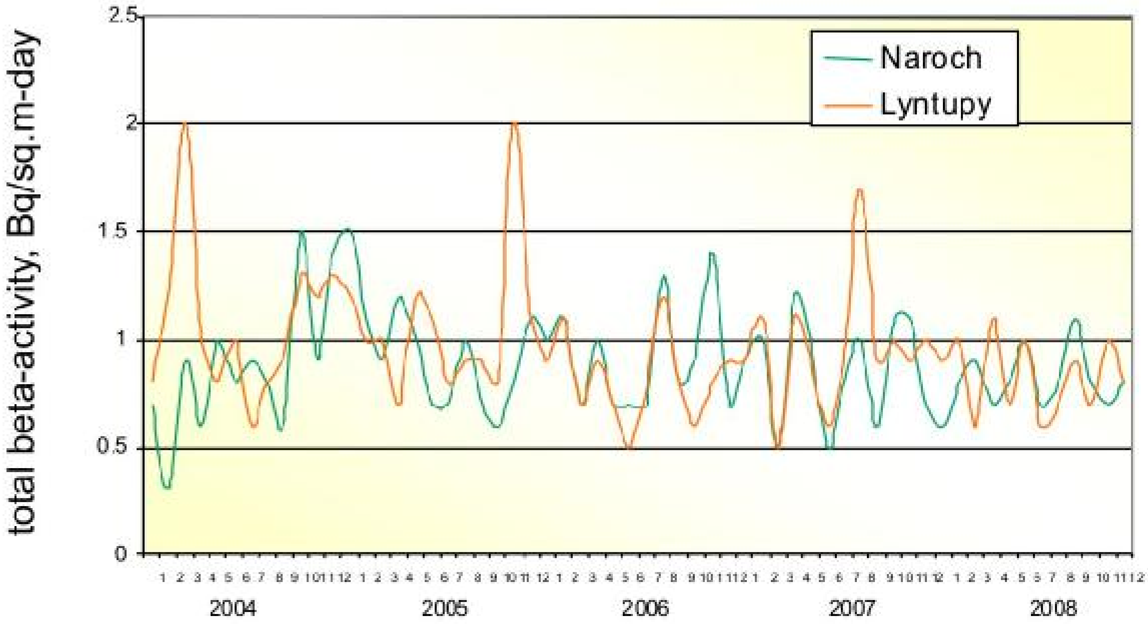



**Figure 64 - Time history of the total beta-activity change in samples of radioactive fallouts taken in survey points in settlement Lyntupy and health resort Naroch, Minsk Region for the period of 2004-2008**

During the field studies made in 2008, atmosphere samples for detection of radioactive aerosol were taken using mobile filter units.

Bleed down time is 8 hours, air volume is 1109,2 cubic meters. Measurement of activity concentration of $^{137}$Cs in the atmosphere samples was made in gamma-spectrometric laboratory of the Republican Center of Radiation Control and Environment Monitoring. Compound assay made of 4 radioactive aerosol samples was analyzed. The assay was analyzed with the help of gamma spectrometer ADCAM/100. ORTEC, USA, gamma range: 50-3000 keV. Measurement error was 20-25 %. Content of $^{137}$Cs in radioactive aerosol compound assay corresponded to the long-term level typical for this district and amounted to $0{,}12 \cdot 10^{-5}$ Bq/cubic meter.

## 13.3 Meteorological and aerological conditions

According to climate classification by B.P.Alisov which is based on atmosphere circulation conditions, 30-km area of the Belarusian NPP is situated in temperate climatic zone, where air mass of middle latitudes prevails.

Subject to climatic zonation [National Security Standard 2.04.02-2000 Construction climatology], the territory of interest is in the second climatic region (subregion IIB).

Maritime and continental types of climate are identified in a temperate zone depending on maritime or continental air mass origin. The nature and intensity of primary climate factors considerably vary with the seasons.

*Winter.* In the area of the NPP, winter is mostly mild due to the influence of warm maritime air masses from the Atlantic and the Mediterranean Sea. Frequent change of these air masses with cold arctic and continental masses leads to constant change of frost and thaw periods. In winter cloudy weather prevails, precipitation is characteristic of more than half of winter days. Precipitation is mostly in the form of snow, but in thaw periods they can also be in the form of drizzle, continuous rain or snowy rain. The coldest winter month is January and its monthly mean air temperature ranges between 6.5 below zero to 6.7 °C below zero.

*Spring.* In spring there is a quick rise in air temperature and intensive snow melting. Cloudiness and air relative humidity decreases. Nevertheless, in spring there could be periodical returns of cold weather because of Arctic air intrusion. Arctic air leads to sudden fall of temperature and air and ground frosts. This could last till mid-May, and sometimes could be even occur in June. In spring there are about 12-15 days with precipitation in each month. Precipitation pattern changes and continuous rains change into downpour.

*Summer* is warm, temperate and humid. In summer circulating processes slacken, and the role of solar radiation in weather formation increases. This accounts for more settled weather in summer. In some years even in the middle of summer a fall of temperature is possible because of Arctic air mass intrusion, when maritime air from the Atlantic Ocean brings cool and rainy weather. About 12-15 days of each month may be with heavy but not continuous rains. Downpour is frequently accompanied with thunderstorms and sometimes hails. The warmest month is July, its monthly mean air temperature is 16.9-17.0 °C, but in some years the highest temperatures were noted in August or June.

*Autumn.* In autumn solar radiation inflow decreases and cloudiness increases. Cyclonic activity and western air-mass transfer increases and brings much moisture which leads to continuous cloudiness and precipitation. In spite of general weather deterioration and temperature decrease, there could be returns of warm weather in autumn. Temperature fall is accompanied with an increase of relative air humidity. Cloudy days grow in number. Foggy days are frequent. In November, the first snow cover could be formed.

The primary characteristics of regional climate within the 30-km area of the Belarusian NPP are presented on the basis of observation data of nearby meteorological stations in Oshmyany and Lyntupy. The said meteorological stations are situated at a distance of 30 and 40 km from the NPP location (Lyntupy and Oshmyany, respectively). Aerological characteristics of atmospheric boundary layer were given on the basis of data collected by aerological stations in Minsk and Kaunas. In several cases aerological data supplied by the aerological stations in Mozyr (Gomel region) and Brest were used for assessment.

Meteorological conditions of the northern part of 30-km NPP area have been supplied by the Lyntupy meteorological station and those of the southern part by the Oshmyany meteorological station. Such conditional zoning of the 30-km area was adopted to find out zonality (regularity) in the change of various meteorological features within the area. However, with the area being very small and located within the same physiographic region, its meteorological features (temperature and air humidity, cloudiness, exhalation, solar radiation, prevailing wind transfer, snow cover, etc) are mostly similar to those of the whole zone. The above-mentioned meteorological stations have a long-term experience (more than 40 years) in observation and recording by main meteorological parameters, which provide their reliability.

### *13.3.1 Meteorological conditions*

#### *13.3.1.1 Insolation*

Solar radiation in the NPP area is measured on the basis of long-term data records of the nearest meteorological station which has been carrying out complete actinometrical observation (city of Minsk). The station is a model one for the 30-km area of the Belarusian NPP under consideration. Information on sunshine duration is submitted by the (more than 40 years) meteorological station (MS).

The following data are considered: direct, diffused and total solar radiation over horizontal surface and radiation balance under average cloudiness, and also sunshine duration (Table 61).

Solar radiation is the highest in June – July, the lowest – in December. Annual total of direct solar radiation within the 30-km NPP area is 1705 mJ/sq.m, and that of diffused solar radiation is 1973 mJ/sq.m.

**Table 61 – Total amount of direct, diffused and total solar radiation over horizontal surface and radiation balance under average cloudiness mJ/sq.m, sunshine duration in hours**

| Month | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | |
| Direct solar radiation | | | | | | | | | | | | |
| 15 | 39 | 116 | 179 | 282 | 309 | 300 | 241 | 140 | 61 | 15 | 8 | 1705 |
| Diffused solar radiation | | | | | | | | | | | | |
| 49 | 89 | 160 | 221 | 284 | 293 | 292 | 245 | 166 | 97 | 45 | 32 | 1973 |
| Total solar radiation | | | | | | | | | | | | |
| 64 | 128 | 276 | 400 | 566 | 602 | 592 | 486 | 306 | 158 | 60 | 40 | 3678 |
| Radiation balance over active surface | | | | | | | | | | | | |
| -18 | -6 | 56 | 190 | 294 | 322 | 315 | 241 | 126 | 42 | -4 | -18 | 1540 |
| Sunshine duration | | | | | | | | | | | | |
| 37 | 59 | 126 | 173 | 262 | 252 | 270 | 236 | 142 | 109 | 39 | 25 | 1730 |

Sunshine duration is determined by time when the Sun is over the horizon and by cloudiness. It is influenced by shielding of horizon with buildings (especially in cities), forests, and hills.

Sunshine duration during a year amounts to 1730 hours. The lowest sunshine duration is noted in December (25 hours), the highest in July (270 hours). The six warm months account for almost 80 % of the annual sunshine.

#### *13.3.1.2 Air temperature*

One of the main climatic features describing peculiarities of thermal conditions in the region is a mean air temperature. Its annual change depends on radioactive conditions and seasonal changes in atmospheric circulation and is characterized by small variation from month to month in winter and summer and drastic variation in mid-seasons (spring and autumn).

Annual change in the monthly mean air temperature within the 30-km area of the Belarusian NPP is characterized by the highest values in July (16.9-17.0 °C) and the lowest values – in January (6.5 °C below zero … 6.7 °C below zero).

In some years monthly mean air temperature in July was just 13.2-13.4 °C (1979 ) or reached 2.0-21.3°C (2001); in relatively mild winters mean air temperature in January rose above zero by 0.5-0.6°C (1989), and in severe winters monthly mean air temperature declined to 16.2 °C below zero … 16.3 °C below zero (1987). Maximum air temperature characterizes the hottest part of the day and is about 14 – 15 o'clock. Annual change of maximum air temperature is similar to annual change of monthly mean air temperature. The lowest values are recorded in winter months, the highest – in summer.

Absolute maximum and absolute minimum of air temperature illustrates its highest and lowest values in particular days.

In the period between December and February, the absolute maximum of air temperature is 9-14°C; after final loss of snow cover its values grow intensively and reach 18-19 °C in March, 26-28 °C in April, 30-31°C in May. The highest temperature is observed in July – August (34-35 °C).

In October temperature decreases, however return of warm weather could lead to a rise in air temperature to 22-23°C. In December absolute maximum of air temperature falls to 9-10°C.

Absolute maximum air temperature of 34.6°C has been accepted as an absolute maximum for the 30-km area of the Belarusian NPP. During the observation periods of interest, the hottest summer was in 1999.

Considerable fall of air temperature occurs due to travel of cold arctic masses with low humidity, and also due to inflow of cold continental air from the East.

The lowest air temperature is in January-February. Extremely low air temperature (absolute minimum) is also recorded during these months. Within the area of interest, the absolute minimum is 37.3 °C below zero …39.8 °C below zero. In the area of interest, the coldest winter was recorded in the periods 1962-1963 and 1984-1985.

In the area of interest, frost-free season lasts about 140-149 days. Its longest duration was observed in 1967 (181 days), the shortest – in 2004 (109 days).

Diurnal change of air temperature depends on weather type. In summer this dependence is more pronounced than in winter. For calm and clear weather, diurnal temperature is almost twice as high as that of cloudy and windy weather. In winter, significant diurnal variation in temperature is caused by passage of atmospheric fronts and sudden change of air masses. In spring and autumn, significant diurnal variation in temperature is observed if air is well warmed and well cooled at night because of nocturnal radiation.

In the area of interest, maximum diurnal variation in air temperature is normally observed in summer, and minimum variation in November.

The analysis of temperature condition within the 30-km area of the Belarusian NPP shows that temperature characteristics of air are almost similar over the area.

*13.3.1.3 Soil temperature*

The temperature of soil depends on many factors – air temperature, physical and mechanical soil composition, moisture content of soil, plant or snow cover, height of station, etc. Vertical temperature gradients of soil are opposite in sign in winter and summer periods. In warm seasons, the temperature of soil falls when passing to more deep soil layers, and in cold seasons the temperature rises. Diurnal fluctuation in soil temperature is pronounced.

The highest temperature of soil is observed in July. In August the temperature of soil starts to decrease. During successive months (September to October), the decrease in temperature becomes more intensive. The lowest temperature of soil surface is in January to February. Table 62 shows the annual change of monthly mean temperature of soil surface as well as the absolute maximum and minimum temperatures.

In the territory of interest, the average annual temperature of soil surface is 6-7 ºC, and the said temperature is a little bit higher than the average annual air temperature (5.2-5.4 ºC). The absolute minimum of soil surface temperature is within 54-60 ºC, and the absolute minimum reaches 36 ºC below zero.

In spite of the fact that the surface soil layer differs in type, its temperature is characterized by practically the same values in the territory of interest.

**Table 62 – Annual and monthly average temperature. Maximum and minimum soil surface temperature, ºC**

| Feature | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | Год |
| Meteorological station Oshmyany, sandy loam | | | | | | | | | | | | | |
| Average | -7 | -6 | -2 | 6 | 15 | 19 | 20 | 19 | 12 | 6 | 1 | -4 | 7 |
| Absolute maximum | 11 | 13 | 28 | 43 | 47 | 50 | 54 | 47 | 45 | 32 | 16 | 9 | 54 |
| Absolute minimum | -32 | -35 | -28 | -9 | -6 | 1 | 6 | 4 | -3 | -11 | -24 | -36 | -36 |
| Meteorological station Lyntupy, loamy sand | | | | | | | | | | | | | |
| Average | -7 | -7 | -4 | 6 | 15 | 20 | 21 | 19 | 12 | 6 | 0 | -4 | 6 |
| Absolute maximum | 9 | 12 | 32 | 49 | 54 | 58 | 60 | 54 | 45 | 31 | 17 | 9 | 60 |
| Absolute minimum | -34 | -36 | -33 | -16 | -6 | 0 | 3 | 3 | -6 | -20 | -26 | -36 | -36 |

Analysis of data on average monthly and annual soil temperature measured at standard depth with a pull-out temperature meter shows that the average annual soil temperature is almost the same regardless of the depth.

In cold seasons a slightly subzero temperature is only recorded at the depth of 0.2 m and is 0.1 ºC below zero … 0.5 ºC below zero. In deeper layers the temperature remains above zero but continues to fall till March-April.

At the depth of 3.2 m, the highest soil temperature is noted in September (10.6-11.0 ºC), while the maximum temperature at the depth of 0.2m is recorded in July (17.0 - 18.2 ºC).

*13.3.1.4 Atmospheric humidity*

Atmospheric humidity is determined by the content of water vapor in the air. Atmospheric humidity influences such natural processes as evaporation rate on water reservoir surface and soil surface, transpiration from vegetation, appearance of frosts and mists.

Atmospheric humidity is characterized by the following factors: partial pressure of water vapor, relative humidity, and saturation deficit (Table 63).

Annual change of air relative humidity is characterized by the highest values during cold period of a year and the lowest – during warm period, while annual change of partial pressure and saturation deficit follow the annual change of air temperature, i.e. the highest values are observed in the hottest summer months, the lowest are observed in winter months.

**Table 63 – Average monthly and annual values of atmospheric humidity**

| MS | Month | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | |
| Oshmyany | Relative air humidity, % | | | | | | | | | | | | |
| | 87 | 85 | 80 | 74 | 69 | 72 | 75 | 76 | 81 | 85 | 89 | 90 | 80 |
| | Partial pressure of water vapor | | | | | | | | | | | | |
| | 3,8 | 3,9 | 4,8 | 6,8 | 9,7 | 12,6 | 14,1 | 13,5 | 10.8 | 8,2 | 6,0 | 4,6 | 8,2 |
| | Saturation deficit, hPa | | | | | | | | | | | | |
| | 0,4 | 0,5 | 1,2 | 2,9 | 5,3 | 5,9 | 5,7 | 4,8 | 2,8 | 1,5 | 0,6 | 0,4 | 2,7 |
| Lyntupy | Relative air humidity, % | | | | | | | | | | | | |
| | 88 | 86 | 81 | 75 | 69 | 72 | 75 | 78 | 83 | 86 | 90 | 91 | 81 |
| | Partial pressure of water vapor, hPa | | | | | | | | | | | | |
| | 3,9 | 3,8 | 4,5 | 6,7 | 9,4 | 12,4 | 14,1 | 13,7 | 10,9 | 8,1 | 5,9 | 4,6 | 8,2 |
| | Saturation deficit, hPa | | | | | | | | | | | | |
| | 0,5 | 0,6 | 1,2 | 3,0 | 5,5 | 5,8 | 5,7 | 5,4 | 3,2 | 1,6 | 0,7 | 0,5 | 2,8 |

Characteristics of atmospheric humidity within the territory of interest shown in Table 63 are almost similar:

- average annual relative humidity is 80-81 %;
- average annual partial pressure of water vapor is similar for both stations and is 8.2 hPa;
- saturation deficit is 2.7-2.8 hPa.

Generally, the number of humid days over a year, i.e. days with relative humidity of 80 % and more, is great – 145-147 days. Their maximum quantity is observed in December – 26-27 days, minimum in May – 4 days.

In the area of interest, the number of dry days when relative humidity falls below 30 % in daytime is low – 11-12 days. They are typical for warm period of the year and their maximum quantity is recorded in May – about 5 days.

*13.3.1.5 Cloudiness*

Cloudiness is determined by interaction of the primary climatic factors such as atmospheric circulation, radiation and geological substrate. The key one among them is atmospheric circulation, especially in the cold part of the year.

This chapter discusses the key quantitative characteristics of cloudiness such as total and lower cloudiness and the number of clear and cloudy days (Table 64).

**Table 64 – Average monthly and annual total and lower cloudiness, points**

| Cloudiness | Month | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | |
| Oshmyany | | | | | | | | | | | | | |
| Total | 7,9 | 7,7 | 6,7 | 6,5 | 5,8 | 6,0 | 6,0 | 5,5 | 6,3 | 7,0 | 8,3 | 8,5 | 6,9 |
| Lower | 6,9 | 6,5 | 5,2 | 4,6 | 3,8 | 4,0 | 4,1 | 3,6 | 4,8 | 5,8 | 7,5 | 7,8 | 5,4 |
| Lyntupy | | | | | | | | | | | | | |
| Total | 8,1 | 7,8 | 6,7 | 6,6 | 6,1 | 6,3 | 6,3 | 6,1 | 6,6 | 7,3 | 8,5 | 8,5 | 7,1 |
| Lower | 6,8 | 6,1 | 4,8 | 4,2 | 3,3 | 3,5 | 3,6 | 3,5 | 4,4 | 5,6 | 7,5 | 7,6 | 5,1 |

Annual cloudiness within the territory of interest amounts to 6.9-7.1 points by total cloudiness and 5.1-5.4 points by lower cloudiness. In a cold period, the sky is mostly covered with clouds (6.7-8.5 points by total cloudiness). The lower cloudiness is more pronounced in November-December (7.5-7.8 points). The lowest total cloudiness is observed in August (5.5-6.1 points), the lowest lower cloudiness is observed in May (3.3-3.8 points). In cold periods, diurnal variation in cloudiness is slight, in warm periods the highest cloudiness is observed at midday hours, when convective processes are more developed, the lowest cloudiness is observed at night.

Annual change of clear and cloudy days by total and lower cloudiness is well-defined (Table 65). During the year, for the total cloudiness clear days are mostly observed in August, for lower cloudiness they are observed in May and August, the lowest number of them is in November-December. Most cloudy days are observed in the cold period of the year with the maximum number of them in December, the lowest number of them is in the warm period of the year with the minimum number in July-August.

**Table 65 – Average number of clear and cloudy days for total and lower cloudiness**

| **Cloudiness** | Month | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | |
| Oshmyany | | | | | | | | | | | | | |
| Clear days | | | | | | | | | | | | | |
| Total | 1,7 | 1,4 | 3,4 | 2,7 | 3,0 | 2,1 | 2,1 | 3,3 | 2,6 | 2,2 | 1,0 | 0,9 | 26 |
| Lower | 3,3 | 3,3 | 6,4 | 6,1 | 7,5 | 5,9 | 5,2 | 7,6 | 5,1 | 4,4 | 1,9 | 1,7 | 58 |
| Cloudy days | | | | | | | | | | | | | |
| Total | 18,2 | 15,3 | 12,6 | 10,5 | 7,6 | 8,1 | 8,2 | 5,7 | 9,3 | 13,4 | 18,4 | 20,0 | 147 |
| Lower | 14,1 | 11,7 | 7,8 | 4,8 | 2,9 | 2,7 | 2,1 | 2,1 | 5,2 | 9,5 | 15,9 | 17,3 | 96 |
| Lyntupy | | | | | | | | | | | | | |
| Clear days | | | | | | | | | | | | | |
| Total | 1,5 | 1,3 | 2,9 | 2,3 | 2,6 | 2,1 | 1,8 | 2,7 | 2,2 | 1,7 | 0,8 | 0,8 | 23 |
| Lower | 4,3 | 4,4 | 7,7 | 8,7 | 11,2 | 8,7 | 7,9 | 9,7 | 6,8 | 5,3 | 2,2 | 2,1 | 79 |
| Cloudy days | | | | | | | | | | | | | |
| Total | 18,4 | 15,2 | 13,0 | 10,9 | 8,9 | 9,3 | 9,9 | 7,3 | 11,0 | 13,5 | 19,1 | 19,6 | 156 |
| Lower | 13,5 | 10,7 | 7,4 | 4,5 | 2,3 | 2,2 | 1,9 | 1,3 | 4,2 | 7,7 | 14,5 | 15,9 | 86 |

*13.3.1.6 Atmospheric precipitation*

As to the amount of atmospheric precipitation received, the area of interest and Belarus as a whole may be sufficiently moisturized zone. All types of precipitation are recorded here: rain precipitations, solid precipitations and combined precipitations (Table 66). Precipitation distribution is irregular over the year. Total amount of winter precipitation is just about 17 % of annual precipitation, while spring accounts for 21 %, summer for 37 %, and autumn for 25 %.

In annual variation of precipitation, the lowest monthly precipitation is observed in February (31-39 mm). The amount of precipitation gradually increases starting from March to July, when the maximum monthly precipitation (89-91mm) is observed. The amount of precipitation gradually decreases starting from August and reaches 35-44 mm in January. Annual precipitation in the northern area is 741 mm, and that in the southern area is 645 mm.

According to the type of atmospheric precipitation, a year may be divided into two periods: cold (November-March), where solid precipitation prevails, and warm, where rain precipitation prevails (April-October). Within the 30-km area of the Belarusian NPP, the cold period accounts for 29-32 % of annual precipitation and the warm period for 68-71 % of annual precipitation.

Thus, within the area of interest precipitation annual change of continental type is observed, where total precipitation of a warm period exceeds total precipitation of a cold period.

Within the 30-km area of the Belarusian NPP/ the maximum annual total precipitation is 1075 mm in the northern part and 828 mm in the southern part. The minimum monthly total precipitation of 215-322 mm is recorded in August.

The least annual total precipitation within the 30-km area of the Belarusian NPP changes from 445 mm in the southern part of the area to 527 mm in the northern part.

**Table 66 – Monthly and annual amount of rain, solid and combined precipitation, mm**

| Precipitation | Month | | | | | | | | | | | | Year | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | мм | % |
| Oshmyany | | | | | | | | | | | | | | |
| Solid | 15 | 16 | 16 | 3 | | | | | | | 6 | 13 | 69 | 11 |
| Rain | 5 | 6 | 9 | 30 | 51 | 76 | 91 | 83 | 59 | 48 | 24 | 16 | 498 | 77 |
| Combined | 15 | 9 | 9 | 9 | 3 | | | | | 4 | 16 | 13 | 78 | 12 |
| Lyntupy | | | | | | | | | | | | | | |
| Solid | 34 | 27 | 18 | 2 | 1 | | | | | 1 | 10 | 21 | 114 | 15 |
| Rain | 1 | 2 | 8 | 27 | 56 | 87 | 89 | 86 | 68 | 50 | 29 | 12 | 515 | 70 |
| Combined | 9 | 10 | 17 | 20 | 3 | | | | 3 | 10 | 19 | 21 | 112 | 15 |

Solid and combined precipitations are specific for autumn, winter and spring months/ The amount of solid precipitations is 11-15 % of their total annual amount, amount of rain precipitations is 70-77 % and that of combined precipitations is 12-15 %.

Daily precipitation differs from precipitation within long periods of time and has more pronounced local peculiarities.

In the southern part of the territory of interest, the maximum diurnal precipitation was recorded in May, in the northern part – in June. Moreover, the maximum diurnal precipitation in the southern part of the area (101 mm) exceeded the maximum diurnal precipitation in the northern part of the area (80 mm).

The lowest maximum diurnal precipitation is observed in the cold period of the year (13-17 mm).

In warm seasons of the year, the amount of diurnal precipitation could be close to monthly precipitation or exceed it.

Rain which brings more than 30 mm of precipitation for a 24-hour period is classified as abundant and considered to be dangerous for national economy. For the most part, they fall in summer; however they are also possible in May and September.

Within the 30-km area of the Belarusian NPP, the average number of days with precipitation varies from 184 days to 193 days, the maximum number varies from 206 days to 235 days. The maximum number of days with precipitation is in July – about 15.

The average and maximum monthly and annual duration of all precipitation type is shown in Table 67, values are in hours.

**Table 67 – Average and maximum monthly and annual duration of all precipitation type, hours**

| Settlement | Month | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | |
| Oshmyany | Average duration of precipitation | | | | | | | | | | | | |
| | 156 | 157 | 110 | 68 | 54 | 43 | 42 | 40 | 51 | 78 | 115 | 150 | 1064 |
| | Maximum duration of precipitation | | | | | | | | | | | | |
| | 236 | 221 | 205 | 117 | 104 | 87 | 107 | 138 | 123 | 201 | 160 | 205 | 1329 |
| Lyntupy | Average duration of precipitation | | | | | | | | | | | | |
| | 191 | 187 | 138 | 92 | 69 | 60 | 47 | 54 | 68 | 118 | 151 | 180 | 1355 |
| | Maximum duration of precipitation | | | | | | | | | | | | |
| | 276 | 246 | 236 | 182 | 139 | 126 | 124 | 176 | 148 | 234 | 205 | 243 | 1669 |

In the northern part of the 30-km area, duration of precipitation is longer than in the southern part. The most long-lasting precipitation is in winter, when the average duration of precipitation is 150-191 h/month.

Data on maximum precipitation rate within various time periods are introduced for the period of 1991-2008 and submitted by the Oshmyany meteorological station, where the recording rain gauge is located (Table 68).

**Table 68 – Maximum precipitation rate within various time periods, mm/minute (observed)**

| Feature | Size | Time period | | | | |
|---|---|---|---|---|---|---|
| | | Minute | | | Hour | |
| | | 10 | 20 | 30 | 1 | 6 |
| Rate | mm/min | 1,65 | 1,12 | 1,07 | 0,86 | 0,25 |
| Precipitation deoth | | 16,5 | 22,4 | 32,0 | 51,5 | 88,5 |
| Date | | 15.06.1998 | 28.05.2002 | | | |

Analyses of data on atmospheric precipitation within the 30-km area of the Belarusian NPP show:

- precipitation distribution over the territory is local. In the northern part of the area, average annual precipitation is the highest (741 mm), in the southern part is the lowest (645 mm);
- diurnal maximum of precipitation reaches its highest values in the southern part of the area (101 mm) and lowest values – in the northern part (80 mm) of the same;
- precipitation rate within various periods of time is approximately accepted as the same for the whole area.

*13.3.1.7 Snow cover*

During cold period of the year, part of precipitation falls in the form of snow. Position of snow cover is characterized by its depth, density and water content in snow.

Snow cover in the territory of interest is formed within approximately a month starting from the date of snow cover appearance to formation of steady snow cover, i.e. from November 6 -7 to December 7-14.

In some years snow cover could be formed before the mentioned mean dates or after them.

Generally, first snow doesn't' lie during the whole winter, it melts and goes away and then is formed again.

Fracture of stable snow cover is observed in March. Therefore, within the 30-km area of the Belarusian NPP, the number of days with snow is 11-120 days (Table 69). Intensity of stable snow cover fracture and its loss depends on local conditions. In low protected places and in forests snow melting goes slower. Last dates of stable snow cover fracture – are April 14-30.

**Table 69– Average number of days with snow cover, dates of formation and loss of snow cover**

| Settlement | Date of snow cover formation | Date of stable snow cover formation | Date of stable snow cover fracture | Date of snow cover loss | Number of days with snow cover |
|---|---|---|---|---|---|
| Oshmyany | 6,11 | 14,12 | 9,03 | 14,04 | 111 |
| Lyntupy | 7,11 | 7,12 | 28,03 | 14,04 | 120 |

Since the formation of stable snow cover its depth gradually grows during winter and reaches its maximum depth in the third ten-day period of February. In the territory of interest, the average ten-day period snow cover depth is 19-26 cm at the end of February; the deepest of the average snow cover is 25-34 cm. The maximum depth of snow cover is 58-72 cm during winter and was recorded in the first ten-day period of March.

Density of snow cover depends on weather conditions. Average values of snow cover density in December, when new snow is still friable and not compact, are 0.19-0.22 g/cubic cm. In March when snow is melting and compacts, the snow cover density raises up to 0.26-0.32 g/cubic cm. the average density of snow cover at its highest ten-day depth is 0.24-0.25 g/cubic cm.

Water storage in the snow cover at the beginning of winter (December) is 15-23 mm; it increases to the end of February up to 49-69 mm. During winter the highest water storage in snow cover was 195 mm. Water storage in snow mostly depends on its location altitude, its protection and relief.

Seasonal earth freezing depends on many factors: soil moisture, depth of snow cover, type of soil and its mechanical composition, and lay of land, etc.

The average of the highest earth freezing depth recorded by Oshmyany station over the year is 78 cm, the highest is 142 cm. Soil in this district is in the form of light silty loam underlaid by moraine loam at depth of 0.5 m. In Lyntupy, soil is a sandy loam underlaid by sand. The average of the highest earth freezing depth in winter here is 63 cm, the highest is 123 cm.

### *13.3.1.8 Evaporation*

Evaporation is an inflow of water vapor into atmosphere from water, snow, ice, moistened soil surface, etc.

Evaporation from water surface or evaporation from overmoistened land represents a potentially possible evaporation in the present location in atmospheric conditions typical for it.

Total evaporation from soil and vegetation is defined with the help of evaporation tank by changing of weight soil monolith with vegetation on it for a period between separate weighting of evaporator.

Evaporation observation starts in spring after snow cover loss when the soil becomes well-moistened and continues to freezing of soil to the depth of more 5 cm in autumn or to formation of stable snow cover.

Data on evaporation from soil and vegetation in the territory of interest is shown in Table 70 (by information submitted by meteorological station in Volkovysk).

**Table 70– Total evaporation from soil and vegetation during warm period, mm**

| Month | | | | | | 05-10 |
|---|---|---|---|---|---|---|
| 05 | 06I | 07 | 08 | 09 | 10 | |
| 82 | 75 | 83 | 64 | 39 | 27 | 370 |

Total land evaporation (gross evaporation) during warm period within the territory of interest is 370 mm, the highest monthly amount is 83 mm, and falls in July.

Depending on meteorological conditions of each year, evaporation values sufficiently deviate from mean values.

**Table 71 – Evaporation from water surface within period when ice is not formed in years which differ by moistening (calculated), mm**

| Year characteristic, P % | Month | | | | | | | | April-November period |
|---|---|---|---|---|---|---|---|---|---|
| | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | |
| Average, 50 % | 20 | 66 | 92 | 112 | 97 | 61 | 35 | 25 | 509 |
| Dry, 95 % | 25 | 82 | 113 | 139 | 120 | 76 | 44 | 31 | 630 |

During a year of average moisture (50 % of exceeding probability) total evaporation from water surface within a period when ice is not formed in the territory of Ostrovets district, the Grodno region, is 509 mm, during a dry year (moisture is 95 % of exceeding probability) – 630 mm (Table 71).

The highest monthly total evaporation from water surface is observed during the period between June and August and in dry year it could amount to 113–139 mm monthly. In a year of average moisture during the same period evaporation amounts to 92–112 mm monthly, this is 19 % less.

### *13.3.2 General atmospheric circulation*

General atmospheric circulation is one of the factors affecting the climate system and has a great impact on the formation of climate regime of individual regions. The main elements of the general atmospheric circulation are low-pressure cells (cyclones) and high-pressure cells (anticyclones).

Atmospheric processes are the main factors determining the diffusing power of atmosphere over any location. The circulation condition defines the aeroclimatic parameters and characteristics of the location, including: repeatability, yield and intensity of temperature inversions (near the ground, when the temperature rise starts from the ground surface, and raised, when the temperature rise starts from a certain point above the ground surface), the direction and speed of the wind on heights, necessary to calculate the diffusing power of the atmosphere.

Based on the results of long-term observations of atmosphere pollution, the following unfavorable synoptic situations, which define the formation of long periods pertaining to the high pollution level, have been detected:

- a non-mobile cyclone or wedge;
- a degraded gradientless baric field;
- periphery of a cyclone or wedge.

Air masses, moving from the Atlantic Ocean, prevail over the territory of the Republic of Belarus. Transfer of the air masses takes place in the course of various circulation processes as a result of activity of the cyclones, which move in series, and anticyclones or high-pressure wedges, which form in the rear of the cyclones. Cyclones, which generally move from the East to the West (due to the influence of the Coriolis force), bring the sea air with great deposit of moisture. In most cases cyclones, while moving to the East, are filled or do not change their intensity, and only a few, which pass over the territory of Belarus, continue deepening. After filling, some cyclones become non-mobile, and then cloudy weather with slight frost and snowfall is observed for a few days in winter, and in summer the weather is cloudy and rainy at the beginning, and then, when the air warms up, it changes to unsteady with showery rains and thunderstorms. These conditions are unfavorable for the development of inversions and accumulation of polluting substances.

In all seasons the repetitiveness of the cyclonic circulation form in the territory of the Republic of Belarus, as well as over the territory under review, is more anticyclonic. The weather is often influenced by peripheral parts of cyclones and anticyclones. At average, cyclonic processes are observed for up to 200 days (55 %) a year, and anticyclonic – for up to 150 days a year (about 40 %).

In winter, the territory of the Republic of Belarus is usually influenced by North-Western and Western cyclones. Long-term warming takes place, when the North of Western Europe is occupied by a vast area of low pressure, and the South – by a high pressure area or a wedge of the Azores anticyclone. In that case, Western flows prevail, carrying warm moist air from the Atlantic to the territory of the Republic. The spread of warm air masses takes place in the course of other atmospheric processes as well. The most intensive warming with thaw, considerable rainfall, snowstorms and glaze are observed when South-Western (Mediterranean) and Southern (Black Sea) cyclones emerge, bringing very warm air from corresponding seas in their warm sectors. Heat efflux is observed less frequently under North-Western current, when cyclones from the North of the Atlantic “dive” into the South-Eastern part of Western Europe along the periphery of the anticyclone, which occupies Western Europe. The approach of such cyclones causes short-term warming, which alternates to a cold snap after the cyclone passes. The latter is accompanied by a significant wind power increase, snowfalls and snowstorms. Raised inversions usually form in these transitional baric fields, which are characterized by heat efflux.

The invasion of colder air masses – arctic air – takes place in the rear of cyclones and in the front area of anticyclones. With the invasion of arctic air the weather changes significantly. From the North-West, from the area of the Norwegian and Greenland seas Arctic sea air invades, which soon cools down while moving over the snow mantle of land. It comes to Belarus thoroughly cooled and is often accompanied by mainly clear weather. Continental Arctic air occurs in the area of territories under consideration much less frequently. It invades from the direction of Kara and Barents seas and brings about clear weather. Alongside with that further cooling occurs, a motionless cyclone is formed and powerful ground inversions develop.

In spring, winter processes gradually change to summer ones. The repetitiveness of South-Western and Southern cyclones increases, which is closely connected with the powerful warm air flow from the Mediterranean. These first long-term heat effluxes are unmistakable signs of spring coming. In many cases in the areas of territories under consideration returns of cold weather are observed, caused by the flow of Arctic air from North-West, North or North-East. It brings about cold snaps and ground frost.

In summer the influence of Black Sea and static cyclones, which bring about intense and long-lasting rains, increases. Intense cold bursts, which are often accompanied with storm and hail, are observed in the course of transit of slowly moving cold fronts with waves and withdrawal of Southern cyclones. Rainfall takes place in plain air masses in case of development of thermal convection in the second half of the day.

In summer the wedge of the Azores cyclone develops significantly, which brings about very warm dry weather to the Republic. The most dry and hot weather is observed in case of settlement of the anticyclone over the South-Eastern part of Eastern Europe and low-gradient areas of high pressure, formed in warm dry air. Hot weather is also caused by Southern cyclones, in the warm sectors of which tropical air efflux takes place.

In autumn summer, processes change to winter ones, therefore the repetitiveness of North-Western and Western cyclones increases. During this period the weather is cloudy and it often rains. Most rainfall is carried by cyclones, moving from the Mediterranean and Black Seas, but their repetitiveness is low. Warm and sunny days also occur in autumn (also known as “Indian summer”). Such weather is preconditioned by the efflux of air masses from the South along the Western periphery of a motionless anticyclone, located over the South-Eastern part of Eastern Europe, or the influence of the Azores anticyclone wedge. The invasion of Arctic air masses and their additional cooling at night under the anticyclonic weather regime causes the formation of powerful ground inversions in Belarus.

In general, in connection with the variability of the atmospheric circulation and interchange of air masses, which vary in their characteristics, quite favorable conditions for the spread of pollutants over the territory of Belarus, especially in its North-Eastern part, are observed.

#### *13.3.2.1 Wind regime (in accordance with the data from surface observations)*

Wind is the horizontal movement of air against ground surface. Wind speed and its direction are considered to be its characteristics. Both of them are defined by the baric field, which is, in this case, characteristic of Belarus as a whole and the roughness of the geological substance of the territory under consideration.

Wind regime is the main factor, defining the spread of pollutants. Horizontal transmission of polluting substances, their evacuation from the emission point and removal beyond the boundaries of the 30-killometer area is connected with the wind.

Unfavorable conditions for the spread of pollutants and atmosphere self-purification are formed in case of weak winds at the speed of less than 2 m/s and still air.

For the analysis of wind within the 30-killometer zone of the Belarusian nuclear power plant the observation data from Oshmyany and Lyntupy weather stations were used.

In the course of the year within the 30-killometer zone of the Belarusian nuclear power plant winds from the South-Western quarter of the horizon prevail, whereas in the Southern part the most clearly marked is the Western direction (11 %) and in the northern part - the southern one (12 %).

In winter the repetitiveness of winds of Western and South-South-Western directions (12 % each) in the Southern part of the 30-killometer zone is the highest, in the Northern part the repetitiveness of winds of the Southern direction is the highest (13 %).

In spring winds of the Western direction prevail in the Southern part of the zone (9 %), in the Northern part – the winds of the Southern direction (10 %).

In summer in the Southern and Northern parts of the zone winds of the Western direction prevail (13 %).

In autumn the repetitiveness of winds of Sothern, South-South-Western, South-Western and Western-Southern-Western directions (11 % each) in the Southern part of the 30-killometer zone is the highest, in the Northern part the repetitiveness of winds of the Southern direction is the highest (15 %).

The number of calmness periods during the year is the greatest in the Northern part of the zone (9%), and the least in the Southern part (3 %).

Showing individual seasons the greatest number of calmness periods occurs in summer with 5 % in the Southern part of the zone and 14 % in the Northern part.

In Tables 72 and 73 data on repetitiveness of wind directions in various parts of the territory of the 30-killometer zone of the Belarusian nuclear power plant are given per month, per season and per year.

Characteristics of wind speeds according to directions in the territory under consideration are also given in Tables 72 and 73, and without directions – in Table 74.

As you can see from Tables 72 and 73 winds of Southern, South-South-Western, South-Western and West-South-Western directions have the highest average speeds per direction (2,9-3,0 m/s) within of the territory of the 30-killometer zone of the Belarusian nuclear power plant during the year, winds of North-North-Western, Northern and North-North-Eastern directions have the lowest (1.8-1.9 m/s) speed.

Showing individual seasons the highest average seasonal speeds in spring and autumn (3.0 m/s) belong to winds of Sothern and South-Western directions. In winter the highest average seasonal speeds (3.2 m/s) belong to winds of Southern, South-South-Western and South-Western directions. In summer the highest average seasonal speeds belong to winds of South-Western and West-South-Western directions (2.6 m/s).

Within the year in the Southern part of the 30-killometer area of the Belarusian nuclear power plant the highest yearly average wind speeds according to directions (4.1 m/s) belong to winds of Western and West-North-Western directions, the lowest speeds (2,4 m/s) belong to winds of East-North-Eastern and Eastern directions.

**Table 72 – Repetitiveness of wind directions and calmness periods according to directions in the southern part of the 30-killometer area of the Belarusian nuclear power plant, Oshmyany weather station**

| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Calmness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 5 | 9 | 13 | 12 | 13 | 12 | 5 | 3 | 3 | 3 |
| II | 4 | 5 | 7 | 6 | 6 | 5 | 5 | 4 | 8 | 10 | 9 | 9 | 11 | 4 | 4 | 3 | 3 |
| III | 3 | 4 | 6 | 7 | 8 | 7 | 5 | 5 | 9 | 9 | 8 | 9 | 10 | 4 | 3 | 3 | 3 |
| IV | 6 | 6 | 7 | 7 | 8 | 6 | 5 | 5 | 6 | 6 | 6 | 8 | 9 | 5 | 5 | 5 | 4 |
| V | 7 | 8 | 8 | 7 | 8 | 5 | 4 | 4 | 6 | 5 | 5 | 7 | 9 | 6 | 6 | 5 | 4 |
| VI | 7 | 6 | 6 | 5 | 5 | 3 | 2 | 3 | 6 | 6 | 6 | 10 | 14 | 8 | 7 | 6 | 5 |
| VII | 6 | 6 | 6 | 5 | 5 | 3 | 3 | 3 | 5 | 7 | 8 | 10 | 12 | 8 | 7 | 6 | 5 |
| VIII | 5 | 5 | 6 | 6 | 5 | 3 | 3 | 4 | 7 | 8 | 8 | 11 | 13 | 7 | 5 | 4 | 7 |
| IX | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 9 | 10 | 10 | 11 | 10 | 5 | 5 | 3 | 5 |
| X | 3 | 3 | 3 | 4 | 5 | 5 | 5 | 5 | 10 | 11 | 12 | 11 | 10 | 5 | 4 | 4 | 3 |
| XI | 3 | 3 | 3 | 4 | 5 | 3 | 5 | 8 | 13 | 12 | 12 | 11 | 9 | 3 | 3 | 3 | 3 |
| XII | 3 | 2 | 3 | 3 | 4 | 4 | 4 | 6 | 11 | 13 | 13 | 11 | 11 | 5 | 4 | 3 | 2 |
| Winter | 3 | 3 | 5 | 4 | 5 | 4 | 4 | 5 | 9 | 12 | 11 | 11 | 12 | 5 | 4 | 3 | 3 |
| Spring | 5 | 6 | 7 | 7 | 8 | 6 | 5 | 5 | 7 | 6 | 6 | 8 | 9 | 5 | 5 | 5 | 4 |
| Summer | 6 | 6 | 6 | 5 | 5 | 3 | 3 | 3 | 6 | 7 | 7 | 10 | 13 | 8 | 7 | 5 | 5 |
| Autumn | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 5 | 11 | 11 | 11 | 11 | 10 | 4 | 4 | 3 | 3 |
| Year | 5 | 5 | 5 | 5 | 6 | 4 | 4 | 5 | 8 | 9 | 9 | 10 | 11 | 5 | 5 | 4 | 4 |
| I | 4,3 | 3,1 | 3,0 | 2,2 | 2,4 | 2,7 | 2,8 | 3,7 | 4,0 | 4,3 | 4,3 | 4,5 | 4,6 | 4,9 | 4,3 | 4,5 | |
| II | 3,6 | 3,7 | 3,3 | 2,7 | 2,3 | 3,1 | 3,0 | 4,0 | 3,7 | 4,2 | 3,9 | 4,1 | 4,2 | 4,1 | 4,0 | 4,0 | |
| III | 4,3 | 3,3 | 3,2 | 2,9 | 2,6 | 3,0 | 3,6 | 4,0 | 3,9 | 4,0 | 3,8 | 3,9 | 4,5 | 4,8 | 4,3 | 3,7 | |
| IV | 4,1 | 3,7 | 3,3 | 2,8 | 2,7 | 3,2 | 3,7 | 4,0 | 4,0 | 4,0 | 3,5 | 3,6 | 4,1 | 4,1 | 4,1 | 4,2 | |
| V | 3,8 | 3,6 | 3,2 | 2,7 | 2,5 | 2,3 | 3,3 | 3,5 | 3,8 | 3,3 | 3,1 | 3,2 | 3,8 | 3,8 | 3,8 | 3,9 | |
| VI | 3,7 | 3,3 | 2,9 | 2,4 | 2,3 | 2,8 | 2,8 | 3,2 | 3,2 | 3,1 | 2,9 | 3,2 | 3,6 | 3,7 | 3,7 | 3,6 | |
| VII | 3,2 | 2,9 | 2,6 | 2,2 | 2,1 | 2,4 | 2,7 | 2,7 | 3,0 | 2,9 | 3,1 | 3,0 | 3,4 | 3,3 | 3,4 | 3,5 | |
| VIII | 3,0 | 2,9 | 2,5 | 2,0 | 2,0 | 2,1 | 2,5 | 3,1 | 3,1 | 2,9 | 2,8 | 3,0 | 3,6 | 3,6 | 3,6 | 3,2 | |
| IX | 3,6 | 3,1 | 2,9 | 2,3 | 2,2 | 2,7 | 3,2 | 3,4 | 3,7 | 3,5 | 3,2 | 3,5 | 3,8 | 3,8 | 3,7 | 3,4 | |
| X | 3,8 | 3,1 | 2,5 | 2,2 | 2,1 | 2,9 | 3,5 | 3,9 | 3,9 | 3,9 | 3,9 | 4,0 | 4,3 | 4,1 | 3,5 | 3,8 | |
| XI | 3,9 | 2,9 | 2,4 | 2,3 | 2,6 | 2,8 | 3,6 | 4,0 | 4,2 | 4,1 | 4,2 | 4,2 | 4,7 | 4,0 | 3,8 | 4,2 | |
| XII | 3,8 | 3,5 | 3,3 | 2,4 | 2,6 | 2,8 | 3,4 | 3,7 | 4,1 | 4,4 | 4,3 | 4,6 | 4,7 | 4,6 | 4,5 | 4,2 | |

Table 72 (continued)

| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Calmness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter | 3,9 | 3,4 | 3,2 | 2,4 | 2,4 | 2,9 | 3,1 | 3,8 | 3,9 | 4,3 | 4,2 | 4,4 | 4,5 | 4,5 | 4,3 | 4,2 | |
| Spring | 4,1 | 3,5 | 3,2 | 2,8 | 2,6 | 2,8 | 3,5 | 3,8 | 3,9 | 3,8 | 3,5 | 3,6 | 4,1 | 4,2 | 4,1 | 3,9 | |
| Summer | 3,3 | 3,0 | 2,7 | 2,2 | 2,1 | 2,4 | 2,7 | 3,0 | 3,1 | 3,0 | 2,9 | 3,1 | 3,5 | 3,5 | 3,6 | 3,4 | |
| Autumn | 3,8 | 3,0 | 2,6 | 2,3 | 2,3 | 2,8 | 3,4 | 3,8 | 3,9 | 3,8 | 3,8 | 3,9 | 4,3 | 4,0 | 3,7 | 3,8 | |
| Year | 3,8 | 3,3 | 2,9 | 2,4 | 2,4 | 2,7 | 3,2 | 3,6 | 3,7 | 3,7 | 3,6 | 3,7 | 4,1 | 4,1 | 3,9 | 3,9 | |

**Table 73 – Repetitiveness of wind directions and calmness periods according to directions in the southern part of the 30-kilometer area of the Belarusian nuclear power plant, Lyntupy weather station**

| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Calmness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 2 | 3 | 3 | 2 | 3 | 5 | 6 | 8 | 12 | 12 | 12 | 11 | 10 | 5 | 4 | 2 | 5 |
| II | 4 | 5 | 5 | 5 | 4 | 4 | 6 | 8 | 12 | 9 | 9 | 9 | 9 | 5 | 3 | 3 | 5 |
| III | 3 | 4 | 5 | 5 | 6 | 5 | 6 | 10 | 14 | 8 | 7 | 9 | 8 | 4 | 3 | 3 | 8 |
| IV | 4 | 6 | 6 | 7 | 6 | 5 | 5 | 8 | 9 | 5 | 7 | 8 | 10 | 5 | 4 | 5 | 10 |
| V | 6 | 8 | 8 | 7 | 5 | 5 | 4 | 7 | 8 | 5 | 6 | 7 | 9 | 5 | 4 | 6 | 12 |
| VI | 5 | 7 | 8 | 5 | 4 | 3 | 3 | 6 | 7 | 6 | 7 | 11 | 12 | 6 | 4 | 6 | 12 |
| VII | 5 | 7 | 6 | 4 | 3 | 3 | 3 | 5 | 7 | 6 | 8 | 12 | 14 | 7 | 5 | 5 | 13 |
| VIII | 4 | 6 | 6 | 3 | 3 | 3 | 3 | 5 | 10 | 7 | 9 | 13 | 14 | 6 | 3 | 5 | 16 |
| IX | 4 | 5 | 5 | 4 | 3 | 3 | 4 | 7 | 12 | 9 | 11 | 12 | 12 | 4 | 2 | 3 | 12 |
| X | 3 | 3 | 3 | 2 | 3 | 4 | 6 | 9 | 15 | 11 | 11 | 10 | 9 | 5 | 3 | 3 | 6 |
| XI | 3 | 3 | 3 | 3 | 4 | 3 | 6 | 8 | 18 | 12 | 12 | 9 | 7 | 4 | 2 | 3 | 3 |
| XII | 3 | 3 | 3 | 2 | 3 | 3 | 4 | 8 | 16 | 13 | 12 | 11 | 9 | 4 | 3 | 3 | 4 |
| Winter | 3 | 4 | 4 | 3 | 3 | 4 | 5 | 8 | 13 | 11 | 11 | 10 | 9 | 5 | 3 | 3 | 5 |
| Spring | 4 | 6 | 6 | 6 | 6 | 5 | 5 | 8 | 10 | 6 | 7 | 8 | 9 | 5 | 4 | 5 | 10 |
| Summer | 5 | 7 | 7 | 4 | 3 | 3 | 3 | 5 | 8 | 6 | 8 | 12 | 13 | 6 | 4 | 5 | 14 |
| Autumn | 3 | 4 | 4 | 3 | 3 | 3 | 5 | 8 | 15 | 11 | 11 | 10 | 9 | 4 | 2 | 3 | 7 |
| Year | 4 | 5 | 5 | 4 | 4 | 4 | 5 | 7 | 12 | 9 | 9 | 10 | 10 | 5 | 3 | 4 | 9 |
| I | 1,6 | 1,7 | 1,7 | 1,6 | 2,1 | 1,9 | 2,1 | 2,8 | 3,1 | 3,2 | 3,3 | 3,3 | 3,1 | 2,4 | 2,3 | 1,9 | |
| II | 1,6 | 2,0 | 2,0 | 1,8 | 2,0 | 2,0 | 2,6 | 2,9 | 3,2 | 3,1 | 3,1 | 3,1 | 2,8 | 2,4 | 1,9 | 1,9 | |
| III | 2,1 | 2,0 | 2,3 | 2,3 | 2,6 | 2,1 | 2,4 | 2,7 | 3,2 | 3,0 | 3,2 | 3,1 | 3,1 | 2,6 | 2,3 | 2,2 | |

Table 73 (continued)

| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | Calmness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IV | 2,2 | 2,2 | 2,5 | 2,4 | 2,5 | 2,5 | 2,3 | 2,6 | 2,9 | 3,0 | 2,9 | 2,9 | 2,9 | 2,5 | 2,2 | 2,1 | |
| V | 2,1 | 2,2 | 2,5 | 2,6 | 2,4 | 2,3 | 2,3 | 2,5 | 2,8 | 2,7 | 2,8 | 2,6 | 2,5 | 2,2 | 2,2 | 2,1 | |
| VI | 1,9 | 1,8 | 2,1 | 2,2 | 2,2 | 2,1 | 2,0 | 2,3 | 2,4 | 2,5 | 2,6 | 2,7 | 2,6 | 2,1 | 1,9 | 1,9 | |
| VII | 1,7 | 1,8 | 2,1 | 1,8 | 1,9 | 1,9 | 2,1 | 2,2 | 2,4 | 2,5 | 2,7 | 2,6 | 2,4 | 2,1 | 2,0 | 1,6 | |
| VIII | 1,5 | 1,8 | 2,0 | 2,0 | 1,7 | 1,8 | 1,8 | 2,2 | 2,6 | 2,4 | 2,5 | 2,6 | 2,4 | 2,1 | 1,9 | 1,8 | |
| IX | 2,0 | 1,9 | 2,2 | 2,0 | 2,3 | 2,3 | 2,0 | 2,4 | 2,8 | 2,7 | 2,7 | 2,7 | 2,5 | 2,1 | 2,1 | 1,8 | |
| X | 1,7 | 1,9 | 1,9 | 1,8 | 2,0 | 2,2 | 2,7 | 2,7 | 3,0 | 3,0 | 3,1 | 2,9 | 2,7 | 2,2 | 1,7 | 1,9 | |
| XI | 1,8 | 1,7 | 1,9 | 1,7 | 1,9 | 2,1 | 2,4 | 2,8 | 3,2 | 3,1 | 3,2 | 3,0 | 2,8 | 2,4 | 2,1 | 2,0 | |
| XII | 1,8 | 1,9 | 1,6 | 2,0 | 1,8 | 1,9 | 2,7 | 2,8 | 3,4 | 3,2 | 3,3 | 3,0 | 3,0 | 2,6 | 2,2 | 1,8 | |
| Winter | 1,7 | 1,9 | 1,8 | 1,8 | 2,0 | 1,9 | 2,5 | 2,8 | 3,2 | 3,2 | 3,2 | 3,1 | 3,0 | 2,5 | 2,1 | 1,9 | |
| Spring | 2,1 | 2,1 | 2,4 | 2,4 | 2,5 | 2,3 | 2,3 | 2,6 | 3,0 | 2,9 | 3,0 | 2,9 | 2,8 | 2,4 | 2,2 | 2,1 | |
| Summer | 1,7 | 1,8 | 2,1 | 2,0 | 1,9 | 1,9 | 2,0 | 2,2 | 2,5 | 2,5 | 2,6 | 2,6 | 2,5 | 2,1 | 1,9 | 1,8 | |
| Autumn | 1,8 | 1,8 | 2,0 | 1,8 | 2,1 | 2,2 | 2,4 | 2,6 | 3,0 | 2,9 | 3,0 | 2,9 | 2,7 | 2,2 | 2,0 | 1,9 | |
| Year | 1,8 | 1,9 | 2,1 | 2,0 | 2,1 | 2,1 | 2,3 | 2,6 | 2,9 | 2,9 | 3,0 | 2,9 | 2,8 | 2,3 | 2,1 | 1,9 | |

Showing individual seasons the highest average seasonal speeds in winter (4.5 m/s) belong to winds of the Western and West-North-Western directions. In spring the highest speeds (4.2 m/s) belong to winds of the West-North-Western direction. In summer the highest seasonal average speeds (3.6 m/s) belong to winds of the North-Western direction. In autumn the highest speeds belong to winds of the Western direction 4.3 m/s).

**Table 74 – Average monthly and annual winter speed without directions, m/s**

| Settlement | Month | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | |
| Oshmyany | 4,3 | 4,0 | 3,8 | 3,7 | 3,4 | 3,3 | 3,1 | 2,9 | 3,4 | 3,9 | 4,1 | 4,2 | 3,7 |
| Lyntupy | 2,9 | 2,8 | 2,7 | 2,4 | 2,2 | 2,1 | 2,0 | 1,9 | 2,2 | 2,6 | 2,9 | 2,9 | 2,5 |

As you can see from Table 74 the yearly average speed (without directions) in the territory of the zone under consideration increases from 2.5 m/s in the Northern part of the zone to 3.7 m/s in the Southern part. In winter monthly average speeds are between 2.8-2.9 m/s in the Northern part and 4.0-4.3 m/s in the Southern part.

The repetitiveness of various wind speeds (without directions) is given according to the data from Oshmyany weather station in Table 75.

**Table 75– The repetitiveness of various wind speeds (without directions) (% from the whole number of periods of wind observation)**

| Month | Wind Speed, m/s | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-1 | 2-3 | 4-5 | 6-7 | 8-9 | 10-11 | 12-13 | 14-15 | 16-17 |
| I | 7,2 | 28,6 | 36,7 | 18,5 | 6,0 | 2,0 | 0,8 | 0,2 | 0,04 |
| II | 9,3 | 31,1 | 37,2 | 16,0 | 5,3 | 0,9 | 0,2 | 0,04 | |
| III | 10,9 | 36,2 | 32,7 | 14,9 | 4,4 | 0,8 | 0,1 | | |
| IV | 15,4 | 38,4 | 29,7 | 12,1 | 3,8 | 0,4 | 0,2 | | |
| V | 15,0 | 38,8 | 29,1 | 12,6 | 3,6 | 0,8 | 0,1 | | |
| VI | 16,3 | 42,5 | 27,9 | 10,8 | 2,1 | 0,4 | 0,04 | | |
| VII | 18,9 | 42,9 | 27,7 | 8,4 | 1,6 | 0,4 | 0,1 | | |
| VIII | 20,6 | 43,9 | 26,6 | 6,9 | 1,6 | 0,4 | | | |
| IX | 18,3 | 41,8 | 27,0 | 10,0 | 2,5 | 0,4 | | | |
| X | 11,7 | 38,6 | 32,7 | 12,9 | 3,6 | 0,4 | 0,1 | | |
| XI | 8,8 | 35,1 | 37,6 | 14,2 | 3,8 | 0,4 | 0,1 | | |
| XII | 7,3 | 33,9 | 39,0 | 14,9 | 4,4 | 0,4 | 0,1 | | |
| Year | 13,3 | 37,6 | 32,0 | 12,7 | 3,6 | 0,6 | 0,2 | 0,02 | 0,003 |

Within the year wind at the speed of up to 5 m/s (82.9 % of cases) is observed, speeds of 6-9 m/s are observed in approximately 16.3 % of cases, and speeds of 10 m/s – in less than 1 % of cases.

In summer the repetitiveness of low wind speeds rises significantly. Wind speeds of 2.5 m/s are observed in all wind directions and show to be most sustained.

In summer the number of calmness periods rises significantly – from 5 % at Oshmyany weather station to 14 % at Lyntupy weather station.

According to observations at Oshmyany weather station wind speed of 13 m/s can be observed once in 2 years, 16 m/s – once in 5 years, 18 m/s – once in 10 years, 20 m/s – once in 20 years and 24 m/s – once in 50 years. Maximum wind speed was recorded in 1969 and constituted 30 m/s, the maximum stormy gust of 36 m/s was recorded in 1967.

*13.3.2.2 Wind regime (according to the data from up-air observations). Wind diagrams at the height of 100, 200, 300 and 500 m*

Description of the wind regime for the heights of 100, 200, 300 and 500 meters above the sea level. Average wind speeds and repetitiveness of wind directions are estimated. According to the data from observations of upper-air stations in Belarus within a year winds of Western directions prevail in the wind diagrams during the year with a slightly overwhelming repetitiveness of winds of the South-Eastern quarter marked in spring (see Table 76).

**Table 76 – Repetitiveness of wind directions at the height of 100, 200, 300 and 500 meters according to 16 points showing individual seasons and per year (wind diagram) according to the data from the Minsk upper-air station, %**

| Season | Repetitiveness, %, of wind directions (%) according to 16 points | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
| at the height of 100 m | | | | | | | | | | | | | | | | |
| Winter | 2 | 2 | 2 | 2 | 2 | 5 | 7 | 5 | 7 | 9 | 10 | 12 | 12 | 12 | 11 | 4 |
| Spring | 7 | 4 | 5 | 5 | 6 | 7 | 9 | 9 | 6 | 7 | 6 | 5 | 5 | 6 | 6 | 6 |
| Summer | 7 | 5 | 4 | 3 | 3 | 4 | 3 | 3 | 5 | 6 | 7 | 9 | 9 | 11 | 11 | 9 |
| Autumn | 5 | 3 | 2 | 2 | 3 | 3 | 6 | 7 | 7 | 9 | 10 | 10 | 10 | 11 | 8 | 6 |
| Year | 5 | 4 | 3 | 3 | 4 | 5 | 6 | 6 | 6 | 8 | 8 | 9 | 9 | 10 | 9 | 6 |
| at the height of 200 m | | | | | | | | | | | | | | | | |
| Winter | 3 | 2 | 2 | 2 | 2 | 3 | 7 | 6 | 8 | 8 | 10 | 10 | 13 | 11 | 8 | 5 |
| Spring | 6 | 5 | 4 | 5 | 4 | 5 | 8 | 10 | 6 | 7 | 7 | 5 | 7 | 8 | 7 | 6 |
| Summer | 7 | 6 | 5 | 3 | 3 | 2 | 4 | 3 | 5 | 6 | 7 | 7 | 11 | 11 | 10 | 10 |
| Autumn | 5 | 4 | 2 | 1 | 2 | 3 | 6 | 6 | 9 | 7 | 9 | 9 | 13 | 9 | 10 | 5 |
| Year | 5 | 4 | 4 | 3 | 3 | 3 | 6 | 6 | 7 | 7 | 8 | 8 | 11 | 10 | 9 | 6 |
| at the height of 300 m | | | | | | | | | | | | | | | | |
| Winter | 3 | 3 | 2 | 2 | 4 | 6 | 11 | 10 | 9 | 9 | 8 | 6 | 9 | 7 | 6 | 5 |
| Spring | 6 | 2 | 6 | 5 | 5 | 5 | 7 | 8 | 9 | 8 | 11 | 7 | 7 | 6 | 5 | 3 |
| Summer | 9 | 8 | 6 | 4 | 3 | 3 | 1 | 5 | 3 | 6 | 4 | 6 | 16 | 13 | 7 | 6 |
| Autumn | 3 | 1 | 1 | 1 | 1 | 0 | 1 | 4 | 8 | 6 | 13 | 11 | 15 | 17 | 10 | 7 |
| Year | 5 | 4 | 4 | 3 | 3 | 3 | 5 | 7 | 7 | 7 | 9 | 8 | 12 | 11 | 7 | 5 |
| at the height of 500 m | | | | | | | | | | | | | | | | |
| Winter | 5 | 1 | 3 | 2 | 4 | 4 | 9 | 10 | 7 | 10 | 10 | 6 | 7 | 9 | 7 | 6 |
| Spring | 7 | 3 | 4 | 4 | 2 | 4 | 8 | 10 | 9 | 9 | 10 | 6 | 8 | 7 | 5 | 4 |
| Summer | 8 | 10 | 5 | 4 | 4 | 3 | 4 | 3 | 4 | 5 | 4 | 5 | 12 | 11 | 11 | 7 |
| Autumn | 4 | 2 | 1 | 1 | | 1 | | 2 | 6 | 7 | 11 | 14 | 16 | 15 | 12 | 8 |
| Year | 6 | 4 | 3 | 3 | 3 | 3 | 5 | 6 | 6 | 8 | 9 | 8 | 11 | 10 | 9 | 6 |

According to the data from upper-air stations in general moderate winds are characteristic of the territory of Belarus up to the height of 500 meters: annual average values change from year to year within the range of airs of 4-6 m/s at the height of

100 meters to 10-13 m/s at the height of 500 meters. In wind speed distribution there is a consistent, almost synchronic increase connected with the increase of height. A general tendency of average wind speed increase with the increase of height is observed in the cold season of the year.

**Table 77 – Distribution of average wind speeds at the heights of 16 (at the meteorological pad), 100, 200, 300 and 500 meters per season and per year, m/s**

| Height, m | Winter | Spring | Summer | Autumn | Year |
|---|---|---|---|---|---|
| 16 | 3,1 | 2,8 | 2,2 | 2,7 | 2,7 |
| 100 | 8,1 | 6,7 | 6,0 | 6,8 | 6,9 |
| 200 | 9,4 | 7,6 | 6,7 | 8,2 | 8,0 |
| 300 | 9,9 | 8,0 | 7,1 | 9,0 | 8,5 |
| 500 | 11,7 | 9,0 | 7,7 | 10,4 | 9,7 |

In wind speed distribution there is a consistent, almost synchronic increase connected with the increase of height. Of all seasons, winter is marked with the highest wind speeds, the lowest wind speeds are observed in summer, with spring and autumn showing intermediate values. The speed of autumn winds increases more significantly with the increase of height.

As it can be seen from Table 78, the distribution of average speed in points has a seasonal pattern: the highest speeds at the heights of 100, 200, 300 and 500 meters are recorded in autumn and winter and fall at the winds of the Western, Southern and Northern quarter and range from 6-7 m/s at the height of 100 meters to 12-13 m/s at the height of 500 meters. Summer is characterized by minimum wind speed values, although in the directions, mentioned above, speeds are the highest. The lowest speeds fall at the North-Eastern and Eastern points in almost all seasons of the year.

**Table 78 – Distribution at the height of 100, 200, 300 and 500 meters according to 16 points per season and per year, m/s**

| Season | Repetitiveness, % of wind directions (%) according to 16 points | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
| at the height of 100 m | | | | | | | | | | | | | | | | |
| Winter | 4,4 | 4,4 | 4,9 | 5,7 | 5,4 | 8,4 | 7,4 | 7,3 | 6,6 | 6,7 | 7,0 | 6,6 | 7,1 | 6,8 | 6,5 | 6,1 |
| Spring | 5,5 | 5,0 | 4,9 | 5,8 | 5,7 | 5,9 | 6,6 | 6,7 | 6,4 | 6,2 | 5,8 | 5,7 | 6,0 | 5,4 | 6,0 | 5,1 |
| Summer | 4,4 | 4,3 | 4,0 | 4,1 | 4,2 | 4,6 | 5,4 | 5,5 | 6,0 | 5,5 | 4,9 | 5,1 | 4,9 | 5,1 | 5,0 | 4,5 |
| Autumn | 5,4 | 4,0 | 3,5 | 4,3 | 5,5 | 7,0 | 6,9 | 7,3 | 5,8 | 5,3 | 6,7 | 6,0 | 6,0 | 6,0 | 5,6 | 4,9 |
| Year | 4,9 | 4,4 | 4,3 | 5,0 | 5,2 | 6,5 | 6,7 | 6,8 | 6,2 | 5,9 | 6,2 | 5,9 | 6,0 | 5,8 | 5,8 | 5,2 |
| at the height of 200 m | | | | | | | | | | | | | | | | |
| Winter | 5,7 | 5,9 | 6,3 | 7,3 | 7,4 | 9,2 | 10,6 | 9,4 | 8,6 | 8,6 | 9,3 | 9,5 | 9,6 | 9,6 | 9,5 | 8,6 |
| Spring | 7,3 | 6,5 | 6,9 | 7,3 | 7,9 | 7,4 | 7,8 | 8,7 | 8,3 | 7,9 | 7,8 | 8,0 | 8,2 | 7,5 | 6,6 | 6,2 |

Table 78 (continued)

| Season | Repetitiveness. %. of wind directions (%) according to 16 points | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
| Summer | 6,1 | 6,3 | 5,7 | 5,6 | 5,3 | 5,3 | 5,9 | 7,2 | 7,0 | 7,2 | 6,4 | 7,0 | 6,7 | 6,9 | 7,4 | 6,6 |
| Autumn | 7,4 | 6,7 | 6,1 | 5,0 | 6,0 | 8,1 | 9,2 | 8,8 | 7,7 | 8,8 | 8,5 | 7,6 | 8,5 | 8,9 | 8,0 | 7,6 |
| Year | 6,6 | 6,4 | 6,3 | 6,3 | 6,7 | 7,5 | 8,4 | 8,5 | 7,9 | 8,1 | 8,0 | 8,0 | 8,3 | 8,2 | 7,9 | 7,3 |
| at the height of 300 m | | | | | | | | | | | | | | | | |
| Winter | 6,8 | 7,4 | 7,5 | 6,5 | 7,7 | 11,8 | 10,6 | 9,7 | 9,1 | 8,4 | 9,4 | 9,7 | 11,5 | 9,7 | 8,9 | 10,1 |
| Spring | 6,6 | 6,6 | 6,5 | 6,2 | 5,5 | 5,9 | 8,3 | 6,8 | 8,3 | 9,4 | 8,6 | 8,2 | 8,1 | 7,4 | 7,6 | 7,3 |
| Summer | 7,7 | 7,9 | 5,5 | 7,5 | 5,4 | 4,3 | 5,6 | 9,0 | 6,9 | 6,6 | 4,8 | 6,6 | 6,7 | 5,6 | 8,0 | 5,8 |
| Autumn | 6,3 | 8,5 | 6,3 | 5,3 | 4,0 | 4,0 | 6,7 | 10,0 | 9,6 | 10,7 | 10,8 | 10,0 | 10,9 | 10,2 | 9,3 | 11,4 |
| Year | 6,9 | 7,6 | 6,4 | 6,4 | 5,7 | 6,5 | 7,8 | 8,9 | 8,5 | 8,8 | 8,4 | 8,6 | 9,3 | 8,2 | 8,4 | 8,6 |
| at the height of 500 m | | | | | | | | | | | | | | | | |
| Winter | 7,8 | 9,8 | 7,2 | 6,2 | 6,6 | 7,0 | 9,7 | 11,3 | 9,4 | 9,6 | 8,8 | 9,6 | 12,0 | 12,5 | 9,9 | 10,8 |
| Spring | 6,8 | 6,6 | 7,5 | 6,7 | 7,7 | 6,6 | 7,6 | 6,8 | 9,6 | 8,7 | 10,3 | 9,1 | 9,3 | 8,5 | 7,7 | 6,0 |
| Summer | 6,7 | 6,8 | 6,3 | 6,7 | 6,0 | 6,4 | 6,1 | 6,6 | 7,6 | 9,4 | 6,8 | 6,7 | 7,6 | 8,2 | 6,9 | 7,8 |
| Autumn | 9,1 | 6,3 | 6,0 | 5,4 | 5,4 | 6,0 | 6,0 | 8,3 | 12,5 | 11,3 | 9,2 | 11,1 | 12,6 | 10,1 | 10,3 | 12,0 |
| Year | 7,6 | 7,4 | 6,8 | 6,3 | 6,4 | 6,5 | 7,4 | 8,2 | 9,8 | 9,7 | 8,8 | 9,1 | 10,4 | 9,8 | 8,7 | 9,2 |

In the repetitiveness of wind according to the grading a consistent growth of repetitiveness of high wind speeds with the increase of height is observed (see Table 79). Strong winds (16 m/s and higher) are observed in from less than 0.5 % of cases at the height of 100 m and to 9 % of cases at the height of 500 m. In some seasons of the year (in winter mostly) this value rises to 10-15 %.

**Table 79 - Repetitiveness of average wind speeds according to grading at the height of 100, 200, 300 and 500 meters per season and per year, %**

| Season | Repetitiveness, %, of average wind speeds according to grading | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0-1 | 2-3 | 4-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 |
| at the height of 100 m | | | | | | | | |
| Winter | 2 | 11 | 17 | 54 | 15 | 1 | | |
| Spring | 2 | 19 | 31 | 43 | 5 | | | |
| Summer | 4 | 29 | 28 | 35 | 4 | 0 | | |
| Autumn | 2 | 9 | 21 | 58 | 10 | | | |
| Year | 2 | 17 | 24 | 48 | 9 | 0 | | |
| at the height of 200 m | | | | | | | | |
| Winter | 1 | 7 | 11 | 44 | 32 | 5 | | |
| Spring | 1 | 14 | 23 | 45 | 16 | 1 | | |
| Summer | 2 | 17 | 25 | 42 | 12 | 2 | | |
| Autumn | 0 | 5 | 12 | 53 | 28 | 2 | | |
| Year | 1 | 11 | 18 | 46 | 22 | 2 | | |
| at the height of 300 m | | | | | | | | |
| Winter | 0 | 7 | 11 | 37 | 32 | 12 | 1 | |
| Spring | 1 | 12 | 20 | 45 | 20 | 2 | | |

Table 79 (continued)

| Season | Repetitiveness, %, of average wind speeds according to grading | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0-1 | 2-3 | 4-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 |
| Summer | 3 | 20 | 21 | 39 | 15 | 2 | 0 | |
| Autumn | 1 | 4 | 10 | 41 | 36 | 8 | | |
| Year | 1 | 11 | 15 | 41 | 26 | 6 | | |
| at the height of 500 m | | | | | | | | |
| Winter | 1 | 6 | 12 | 34 | 28 | 15 | 4 | 0 |
| Spring | 2 | 10 | 18 | 45 | 19 | 5 | 1 | |
| Summer | 4 | 18 | 22 | 36 | 12 | 7 | 1 | |
| Autumn | 0 | 5 | 7 | 40 | 36 | 10 | 2 | 0 |
| Year | 2 | 10 | 15 | 38 | 24 | 9 | 2 | 0 |

One of the main factors, defining the air pollution potential, is the wind regime, the regime of calmness (low wind) at the speed of 0-1 m/s in particular. Numerous cases of dangerous air pollutions are often attributed to low wind speeds. In order to estimate the impact of the nuclear power plant on the environment it is necessary to analyze the repetitiveness of various wind speeds, including calmness (low wind).

In accordance to the zonation carried out in the territory of the former USSR the territory of the Republic of Belarus lies in the second zone after the zone of sea and ocean coasts. In the open and elevated areas of the country calmness periods (0-1 m/s) are possible in 20-25 % of cases during the year, in some areas (topographic low; along the valleys of small rivers) in up to 30-35 %, and in some cases – up to 40 %.

The distribution of polluting substances in the atmosphere depends on the pattern of daily and yearly calmness (low wind) frequency. A smooth rise in frequency of low wind up to the height of 0,2 km form winter to summer takes place over almost the whole European territory of Russia and CIS countries (including the territory of the Republic of Belarus and neighboring Lithuania) (see Table 80).

**Table 80 – Repetitiveness of calmness (0-1 m/s) up to the height of 0,2 km per season and per year, %**

| Aerological stations | Winter | Spring | Summer | Autumn | Year |
|---|---|---|---|---|---|
| Minsk | 2,3 | 3,8 | 3,0 | 1,6 | 10,7 |
| Kaunas | 2,4 | 4 | 6 | 3,9 | 16,3 |
| Mozyr (Gomel region) | 6 | 11 | 16 | 9 | 42 |

The highest value of repetitiveness of calmness falls at the Southeastern, most continental areas of the republic (Mozyr upper-air station).

Apart from the yearly pattern, a daily pattern of repetitiveness of low wind up to the height of 0,2 km is observed. Its range is different and depends on the season of the year, as well as the geographical position and the altitude of the station above the Baltic sea level: an increase in frequency of calmness periods with a move towards South-East, i.e. towards the most continental part of the Republic of Belarus, is tracked (see Table 81).

**Table 81 – Daily pattern of repetitiveness of calmness (0-1 m/s) season and per year, %**

| Aerological station | Time of day | Winter | Spring | Summer | Autumn |
|---|---|---|---|---|---|
| Minsk | night | 3 | 2,3 | 3,6 | 0,6 |
| | morning | 2 | 5 | 5 | 5 |
| | day | 2,3 | 3,6 | 3 | 1,4 |
| | evening | 2,3 | 4,3 | 2,2 | 2,2 |
| Kaunas | night | 1,4 | 2 | 3,3 | 1,3 |
| | morning | 4 | 4,6 | 10 | 2,9 |
| | day | 2 | 5 | 6 | 4 |
| | evening | 2,3 | 6 | 7 | 2,2 |
| Mozyr | night | 4,7 | 9 | 9 | 8 |
| | morning | 6,5 | 12 | 18 | 8 |
| | day | 10 | 14 | 15 | 11 |
| | evening | 2,5 | 8,5 | 16 | 6 |

The duration and vertical longitude of calmness are, first of all, connected with the synoptic processes, particularly with motionless anticyclones or non-gradient fields of the type, such as degraded anticyclone or baric saddle. The territory of the Republic of Belarus is included into the second zone (according to the zonation carried out in the territory of the former USSR), where the uninterrupted duration of low wind (0-1 m/s) is up to 1-5 days a month.

Powerful layers of long-lasting low wind form, as a rule, in the anticyclone field, less frequently – in the conditions of filling cyclones. The repetitiveness of low wind (0-1 m/s) in the ground layer up to the height of 0,2 km, according to the data from ground level and upper-air observations for various geographical points of the Republic of Belarus, all other synoptic processes being equal, is closely connected. As the repetitiveness of calmness periods at the height of 300 meters and 500 meters constitutes less than 0,5 %, they were not estimated.

**Table 82 – The dependency of repetitiveness of low wind (0-1 m/s) in the layer up to 0,2 km and ground level data per season and per year, %**

| Station | Minsk | | Mozyr | | Brest | |
|---|---|---|---|---|---|---|
| | 0,01 km | 0,2 km | 0,01 km | 0,2 km | 0,01 km | 0,2 km |
| Winter | 3 | 1 | 7 | 2 | 4 | 1 |
| Spring | 5 | 1 | 10 | 4 | 6 | 2 |
| Summer | 8 | 1 | 14 | 5 | 8 | 3 |
| Autumn | 5 | 1 | 10 | 3 | 7 | 1 |
| Year | 5 | 1 | 10 | 4 | 6 | 2 |

### *13.3.3 Categories of atmospheric stability*

Evaluations of repetitiveness of categories of atmospheric stability per month and per year are given in Table 83, rated yearly average repetitiveness of categories of atmospheric stability is given in Table 84, and rated annual average repetitiveness of categories of atmospheric stability at the Oshmyany weather station for the period of 1999-2008 is given in Table 85.

**Table 83 - Repetitiveness of categories of atmospheric stability, %, Oshmyany weather station, for the period of 1999-2008**

| Category of stability | Month | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | |
| A | 0,0 | 0,0 | 0,2 | 1,0 | 3,6 | 4,4 | 5,3 | 2,5 | 1,0 | 0,1 | 0,0 | 0,0 | 1,5 |
| B | 0,0 | 0,2 | 4,7 | 12,3 | 13,6 | 16,6 | 16,9 | 14,3 | 10,9 | 1,8 | 0,3 | 0,0 | 7,6 |
| C | 1,0 | 6,3 | 11,6 | 17,6 | 21,6 | 20,5 | 22,2 | 21,3 | 13,7 | 8,7 | 2,7 | 0,2 | 12,3 |
| D | 46,5 | 43,3 | 44,1 | 38,5 | 35,4 | 31,8 | 27,3 | 30,0 | 39,0 | 63,7 | 67,9 | 56,9 | 43,7 |
| E | 16,1 | 13,6 | 9,4 | 9,5 | 9,1 | 10,3 | 10,4 | 10,1 | 7,9 | 10,3 | 8,3 | 12,3 | 10,6 |
| F | 22,9 | 21,7 | 16,7 | 13,0 | 11,9 | 12,3 | 12,7 | 14,3 | 18,5 | 11,2 | 13,5 | 20,2 | 15,7 |
| G | 13,5 | 15,0 | 13,3 | 8,0 | 4,7 | 4,0 | 5,2 | 7,6 | 9,0 | 4,2 | 7,3 | 10,5 | 8,5 |

The categories of atmospheric stability were calculated by the Hydrometeorological Center of the Republic of Belarus based on the data from observations for the period between 1999 and 2008. Terner’s classification, modified by IEM, was applied for stability estimation.

In this classification the stability state of the atmosphere is described in seven categories:

– A – very strong instability;
– B – moderate instability;
– C – weak instability;
– D – indifferent state;
– E – weak stability;
– F – moderate stability;
– G – very strong stability.

In general, in the course of the year indifferent state is recorded most frequently (D category). Repetitiveness of instable states (categories A-C) is low and constitutes 21,4 %. The indifferent state is marked in 43.7% of cases, and stable states (categories E-G) are marked in 34,8 % of cases. Category A (very strong instability) has the lowest frequency of occurrence (1,5 %) and is not recorded from November to February. Category A occurs most frequently in July. All the instable states have a similar yearly pattern with a maximum in summer and minimum in winter. Category C prevails during the whole year. The highest frequency of stable states is marked in the winter months. The Indifferent state has a yearly pattern different from all the other states and has the maximum frequency of occurrence in October and November. It is due to the increase of cyclonic activity, which was suppressed by the Azores maximum in summer, the increase of cloudage and higher wind speed. A slight secondary maximum is marked in April, which is also connected with the circulation processes – the Siberian anticyclone loses its ground and the activity of cyclones increases. The minimum frequency of occurrence of D categories falls at summer months.

Depending on wind direction (see Table 83) winds of point E have the highest frequency of occurrence for the categories of atmospheric stability A and B, winds of point W have the highest frequency of occurrence for categories C,D, E, F, winds of point WSW have the highest frequency of occurrence for category G.

**Table 84 - Rated annual average repetitiveness of atmospheric stability categories (per mile), Oshmyany weather station, for the period of 1999-2008**

| Point | Categories of stability | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | |
| NNE | 1 | 4,8 | 7,2 | 16,4 | 5,4 | 5,8 | 4 | 44,6 |
| NE | 1 | 5,1 | 7,1 | 15,1 | 5,8 | 6,7 | 4,4 | 45,2 |
| ENE | 1,3 | 5,8 | 7,8 | 15,5 | 4,5 | 11,2 | 8,3 | 54,4 |
| E | 1,4 | 7,7 | 8,4 | 16,5 | 4,3 | 13,6 | 9,7 | 61,6 |
| ESE | 1 | 4 | 5,9 | 12,1 | 3,5 | 6,3 | 4,4 | 37,2 |
| SE | 0,5 | 3,5 | 4,6 | 14,9 | 4,1 | 5 | 2,4 | 35 |
| SSE | 0,9 | 2,9 | 6 | 21,9 | 5,4 | 6,4 | 1,7 | 45,2 |
| S | 1,1 | 5,2 | 8,8 | 35 | 8,8 | 10,6 | 4,8 | 74,3 |
| SSW | 0,8 | 5,7 | 8,7 | 41,3 | 9,4 | 13,9 | 6,9 | 86,7 |
| SW | 1 | 4,4 | 8,4 | 39 | 8,4 | 13,2 | 6,2 | 80,6 |
| WSW | 1,1 | 6 | 10,9 | 49,9 | 9,8 | 17,8 | 10,1 | 105,6 |
| W | 1,3 | 7,4 | 13,7 | 74,3 | 13,3 | 21 | 9,7 | 140,7 |
| WNW | 0,7 | 3,7 | 8,1 | 26,8 | 6,1 | 6,8 | 3,9 | 56,1 |
| NW | 0,7 | 3,4 | 5,6 | 19,7 | 5,7 | 6,3 | 2,3 | 43,7 |
| NNW | 0,7 | 3,3 | 5,8 | 18,4 | 5,9 | 5,6 | 2,4 | 42,1 |
| N | 0,8 | 3,7 | 6,2 | 20,4 | 5,6 | 6,8 | 3,9 | 47,4 |
| Total | 15,3 | 76,6 | 123,2 | 437,2 | 106 | 157 | 85,1 | 1000 |

**Table 85 - Total table of stability categories, speed and direction of wind for the 16 main points (per mille per grading) at the height of 10 m, Oshmyany weather station, for the period of 1999-2008**

| Point 1 N (Direction from the North to the South) | | | | | | | |
|---|---|---|---|---|---|---|---|
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,44 | 0,41 | 1,16 | 1,13 | 0 | 2,46 | 2,26 |
| 1-2 | 0,31 | 1,13 | 1,13 | 1,81 | 1,51 | 1,06 | 1,61 |
| 2-3 | 0 | 0,82 | 0,92 | 3,87 | 1,37 | 1,98 | 0 |
| 3-4 | 0 | 0,96 | 0,72 | 4,55 | 0,75 | 1,33 | 0 |
| 4-5 | 0 | 0,41 | 1,13 | 3,39 | 1,2 | 0 | 0 |
| 5-6 | 0 | 0 | 0,92 | 1,92 | 0,75 | 0 | 0 |
| >6 | 0 | 0 | 0,24 | 3,7 | 0 | 0 | 0 |
| Point 2 NNE | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,58 | 0,68 | 1,33 | 1,2 | 0 | 1,92 | 2,5 |
| 1-2 | 0,44 | 1,61 | 1,57 | 1,16 | 1,4 | 1,06 | 1,51 |
| 2-3 | 0 | 1,2 | 0,86 | 2,87 | 1,3 | 1,64 | 0 |
| 3-4 | 0 | 0,99 | 0,92 | 3,63 | 0,51 | 1,16 | 0 |
| 4-5 | 0 | 0,34 | 1,44 | 2,74 | 1,61 | 0 | 0 |
| 5-6 | 0 | 0 | 0,65 | 1,68 | 0,58 | 0 | 0 |
| >6 | 0 | 0 | 0,41 | 3,11 | 0 | 0 | 0 |
| Point 3 NE | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,62 | 0,79 | 1,47 | 0,86 | 0 | 1,95 | 2,22 |

Table 85 (continued)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1-2 | 0,38 | 1,33 | 2,12 | 1,71 | 2,02 | 1,2 | 2,19 |
| 2-3 | 0 | 1,13 | 0,89 | 3,28 | 1,37 | 2,16 | 0 |
| 3-4 | 0 | 1,3 | 0,75 | 4 | 0,58 | 1,44 | 0 |
| 4-5 | 0 | 0,51 | 0,92 | 2,26 | 1,23 | 0 | 0 |
| 5-6 | 0 | 0 | 0,75 | 1,09 | 0,58 | 0 | 0 |
| >6 | 0 | 0 | 0,17 | 1,85 | 0 | 0 | 0 |
| Point 4 ENE | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,79 | 1,03 | 2,02 | 1,81 | 0 | 3,35 | 4,04 |
| 1-2 | 0,48 | 1,88 | 2,5 | 2,5 | 1,75 | 2,29 | 4,28 |
| 2-3 | 0 | 1,61 | 1,13 | 3,94 | 0,65 | 4,24 | 0 |
| 3-4 | 0 | 0,99 | 0,79 | 3,35 | 0,31 | 1,3 | 0 |
| 4-5 | 0 | 0,27 | 0,82 | 2,16 | 0,92 | 0 | 0 |
| 5-6 | 0 | 0 | 0,48 | 0,79 | 0,86 | 0 | 0 |
| >6 | 0 | 0 | 0,03 | 0,92 | 0 | 0 | 0 |
| Point 5 E | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 1,03 | 1,33 | 2,26 | 2,16 | 0 | 5,2 | 5,47 |
| 1-2 | 0,34 | 3,18 | 2,98 | 2,7 | 2,05 | 3,11 | 4,24 |
| 2-3 | 0 | 1,51 | 1,13 | 4,48 | 0,82 | 3,32 | 0 |
| 3-4 | 0 | 1,44 | 0,65 | 3,9 | 0,55 | 1,98 | 0 |
| 4-5 | 0 | 0,21 | 0,89 | 1,71 | 0,62 | 0 | 0 |
| 5-6 | 0 | 0 | 0,44 | 0,65 | 0,24 | 0 | 0 |
| >6 | 0 | 0 | 0,07 | 0,86 | 0 | 0 | 0 |
| Point 6 ESE | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,75 | 0,62 | 1,2 | 1,68 | 0 | 2,26 | 2,02 |
| 1-2 | 0,21 | 1,37 | 1,57 | 2,05 | 1,54 | 1,2 | 2,36 |
| 2-3 | 0 | 1,03 | 0,68 | 2,6 | 0,62 | 1,98 | 0 |
| 3-4 | 0 | 0,72 | 0,86 | 2,4 | 0,27 | 0,86 | 0 |
| 4-5 | 0 | 0,31 | 0,99 | 1,54 | 0,89 | 0 | 0 |
| 5-6 | 0 | 0 | 0,34 | 0,82 | 0,17 | 0 | 0 |
| >6 | 0 | 0 | 0,27 | 0,99 | 0 | 0 | 0 |
| Point 7 SE | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,48 | 0,27 | 0,41 | 0,92 | 0 | 1,03 | 1,06 |
| 1-2 | 0,07 | 1,3 | 1,13 | 1,33 | 1,23 | 0,48 | 1,33 |
| 2-3 | 0 | 0,86 | 0,55 | 3,28 | 0,72 | 2,4 | 0 |
| 3-4 | 0 | 0,79 | 0,72 | 3,28 | 0,62 | 1,09 | 0 |
| 4-5 | 0 | 0,31 | 0,96 | 2,84 | 1,2 | 0 | 0 |
| 5-6 | 0 | 0 | 0,72 | 1,23 | 0,34 | 0 | 0 |
| >6 | 0 | 0 | 0,14 | 1,95 | 0 | 0 | 0 |
| Point 8 SSE | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,55 | 0,31 | 0,68 | 1,2 | 0 | 1,44 | 0,65 |
| 1-2 | 0,34 | 0,82 | 0,86 | 1,47 | 1,09 | 0,68 | 1,03 |
| 2-3 | 0 | 0,72 | 0,75 | 3,7 | 1,03 | 2,26 | 0 |
| Point 8 SSE | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 3-4 | 0 | 0,82 | 1,09 | 5 | 0,72 | 2,02 | 0 |
| 4-5 | 0 | 0,27 | 1,68 | 4,62 | 1,92 | 0 | 0 |
| 5-6 | 0 | 0 | 0,82 | 2,12 | 0,68 | 0 | 0 |
| >6 | 0 | 0 | 0,14 | 3,8 | 0 | 0 | 0 |

Table 85 (continued)

| Point 9 S | | | | | | | |
|---|---|---|---|---|---|---|---|
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,96 | 0,82 | 1,54 | 2,6 | 0 | 3,08 | 2,63 |
| 1-2 | 0,14 | 1,47 | 1,06 | 3,18 | 1,75 | 1,03 | 2,16 |
| 2-3 | 0 | 1,16 | 1,13 | 7,19 | 1,71 | 3,8 | 0 |
| 3-4 | 0 | 1,13 | 1,54 | 8,21 | 0,99 | 2,67 | 0 |
| 4-5 | 0 | 0,58 | 2,09 | 6,09 | 3,18 | 0 | 0 |
| 5-6 | 0 | 0 | 0,96 | 2,81 | 1,16 | 0 | 0 |
| >6 | 0 | 0 | 0,44 | 4,93 | 0 | 0 | 0 |
| Point 10 SSW | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,62 | 0,99 | 1,64 | 2,33 | 0 | 3,59 | 3,42 |
| 1-2 | 0,21 | 1,71 | 2,16 | 4,48 | 2,43 | 1,68 | 3,52 |
| 2-3 | 0 | 1,37 | 1,37 | 8,42 | 1,95 | 5,34 | 0 |
| 3-4 | 0 | 1,2 | 1,33 | 9,14 | 1,27 | 3,32 | 0 |
| 4-5 | 0 | 0,41 | 1,03 | 7,66 | 2,94 | 0 | 0 |
| 5-6 | 0 | 0 | 0,82 | 3,08 | 0,82 | 0 | 0 |
| >6 | 0 | 0 | 0,31 | 6,19 | 0 | 0 | 0 |
| Point 11 ЮЗ | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,68 | 0,75 | 1,68 | 2,26 | 0 | 2,98 | 2,57 |
| 1-2 | 0,31 | 1,54 | 2,19 | 4,11 | 1,95 | 1,68 | 3,59 |
| 2-3 | 0 | 0,89 | 1,16 | 7,87 | 1,81 | 4,86 | 0 |
| 3-4 | 0 | 0,92 | 1,13 | 8,18 | 0,82 | 3,66 | 0 |
| 4-5 | 0 | 0,27 | 1,51 | 6,3 | 2,98 | 0 | 0 |
| 5-6 | 0 | 0 | 0,51 | 3,87 | 0,82 | 0 | 0 |
| >6 | 0 | 0 | 0,21 | 6,43 | 0 | 0 | 0 |
| Point 12 WSW | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,79 | 1,3 | 2,4 | 2,53 | 0 | 3,05 | 4,28 |
| 1-2 | 0,31 | 2,12 | 3,46 | 5,71 | 2,02 | 3,25 | 5,82 |
| 2-3 | 0 | 1,23 | 1,2 | 9,58 | 2,36 | 7,77 | 0 |
| 3-4 | 0 | 1,03 | 0,86 | 9,68 | 1,27 | 3,73 | 0 |
| 4-5 | 0 | 0,31 | 1,4 | 8,52 | 3,18 | 0 | 0 |
| 5-6 | 0 | 0 | 1,27 | 4,48 | 0,99 | 0 | 0 |
| >6 | 0 | 0 | 0,31 | 9,41 | 0 | 0 | 0 |
| Point 13 W | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,79 | 0,82 | 2,26 | 3,08 | 0 | 4,11 | 3,7 |
| 1-2 | 0,55 | 2,6 | 3,11 | 5,54 | 2,87 | 2,98 | 6,02 |
| 2-3 | 0 | 2,02 | 1,68 | 13,31 | 3,28 | 9,68 | 0 |
| 3-4 | 0 | 1,44 | 2,02 | 14,75 | 1,78 | 4,28 | 0 |
| 4-5 | 0 | 0,55 | 2,81 | 13,17 | 3,87 | 0 | 0 |
| Point 13 W | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 5-6 | 0 | 0 | 1,33 | 7,73 | 1,54 | 0 | 0 |
| >6 | 0 | 0 | 0,48 | 16,7 | 0 | 0 | 0 |
| Point 14 WNW | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,62 | 0,65 | 1,44 | 1,03 | 0 | 1,95 | 1,68 |
| 1-2 | 0,1 | 0,75 | 1,47 | 1,71 | 1,33 | 0,89 | 2,22 |
| 2-3 | 0 | 1,13 | 1,09 | 4,21 | 1,57 | 2,63 | 0 |
| 3-4 | 0 | 0,96 | 1,44 | 5,03 | 0,48 | 1,33 | 0 |

Table 85 (continued)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4-5 | 0 | 0,24 | 1,61 | 4,55 | 1,68 | 0 | 0 |
| 5-6 | 0 | 0 | 0,89 | 2,67 | 1,06 | 0 | 0 |
| >6 | 0 | 0 | 0,21 | 7,6 | 0 | 0 | 0 |
| Point 15 NW | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,41 | 0,44 | 0,65 | 1,13 | 0 | 1,51 | 1,03 |
| 1-2 | 0,27 | 0,72 | 1,03 | 1,09 | 1,71 | 0,68 | 1,23 |
| 2-3 | 0 | 0,96 | 0,65 | 3,7 | 1,27 | 2,57 | 0 |
| 3-4 | 0 | 0,96 | 1,03 | 4,35 | 0,68 | 1,51 | 0 |
| 4-5 | 0 | 0,27 | 1,16 | 3,52 | 1,51 | 0 | 0 |
| 5-6 | 0 | 0 | 0,96 | 1,68 | 0,51 | 0 | 0 |
| >6 | 0 | 0 | 0,1 | 4,24 | 0 | 0 | 0 |
| Point 16 NNW | | | | | | | |
| U m/s | A | B | C | D | E | F | G |
| 0-1 | 0,,41 | 0,41 | 0,96 | 0,72 | 0 | 1,81 | 1,23 |
| 1-2 | 0,31 | 1,09 | 0,96 | 1,33 | 1,4 | 0,72 | 1,16 |
| 2-3 | 0 | 0,44 | 1,06 | 3,25 | 1,27 | 2,05 | 0 |
| 3-4 | 0 | 1,13 | 0,65 | 3,97 | 0,75 | 106 | 0 |
| 4-5 | 0 | 0,17 | 1,23 | 2,94 | 1,57 | 0 | 0 |
| 5-6 | 0 | 0 | 0,68 | 1,81 | 0,86 | 0 | 0 |
| >6 | 0 | 0 | 0,24 | 4,35 | 0 | 0 | 0 |

In the course of analysis of stability categories for various wind directions depending on wind speed (Table 85) it can be noted that for winds of points N, NNE, S, SSW, SW,SWS and NW the highest repetitiveness for atmospheric stability category D is observed at wind speed of 3-4 m/s. For winds of points NE and SE the highest repetitiveness for atmospheric stability category D is observed at wind speed of 2-3 m/s. For winds of points ENE and ESE the highest repetitiveness for atmospheric stability category G is observed at wind speed of 0-1 m/s. For winds of point SSE the highest repetitiveness for atmospheric stability category D is observed at wind speed of 4-5 m/s. For winds of points W, WNW and NNW the highest repetitiveness for atmospheric stability category D is observed at wind speed of ≥6 m/s.

### *13.3.4 Strong wind, squalls, whirlwinds*

### *13.3.4 Strong wind, squalls, whirlwinds*

Dangerous meteorological phenomena, including strong wind, squalls, whirlwinds, are characterized by high variability in time and space and vary greatly in complexity and other characteristics. Very limited information is available due to the fact that a part of the occurrences doesn’t fall into the scope of research because of discreteness and short duration. Therefore generalization of data is carried out not for separate points but for certain areas. In connection with those dangerous weather phenomena, including strong wind, squalls, whirlwinds, characteristic of the 30-killometer zone of the Belarusian nuclear power plant can be found in an area, larger than the 30-killometer area of the Belarusian nuclear power plant. In this case the territory of the following administrative regions: Grodno, Vitebsk and Minsk region.

Strong wind (instantaneous speed ≥25 m/s). In general for the period under consideration strong wind (instantaneous speed ≥25 m/s) in the territory of Vitebsk and Grodno regions was marked in 25 years out of 33-35 in at least one point of the region. The repetitiveness of years with strong wind in at least one of the points of the region constituted correspondingly 69 and 71 %. In the territory of the Minsk region such wind was marked in 20 years 35 in at least one point of the region, the repetitiveness of years with strong wind in at least one of the points of the region constituted 63 % (see Table 86).

Squalls (a short-time increase of wind speed up to 21-35 m/s). Squalls are sharp, short-time wind speed increases, occurring usually prior to storms. A squall is a whirlwind with a horizontal axis, emerging in a powerful cumulonimbus cloud or under it and reaching ground. It is characterized not only by high speed, but also by swift changes of wind direction. Squalls form, mainly, when a cold front passes and can emerge almost simultaneously in different places along the front line, air-mass squalls are recorded less frequently. At average squalls are recorded once in 5 years in one point, generally during the warm half of the summer. At that time the speed exceeds 10 m/s, but usually constitutes 16-20 m/s. Squalls with the wind speed exceeding 25 m/s are most dangerous, bringing damage to buildings, communication and power lines. As the area of spread of squalls is not large, the data available is incomplete. Destructive squalls are rare in one point.

Whirlwind is a strong small-scale tornado, which forms under well-developed cumulonimbus clouds and spreading in the form of a gigantic cloud belch, which goes down to the ground or sea surface in the form of a funnel. The wind speeds that develop in these vertical whirlwinds, going down from the clouds in the form of a cloud funnel, can reach 50 m/s and more. As a result of spinning exhaustion occurs within the whirlwind and strong, up to 70-90 m/s ascending air motions. This leads to heavy objects in the way of the whirlwind being sucked into the whirlwind area, lifted by it and carried away for long distances. Whirlwind is a short-term occurrence. It usually lasts for only a few minutes in one point, and its zone of destruction is relatively small – several tens or hundreds of meters wide and a few kilometers or tens of kilometers long.

According to the contour map of zonation of the territory of the former USSR according to whirlwind danger and the catalogue of whirlwinds in the territory of the former USSR (РБ-022-01) and the Republic of Belarus, the territory of the 30-killometer zone of the Belarusian nuclear power plant refers to the areas with high whirlwind danger. In general, during the period under consideration in the territory of Grodno region, where the platform of the Belarusian nuclear power plant is situated, Vitebsk and Minsk regions, located in immediate neighborhood of the Belarusian nuclear power plant, 3,8 and 9 cases of whirlwind were recorded correspondingly (see Table 87). The possibility of occurrence of a whirlwind in the territory of Grodno region (in one of the points) is 5 % (once in 20 years), in the territory of Vitebsk region (in one of the points) – 14 % (once in 7 years), in the territory of Minsk region (in one of the points) – 16 % (once in 6 years). Most of them refer to 1-2 intensity class on the Fujitah scale (Table 88).

On the 6$^{th}$ of September 1997 a whirlwind occurred in the territories of Oshmyany and Smorgonsky districts, neighboring to Ostrovetsky district. It rooted out and broke trees, tore away roofs of houses, destroyed household outbuildings and damaged power lines in its way. As explained by the eye-witnesses, the storm lasted about 20 minutes. According to the damage it can be referred to the 2$^{nd}$ class on Fujitah scale. Although no whirlwinds have been registered in the territory of the platform under consideration during the observation period, the possibility of their occurrence cannot be ruled out. The territory may incur whirlwinds, strong enough to be referred to class 3 of intensity. In accordance with RB-022-01, the calculated characteristics of the whirlwind are given for the class 3 whirlwind (Table 89).

**Table 86 – Repetitiveness (number and %) with strong wind (instantaneous speed ≥25 m/s) in at least one point of the region**

| Number of years with the occurrence | % | Number of years generalized |
|---|---|---|
| Vitebsk region | | |
| 25 | 69 | 33 |
| Minsk region | | |
| 20 | 63 | 32 |
| Grodno region | | |
| 25 | 71 | 35 |

**Table 87– Repetitiveness (number and %) with destructive squalls and whirlwinds in general per region (in at least one district of the region)**

| Region | Destructive squall | | | Destructive whirlwind | | |
|---|---|---|---|---|---|---|
| | Number of years with the occurrence | % | Number of years generalized | Number of years with the occurrence | % | Number of years generalized |
| Vitebsk | 17 | 49 | 35 | 8 | 14 | 56 |
| Minsk | 13 | 37 | 35 | 9 | 16 | 56 |
| Grodno | 14 | 40 | 35 | 3 | 5 | 56 |

**Table 88– Whirlwinds with the intensity of 1-2 points, recorded in Grodno, Vitebsk and Minsk regions.**

| Place of record | Date | Intensity class |
|---|---|---|
| Chashniki district, Vitebsk region | 06.07.1947 | 1 |
| Molodechno, Minsk Region | 09.06.1950 | 1 |
| Ushachi district, Vitebsk region | 17.06.1951 | 1 |
| Cherveni district, Minsk region | 18.08.1956 | 2 |
| Mozolevshchina village, Minsk region | 28.05.1966 | 1 |
| Krupki district, Minsk region | 23.05.1967 | 2 |
| Malyi Zboisk Farm Yard, Grodno region | 21.09.1967 | 1 |
| Zamoshye district, Minsk region | 13.05.1969 | 2 |
| Ananitsy settlement, Minsk region | 15.05.1969 | 1 |
| Uzdf district, Minsk region | 31.05.1969 | 2 |
| Novogrudok district, Grodno region | 14.08.1982 | 1 |
| Miory district, Vitebsk region | 11.08.1990 | 2 |
| Oshmyany and Smorgon districts, Grodno region | 06.09.1992 | 2 |
| Volozhin district, Minsk region | 06.09.1992 | 2 |
| Sharkovshchina district, Vitebsk region | 17.08.1993 | 2 |

**Table 89- Estimated characteristics of whirlwinds with specified reliability**

| Estimated characteristics of whirlwinds | Value for a whirlwind with reliability $1 \cdot 10^{-5}$ | Value for a whirl-wind with reliabil-ity $1 \cdot 10^{-6}$ |
|---|---|---|
| Estimated class of the possible whirlwind, $k_p$ | 1,5 | 3,0 |
| Possibility of exceeding (occurance/year) | $1 \cdot 10^{-5}$ | $1 \cdot 10^{-6}$ |
| Maximum vortex rotation rate, $V_p$ (м/с) | 50 | 81 |
| Speed of the forward motion of the whirlwind, $U_p$ (m/s) | 12,6 | 20,3 |
| Pressure differential between the center and the periphery funnel of the whirlwind ΔPp (hPa) | 31,0 | 81 |
| Length of the whirlwind pathway, $L_p$ (km) | 5,0 | 28,6 |
| Width of the whirlwind pathway, $W_p$ (km) | 0,05 | 0,29 |

## 13.4 Surface waters. Quantitive and qualitative charcteristics

### *13.4.1 Provisional scheme of water drain, water supply and water discharge of the Belarusian NPP. Alternatives.*

The river Viliya is considered as the main source of technical water supply of the Belarusian NPP. The area of the village Malye Sviryanki - village Muzhily" (Figure 65) was chosen for industrial water supply of the Belarusian NPP for the placement of the surface water intake. It is planned to place a surface water intake at the river Viliya for two power units lower than the village Malye Sviryanki. Water from the river Viliya is taken in and is pumped over to the NPP site by means of pressure conduits of the first and second stages. Taking into consideration the information of the Industrial Republican Enitary Enterprise "Belcommunproject", the length of the supposed tracks of the drainage system from water intake site at the given area to the NPP site is 9.9 km. Water intake constructions at the river Viliya are located at the left bank.

**Figure 65 – the river Viliya at the area of location of surface water intake at 500 m lower than the village Malye Sviryanki**

Productivity of the pump station is 220 000 $m^3$/day, first reliability category. Pumps are placed under the inlet from minimal expected water level in the river.

Reliability category of power supply of the pump station – I.

Water delivery from water intake at the river Viliya to the NPP site is provided by two strings of steel water conduits with diameter of 1000 mm. Each string of water conduits is meant for passing of 70 % from consumption for industrial water supply of two power units of NPP.

Reserve water supply sources could be used for providing of guaranteed uninterupted water supply mode of NPP.

- Vileika reservoir with a distance from water intake of the Belarusian NPP to the weir of reservoir up to 140 km, water volumes in the reservoir could vary from 260 million $m^3$ to 25,1 million $m^3$ (project drawdown of the reservoir is 6.0 m);
- Olkhovskiy reservoir of bed-type at the river Stracha (reservoir of Olkhovskaya hydroelectric powerplant) with a distance through watercourses to the area of water abstraction up to 19,2 km (payload volume is 1,4 million $m^3$, maximum level difference is 3,0 m, water-surface area 0,7 $km^2$, average depth is 3 m);
- Snigyanskiy reservoir of bed-type at the river Oshmyanka (reservoir of Oshmyankaya hydroelectric powerstation) with a distance through watercourses to the area of water abstraction up to 55 km (payload volume is 1,21 million $m^3$, maximum level difference is 5,0 m, water-surface area 1,5-$km^2$, average depth is 1,42 m).

Drinking and technical (during construction) water supply of NPP in volume up to 1 850 $m^3$/day will be provided from underground water abstraction which will be placed at the distance of 3,0-4,5 km to the north from the centre of the site.

Technical sewage water in a volume of 0,48-0,69 $m^3$ (41,47-59,62 thousand $m^3$/day – 1EB), 0,96-1,38 $m^3$/day (82,94-119,24 thousand $m^3$/day – 2 EB) will be drained into the river Viliya through separate water conduit and will be disposed into the river at the approximate distance of 2,7 km lower than water abstraction near village Malye Sviryanki (directly downstream from the village Muzhily).

Utilities sewage water from the NPP site throughout the system of collectors go to the sewage pump station and with the help of pumps is pumped over to the station of sewage treatment plant. Sewage treatment plant is planned to build in the buffer area of the NPP. Sewage treatment is full biological with full removal of nitrogen and phosphorus and with post-treatment. Volume of sewage discharge is supposed to be 910,9 $m^3$/day, it will be discharged into one of the nearest watercourse which is the river Polpe (right tributary of the river Viliya). The placement of housing settlement is supposed to be on the base of the township Ostrovets, so discharge of sewage from the settlement area is supposed to be made using existing treatment facilities with their reconstruction and expansion.

Rainfall from the territory of NPP's site is collected into existing pump station of rain sewage waters by means of transfer with the help of free-flow nets which efficiency is 100 $m^3$/hour with balance tank which capacity is 60 $m^3$ and then it is pumped into free-flow nets of the district rain sewage of the joint auxiliary unit. Annual volume of rainfalls which are directed into water body is 66 thousand $m^3$/year.

Provisional scheme of water intake, water supply and water discharge of the Belarusian NPP is given in Figure 66.

Principal technological scheme of water treatment for circulating water system feed with splash pools includes:

- treatment from particulate pollutants by means of screen filters of coarse purification;
- direct-flow coagulation;
- removal of suspended matters and organic impurities at the ultrafiltration plant;
- acidation with sulfuric acid for bicarbonate destruction; disperse particles removal at cartridge filters;
- demineralization of water at the reverse osmosis plant.

Post-treatment of demineralized water in order to replace losses in the NPP contours after reverse osmosis is made by the scheme:

– hydrogen cycle in counterflow filters;
– removal of carbonic acid in precalciners;
– anion echange in double-chamber counterflow filters;
– deep desalting and desiliconization of water in mixed bed filters.

Efficiency of water treatment plant on demineralized water for feed of splash pools of two power units of the NPP is 174 $m^3$/hour.


**Reference designations:**

- Ostrovets site of Belarusian NPP

— - Route of water conduits of industrial water supply of Belarusian NPP
— - Route of water conduits of utility drinkable water supply of Belarusian NPP
— - Route of pipelines for outlet of public utility wastewater of Belarusian NPP
— - Outlet of technical wastewaters of Belarusian NPP

| | |
|---|---|
| Отвод технических сточных вод | Disposal of technical sewage water |
| Мал. Свирянки | Malye Sviryanki |
| Мужилы | Muzhily |
| р. Вилия | the river Viliya |
| водозабор производственного водоснабжения | water intake of industrial water supply |
| площадка сооружений II подъема | Constrictions site of the II height |
| Михалишки | Mikhalishiki |
| водозабор хоз-питьевого водоснабжения | water intake of utility and drinking water supply |
| площадка станции очистки воды хоз-питьевого водоснабжения | site of the treatment plant of utility and drinking water supply |
| Гора | Goza |
| р. Полпе | the river Polpe |
| Волейкуны | Voleykuny |
| площадка станции очистки комунально-бытовых сточных вод | area of public utility sewage treatment plant |
| Загозь | Zagoz |

**Figure 66 – Provisional scheme of water intake, water supply and water discharge of the Belarusian NPP (two power units)***

* According to the data of Republican Unitary Enterprise “Belcommunproject”.

### *13.4.2 Current state of surface water*

#### *13.4.2.1 Hydrographic characteristics within 30-km area of the NPP site*

Site territory is situated in north-western part of Belarus in bounds of western part of Narochansko-Vileika plain and it is a flat and wavy plain which consists of clod massifs, high and wavy thin plains and not very high and sloping wavy fluavisive plains and low places of the Poozersk age. Underground reservoir and complexes are represented by accumulation of ground water mainly in sandy-clay-boulder rocks.

Agricultural development of lands is 50-60%. Land resourses are represented mainly by forest and open lands and by land under constant crops. Intensity of usage of agricultural lands is 35-45 %. Amount of forests on the territory is 40-50 %. Territory with favourable conditions for rest and relaxation.

**Hydrographic network** within the 30-km area of the Belarusian NPP includes 70 water objects, 5 of them are transboundary, 52 of them are situated at the territory of Belarus, 13 are situated at the territory of Lithuania. The list of water objects, their hydrographic and main morphometric characteristics are given in Table 90 [76. 77].

Such rivers as the Viliya, the Polpe, the Gozovka, the Stracha, the Oshmyanka, the Losha, Snigyanskoye reservoir (reservoir of the Rachunskaya hydroelectric powerplant), reservoir of Olkhovskaya hydroelectric power plant are the main water objects of locatiothe n of Belarusian NPP. The scheme of hydrographic network within the 15-kilometer area of the Belarusian NPP is shown in Figure 67.

**Table 90 – List of water objects within the 30-km area of NPP site, their hydrographic and main morphometric and hydraulic characteristics**

| Tributary order | Name of water-course | Length, km | Catchment basin, km$^2$ | Forest coverage, % | Bogginess, % | Lakeness, % | Tilled condition, % | River network density, km/km$^2$ | Water surface slope, ‰ | Average annual waterflow, m$^3$/day |
|---|---|---|---|---|---|---|---|---|---|---|
| **Transboundary watercourses** | | | | | | | | | | |
| - | Viliya | 498 | 25100 | 30 | 5 | 2 | 45 | 0,45 | 0,3 | 186 |
| 1 | Baloshinka | 14 | 64,5 | 40 | 21 | 1 | 35 | 0,74 | 2,9 | 0,44* |
| 2 | Struna | 31 | 194 | 35 | 25 | 1 | 25 | 0,63 | 0,8 | 1,5 |
| 1 | Vilnya | 80 | 624 | 60 | 5 | 2 | 25 | 0,46 | 1 | 4,28* |
| 2 | Kaponishkyu | 6,1 | 16,1 | 80 | 3 | 1 | 10 | 0,41 | 5,1 | 0,11* |
| **Territory of the Republic of Belarus** | | | | | | | | | | |
| 1 | Polovoyka | 14 | 48 | 17 | 27 | 0 | 55 | 0,46 | 3,4 | 0,33* |
| 1 | Ustizerki | 11 | 47 | 65 | 8 | 1 | 10 | 0,23 | 2 | 0,32* |
| 1 | Oshmyanka | 105 | 1490 | 20 | 12 | 1 | 50 | 0,41 | 0,8 | 13,4 |
| 1 | Polpe | 9,2 | 30,8 | 10 | 1 | 1 | 80 | 0,43 | 3,2 | 0,0016* |
| 1 | Stracha | 59 | 1140 | 40 | 5 | 10 | 35 | 0,39 | 1 | 9,1 |
| 1 | Sorochanka | 29 | 201 | 40 | 10 | 1 | 10 | 0,32 | 1,4 | 1,75 |
| 1 | Dudka | 8,5 | 34,6 | 22 | 11 | 0 | 50 | 0,69 | 6,37 | 0,24* |
| 1 | Gozovka | 17 | 88 | 15 | 17 | 1 | 65 | 0,44 | 2,5 | 0,41* |
| 1 | Rytenka | 9,3 | 38,2 | 15 | 2 | 2 | 60 | 0,64 | 4,9 | 0,26* |
| 1 | Senkanka | 13,2 | 45 | 26 | 3 | 1 | 60 | 0,37 | 4,35 | 0,31* |
| 1 | Tartak | 5 | 28 | 18 | 1 | 1 | 40 | 0,32 | 7,4 | 0,05* |
| 1 | Bystritsa | 3,8 | 4,7 | 40 | 1 | 3 | 40 | 0,71 | 7,2 | 0,031* |
| 1 | Mikhaylovo | 6,4 | 15,2 | 50 | 2 | 3 | 30 | 0,52 | 7,1 | 0,1* |
| 2 | Gaigolka | 4,7 | 16,4 | 5 | 1 | 1 | 85 | 0,44 | 4,1 | 0,11* |
| 2 | Losha | 55 | 455 | 40 | 2 | 2 | 40 | 0,46 | 1,34 | 3,9 |
| | Ratagol | 12 | 29 | 40 | 7 | 0 | 40 | 0,35 | 1,5 | 0,2* |
| 2 | Kernova | 19 | 103 | 16 | 11 | 0 | 60 | 0,42 | 2 | 0,71* |
| 2 | Sikunya | 12 | 75 | 15 | 7 | 0 | 70 | 0,63 | 4,9 | 0,52* |
| 3 | Komar | 5 | 17,4 | 10 | 5 | 1 | 75 | 0,58 | 2,9 | 0,12* |
| 3 | Kamenka | 7,4 | 18,2 | 30 | 4 | 1 | 55 | 0,57 | 3,9 | 0,13* |
| 4 | Malka | 10 | 25,2 | 50 | 8 | 1 | 30 | 0,53 | 2,1 | 0,17* |
| 4 | Paroka | 14 | 102 | 24 | 13 | 1 | 50 | 0,39 | 3,2 | 0,12* |
| 2 | Tushchanka | 11 | 86 | 12 | 25 | 2 | 30 | 0,81 | 1,2 | 0,59* |
| 2 | Sikunka | 11 | 89 | 40 | 10 | 3 | 20 | 0,29 | 0,9 | 0,61* |
| 2 | Yazvinka | 5 | 18,6 | 90 | 5 | 1 | 2 | 0,45 | 7,9 | 0,13* |
| 3 | Pelenka | 21,1 | 80,9 | 50 | 15 | 0 | 10 | 0,68 | 2,8 | 0,56* |
| **Territory of the Republic of Lithuania** | | | | | | | | | | |
| 2 | Skyardiksna | 13,12 | 46,96 | 45 | 25 | 5 | 20 | 0,41 | 2,67 | 0,32* |
| 2 | Myara | 48,9 | 186,4 | 60 | 15 | 10 | 10 | 0,38 | 1,84 | 1,28* |

* Water flow rate is calculated in accordance with the Construction Norms and Rules, SNiP 2.01.14-83, "Hydrologic Characteristics Calculation" (2000 г.), Annex P1-98.

Table 90 (continued)

| Basin name | Water-surface area, km$^2$ | Length, km | Maximum width, km | Bank-line length, km |
|---|---|---|---|---|
| Hydrographic characteristics of the reservoirs within the 30-kilometer area of the Belarusian NPP | | | | |
| **Territory of the Republic of Belarus** | | | | |
| the lake Gomel | 0,07 | 0,38 | 0,23 | 1,01 |
| the lake Slobodskoye | 0,075 | 0,44 | 0,26 | 1,16 |
| the lake Byk | 0,14 | 0,49 | 0,36 | 1,36 |
| the lake Ryizheye | 0,59 | 1,16 | 0,72 | 1,88 |
| the lake Mertvoye | 0,27 | 0,84 | 0,38 | 2,26 |
| ponds of fishery “Soly” | 1,63 | 2,01 | 1,17 | 6,01 |
| lake Tusha | 0,34 | 0,85 | 0,66 | 2,83 |
| lake Bildzhio | 0,096 | 0,5 | 0,31 | 1,42 |
| ***Group of lakes “Sorochanskaya”*** | | | | |
| lake Vorobyi | 0,46 | 1,12 | 0,57 | 2,9 |
| lake Gulbeza (Gubeza) | 0,23 | 0,94 | 0,39 | 1,94 |
| lake Edi (Edovo,Edovskoye) | 0,61 | 1,6 | 0,52 | 3,74 |
| lake Golodyanka (Podkostelok) | 0,33 | 0,9 | 0,49 | 2,59 |
| lake Golodno (Golubina) | 0,14 | 0,78 | 0,25 | 1,81 |
| lake Tumskoye | 0,86 | 3,22 | 0,45 | 7,6 |
| lake Kaiminskoye (Kaimin) | 0,43 | 1,55 | 0,38 | 4,3 |
| lake Zolovskoye | 0,24 | 0,87 | 0,37 | 2,56 |
| lake Turoveiskoye (Turovie) | 0,38 | 1,57 | 0,39 | 3,87 |
| lake Beloye | 0,34 | 1,05 | 0,39 | 2,8 |
| lake Klevel (Klevie) | 0,12 | 0,85 | 0,23 | 2,26 |
| lake Baranskoye | 0,17 | 1,08 | 0,3 | 2 |
| ***The lakes of the National Park “Narochanskiy”*** | | | | |
| lake Vishnevskoye | 9,97 | 4,38 | 3,52 | 13,6 |
| lake Svir | 22,28 | 14,12 | 2,27 | 31,15 |
| lake Glukhoye | 0,15 | 0,55 | 0,38 | 1,35 |
| Svirnishche | 0,38 | 0,87 | 0,57 | 2,39 |
| ***Reservoirs*** | | | | |
| Olkhovskoye | 0,7 | 3,7 | 0,3 | 11,5 |
| Yanovskoye | 1,1 | 7,7 | 0,4 | 10,8 |
| Snigyanskoye (reservoir of the Ra-chunskaya hydroelectric power plant) | 1,5 | 5,5 | 0,8 | 12,7 |
| **Territory of the Republic of Lithuania** | | | | |
| ponds of fishery “Margeiskiy’ | 7,42 | 4,01 | 3,61 | 14,32 |
| lake Karotski | 0,16 | 0,66 | 0,36 | 1,69 |
| lake Vakstel | 0,065 | 0,52 | 0,19 | 1,22 |
| lake Rakovina | 0,16 | 0,92 | 0,27 | 2,28 |
| lake Dyatlovina | 0,078 | 0,31 | 0,29 | 1,01 |
| lake Ungurinis | 0,35 | 1,72 | 0,4 | 5,14 |
| lake Skeima | 0,085 | 0,43 | 0,39 | 1,4 |
| lake Pyarunas | 0,29 | 0,71 | 0,55 | 2,03 |
| lake Atimets | 0,31 | 0,87 | 0,41 | 2,36 |
| lake Glyadne | 0,12 | 0,42 | 0,29 | 1,21 |

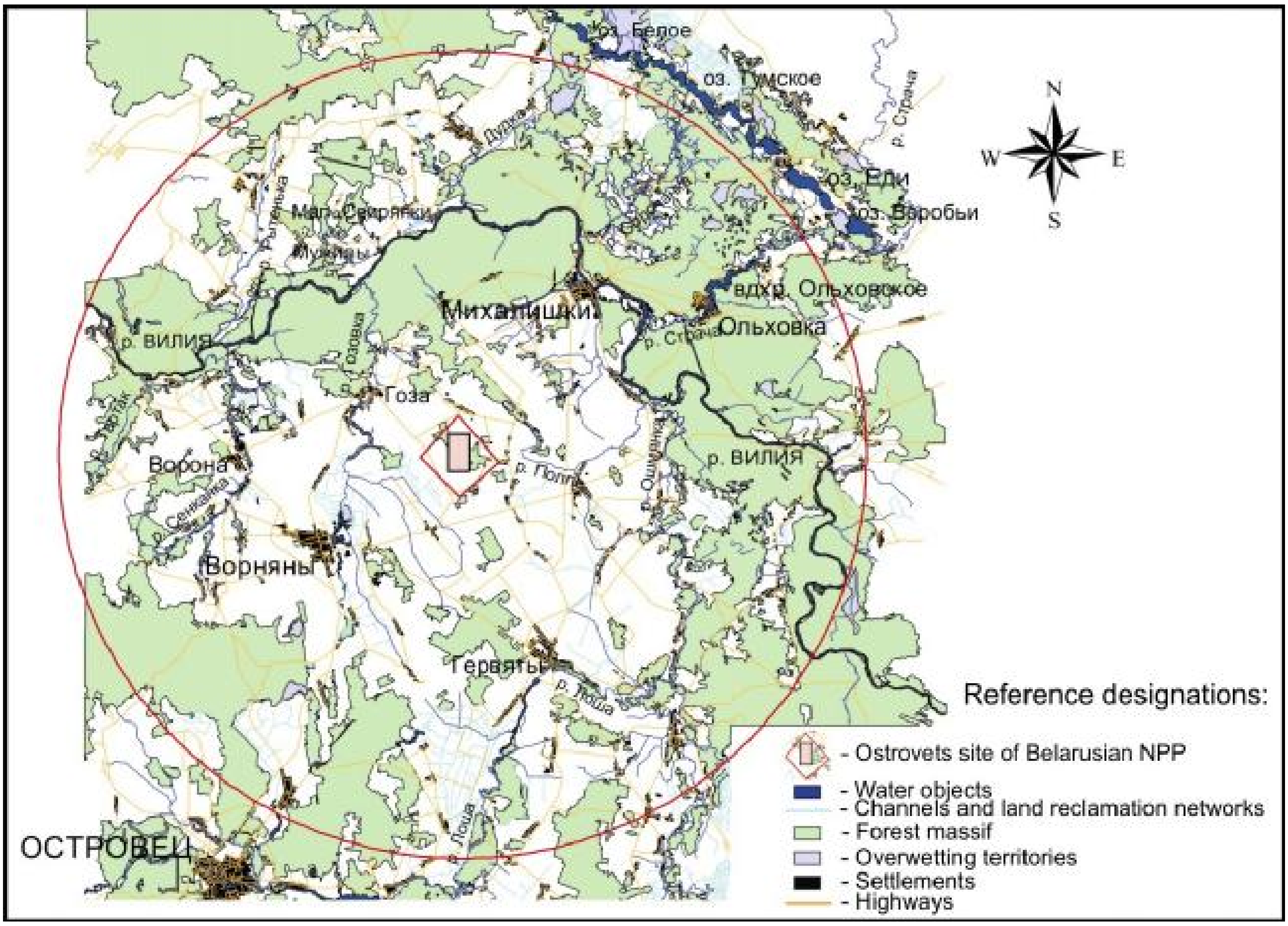



**Figure 67 – Scheme of the hydrographic network within the 15-km area of the Belarusian NPP**

The river Viliya is the main source of water supply for the industrial purposes of the Belarusian NPP. The Viliya is the biggest tributary of the Neman. It flows from a small swamp, located in 1 km to south-west to Velikoye Pole village, Dokshitsy district. It flows into the Neman near Kaunas. The river length is 498 km. The length on the territory of Belarus is 264 km. The total area of the river basin is 25 100 $km^{2.}$ in Belarus – 11 050 $km^2$. The total inflow within the territory of Belarus is 90,6 m, the water surface slope is 0,3 %, the rate of sinuosity is 1,98.

The main tributarys are the Servech, the Naroch, the Stracha, left – the Dvinosa, the Iliya, the Usha, the Oshmyanka. The network of the river is well developed and includes 1570 rivers those length is more than 1km. The Vileika reservoir is built on the river, part of water of which is directed to the Svisloch through Vileysko-Minsk hydrologic system.

The drainage is symmetrical (α=0,05), with insignificant prevalence of the left-bank, has the shape of the improper square (IV type). It si situated in Narochansko-Vileika lowland. It is limited by the southern slopes of Svencenski range from the North, by Minsk upland in the South, by Oshmyany upland in the South-West. It is related to the Vileika hydrologic district. The watershed is quite accurate and has complex contour. The terrain is represented by terminal moraines formation, abounding with ranges of hills and groups of hills with swampy lowlands between them. The highest point with average heights up to 100 m (some hills of the Minsk upland) goes to the Narochansko-Vileika lowland.

The average height of water drainage is 190 m, the average slope is 9, 24 %. The soils are mainly sandy-loam and loamy including boulders and pebbles, peaty in low-land. The total percentage of forest land is about 30 %, including 5 % of swampy forests.

The lakes occupy 2 % of the catchment area, they are mostly located on the right bank. The biggest of them are the Naroch, Myastro, Svir, Vishnevskoye, Bolshiye Shkvashty. Weighted average of the lakes is 0,03 %. Swamp massive and marshy lands are situated mainly in the upper part of the catchment area and make 10 % of its area.

The valley of the river is sinuous. It narrows from 1-3 km in the upper flow to 0,2-0,4 km to the mouth along the whole length of the terrace. Flood plain in the upper flow is mainly swampy. Its width is 200-400 m, the lower part is interrupted. It’s width is 50-70 m, in some places is 600 m. In the distance between the settlements Stakhi and Bolshiye Razdory there are many former river beds. The riverbed in the riverhead is highly sinuous. The width is from 1 to 2 m. At the mouth of the Usha – 40-60 m (100 m in some places) up to influx of the Baloshinka is 60-70 m. There are many islands, sand bars, sometimes there are places full of rapids. The banks in the riverheads are peaky.

The flood begins in the end of March and lasts about 50 days. The river regime is significant with intensive spring flood (about 45 % of flow) and low water standing in summer normal water level. After the Vileika reservoir was put into service, level and drain regimes lower from the dam on the territory of Belarus are controlled. The river freezes in the upper flow in the beginning of December, in the central and lower parts – in the beginning of January. Drifting of ice starts in the second half of March from the mouth to the riverhead.

Spring flood starts at the end of March and it continues for about 50 days. River mode has a peculiarity of intensive spring flood (about 45 % flow) with low water standing in summer water standing. After putting into operation of the Viliya reservoir level mode and flow mode which are situated lower than weir in Belarus are regulated. The river freezes in upcoarse at the beginning of December, in middle course and lower courses it freezes at the begginig of January. Ice drift starts at the second half of March from the mouth to riverhead.

In the riverhead there is a hydrologic wildlife area VerkhneVileika, in the mouth there is a nature monument Berezkovskiy giant oak. Recreation zones Vileika, Plesy, sanatoriums “Zalesie”, “Lesnaya polyana” are situated at the banks. [78].

According to the construction peculiarities of the valley and of the riverbed two areas could be selected: the first (upper) is “riverbed – mouth of the river Usha” (the length is 151 km), the second (lower) is “mouth of the river Usha – mouth of the river Baloshinka” (length is 125-km).

NPP site is situated in the district 2 of (lower) area. At this area the valley is trough-shaped, very twisting, its width is 300-400 km, and maximal is 1 km. The slopes are steep sometimes abrupt with height of 10-20 m, in some places up to 30 m, they are crossed by deep ravines, consist of sandy and argillo-arenaceous deposits. Almost all the time the terraces could be seen. Flood plain is discrete, it alternates on the banks, narrow, with width of 50-70 m, only at area from settlement Rudnya to settlement Danushevo, from settlement Markuni to settlement Mikhalishiki it is expanded to 0.6 km. Flood plain’s surface is wavy, more often it is sandy. Predominant widths of the mouth are 60-70 m, separate broadenings (mouth of the river Stracha) reach 200 m. Along the whole length there are small sandy islands, sand bars and braid bars. At the area between settlement Garavishki and settlement Dubok the riverbed is notable by considerable rapids. The bottom is sandy and stony, lower settlement Garavishki it is rich with separate boulders of different size. Banks are mainly steep, quite often are abrupt with height of 2-10 m, sandy-loam and are cut with ravines everywhere. There are outlets of groundwater in some areas.

The river Viliya and its tributarys are of great importance for providing favorable conditions for migratory, fluvial anadromous and other types of fish and also for preserving biological and landscape diversity of hinterlands. Lithuanian part of the river Viliya (the Neris) is an area “Natura-2000”, which was created for protection of salmon, otter, lampern, bitterling and other types of fish.

***The river Oshmyanka*** is a left tributary of river Viliya. The river is situated in Grodno Region. The length is 105 km, catchment basin is 1490 km$^2$, average water surface slope is 0,8 %, average annual consumption in the mouth is 13,4 m$^3$/sec. The river takes its begging near the settlement Murovannaya Oshmyanka, in the riverhead it flows through central part of Oshmyany elevation, in middle and lower regions it flows through Narochansko-Vileika lowland. The main tributaries: right tributaries are the rivers Panarka, Goruzhanka, Sikunka; left tributaries are the rivers Losha, Kernova. Valley is expressive, its width is 200-300 m, there are few lakes there, the biggest one is the lake Ryzheye. The riverbed in low water up to the mouth of the river Goruzhanka has a width of 3-5 m, lower - 15-20 m, for a distance of 6,3 km it is canalized from settlement Murovannaya Oshmyanka to the mouth of the river Zabolot. The banks are abrupt. It freezes at the middle of December, the floating of ice is at the end of March. The Snigyanskiy reservoir (the reservoir of Rachunskaya hydroelectric powerplant). At the banks of the river there are recreation area Osmyanka and medical rehabilitation center “Oshmyany” [76].

***The river Stracha*** is the right tributary of the Viliya. It flows through the territories of Postavy district, Ostrovets district and Myadel district. The length is 59 km, catchment basin is 1140 km$^2$, average water surface slope is 1 %, average annual consumption in the mouth is 9,1 m$^3$/sec. The river takes its begging from the lake Malye Shvakshty, it flows through south-western slopes of Svencyanski ridges, flows into the Viliya in 2 km from south-east from settlement Mikhalishiki. The riverhead is situated at the territory of hydrologic wildlife area Shvakshty. The main tributaries: right tributaries are the rivers Lyntupka, Struna; left tributaries are the rivers Sviritsa, Tushchanka. In the basin there are a lot of lakes with which it is connected by rivers, brooks, channels (Svir, Vishnevskoye, Bolshiye and Maliye Shvakshty, Balduk, Glublya, Glubelka, Vorobii, Gubeza, Edi and others). The valley at the upstream is indistinct, along the rest of the length of the river is trapeziform. The flood plain is double-sided, swampy, its lengh is 50-150 m. The riverbed is twisting in the upper flow and it is full of rapids, its width in low waters in upper and middle is 8-12 m, in lower - 15-20 m. The river is canalized at the length of 6,1 km from the settlement Olshavy to settlement Selevichi. The river takes the flow of land reclamation channels. The river is a popular place for water tourism [76].

***The river Gozovka*** – the left tributary is the river Viliya. The river flows through the territory of the Ostrovets district. The length is 17 km, catchment basin is 88 km$^{2.}$ average water surface slope is 2,5 %. The river takes its begging from the settlement Chizhovshchina, it flows into the river Viliya to the south-east from the settlement Potoki, in the lower reach it flows through the forest massif. At the length of 9,6 km the riverbed is canalized [76].

***The river Polpe*** - the left tributary is the river Viliya. The river source is situated at the west of the settlement Poboli of the Ostrovets district in Grodno region. The river Polpe flows into the river Viliya at the east of the settlement Markuny of the Ostrovets district in Grodno region. The length of the river is 9,2 km. Catchment basin is 30,8 km$^2$.

***Olkhovskiy reservoir*** is the reservoir of Olkhovskaya hydroelectric power plant; it is situated in the Ostrovets district at the river Stracha. It was built in 1951 at the river

Stracha in 26 km to the north-east from the settlement Ostrovets for water supply of the cardboard factory “Olkhovka”. Maximal water level difference between upper and lower pools is 3,0 m, water volume is 2,1 million $m^3$, catchment basin is 1140 $km^2$, conservation area is 1,4 million $m^3$, water-surface area is 0,7 $km^2$, average depth is 3 m, full depth is 5,2 m, length is 3,7 km, full width is 0,3 km. The banks are abrupt, in some places the height is up to 7 m, become overgrown with forest. Bottom is slimy. There are three islands with gross area of 0,1 hectare [76]. The distance from the site of surface water abstraction of NPP at the river Viliya is not less than 5 km. This reservoir could be used as one of reserve sources of industrial water supply of NPP.

***Snigyanskiy reservoir (reservoir of the Rachunskaya hydroelectric power plant)*** is situated in Smorgon district at the river Oshmyanka. It was built in 1958-1959 in 13 km to the north-west from Smorgon for the needs of energy sector (Rachunskaya hydroelectric power plant). Maximal level difference between upper and lower pools is 5,0 m, water volume 1,21 million $m^3$, water-surface area is 1,5-$km^2$, average depth is 1,42 m, full depth is 4,7 m, length is 5,5-km, full width is 0,8 km, water volume is 2,29 million $m^3$, catchment basin is 840 $km^2$. It is used for fish breeding. The kettle consists of two bays, the banks are mainly high, near the sothern part of the reservoir there is an island of 0,1 $km^2$. It is overgrown. At the banks there are the house of the fisher and boating station. The distance to the area of placement of surface water abstraction at the river Viliya is not more than 41,5 km. It could be used as a reserve source of industrial water supply of NPP.

**The river Losha –** left tributary of the river Ohmianka. It flows through the territories of the Ostrovets and Oshmyani districts. The length is 55 kilometers, the area of catchment is 455-$km^2$, middle water surface slope is 1,34 %, average annual consumption in the mouth is 3,9 $m^3$/s. It takes the beginning in 1,5 km from south-east of settlement Volkovshchina, in the river head it flows through south slopes of Oshmyany upper land, than through small woodland. It flows into the river Oshmyanka at south-north from the river Zarechye. Main tributary is the river Kovalevka. River valley up to Losha settlement is inexpressive, lower is trapeziform with width of 200-300 m, between settlements Polushi and Ostrovets up to 1 km. The flood plain is double-sided, mainly of 100-150 m wide. For a distance of 12 km from the river head the riverbed is canalized and at reminded area is twisting. The banks at the riverhead are abrupt. Yanovskiy reservoir is built at that river. [76].

### *13.4.2.2 Change in direction and intensity of the conditions of the structure of the drainage area*

The bulk of the reservoirs in catchment area of the Viliya river refers to the category of small reservoirs (which is the bulk volume is less then 30 mln. of cubic metres), which perform the daily or shallow season regulation of the drainage. Their impact on the stream flow is insignificant and die out very fast to the downstream. Many of reservoirs were created on the base of the lakes with the small domatic crystals drawdown and those reservoirs are designed to maintain a fixed level of the lake reservoir and has no impact to the water resources of those reservoirs. A change of annual distribution of stream flow for those two types of reservoirs, which differ from one to another by small-percentage of the active storage capacity as regards to the stream flow of the regulated river, happens within the natural variability.

The largest reservoir is the Vileika reservoir. This reservoir allows essentially changing the annual distribution of the the Viliya.

An agricultural reclamation takes an extra place and represents by itself the largest pattern impact to the environnement. In the river basin of the Viliya, 60 channels were regulated all along (1.22% from total number) of 518 km, 94 channels were regulated partially (5.9% from total number) of 565.3 km. Primary the rivers of the mileage to 25 km were totally regulated (94,5 %). Overwhelmingly the cutoff must be made under the particulate channel regulation.

### *13.4.3 Drain characteristics of water objects*

The drain characteristics of water objects within the 30-km area of the Belarusian NPP are defined essentially by the distribution according to their catchment-basin of the flow rates l/(s*km$^2$), wherefore the schematic maps are working up.

The schematic maps of the flow rates are used essentially to define the rates of the annual flow. The hydrological map of Belarus made in 2000 (Annex 1-98 to SNiP 2.01.14-83) is the fullest. An average error of the standart-settings of annual stream flow by map, using the interpolation method, is about 10-15 % and depends on the duration of the series of observations, drainage density in the given region, terrain smoothness in the given region and some other parameters. Flow rate parameters for catchment basins of the main channels of the Belarusian NPP site are given in Table 91.

**Table 91 – Flow rate parameters for catchment basins of the main channels of the Belarusian NPP site**

| River | Cathcment basins, km$^2$ | Average longstanding consump-tion, m$^3$/s | Annual flow rates, l/s km$^2$ | | |
|---|---|---|---|---|---|
| | | | avaverage longstand-ing | maximal | minimal |
| Viliya | 11050 | 79,6 | 7,2 | 9,67 | 4,86 |
| Oshmyanka | 1490 | 13,4 | 9,0 | 9,7 | 6,84 |
| Losha | 455 | 4,10 | 9,0 | 9,9 | 6,5 |
| Stracha | 1140 | 8,55 | 7,5 | 8,50 | 4,80 |

The hydrological regime of the Viliya has been changed in the given area due to the creation of Vileysko-Minsk hydrologic system (VMHS), including the Vileika reservoir. The Vileika reservoir was designed to provide a diversion of runoff flow to the Svisloch river and ensure some sanitary expenditures. Main characteristics of the Vileika reservoir are given in the Table 92.

**Table 92 - Main characteristics of the Vileika reservoir**

| Parametres | Characteristics | Computed values |
|---|---|---|
| Water levels, m BS | highest water level | 159,80 |
| | normal water level | 159,00 |
| | lower water level | 153,00 |
| Water volume, million m$^3$ | highest water level | 330 |
| | normal water level | 260 |
| | lower water level | 25,1 |
| Surface area of reservoir, hectare | highest water level | 9000 |
| | normal water level | 7700 |
| | lower water level | 1500 |

According to the water balance of the reservoir from the project specification of Vileysko-Minsk hydrological system for one year of 95 % of security [79] the water transfer is planned to 13,2 $m^3$/s.

Water levels in this reservoir are changing from 260 mln $m^3$ to 25,1 mln $m^3$ (the reservoir drawdown is planning for 6,0 m).

An observation data for the level-sensitive mode of the Vileika reservoir shows that the stream flow control of the Viliya is realized not by the full capacities provided by the project specifications. So, for example in 2005 the water levels were changing in low ranges - from 159,31 to 157,78 m (by 1.73 m). For the last years the transfer of the flow through the Vileysko-Minsk hydrological system decreased, especially for irrigation of the river Svisloch. According to the data of the Administration of the Vileysko-Minsk hydrological system from 1993 and till now the transfer of the flow from the river Viliya decreased from 7,06 million $m^3$ to 5,04 million $m^3$ (almost by 30 %). At the regular volume of the transfer of the flow into the reserve reservoir of the Vileysko-Minsk hydrological system, the transfer of the flow into the river Svisloch decreased from 3.80 million $m^3$ to 1,70 million $m^3$ (almost by 55 %). Total change of flow of the Viliya (to which extent has water consumption in comparison to natural mode decreased) in the range of the Vileika reservoir (lower reach) at the project consuption of the reservoir was 11,0-15,0 $m^3$/s (considering losses for evaporation and ice formation). For the last years due to the decrease of water diversion into the Vileysko-Minsk hydrological system, the consumption is approximately decresed twicely - for 6 $m^3$/s.

Maximal water consumption in the river Viliya of security are not less than 1 % lower than settlement Mikhlishiki for natural conditions can be more than 1600 $m^3$/sec. According to the project of the Vileika reservoir, the maximal regulated outlet of water consumption of the spring flood is 0,01 % of security is considered equal to 1560 $m^3$/s, and in the year - 1 % of security – 993 $m^3$/s. Changing of the hydrologic mode which is connected with the creation of the Vileysko-Minsk hydrological system at the period of the spring flood plays a positive role, decreasing negative consequences.

So at the distance from the Vileika reservoir to the border with Lithuania the flow rate from catchment basins of more than 6000 $km^2$ is formed, the regulating influence of reservoir is not considerable (except big flows when the volume of flow can be decreased by keeping of its part which falls to the catchment basin higher than the weir is in the Vileika reservoir).

Flowing characteristics (estimated volume flow of the given probability of excess) are estimated with the usage of Annex 1-98 to SNiP 2.01.14-83 according to observation data for water mode of the Viliya in the river range near the settlement Mikhalishki with revised estimation to the range of the placement of surface water abstraction and to the transboundary range (tables 93 – 95).

The full complex of hydrologic researches and calculations is made at the stage of choice explanation for the NPP site for ranges of the Viliya near the settlement Muzhily and for the transboundary range. Water intake flow near the settlement Malye Sviryanki is situated 2,4 km higher than the flow near the settlement Muzhily. At this given area there are no concentrated tributaries, water intakes and discharge water. So taking into consideration the change of the area of water abstraction, water consumption in the river in the range of the settlement Malye Sviryanki differs from water consumption in the settlement Muzhily for not more than to 0,5 %, which is in the limits of error of hydrologic parameters. So for the water abstraction point of the settlement Muzhily - settlement Malye Sviryanki, the estimated flow rates for the water abstraction point of the settlement Muzhily should be taken into account.

**Table 93 – Estimated annual average water consumption in the river Viliya (variation coefficient $C_v$ =0,244. Asymmetry factor $C_s$=5,5 $C_v$)**

| Possibility of excess | Water consumptions, $m^3/s$ "Mikhalishiki settlement – fall of the Stracha") | Water consumption, $m^3/s$ (water abstraction point "Muzhily settlement – Malye Sviryanki settlement" | Water consumption, $m^3/s$ (transboundary cross line) |
|---|---|---|---|
| average long-term | 63,50 | 64,90 | 68,12 |
| 50 % | 62,70 | 64,08 | 67,26 |
| 75 % | 55,00 | 56,21 | 59,00 |
| 80 % | 53,20 | 54,37 | 57,07 |
| 90 % | 48,90 | 49,98 | 52,46 |
| 95 % | 45,70 | 46,71 | 49,03 |
| 97 % | 43,80 | 44,76 | 46,99 |

**Table 94 – Estimated maximum water consumption in the river Viliya ($C_v$ =0,491. $C_s$=4,5 $C_v$)**

| Possibility of excess | Water consumptions, $m^3/s$ Mikhalishiki settlement | Water consumption, $m^3/s$ (water abstraction point "Muzhily settlement – Malye Sviryanki settlement" | Water consumption, $m^3/s$ (transboundary cross line) |
|---|---|---|---|
| 0.01 % | 4248 | 4341 | 4557 |
| 0.1 % | 2857 | 2920 | 3065 |
| 0.5 % | 1903 | 1945 | 2042 |
| 1.0 % | 1567 | 1601 | 1681 |
| 5.0 % | 918 | 938 | 985 |
| Maximum unfixed water consumption (1958) | 1570 | 1605 | 1684 |

**Table 95 – Minimal estimated water consumption in the river Viliya**

| Hydrological conditions | Possiblility of excess | Water consumptions, m³/s Mikhalishiki settlement | Water consumption, m³/s (water abstraction point "Muzhily settlement – Malye Sviryanki settlement" | Water consumption, m³/s (transboundary cross line) |
|---|---|---|---|---|
| The minimal daily water consumption in low-water winter period | 95 % | 18,20 | 18,60 | 19,52 |
| | 97 % | 17,50 | 17,89 | 18,77 |
| The minimal monthly water consumption in low-water winter period | 95 % | 30,85 | 31,53 | 33,10 |
| | 97 % | 29,90 | 30,56 | 32,08 |
| The minimal daily water consumption in low-water summer-autumn period | 95 % | 23,60 | 24,12 | 25,32 |
| | 97 % | 22,40 | 22,89 | 24,03 |
| The minimal monthly water consumption in low-water summer-autumn period | 95 % | 30,30 | 30,97 | 32,51 |
| | 97 % | 29,20 | 29,84 | 31,33 |
| The minimal ever registered water consumption (august 1992) | | 23,9 | 24,43 | 25,64 |

In Table 96 you can see an annual flow distribution for different hydrological conditions. It was calculated with help of period-composition method.

**Table 96 – An annual flow distribution in the river Viliya for transboundary cross line.**

| Month | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| An average dryness of the year | | | | | | | | | | | | |
| Month | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| % from annual flow | 6,49 | 5,63 | 13,44 | 18,23 | 9,71 | 7,65 | 6,19 | 5,00 | 5,14 | 6,19 | 7,93 | 8,40 |
| Water consumption | 52,35 | 45,38 | 108,4 | 147,0 | 78,31 | 61,69 | 49,89 | 40,34 | 41,41 | 49,89 | 63,94 | 67,69 |
| Shallow year 95 % possibility of excess | | | | | | | | | | | | |
| Month | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| % from annual flow | 5,65 | 5,14 | 16,10 | 21,15 | 11,51 | 6,80 | 5,63 | 4,94 | 4,91 | 5,38 | 5,93 | 6,86 |
| Water consumption | 33,26 | 30,25 | 94,73 | 124,4 | 67,69 | 40,02 | 33,15 | 29,07 | 28,86 | 31,65 | 34,87 | 40,34 |
| Very shallow year 97 % possibility of excess | | | | | | | | | | | | |
| Month | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| % from annual flow | 8,05 | 8,89 | 14,57 | 17,95 | 10,48 | 6,76 | 5,49 | 4,84 | 4,88 | 5,36 | 5,94 | 6,78 |
| Water consumption | 45,49 | 50,21 | 82,28 | 101,4 | 59,22 | 38,19 | 31,00 | 27,36 | 27,57 | 30,25 | 33,58 | 38,30 |

### *13.4.4 Level and velocity mode characteristics*

Water level characteristics of the river Viliya for water consumtion of intended supply can be clearly traced in tables 97-99. The graph of interdependance between water consumption and water level in Muzhily settlement and water abstraction point in Muzhily settlement - Malye Sviryanki settlement can be traced in Table 97.

**Table 97 – Estimated water levels in the river Viliya, which correspond to annual water consumption.**

| Possibility of excess | Water level, m (Mikhalishki settlement) | Water level, m (water abstraction point in Muzhily settlement - Malye Sviryanki settlement) | Water level, m (transboundary cross line) |
|---|---|---|---|
| Average annual flow | 120,00 | 117,10 | 112,30 |
| 50 % | 119,98 | 117,08 | 112,29 |
| 75 % | 119,84 | 116,87 | 112,14 |
| 80 % | 119,80 | 116,89 | 112,10 |
| 90 % | 119,70 | 116,81 | 112,02 |
| 95 % | 119,63 | 116,75 | 111,96 |
| 97 % | 119,58 | 116,71 | 111,92 |

**Table 98 – Estimated water levels in the river Viliya, which correspond to maximal water consumption.**

| Possibility of excess | Water level, m (Mikhalishki settlement) | Water level, m (water abstraction point in Muzhily settlement - Malye Sviryanki settlement) | Water level, m (transboundary cross line) |
|---|---|---|---|
| 0,01 % | 131,00 | 128,58 | 122,22 |
| 0,1 % | 128,14 | 125,63 | 121,34 |
| 0,5 % | 126,18 | 123,61 | 120,39 |
| 1,0 % | 125,49 | 122,89 | 119,81 |
| 5,0 % | 123,87 | 122,47 | 117,84 |
| Within the maximal registered water consumption (1958) | 125,32 | 122,90 | 119,82 |

Nuclear power plant site won't be flooded even in case of maximal water level, because ground surface marks on its territory is 175-176 m. This is 4 m higher than maximal water levels registered in the river Viliya.

**Table 99 – Estimated water levels in the river Viliya, which correspond to minimal water consumption.**

| Hydrological conditions | Possibility of excess | Water level, m (Mikhalishki settlement) | Water level, m (water abstraction point in Muzhily settlement - Malye Sviryanki settlement) | Water level, m (transboundary cross line) |
|---|---|---|---|---|
| The minimal daily water consumption in low-water winter period | 95 % | 118,64 | 116,03 | 111,33 |
| | 97 % | 118,62 | 116,01 | 111,29 |
| The minimal monthly water consumption in low-water winter period | 95 % | 119,12 | 116,37 | 111,68 |
| | 97 % | 119,08 | 116,35 | 111,66 |
| The minimal daily water consumption in low-water summer-autumn period | 95 % | 118,84 | 116,17 | 111,54 |
| | 97 % | 118,80 | 116,14 | 111,51 |
| The minimal monthly water consumption in low-water summer-autumn period | 95 % | 119,10 | 116,36 | 111,66 |
| | 97 % | 119,06 | 116,33 | 111,64 |
| The minimal ever registered water consumption (august 1992) | | 118,86 | 116,18 | 111,54 |

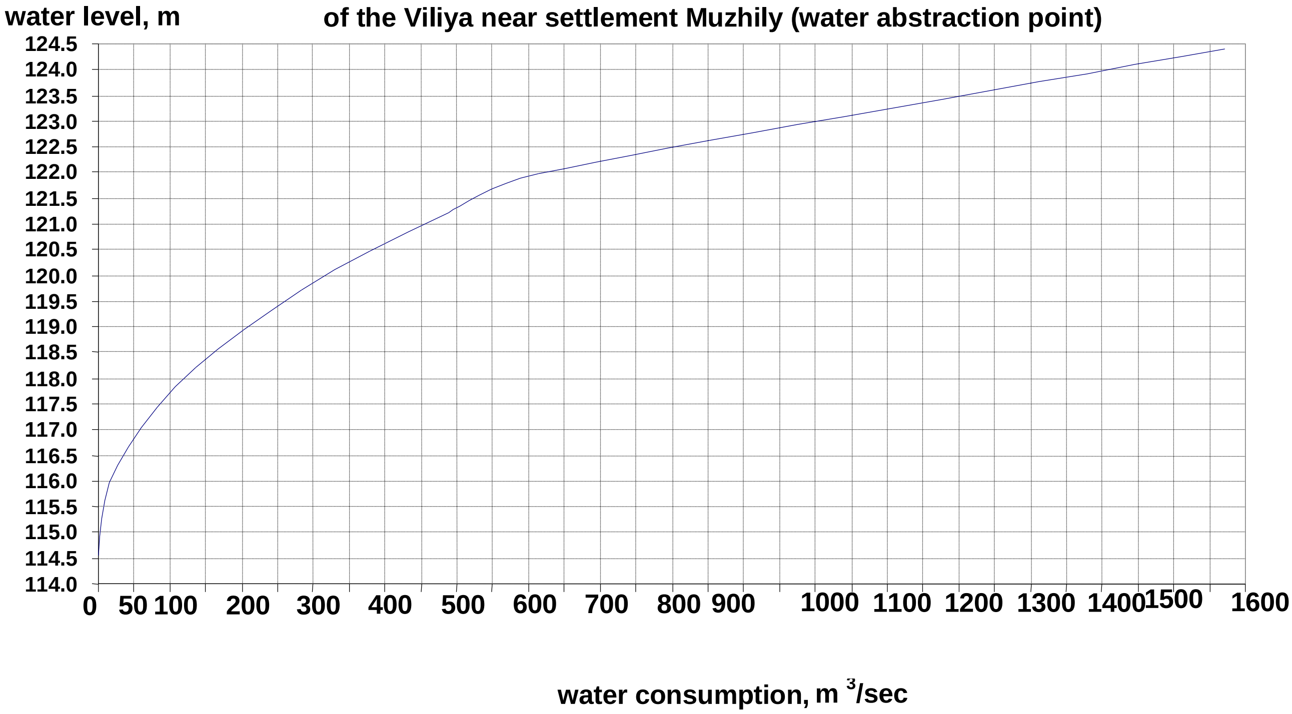



**Figure 68 - Dependence of consumption from water level Q(Y) for cross section**

The Viliya at the area from Mikhalishiki to the Belarusian-Lithuanian border is characterized by rather high velocity of water course. Average velocity within this area vary depending on hydrologic mode from 0,35 (minimal water consumption) to 0.8 m/s.

#### *13.4.5 General characteristics of winter regime*

The first ice formations on the river Viliya in the station of Mikhalishki occur mainly in late November, the earliest was thus marked on 30.10.1979, and the latest – 29.12.1949. The autumn ice drift begins also in the third decade of November in a few days after the first ice formations, only in 1988 it came on January 4, and in 1990 – on December 18. The maximum duration of the autumn ice drift – 96 days – was observed during the autumn-winter period of 1954-1955.

The earliest ice formation was observed on 20.11.1965 and 1994, and later – on 11.03.2005. The maximum duration of ice is 117 days and was observed during the autumn-winter period 1963-1964, and last years – 111 days during the winter period of 1993-1994. The thickness of ice reaches up to 54 cm according to long-term observations and in the recent years – up to 46 cm.

In spring as positive air temperatures set, we can follow thawing and destruction of ice cover. Destruction of ice cover occurs almost simultaneously all over the river Viliya.

The spring ice drift on the river Viliya in the station of of Mikhalishki begins mainly in the end of March, thus the earliest approach of a spring ice drift was observed on January 30, 2002, and later – on April 12, 1963. Duration of spring ice drift varies from 2 to 17 days according to long-term observations and in the recent years – from 1 to 14 days.

Clearance of ice of the river Viliya in the station of Mikhalishki occurs mainly in the end of March, thus the earliest was observed on January 10th, 1990 and the latest - on April 18, 1956.

The maximum duration of the ice period is 131 day (2005) and 39 days (2007) as minimum.

Ice dams on Viliya (during ice thawing in autumn-spring period) are formed almost annually, are powerful and enduring (reached 117 days in 1996). The maximum ice dam height reaches 139 cm (1988) against post "zero" as to a water level before ice dams formation was 117 cm. Estimated value of the maximum rising level during ice dam period at probability of excess P=1 of % makes $\Delta h_{jam,P=1\%} = 125$ cm.

In the station of Mikhalishki on the river Viliya, the ice jamming is not annual. Sometimes it reaches 17 days (1995), and the maximum height of water rising as to «post zero» reached 2 m (1994) which in relation to a water level before jam formation was 109 cm. Estimated value of the maximum rising of water level during the mash period at probability of excess P=1 of % makes $\Delta h_{dam,P=1\%} = 118$ cm.

Evidence of a dangerous ice phenomenon, including ice dams and jams, causes requirements for its monitoring. For that reason monitoring over an ice regime of the Viliya at the relevant area of water abstraction points is essential, as well as taking measures for prevention and decrease in unfavourable effect of the ice phenomena**.**

### *13.4.6 Sediments and characteristics of channel evolution*

The analysis of sediments in the river Viliya at the place of location of water abstraction points "settlement Malye Sviryanki - settlement Muzhily" for industrial water supply of the Belarusian nuclear plant showed that coarse, medium and fine sand mainly dominate here, and coarse sand with pebbles prevail at the right bank. The average diameter of soil particles of sediments d 50 % equals to:

- at the left bank – 0,84 mm;
- in the middle of the river – 0,87 mm;
- at the right bank – 2,81 mm.

Sediments width (thickness) is not significant and varies at the place of location of the water abstraction point of the Belarusian NPP up to 8 cm. Dynamics of sediment movement and areas of its highest accumulation are mostly applicable to the concave parts of the banks. At a distance of 2 m, regardless of the characteristics of the bank (straight, convex and concave), the thickness of sediments can reach 15-20 cm in some places, due to the process of reshaping of the bank during the river meandering.

Characteristics of the bottom sediments contamination of the river Viliya are based on analysis of sediments samples of the water abstraction point "Muzhily settlement-Malye Svirianky settlement" and are presented in Table 100.

**Table 100 – Characteristics of bottom sediments contamination of the river Viliya in the water abstraction point**

| Contamination index | | Unit | 300 m below the Muzhily settlement, water depth is 1,3 m, thickness of sediments – 6 cm | 500 m below Malye Sviryanki settlement, water depth is 1,3 m, thickness of sediments – 8 cm |
|---|---|---|---|---|
| 1 | pH of the aqueous extract | - | 7,62 | 7,46 |
| 2 | Chlorides | mg / kg | 32 | 36 |
| | | % | 0,0032 | 0,0036 |
| 3 | Sulfates | mg / kg | 24 | 43 |
| | | % | 0,0024 | 0,0043 |
| 4 | Petroleum | mg / kg | 3,48 | 5,85 |
| 5 | Copper | mg / kg | 0,95 | 0,90 |
| 6 | Lead | mg / kg | 1,05 | 1,05 |
| 7 | Zinc | mg / kg | 7,25 | 7,30 |
| 8 | Nickel | mg / kg | 5,35 | 5,05 |
| 9 | Cadmium | mg / kg | 0,03 | 0,03 |
| 10 | Chromium total | mg / kg | 4,10 | 4,30 |

Currently, Belarus has no standards for maximum chemicals concentration in sediments allowed, and therefore it is impossible to determine the environmental status of the sediments.

Channel evolution of meandering type dominates in the part of the river Viliya in the nuclear plant site in the Belarusian-Lithuanian border, which characterizes the winding sections of rivers, regulated by natural ways where meandering river channel types are natural. According to estimation no substantial change in river bed is expected.

Despite of the small thickness of sediment layer, the river Viliya is characterized by intensive river bed evolution due to erosion and sedimentation at high midstream speed, which leads to horizontal (plan) and vertical (depth) deformation.

Horizontal (plan) river bed deformation of the Viliya during the 31-year period, equals to average of 11-12 m (up to 40 cm per year), maximum - up to 28 m in the area between firth of the river Dudka and firth of the river Gozovka. Information is based on mapping information and aerospace photos.

Vertical (depth) river bed deformation of the Viliya caused by erosion and sediment transfer are up to 0,45 m, which is based on calculations and field studies in 2008-2009 in the section "settlement Muzhily - Malye Sviryanki settlement". The presence and extent of river bed deformations stipulates the necessity fixing the bank at the place of location of the water abstraction point.

In the past 25 years the river Viliya is characterized by low turbidity. Thus, during the observation period from 1993 to 2006, maximum turbidity was observed during the spring flood in April 1999, which was near the town Vileika - 37 mg / dm $^3$, near the town Steshitsy - 25 mg / dm $^3$. The pilot studies in 2008-2009 showed an average turbidity of the river Viliya near settlement Mikhalishki - 4.9 mg/dm$^3$ and 5,3 mg/dm$^3$ near settlement Muzhily.

Estimated speed of particles intension in suspended sediments depending on hydrological conditions range from 0.001 to 0.012 m / s (increase with the reduction of axial velocities) at the area of location of the water abstraction point "settlement Malye Sviryanki - settlement Muzhily ".

### *13.4.7 Water quality according to hydrochemical properties and its integrated assessment*

#### *13.4.7.1 Water quality assessment of the river Viliya and its tributaries by hydrochemical parameters (as a fishery water body)*

Quality assessment of the river Viliya in the area from Smorgon to settlement Bystrica by the main hydrochemical parameters was carried out according to observations of the National Environment Monitoring System (NEMS) of the Republic of Belarus for the period 2003-2008. Concentrations were compared with standards for fishery water bodies (PDKr/h), as well as with the values of baseline indicators for the River Viliya, based on [80], with the values obtained from observations of water quality in the station of the river Iliya, settlement Ilya, which is the background for the basin of the river Viliya [81].

The average and maximum concentrations of total iron in the researched cross-sections of observations of the river Viliya exceed the values PDKr /h, because of its natural regional origin, since the average concentration does not exceed the background values in the river Iliya settlement Ilya.

The values of salinity, chlorides, sulfates, nitrogen, nitrate, cadmium, phosphorus total during the observations in the river Viliya do not exceed PDKr/h.

Averaged values of suspended solids exceed the background values for the basin of Viliya which is 7 mg / dm 3.

Average and minimum bichromate oxidizability values are within the background values in the alignment of the river Iliya settlement Ilya (48,6 mg / dm $^3$), and increased values of maximum concentrations are due to the influence of sewage in the low-flow period.

Averaged and minimum values of $BOD_5$ meet the standards for fishery water bodies, increased values of maximum concentrations due to sewage enterprises of housing and communal services in low-flow period.

Average and minimum concentration of ammonia nitrogen, nitrite nitrogen, phosphorus, phosphate does not exceed PDKr /h, and some high maximum values are due to flushing in the spring and summer from the territories occupied by animal husbandry, poultry farms, fertilized fields and pastures.

Average and minimum concentration of copper did not exceed its background value (0,005 mg / dm $^3$). Average and minimum nickel concentration does not exceed the value PDKr /h, and the maximum does not exceed the background values for nickel basin of the river Viliya (0,02 mg / dm $^3$).

Average and minimum values of manganese, surfactants are in the range of background values in the alignment of the river Iliya settlement Ilya (0,086 mg / dm $^3$ and 0,029, respectively).

Thus, the average annual concentrations of pollutants comply with good water quality in the river Viliya, and the maximum values are once recorded and have either regional background nature (heavy metals), or the surface destruction of catchment area in the low-flow period.

Integral assessment of water quality in the river Viliya was conducted on water contamination index (WPI) during the period 2003-2008, the calculations were performed using the following formula [82] $WPI = \frac{1}{6}\sum_{i=1}^{6}\frac{C_i}{PDK_i}$ for the annual average concentrations of dissolved oxygen, $BOD_5$, ammonia nitrogen, nitrite nitrogen, phosphorus, phosphate and petroleum products and their standards for water fishery. The calculation results are given in Table 101.

**Table 101 - WPI Values in the river Viliya for the period 2003-2008**

| Observation alignments | 2003 . | 2004 | 2005. | 2006 . | 2007 | 2008 |
|---|---|---|---|---|---|---|
| river Viliya - 4 km NE settlement Smorgon | 0,95 | 0,97 | 0,88 | 0,82 | 0,81 | 0,59 |
| river Viliya - 6 km NE settlement Smorgon | 1,00 | 0,99 | 0,95 | 1,05 | 0,61 | 0,58 |
| river Viliya – 0,3 NE settlement Bystritsa | 0,68 | 0,89 | 0,68 | 1,89 | 0,63 | 0,58 |

As seen from the table, an integral index WPI for the river Viliya during the period 2003-2008, 4 km NE of the settlement Smorgon varies from 0,59 to 0,95 (which corresponds to the classification of [82] II class quality - relatively clean water) in the alignment of 6 km NE settlement of Smorgon, which is located downstream of the previous alignment, it varies from 0,58 (which corresponds to the classification of [82] II class quality, relatively pure water) to 1,05 (which corresponds to the classification of [82] III class quality, moderately polluted water) in the alignment of 0,3 NE settlement Bystritsa, which is a transboundary district, WPI changed from 0,58 (which corresponds to the classification of [82] II class quality, relatively pure water) to 1,89 (which corresponds to the classification of [82] III class quality, moderately polluted). So, the water in the river Viliya is characterized by II-III class quality in its entirety on the territory of Belarus. It should be noted that there is a tendency to water quality improvement over the past 2 years.

According to the field hydrologic study water quality of the major tributaries of the river Viliya within the Belarusian NPP site (rivers Gozovka and Polpe) complies with MAC of fishery, except for total iron and manganese concentrations, which are higher (up to 10 MACs) due to their natural content (the mentioned tributaries do not have sewage water outlets, human pressure in the area is low).

*13.4.7.2 Assessment of water quality in the river Viliya and reservoirs by hydrochemical parameters (as the main source of industrial water supply)*

Comparative analysis of concentrations of pollutants in the river Viliya as the main source of industrial water supply based on cultural and domestic standards of water supply showed that the water in the river Viliya do not satisfy (for maximum value) the specifications for such ingredients as iron total, ammonia nitrogen and $BOD_5$. As mentioned above, this is due to regional natural origin of iron, as well as discharge of sewage and surface water with a catchment area of low-flow period. I.e. using water from the river Viliya for drinking purposes requires iron removal plants.

The results of field studies undertaken during the development of hydrological characteristics of Ostrovets NPP in all phases of the hydrological regime during 2008-2009 showed good water quality for the hydrochemical parameters of the rivers and reservoirs (the source of industrial water supply of the Belarusian nuclear plant): in the river Viliya and its major reservoirs in the area: Olhovskoye and Snigyanskoye (Table 102, 103).

**Table 102 - Characteristics of water quality in the river Viliya for hydrochemical parameters based on field stduies**

| Contamination index | | river Viliya (settlement Muzhily) | | | river Viliya (settlement Mikhalishki) | | | MAC cultural & general/ economic activity require-ments |
|---|---|---|---|---|---|---|---|---|
| | | Aver-age | MAX | MIN | Average | MAX | MIN | |
| 1 | Temperature, C | 12,9 | 23,8 | 5,6 | 11,66 | 23,8 | 5,7 | |
| 2 | Odor at 20 и 60 (point) | 0 | 0 | 0 | 0 | 0 | 0 | |
| 3 | Dry residue (mg/dm3) | 262,3 | 279 | 244 | 249,2 | 267 | 240 | |
| 4 | Chroma (degree) | 18,6 | 26 | 13 | 18,9 | 26 | 12 | |
| 5 | Muddiness (mg/dm3) | 4,94 | 10,2 | 3,2 | 4,65 | 9,8 | 2,2 | |
| 6 | pH Value | 8,09 | 8,29 | 7,96 | 8,044 | 8,25 | 7,9 | 6,5-8,5 |
| 7 | Suspending solids (mg/dm3) | 3,96 | 7,4 | 0,8 | 6,32 | 17,6 | 1,2 | |
| 8 | Calcium, $Ca^{2+}$ (mg/dm3) | 61,23 | 64,91 | 58,46 | 59,15 | 63,71 | 53 | |
| 9 | Magnesium, $Mg^{2+}$ (mg/dm3) | 15,75 | 17,19 | 13,37 | 14,53 | 17,13 | 12 | |
| 10 | Sodium, $Na^{2+}$ (mg/dm3) | 6,65 | 8,12 | 5,6 | 5,96 | 7,75 | 5 | 200 |
| 11 | Potassium, $K^{+}$ (mg/dm3) | 2,65 | 2,96 | 2,25 | 2,27 | 2,5 | 1.9 | |
| 12 | Iron total (mg/dm3) | 0,15 | ***0,312*** | 0,03 | 0,190 | 0,242 | <0,03 | /0,3 |
| 13 | Manganese, $Mn^{2+}$ (mg/dm3) | 0,049 | ***0,138*** | 0,01 | 0,052 | 0,098 | 0 | 0,1 |
| 14 | Aluminium, $Al^{3+}$ (mg/dm3) | 0,028 | 0,049 | 0,007 | 0,025 | 0,043 | 0 | 0,5 |
| 15 | Cuprum, $Cu^{2+}$ (mg/dm3) | 0,015 | 0,02 | <0,001 | 0,002 | 0,002 | <0,001 | 1 |
| 16 | Lead, $Pb^{2+}$ (mg/dm3) | 0,001 | 0,001 | <0,001 | 0,005 | 0,005 | <0,001 | 0,03 |
| 17 | Zinc, $Zn^{2+}$ (mg/dm3) | 0,011 | 0,011 | <0,005 | 0,0083 | 0,013 | <0,005 | 1 |
| 18 | Phosphate, $PO_4^{3-}$ (mg/dm3) | 0,097 | 0,171 | 0,015 | 0,078 | 0,13 | 0 | - |
| 19 | Chloride, $Cl^{-}$ (mg/dm3) | 13,78 | 16,55 | 11.75 | 12,05 | 13,63 | 11 | 350 |
| 20 | Sulfate, $SO_4^{2-}$ (mg/dm3) | 25,88 | 30 | 18.9 | 25,73 | 28,75 | 19 | 500 |
| 21 | Hydrocarbonate (equiv. mg/dm$^3$) | 224,74 | 236,09 | 207.2 | 214,45 | 235,77 | 183 | |
| 23 | Hydrogen sulfide, $H_2S$ (mg/dm3) | not de-tected | not de-tected | not de-tected | not de-tected | not de-tected | not de-tected | |
| 24 | Silicon, $SiO_3^{2-}$ (mg/dm3) | 6,44 | ***10,04*** | 2.4 | 5,35 | 9,21 | 2,2 | 10 |
| 25 | Hardness total (equiv. mg/dm$^3$) | ***4,37*** | ***4,61*** | ***4.02*** | ***4,15*** | ***4,59*** | 3,6 | /4,0 |
| 26 | Carbonate (equiv. mg/dm$^3$) | 3,68 | 3,87 | 3.4 | 3,51 | 3,86 | 3 | |
| 27 | Constant (equiv. mg/dm$^3$) | 0,67 | 0,74 | 0.62 | 0,64 | 0,75 | 0,5 | |
| 28 | Ammonium, $NH_4^{-}$ (mg/dm3) | 0,153 | 0,3 | 0.04 | 0,23 | 0,6 | 0 | 1 |
| 29 | Nitrate, $NO_3^{-}$ (mg/dm3) | 4,29 | 8,4 | 0.8 | 2,67 | 7,8 | 0 | 45 |
| 30 | Nitrites, $NO_2^{-}$ (mg/dm3) | 0,041 | 0,074 | 0.006 | 0,038 | 0,074 | 0 | 3,3 |
| 31 | Petroleum (mg/dm3) | 0,0094 | 0,015 | 0.006 | 0,0084 | 0,013 | 0 | 0,3 |
| 32 | Synthetic surfactants (mg/dm3) | 0,025 | 0,065 | 0.005 | 0,01525 | 0,05 | 0 | 0,5 |
| 33 | Phenol (mg/dm3) | 0,003 | 0,003 | not de-tected | <0,0005 | 0,00157 | не обн. | 0.001 |
| 34 | $BOD_5$ (мг·$O_2$/дм$^3$) | 3,24 | 3,95 | 2.17 | 3,168 | 4,2 | 2,4 | 4 |
| 35 | COD (мг$O_2$/дм$^3$) | 22,99 | 28,1 | 17.4 | 24,83 | ***31,1*** | 20 | 30 |

**Table 103 - Water quality characteristics of the Stracha, Oshmyanka (reservoir Snigyanskoye) for hydrochemical parameters as a result of field studies**

| Contamination index | | river Stracha (350 м down the stanch of the Olhovskiy reservoir) | | | river Oshmyanka (Snigyanskoye reservoir) | | | MAC cultural & general/ economic activity requirements |
|---|---|---|---|---|---|---|---|---|
| | | Average | MAX | MIN | Average | MAX | MIN | |
| 1 | Temperature, C | 10,6 | 24 | 5,6 | 12,88 | 23,5 | 5,7 | |
| 2 | Odor at 20 и 60 (point) | 0 | 0 | 0 | 0 | 0 | 0 | |
| 3 | Dry residue (mg/dm3) | 245 | 263 | 224 | 293,8 | 327 | 276 | |
| 4 | Chroma (degree) | 13,75 | 21 | 4 | 15,6 | 20 | 7 | |
| 5 | Muddiness (mg/dm3) | 2,44 | 4 | 1,7 | 2,85 | 4,7 | 0,8 | |
| 6 | pH Value | 6,21 | 8,14 | 0,8 | 8,08 | 8,2 | 7,89 | 6,5-8,5 |
| 7 | Suspending solids (mg/dm3) | 1,55 | 3,6 | 0,6 | 3 | 5,6 | 1,2 | |
| 8 | Calcium, $Ca^{2+}$ (mg/dm3) | 59,01 | 63,71 | 50,45 | 69,95 | 76,76 | 66,03 | |
| 9 | Magnesium, $Mg^{2+}$ (mg/dm3) | 14,64 | 18,58 | 11,66 | 17,13 | 18,47 | 15,8 | |
| 10 | Sodium, $Na^{2+}$ (mg/dm3) | 5,19 | 5,8 | 3,82 | 8,17 | 9,41 | 6,93 | 200 |
| 11 | Potassium, $K^{+}$ (mg/dm3) | 2,18 | 2,42 | 1,58 | 3,84 | 4,53 | 3,33 | |
| 12 | Iron total (mg/dm3) | 0,212 | ***0,309*** | 0,13 | 0,23 | ***0,401*** | <0,03 | 0,3 |
| 13 | Manganese, $Mn^{2+}$ (mg/dm3) | 0,074 | 0,088 | 0,052 | ***0,103*** | ***0,219*** | 0,042 | 0,1 |
| 14 | Aluminium, $Al^{3+}$ (mg/dm3) | 0,026 | 0,041 | 0,014 | 0,026 | 0,038 | 0,017 | 0,5 |
| 15 | Cuprum, $Cu^{2+}$ (mg/dm3) | 0,0016 | 0,002 | <.0.001 | 0.0011 | 0,0012 | 0,001 | 1 |
| 16 | Lead,$Pb^{2+}$ (mg/dm3) | 0,001 | 0,001 | <.0.001 | <0,001 | <0,001 | <0,001 | 0,03 |
| 17 | Zinc, $Zn^{2+}$ (mg/dm3) | 0,0055 | 0,006 | <0,005 | 0,011 | 0,011 | <0,001 | 1 |
| 18 | Phosphate, $PO_4^{3-}$ (mg/dm3) | 0,238 | 0,82 | 0,008 | 0,181 | 0,253 | 0,034 | - |
| 19 | Chloride, $Cl^-$ (mg/dm3) | 10,4 | 11,69 | 8,8 | 16,05 | 18,6 | 12,66 | 350 |
| 20 | Sulfate, $SO_4^{2-}$ (mg/dm3) | 24,94 | 27,25 | 23,5 | 27,50 | 35,27 | 18,9 | 500 |
| 21 | Hydrocarbonate (equiv. mg/dm$^3$) | 212,32 | 234,49 | 171,5 | 258,11 | 282,68 | 234,49 | |
| 23 | Hydrogen sulfide, $H_2S$ (mg/dm3) | not detected | <0,02 | not detected | not detected | not detected | not detected | |
| 24 | Silicon, $SiO_3^{2-}$ (mg/dm3) | 5,33 | 8,94 | 2,1 | 8,44 | ***12,33*** | 3,5 | 10 |
| 25 | Hardness total (equiv. mg/dm$^3$) | ***4,15*** | ***4,71*** | 3,48 | ***4,90*** | ***5,31*** | ***4,6*** | /4,0 |
| 26 | Carbonate (equiv. mg/dm$^3$) | 3,48 | 3,84 | 2,81 | 4,23 | 4,63 | 3,84 | |
| 27 | Constant (equiv. mg/dm$^3$) | 0,68 | 0,87 | 0,52 | 0,67 | 0,77 | 0,62 | |
| 28 | Ammonium, $NH_4^-$ (mg/dm3) | 0,19 | 0,28 | <0,01 | 0,15 | 0,34 | 0,03 | 1 |
| 29 | Nitrate, $NO_3^-$ (mg/dm3) | 3,18 | 7,1 | 0,6 | 5,48 | 9,8 | 1,3 | 45 |
| 30 | Nitrites, $NO_2^-$ (mg/dm3) | 0,042 | 0,07 | <0,01 | 0,08 | 0,14 | 0,039 | 3,3 |
| 31 | Petroleum (mg/dm3) | 0,007 | 0,009 | <0,005 | 0,0064 | 0,008 | 0,005 | 0,3 |
| 32 | Synthetic surfactants (mg/dm3) | 0,031 | 0,07 | 0,004 | 0,035 | 0,065 | not detected. | 0,5 |
| 33 | Phenol (mg/dm3) | not detected | <0,0005 | not detected | 0,0014 | 0,0014 | not detected | 0,001 |
| 34 | BOD $_5$ (mg·$O_2$/dm$^3$) | 2,58 | 3,46 | 1,96 | 2,98 | 3,77 | 2,16 | 4 |
| 35 | COD (mg$O_2$/dm$^3$) | 24,77 | 30 | 17,89 | 21,56 | 28 | 15,46 | 30 |

### *13.4.8 Environmental health of the main watercourses and water reservoirs*

The sanitary and hygienic state of the major watercourses (rivers Viliya, Polpe, Gozovka) and water basins (Snigyanskoye and Olkhovskoye reservoirs) within the NPP site, which is determined by the sanitary and microbiological values for the different phases of the hydrological regime and results of the field studies showed that the values of the indicators meet the requirements of SanPiN 2.1.2.12-33-2005. No obvious tendencies of water quality deterioration are observed. The following indicators were examined: total coliform bacteria (EDB), thermotolerant coliform bacteria, coliphages, agents of intestinal infections (dysentery, salmonellosis).

### *13.4.9 Thermal regime of water bodies*

To assess the characteristics of the temperature regime of river water we summarized and generated in tables raw data in the station of the river Viliya - settlement Mikhalishki for which a representative observation period of water temperature, taken into account, was 32 years (1976-2007 years). This range is quite sufficient for reliable conclusions on possible natural oscillations of the unfavourable temperature conditions, as this value doesn't vary much in long-term perspectives ($C_V$ = 0,16). Fluctuations in water temperature during the year are also quite smooth seasonal, flat changing annualy.

Basic analysis and calculations were made based on the average water temperature, as due to the low volatility of this index, it is possible to get more detailed specifications, including fixed-term values, using some of the coefficients. For example, special studies on diurnal fluctuations in water temperature showed that the maximum emergency water temperature can exceed the average daily (monthly average) value (on bi-terminable or four-terminable observations) at an average of 1,5 $^0$C. Further we proceed with this data.

Analysis of the initial ranges showed that the estimated range of the period when they can mark the maximum water temperature is from May to August. The probability of occurrence of the maximum temperature in the year in a given month is significantly different: in May 3 %, in June - 26 %, in July - 20%, in August - 5 %, that is the most likely period is at the beginning and middle of summer - in June, July – 83 %.

During June - August intervals fluctuations in water temperature and its availability are following:

- 15 °C – 17 °C – 5,1 %;
- 17 °C – 19 °C – 46,9 %;
- 19 °C – 21 °C – 38,8 %;
- 21 °C – 23 °C – 7,2 %;

-> 23 °C – 2 %.

Curve of the average water temperature and supply curves of the maximum monthly average (for the whole summer) and the maximum term water temperatures were (mutually) constructed for the June-July period. The coefficient of variation $C_V$ = 0,05, assymetry $C_s$ = 0,1 for the constructed curves security. Estimated values of water temperatures in the river Viliya in settlement Mikhalishki with 0,01% occurrence were received using the probability curves. (Table 104).

**Table 104 - Characteristics of the observed and estimated maximum water temperatures of the river Viliya in settlement Mikhalishki**

| Air temperatures observed °C | | | Specified temperature °C, with security P=0,01% | |
|---|---|---|---|---|
| Monthly average high | Max decade (June-July) | Max terminable (daily) | Monthly average high | Max terminable (daily) |
| 23,7 | 23,7 | 27,5 | 26,5 | 28,0 |

### *13.4.10 Water users and consumers*

Since in the basin of the Viliya, Vileika reservoir was built, Vileysko-Minsk hydrological system began to operate since 1976, and drainage of the river Viliya undergone significant changes. After creating the reservoir, average annual runoff of the river Viliya in settlement Mikhalishki decreased by 12 %, maximum – 16 %, minimum – 11 %. according to the observation period from 1976 to 2007

As studies have shown, the value of recent impact of economic activities in the water-shed area on water regime is within the accuracy of calculations.

Regulated runoff from the land is low. There are 100 ponds in the basin of the river Viliya, with total area of 950 ha and a volume of 14,437.3 $m^3$.

The value of water abstraction in the basin of the river Viliya are 104,5 million $m^3$ and 96,59 million $m^3$ from surface of natural water sources, 32,76 million $m^3$ and 30,46 million $m^3$ from groundwater sources according to data for 2007 and 2008 respectively. Removal of runoff from the river at present does not exceed 124 million $m^3$ per year, which is less than 10 % of the annual flow of 97 % security above the settlement Mikhalishki, therefore, there is no significant effect on changes in the drainage regime of the river. Planned growth of non-returnable abstraction for the needs of water usage in the river basin will not exceed 10% of the discharge of 95% security, which is in the range of error of the hydrological variables and will not have significant effects on the hydrological regime of river Viliya.

### *13.4.11 Protected areas of water bodies*

Water protection zones and riverside are protected areas of the water bodies.

According to the designed project of water protection zones and riversides of the river Viliya within the Grodno region [83], which was approved by the Decision of the Grodno Regional Executive Committee dd 30.12.2004 No. 709, the minimum protection zone on the left bank of river Villija should be 700 m in the settlement Mikhalishki and 350 m in the settlement Zabelishki, and the minimum width of the riverside along the left bank of the river should be 50 m.

According to Art. 77 of the Water Code placing sewage ponds, fields, irrigation, sewage, and other objects capable of causing chemical or biological contamination of surface and groundwater, posing a threat to life and health of people who violate other requirements of ecological safety device objects disposal and storage of waste, except for authorized places of temporary storage of waste shall be prohibited within the range of the protected areas.

In addition to the above deployment of facilities for sewage treatment (except for facilities for treatment of storm water) and processing of sewage sludge within the riversides should be prohibited.

Within the riversides the following construction and reconstruction are allowed:

– waterworks, including water wells and water regulating facilities, as well as hydroelectric power plants, pipelines, engineering infrastructure;

– meteorological survey stations;

– other objects defined by the Council of Ministers upon consultation with the President of the Republic of Belarus.

The following can be held within the riversides:

– works related to strengthening the banks of water bodies;

– repair and maintenance of waterworks, including water wells and water regulating facilities, as well as hydroelectric plants, bridges and inland waterways;

– other types of work determined by the Council of Ministers upon consultation with the President of the Republic of Belarus.

Analysis of the size of the water protection zones and locations of sites of the Belarusian nuclear power plant showed that the site is not located in the water protection zone of the river Viliya.

## 13.5 Assessment of aquatic ecosystems within the 30-km area of the Belarusian NPP

### *13.5.1 Aquatic ecosystems condition within the 30-km area of the Belarusian NPP*

Tthere is a number of rivers and reservoirs having a condiderable ological value within the 30-km area of the Belarusian NPP. Ecosystem of the river Viliya and its tributaries is a unique from an ecological point of view, where rare for Belarus species of salmon inhabit and spawn, which are listed in the Red Book. Part of the aquatic ecosystems within the 30-km area is a part of the special protected natural areas. There are very beautiful lakes Sorochanskiye, possessing a high recreational potential, which are the core of the reserve "Sorochanskiye Lakes", as well as large reservoirs - lakes Svir and Vishnevskoye (National Park "Narochanskiy") which are very important for fishery and recreation. Particular attention should be paid to the fact that the 50-km area around the power plant includes a significant area of the National park "Narochanskiy". It includes a unique lake ecosystem, a national Belarusian treasure – Lake Naroch where the largest recreation and rehabilitation center is located.

The special significance of assessing the impact of the nuclear power plant on aquatic ecosystems and above all their biological components, is paid to it because a large amount of any chemical and radionuclide contaminants coming both into the air and soil, later on by the gradient of the surface discharge and then as a result of lateral migration enters the reservoirs. These pollutants can have serious impact on biodiversity and gene pool of water bodies and watercourses, as well as on the formation of water quality, which is carried out mainly by biotic circulation of elements and energy flows as a result of aquatic organism activity.

Biotic community (plankton, periphyton, benthos, macrophytes) in the process of vital activity influence actively on the quality of water, determine the intensity of biological purification and the level of productivity of water bodies. Biological processes considerably determine the behavior of such specific pollutants of nuclear power plants in water bodies, as radionuclides. Among the basic biological processes that determine the transfer of radionuclides into water bodies and regularity of their distribution in the components of aquatic ecosystems are the processes of biosynthesis of organic substances and their further biogenous transformation. Biological structures constantly formed in the process of photosynthesis, such as phytoplankton, periphyton, macrophytes, as well as products of their transformation - the detritus and heterotrophic organisms, immobilize radionuclides, including them in biomasses. Thus, new formation of organic substance (primary product) is connected with the operation of the biological pump, continuously pumping radionuclides from the dissolved form into balanced. The subsequent outcome of radionuclides and other contaminants associated with biological structures is determined by biotic circulation, where trophic relationships of aquatic organisms are considered to be an essential element. Radionuclides transferred into a balanced form migrate through the food chain partly accumulating in the biomass and partly returning to the aquatic environment with the products of metabolism of aquatic organisms.

Microfine biological structures (planktonic algae and bacteria, detritus particles, weighted products of plankton metabolism) and allochthonous dust transfer radionuclides from water into bottom sediments during sedimentation process. Sedimentation to some extent is controlled by the biological processes which modify the dimensional range of the suspension. These processes are microbial aggregation of fine particles and fecal excretion of zooplankton. With an average sedimentation rate of seston less than one meter or about one meter per day, sedimentation rate of fecal pellets and fragments make dozens and hundreds of meters per day.

A critical role in radionuclide migration in aquatic ecosystems plays environmental activity of aquatic organisms. For example, the processes of microbial degradation leads to a change in redox potential of medium, formation of anaerobic zones, production of ammonia, etc., which in turn has a direct influence on the sorption-desorption of radionuclides and, consequently, leads to secondary contamination of the water bodies.

During implementation of the project we made two rounds of field studies of aquatic ecosystems, located within the 30-km area of the Belarusian nuclear power plant. Studies were carried out in spring (May) and in the middle of summer (early August) 2009, periods which reflect the characteristics of the performnce of the aquatic ecosystems in a better way.

The aim was to assess the level and intensity of biological processes that determine the formation of water quality, as well as analysis of the structural organization of communities of aquatic organisms, reflecting the ecological status of the investigated reservoirs and streams. Objects, stations and sites for monitoring are chosen in such a way that the results of their study were given an integral assessment of the ecological situation of water reservoirs and streams, and eventually could be used in a system of environmental monitoring of surface water.

Samples were taken in May at two cross-sections: the river Viliya above NPP - station "Mikhalishki" and downstream – station "Tartak". Samples were taken in the main tributaries of the Viliya: river Stracha - in the reservoir Olkhovo, river Oshmyanka - at the settlement Yatsyny, river Losha - at the settlement Gervyaty, river Gozovka - at the settlement Gozovka. In all cases, samples were taken in the rivers from bridges in the three replicates: the right bank, left bank of the river and the center.

In August, 5 more samples were taken in overlying segment of the river from the the village Kameno (above Vileika reservoir) to settlement Zhodishki, in order to trace the formation of the ecological state of the river Viliya on its way to the 30-km area of the NPP site.

In both periods of observation the group of lakes “Sorochanskiye” were examined Beloye, Turoveyskoye, Zolovskoye, Kayminskoye, Tumskoye, Golubino, Edi, Gubeza, Vorobii, as well as lakes Svir and Vishnevskoe. In May samples were taken at each lake at three stations in shallow lakes - at depth of 1 meter and in deep lakes - at several stations. In August, samples were taken at one station in the pelagic zone of each reservoir in several layers.

The following parameters were specified: transparency, the vertical profile of temperature and dissolved oxygen concentration of suspended solids, chlorophyll content, electrical conductivity (E), pH, organic carbon, total phosphorus, gross and net primary production, destruction, biochemical oxygen demand $BOD_5$, species composition, abundance and biomass of phytoplankton, zooplankton and benthos, periphyton structure, abundance, biomass and morphometric parameters of bacterioplankton composition of macrophytes. Together, they reflect the structural organization and intensity of vital activity processes of biological unit in the examined aquatic ecosystems.

Basic morphometric parameters of the studied lakes are presented in Table 105.

**Table 105 - General information about the examined lakes, located within the 30-km area of the Belarusian NPP**

| Lake name, river basin | Surface area, $km^2$ | Drainage area, $km^2$ | Max depth, m | Average depth, m | Lake volume, mln $m^3$ |
|---|---|---|---|---|---|
| Beloye | 0,34 | н | 4,0 | 2,0 | 0,69 |
| Turoveyskoye | 0,38 | 131,0 | 4,7 | 2,7 | 1,04 |
| Zolovskoye | 0,24 | 140,0 | 12,6 | 4,9 | 1,17 |
| Kayminskoye | 0,43 | 159,0 | 19,5 | 7,6 | 3,26 |
| Tumskoye | 0,86 | 172,0 | 9,2 | 4,8 | 4,16 |
| Golubino | 0,14 | 4,3 | 21,0 | 8,1 | 1,13 |
| Edi | 0,61 | 4,3 | 19,7 | 7,9 | 4,84 |
| Gubeza | 0,23 | 6,0 | 12,9 | 6,6 | 1,32 |
| Vorobii | 0,46 | 8,2 | 3,1 | 2,0 | 0,94 |
| Vishnevskoye | 9,97 | 56,2 | 6,3 | 2,1 | 19,79 |
| Svir | 22,28 | 364,3 | 8,7 | 4,7 | 104,30 |

Published materials, as well as library and archive materials were taken in consideration to assess the ecological status of the aquatic ecosystems located within the 30-km area of the Belarusian nuclear power plant, [84-89].

An earlier-than-normal spring water warp up in 2009 led to intensive development of phytoplankton and its high photosynthetic activity. In early May supersaturation of surface layers of water with oxygen was observed almost all of the studied streams. In the district of the river Viliya in settlement Tartak and river Losha oxygen content was at the highest rate - above 130 %, on the other rivers, it ranged within 105-115 %. In August, the oxygen content in the river Viliya and its tributaries also exceeded 100 % of saturation.

Oxygen supersaturated river water indicate a high level of photosynthetic aeration, which plays an important role in the processes of biological self-purification and formation of water quality. Rapid warming of the surface layers of water in the absence of wind mixing in the period preceding May studies had caused the temperature stratification of water masses, even in shallow lakes from the group Sorochanskiye, which was accompanied by a natural decline in dissolved oxygen along with depth. Attention should be paid to the early formation of a heavy oxygen deficit in the bottom layer in a number of lakes (Lake Beloye, Turoveyskoye, Vishnevskoye).

In May specific for dimiktic lakes temperature and oxygen vertical profile features were formed in deep lakes of the group Sorochanskiye (Gubeza, Edi, Golubino, Kayminskoye) with division of water mass in the epi-, meta- and hypolimnion, as illustrated by Figure 69. Oxygen content decreased heavily in the hypolimnion along with depth.

In August, the oxygen content in the surfacial unit exceeded 100 % of saturation in a group of shallow lakes, except lake Podkostelok. A lack of it, mostly close to zero values in the bottom layer, was observed only in the lakes Beloye and Zolovskoye. In the deep and mid-deep Sorochanskiye lakes (Gubeza, Edi, Golubino, Kayminskoye, Tumskoye) the nature of the temperature and oxygen vertical profiles were similar. In each of these lakes in the entire layer below the upper metalimnion oxygen is absent completely, in the bottom layers marked by the smell of hydrogen sulfide.

As a matter of record it can be suggested that by the middle of the growing season secondary contamination of water layer by some biogenic elements and heavy metals and radionuclides becomes possible in lakes with anaerobic hypolimnion, if they accumulate in sediments as a result of the NPP operation.

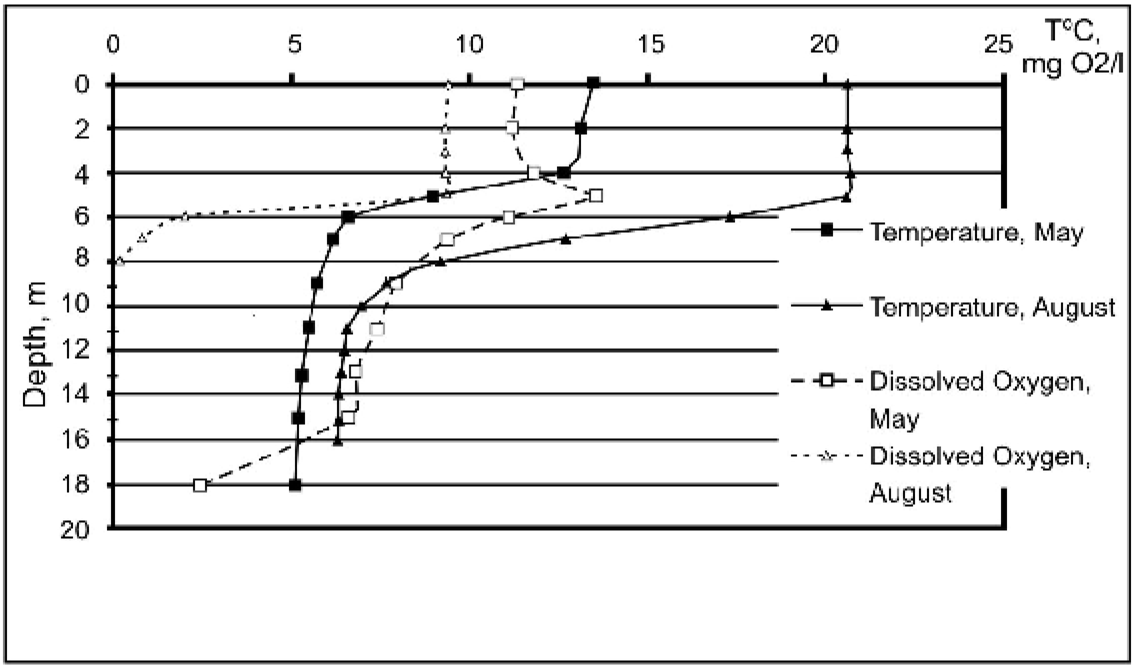



**Figure 69 - Temperature and oxygen content in water of the lake Edi**

A characteristic feature of the aquatic ecosystems is the presence of special structural and functional component - seston (a combination of suspended particles in the water layer). Seston is extremely heterogeneous and includes microscopic forms of living organisms, their debris, as well as vital wastes and rejections of bacterio-, phyto-and zooplankton. The structure of seston consists of organic and mineral particles, formed from physical and chemical processes in the water layer, re-suspended from sediments and entering water from watershed. Also a large part of the substances formed during decomposition of macrophytes and other large benthic and nekton organisms are transformed from the finely divided suspension.

The role of seston in the functioning of aquatic ecosystems is important and diverse. As seston consists of living organisms, all aspects of the metabolism of plankton are closely connected with mentioned structural unit of ecosystem, firstly, main elements of the biotic circulation - production, transformation and mineralization of organic matter. However, not only planktonic organisms, but also the whole complex of seston as a combiation of fine particles has a significant influence on the circulation of substance and energy flows in the ecosystem. For example, suspended solids actively influence on the processes of degradation and activity of microbial community. The dust fully determines the possibility of existence of essential and specific component of aquatic ecosystems - communities of organisms with filtration type of feeding. By means of sedimentation, seston is connected with vital activity of benthic communities and is an important functional element in the system "water - bottom sediment".

A major component of seston is phytoplankton, where chlorophyll "a" is widely used as a marker of fullness in hydrobiological studies - the main photosynthetic pigment involved in the processes of autotrophic biosynthesis of organic substance. Taken together, suspended matter (seston) and chlorophyll "a" are informative indicators of the trophic level of the water body. Data of seston and chlorophyll concentration in the rivers are presented in Table 106.

Seston concentration in the studied parts of the river Viliya is high – 13,7-15,5 mg/l with a significant relative percentage of chlorophyll-a (0,58-0,60 %). The absolute values of chlorophyll- a are very large – 81,4 and 90,2 mg/l in the river stations of settlement Mikhalishki and settlement Tartak respectively. This high level of chlorophyll content shows a high proportion of phytoplankton in the total mass of seston and typical for highly eutrophic aquatic ecosystems.

Trophic level of tributaries of the river Viliya is much lower; however, all of them belong to the class of eutrophic waters. The concentration of dust in the tributaries in May quite similar (5,0-6,4 mg / l), except for a small river Gozovka (3,4 mg / l). The concentration of chlorophyll-a is also almost similar in tributaries (16-20 mg / l), except river Oshmyanka where its content exceeded 40 micrograms per liter. The high degree of correlation (r = 0,96) of dust concentration containing chlorophyll-a indicates the important role of plankton in the formation of suspended solids in the studied rivers.

In August, in the river Viliya in the river station Mikhalishki and Tartak, the concentration of the suspended solids (10,7 and 14,9 mg /l, respectively) differed only slightly from the values observed in May, despite the fact that the absolute content of chlorophyll-a decreased by almost a half, accounting for 42,9 and 49 , 5 mg/l, respectively. As a result, their relative percentage in the dry mass of dust decreased to 0,40 and 0,34 %, reflecting the diminishing role of autotrophic component of plankton in the formation of a common pool of the suspended matter.

**Table 106 - The concentration of seston and chlorophyll-a in the river Viliya and its tributaries**

| River, riverstation | Seston, mg/l | Chlorophyll-*a*, mkg/l | Percentage of chlorophyll in seston, % |
|---|---|---|---|
| Viliya, Mihalishki | 13,7±1,6 | 81,4± 6,0 | 0,60±0,04 |
| Viliya, Tartak | 15,5±1,8 | 90,2±1,8 | 0,58±0,02 |
| Stracha | 5,0±0,23 | 15,8±0,8 | 0,31±0,01 |
| Losha | 6,4±2,6 | 16,3±1,8 | 0,26±0,09 |
| Oshmyanka | 6,2±0,6 | 40,9±2,1 | 0,62±0,03 |
| Gozovka | 3,4 | 20,0 | 0,59 |

As follows from the data presented in Table 107, in May in shallow lakes of the group of lakes "Sorochanskiye", as well as in lakes Svir and Vishnevskoye concentration of suspended solids was close to that observed in the tributaries of the river Viliya being in range of 4,6-8,2 mg / l. A notable uneven distribution of indicators in lakes, with rare exceptions, were not observed. Chlorophyll-a in shallow lakes of the group “Sorochanskiye” was practically similar - 24,2-28,7 mg / l. In larger open lakes Svir and Vishnevskoye, both absolute and relative content of chlorophyll-a was significantly lower – 15,5 mg / l and 0,34 % in the lake Svir and 5,3 mg / l and 0,10 % in the lake Vishnevskoye. The low proportion of chlorophyll-a in sestone of the lake Vishnevskoye – 0,10 % versus 0,31-0,61 % in the other lakes, is due to apparently ingress of silt particles in the suspension at the resuspension of bottom sediments.

In deep lakes Edi, Gubiza and Golubino concentration of seston and chlorophyll-a were lower in both periods of observation than in shallow waters with a pronounced unevenness in depth. In the bottom layer of lakes Gubeza, Kayminskoye, Tumskoye with depths of observation stations of 10,7 and 8,5 m, a sharp increase in the amount of suspended solids at the bottom with a decrease in the relative proportion of chlorophyll-a in their composition had been noted. In all of these lakes a significant part of chlorophyll is due to bacteriochlorophyll under anaerobic conditions of hypolimnion.

**Table 107 - The concentration of seston and chlorophyll-a in the lakes**

| Lakes | Seston, mg/l | Chlorophyll-*a*, mkg/l | Percentage of chlorophyll in seston, % | Transparence, m |
|---|---|---|---|---|
| Beloye | 5,5±0,6 | 24,2±2,1 | 0,45±0,02 | 1,5±0,1 |
| Vorobii | 8,2±0,4 | 25,4±3,0 | 0,31±0,03 | 1,3±0,1 |
| Turiveyskoye | 4,6±0,9 | 28,7±10,5 | 0,61±0,10 | 1,7±0,4 |
| Zolovskoye | 5,4±0,3 | 29,9±3,8 | 0,56±0,08 | 1,6±0,2 |
| Tumskoye | 3,8±0,7 | 18,5±1,3 | 0,50±0,08 | 1,9±0,2 |
| Gubeza | 1,7±0,3 | 1,9±2,0 | 0,13±0,03 | 4,6±0,1 |
| Kayminskoye | 3,4±0,9 | 28,0±8,5 | 0,81±0,12 | 1,6±0,2 |
| Golubino | 2,1±0,3 | 5,4±0,2 | 0,26±0,03 | 2,3±0,2 |
| Edi | 2,0±0,6 | 3,4±0,1 | 0,17±0,03 | 4,7±0,0 |
| Svir | 4,6±0,2 | – | – | 2,3±0,1 |
| Vishnevskoye | 5,3±0,3 | – | – | 1,8±0,1 |

Water quality, biological productivity and overall ecological status of aquatic ecosystem is formed during the complex processes of biotic circulation, which serves as a trigger for the operation of autotrophic communities. Organic matter is growing (primary production) as a result of their vital activity in the process of photosynthesis, which is then transformed and mineralized by heterotrophic communities. In the studied reservoirs and streams within the 30-km area of the Belarusian nuclear power plant, decomposition (rate of consumption of oxygen in the water layer) was determined in conjunction with measurements of gross primary production of plankton, which characterizes the activity of heterotrophic plankton community. A value of biochemical oxygen demand - $BOD_5$ was also measured. The latest value, often used in the practice of health research, describes an important parameter of water quality - the number of labile fraction of organic matter. The values of gross (WFP), net (NPP) primary production, decomposition (D) and $BOD_5$ in the river Viliya and its tributaries are listed in Table 108.

**Table 108 - Primary production, decomposition and $BOD_5$ in the river Viliya and its tributaries**

| River | WFP | D | NPP | $BOD_5$, mg $O_2$/l |
|---|---|---|---|---|
| | mg $O_2$/l per day | | | |
| river Viliya, Mihalishki | 7,89±0,65 | 0,88±0,05 | 7,01±0,60 | 4,01±0,17 |
| river Viliya, Tartak | 7,73±1,37 | 0,96±0,02 | 6,77±0,02 | 4,66±0,43 |
| river Stracha | 1,73±0,08 | 0,49±0,03 | 1,24±0,05 | 2,09±0,24 |
| river Losha | 1,94±0,47 | 0,37±0,09 | 1,57±0,46 | 1,70±0,18 |
| river Oshmyanka | 5,82±0,08 | 0,64±0,12 | 5,18±0,12 | 2,85±0,13 |
| river Gozovka | 1,85 | 0,27 | 1,58 | 1,52 |

Extremely high gross of primary production of plankton was observed in the river Viliya in both river stations (7,9 and 7,7 mg $O_2$ /l • day). At relatively low organic matter decomposition, plankton net production was significant (7.01 and 6,76 mg $O_2$ / l • day). The values of $BOD_5$ – 4,01 and 4,66 mg $O_2$ / l higher than fishery regulations MCL (3,0 mg $O_2$ /l). High values of gross and net primary production were recorded in the river Oshmyanka (5,8 and 5,2 mg $O_2$ /l • day) at a relatively low value of $BOD_5$ (2,85 mg $O_2$ /l • day). In other rivers the values of all examined parameters were significantly low and corresponded to the level typical for reasonably eutrophic waters.

In August the level of all, without exception, quantities of production-destructive performance was reduced in the river Viliya and its tributaries. Especially large changes (more than two orders of ranges) reached the level of primary production in the river Oshmyanka. Thus, WFP in August amounted to 0,38 mg $O_2$ /l day versus 5,82 mg $O_2$ / l day, NWP – 0,10 mg $O_2$ / l day. verus 5,18 mg $O_2$ / l day.

During the both periods of lakes' observation, level of primary production was significantly lower than in the river Viliya. In May, the gross primary production in the surface layer of all the examined lakes was 0,51-2,47 mg $O_2$ /l • day., decomposition – 0,25-0,92 mg $O_2$ /l • day. $BOD_5$ varied in the range from 1,2 mg $O_2$ / l (Lake Edi) to 4,26 mg $O_2$ /l (Lake Vorobii). In August, in lakes contrary to streams, the levels of productionand decomposition indicators increased.

In shallow lakes Beloye, Turoveyskoye, Svir, Vishnevskoye, WFP was in the range of 2,5-3,4 mg $O_2$ /l • day, decomposition 0,6-1,0 mg $O_2$ /l • day., $BOD_5$ – 2,0 -3,7 mg $O_2$ / l. Similar values of the indicators were observed in lakes Zolovskoye, Tumskoye and Kayminskoye. The lowest values of indicators in this group of lakes were observed in the lake Podkostelok - WFP – 1,0 mg $O_2$ /l day., D – 0,5 mg $O_2$ / l day. $BOD_5$ and - 1,5 mg $O_2$ / l, the highest - in the lake Vorobii respectively - 5,9 mg $O_2$ / l day., 1,6 mg $O_2$ / l day and 6,4 mg $O_2$ / l.

Based on materials of observations made in spring, correlation between the studied hydroecological indicators of water quality in river and lake ecosystems was estimated. The results are listed in Table 109.

In the absence of serious violations of the typically -functioning aquatic ecosystems there should be a close relationship between the various parameters characterizing the intensity of production processes and quality of water. Data on the correlation in the studied ecosystems in table 109 indicate their functioning in a normal regime, which is typical for each of the studied reservoirs and streams

**Table 109 - Correlation coefficients (Pearson) between the special hydroecological parameters in the studied lakes and rivers**

| **Lakes** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameters | $C_{sest.}$ | $C_{chl}$ | $C_{org}$ | $P_{total}$ | WFP | D | $BOD_5$ |
| $C_{sest.}$, mg/l | 1,00 | – | – | – | – | – | – |
| $C_{chl}$, mkg/l | **0,75** | 1,00 | – | – | – | – | – |
| $C_{org}$, mg C/l | -0,03 | 0,00 | 1,00 | – | – | – | – |
| $P_{total}$., mg R/l | **0,97** | **0,84** | 0,05 | 1,00 | – | – | – |
| WFP, mg $O_2$/l*day | **-0,60** | -0,54 | -0,15 | **-0,77** | 1,00 | – | – |
| D, mg $O_2$/l*day | -0,11 | -0,28 | **-0,63** | -0,21 | **0,67** | 1,00 | – |
| $BOD_5$, mg $O_2$/l | -0,58 | -0,55 | -0,10 | -0,62 | **0,98** | 0,64 | 1,00 |
| pH | -0,24 | -0,55 | 0,08 | -0,34 | 0,36 | 0,07 | 0,32 |
| Transparency , m | -0,46 | -0,19 | **0,67** | -0,37 | 0,28 | -0,16 | 0,25 |
| **Rivers** | | | | | | | |
| $C_{sest.}$, mg/l | 1,00 | – | – | – | – | – | – |
| $C_{chl}$, mkg/l | **0,94** | 1,00 | – | – | – | – | – |
| $C_{org}$, mg C/l | **0,65** | **0,62** | 1,00 | – | – | – | – |
| $P_{total}$., mg R/l | **0,79** | **0,89** | 0,50 | 1,00 | – | – | – |
| WFP, mg $O_2$/l*day | **0,82** | **0,94** | 0,46 | **0,83** | 1,00 | – | – |
| D, mg $O_2$/l*day | **0,87** | **0,94** | **0,68** | **0,75** | **0,91** | 1,00 | – |
| $BOD_5$, mg $O_2$/l | **0,90** | **0,97** | **0,66** | **0,79** | **0,94** | **0,95** | 1,00 |
| Note - statistically significant coefficients are bold outlined ($p < 0,05$) | | | | | | | |

The aggregate of the given data allows us concluding that the river Viliya with high trophic level and high-speed formation of fine biological structures (phytoplanktonic organisms and products of their transformation) is to be emphasized among the reservoirs and streams within the 30-km area of the nuclear plant stands out. This, undoubtedly, will determine the nature of the processes of biological purification, distribution of individual biological components of river ecosystems and migration of radionuclides and other pollutants entering the river in the course of nuclear power plant activity.

### *13.5.2 Structural organization of biotic communities*

#### *13.5.2.1 Phytoplankton*

Species wealth of phytoplankton in rivers and reservoirs within the 30-km area of the Belarusian NPP is high (Table 110). During the study 209 species were identified.

Comparison of species composition and quantitative development of phytoplankton in the studied rivers and lakes showed that in May, the highest species richness and the highest rates of quantitative development of phytoplankton, as well as the level of its products, shows the river Viliya. In other rivers, as compared with the river Viliya, biomass of phytoplankton, for example, was lower in 5 times.

**Table 110 – Saturation of phytoplankton by algae in May in the studied streams**

| Section, class | river Viliya | river Stracha | river Losha | river Oshmyanka | river Gozovka |
|---|---|---|---|---|---|
| Diatomaceae | 26 | 13 | 15 | 20 | 17 |
| Green: | 21 | 5 | 9 | 19 | 7 |
| - Chlorococcales | 17 | 5 | 9 | 17 | 6 |
| - Volvocales | 3 | 0 | 0 | 2 | 1 |
| - Desmidiaceae | 1 | 0 | 0 | 0 | 0 |
| Chrysophyceae algae | 7 | 10 | 7 | 9 | 5 |
| Cyanobacteriae | 8 | 2 | 1 | 2 | 1 |
| Cryptophyta | 6 | 4 | 4 | 4 | 3 |
| Dinophysis | 2 | 0 | 1 | 2 | 0 |
| Euglenophyta | 3 | 2 | 0 | 3 | 2 |
| Total | 73 | 36 | 37 | 59 | 35 |

The greatest number of species was found in the river Viliya (73), the lowest - in the river Gozovke (35). The second-highest number of species - river Oshmyanka (59). Diatomaceae are of greatest species wealth in all streams. The second highest number of species in all rivers, except for the river Stracha (right tributary of the river Viliya, all the others are left tributaries) are green and Chrysophyceae algae in the river Stracha, where the number of species two times higher than the number of species of green algae. The number of species of Cyanobacteriae and Cryptophyta in the river Viliya appeared more than in other streams, as well as three representatives of Euglenophyta and Volvocales. Chrysophyceae algae held the third place in all streams, except river Viliya.

The studied streams have different divisions of algae species wealth, indicating the peculiarity of their species composition. Diatomaceae dominate in all studied streams. The peculiarity of the studied streams during the study period was excessive development of Chrysophyceae algae. In the river Viliya they made 9,6 % of the total number of species, in the tributaries - 27,8 (river Stracha), 18,0 (river Losha), 15,3 (river Oshmyanka) and 14,3 % (rver Gozovka ). In the most amount of small rivers Chrysophyceae algae belonged to the dominant complex, or were in the rank of the dominant (more than 10 % of the total number of phytoplankton) or subdominants (5,1-10,0 %), yielding the main dominants - representatives of Diatomaceae and Cryptophyta.

Summer phytoplankton of the studied streams differed significantly from the spring ones, which is evident from species wealth, composition of the dominant species complexes, the quantitative indicators of the overall phytoplankton and its divisions of algae. The number of species found in the processing of quantitative sediment samples of phytoplankton in the tributaries of river Viliya in August was considerably lower than in May and only the river Viliya itself showed greater species diversity - 117 species in August against 73 in May. Among the species found in the river, 41 % belonged to the green algae, 81,2 % of which were Chlorococcales, 23,9 % - Diatomaceae – and 17,9 % - Cyanobacteriae, Chrysophyceae algae amounted to 6,8 %, other had only 2,6-3 , 4 %.

As well as in the rivers, in all lakes, except the shallow lake Vorobii there were Diatomaceae which showed the most diversity. Their number was average for all lakes - 33,5 % of the total number of the identified species. The most dominant number along with Diatomaceae (Cyclotella meneghiniana, Aulacoseira ambigua, Aulacoseira granulata, Cyclotella sp., Synedra acus, Fragillaria crotonensis, Tabellaria fenestrata, Melosira varians), was Chrysophyceae algae, also widespread (Dinobryon sociale, Dinobryon divergens, etc .), and rare not only for Belarus but also for other countries (Uroglenopsis apiculata, Uroglena gracilis, Kephyrion sphaericum, Pseudokephyrion entzii). For example, Uroglenopsis apiculata was a member of the dominant complex of biomass in all types of lakes:

- In shallow lakes Beloye and Turoveyskoye its biomass was at some stations up to 42,5 and 56, 3 %, respectively;
- In mid-deep lake Zolovskoye - up to 64,5 %, while in a deep lake Kayminskoye - up to 71,9 %.

Indicators of species diversity (Shannon index) and evenness of community index (Piel) for the lakes, as well as for the rivers were high, close to the upper level of their values. High index values indicate the great diversity of phytoplankton communities and polydominant, and this, in turn, implies a fairly high degree of resistance to environmental factors. The dominance of representatives of Chrysophyceae algae, along with Diatomaceae characterizes the studied lakes as clean.

*13.5.2.2 Zooplankton*

21 species were revealed in the plankton of the rivers within the 30-km area of the Belarusian nuclear power plant during the study and 32 species of invertebrates, indicating a considerable species wealth of zooplankton in the studied region in the plankton of lakes. Among the rivers the greatest number of species was identified in the river Viliya (21), the least - in the river Gozovka (9). The values of abundance and biomass of zooplankton were also maximal in the river Viliya (219,3 ± 108,2 thousand copies. / $m^3$ and 0,415 ± 0,169 g/$m^3$) and exceeded the related values in other rivers 3-13 and 3-20 times. This is compliance with the data of RCRCEM obtained through the fixed network of NEMS during the period 2004-2007. Among the studied lakes the largest number of species was identified in mid-deep Tumskoye (22) and deep lake Kayminskoye (21). In other lakes, the number of zooplankton species was close to 11-14 species. The highest total abundance and biomasses of zooplankton were observed in a shallow lake Vorobii – 3446,4 ind/$m^3$ with biomass of to 6,72 g/$m^3$, which is 1,5 to 30 times more than the value set for the other examined lakes. In rivers and shallow lakes, the bulk of the total number and biomass of zooplankton made rotifers, which are typical for the spring period. In average deep and deep lakes rotifers also dominated, and in biomass - Copepods.

A high indicator value among organisms, zooplankton has rotifers of type Brachionus. Almost all the rivers studied, except for the river Gozovka, the species of this genus were marked - Brachionus angularis, B. calyciflorus and B. urceus urceus. Moreover, in the river Oshmyanka B. angularis was a member of the dominant species with a percentage of the total number of zooplankton equal to 15,4 %. In the three rivers - Viliya, Stracha and Losha - rotifer Brachionus urceus has a relatively small number - 9,7, 1,1 and 0,9 thousand specimens per m3, respectively. It is important to note that this species is an indicator of polluted water and live in the water of increased saprobity. In four of the researched lakes -Beloye, Zolovskoye, Tumskoye and Kayminskoye, the Brachionus urceus was also found. In the lake Kayminskoye Brachionus diversicornis homoceros was found of 1,2 thousand specimens per $m^3$. This species are found in high trophic water bodies. It should be noted that the number of species of Brachionus in zooplankton of the studied rivers and lakes, except for the river Oshmyanka is low. However, the presence of Brachionus indicates the high content of organic matter.

The index of Shannon, which characterizes the overall diversity of the community, and the index Piel, which characterizes the eveness, are high as for the rivers so for the lakes. Thus, the values of Shannon index lie within 1,54-3,07 bits/letter (0,94-2,34 bit / g); index Piel – 0,49-0,96 bits/letter (0,29-0,75 bit / g).

Thus, according to aggregate of the indicators of the structural organization of zooplankton communities, we can conclude that the ecosystems of the studied reservoirs and streams within the 30-km area of the Belarusin NPP are running in steady regime.

*13.5.2.3 Periphyton*

A characteristic feature of any freshwater ecosystem is the presence of large or smaller scale of the boundary surface separating the liquid (water) and solid (the substrate of different nature and origin) phase. There is a complex of specific physical, chemical and hydrodynamic conditions at the interface, which determine the separation of independent biotope - perifital. Perifital is related to the existence of periphyton. According to the existing views, under the periphyton we understand the complex which is formed on the surface of a solid substrate, regardless of the origin of the latter (natural, artificial), in a more mobile conditions than in the bottom of the reservoir, and include autotrophic (algae, cyanobacteria) and heterotrophic (bacteria, fungi, invertebrates) organisms and organic matter from different backgrounds and varying degrees of processing (detritus). Periphyton can be seen as a bright example of "edge effect", i.e. "Thickening of life" at the interface of the liquid (water) and solid (the substrate of different nature and origin) of the phases, which substantially increase species diversity, biomass and metabolic activity of organisms. In small lakes and rivers through periphyton unit a significant flow of material and energy can go. The importance of periphyton in the formation of water quality is significant. Periphyton, along with other intertidal communities, accumules biogenic elements and pollutants coming from the catchment basins, acts as a buffer, and provide the stability of ecosystems to human impacts. Periphyton plays an important role in the processes of self-purification of aquatic ecosystems from contamination, as characterized by extremely high rates of accumulation of radionuclides (up to $10^4$). Periphyton is widely used as a monitor of all types of contamination, including radioactive. The above features of periphyton stipulate a comprehensive study of this block of aquatic ecosystems within the 30-km area of the Belarusian nuclear power plant.

Studies of periphyton in rivers and lakes within the 30-km area of the nuclear plant were made in two directions:

- assessment of the abundance of periphyton as a single complex, combining the biota and detritus, and identification the key indicators of its structural organization;
- study of the species composition and structure of algal communities, which have the highest proportion among the biotic components of the periphyton.

It was specified that the abundance of periphyton in streams varies widely. Maximum number of periphyton observed in the river Viliya (84,9 ± 75,1) mg/10 $cm^2$, which corresponds to the general high trophic level of river, the minimum values found in the river Stracha (1,0 ± 0.3) mg/10 $cm^2$.

Abundance of periphyton on macrophytes in lakes within the 30-km nuclear plant zone is much lower than in rivers. Mean values for the lakes ranged from 3,9 to 25,8 mg/10 $cm^2$. The maximum value of the total mass of periphyton observed in the lake Edi, minimum - in the lake Zolovskoye.

In periphyton of all studied rivers mineral fraction predominates over organic. The minimum value of ash content was 57,3 % (river Stracha), maximum – 78,6 % (river

Viliya). Ash content of periphyton in lakes is much lower compared to periphyton in rivers: in most lakes values fall within the limits (49-61) %. An exception is the Lake Golubino, where periphyton organic fraction is much higher than the mineral one (ash 29,5 %).

An important indicator of the structural organization of the contents of the periphyton is its content in the mass of chlorophyll. It is possible to determine the biomass of algae with a help of chlorophyll, as well as the approximatly estimate the ratio between autotrophic and heterotrophic components of periphyton. The content of chlorophyll in periphyton in the studied rivers varied within a narrow range - from 1,9 to 2,5 mg / mg dry weight of periphyton. The limits of the values in the lakes significantly wider - from 1.0 ug / mg (Lake Gubeza) to 3.9 ug / mg (Lake Beloe).

Periphyton in the studied rivers and reservoirs is characterized by high species wealth of algae. During the study 168 species were identified, including 116 in the rivers and 123 in lakes. The maximum number of species was found in the river Viliya (77), minimum - in the river Gozovke (39).The number of species in lakes ranged from 46 (Lake Golubino) to 59 species (Lake Tumskoye).

Diatomaceae are characterized by the highest species diversity and abundance in rivers and the lakes. They form the basis of the dominant complext of all studied ecosystems.

Indicators of species diversity of communities of periphyton (Shannon index) and the eveness index (Piel) in the rivers are very high. In all studied rivers Shannon index was about 4,5, while the index Piel approximately 0.8 bits / letter. Indicators of diversity of periphyton in lakes are generally lower than in rivers. Index values for different lakes vary considerably. The minimum values of the indices of Shannon and Piel are typical for periphyton in lake Golubino (1,9 and 0,38 bits / letter), the maximum is for the lake Vorobii (4,35 and 0,8 bits / letter).

In general, indicators of the structure of periphyton in the studied reservoirs and streams meet the prevailing opinion about the structural organization of periphyton in aquatic ecosystems of the biochemical type and characterize the regime of their running as normal.

### *13.5.3 Assessment of water quality and ecosystem state by hydrobiological indicators*

Features of the structure and functioning of the aquatic communities are largely related to the quality of the aquatic environment. Many studies have shown that any stressful event leads to significant shifts in the structure and functioning of communities. Therefore, we can solve the inverse problem using the communities' state - to evaluate the quality of the environment. That community's parameters are key for assessing the state of ecosystems and further for calculation of environmental risks. Stress effects lead to significant shifts in the structure and functioning of communities. Therefore, community's parameters are key indicators to assess ecosystem conditions and further calculate an environmental risk.

Water quality in the studied rivers and lakes was evaluated on the basis of structural and functional indicators of biological communities and biotic indices. Key indicators are presented in Tables 111-113.

**Table 111 – Range of changes of the total number of species in different communities of the studied rivers and lakes**

| Type of water bodies | Community | Number of Species |
|---|---|---|
| Rivers | Phytoplankton | 33-65 |
| | Periphyton | 34-54 |
| | Zooplankton | 9-21 |
| Lakes | Phytoplankton | 33-48 |
| | Periphyton | 30-54 |
| | Zooplankton | 9-23 |

**Table 112 - Average values of water quality in the rivers studied (numerator) and the ranking of the rivers descending water quality (denominator)**

| River | Indicators of structural diversity* | | Indicators of Eutrophication | | Indicators of organic contamination* | The average value in a row (descending quality) |
|---|---|---|---|---|---|---|
| | Shanon index, bits /individual | Piel Index | The presence of rotifers in zooplankton Brachionus | WFP /D | Pantle-Buck saprobity index | |
| Viliya | 3,33 / 4 | 0,68 / 4 | 2 % / 3 | 8 / 4 | 1,77 / 4 | 3,8 |
| Stracha | 2,48 / 5 | 0,62 / 5 | 1 % / 2 | 3 / 1 | 1,65 / 2 | 3,0 |
| Losha | 3,68 / 2 | 0,84 / 2 | 2 % / 4 | 5 / 2 | 1,71 / 3 | 2,6 |
| Oshmyanka | 3,47 / 3 | 0,77 / 3 | 17 % / 5 | 9 / 5 | 1,86 / 5 | 4,2 |
| Gozovka | 3,82 / 1 | 0,87 / 1 | – / 1 | 7 / 3 | 1,56 / 1 | 1,4 |

* Mean values for the phytoplankton, periphyton and zooplankton

**Table 113 - Average values of water quality in the studied lakes (numerator) and ranking lakes descending water quality (denominator)**

| Lake | Indicators of structural diversity* | | Indicators of Eutrophication | | Indicators of organic contamination* | The average value in series (descending quality) |
|---|---|---|---|---|---|---|
| | Shanon index, bits /individual | Piel Index | Pantle-Buck saprobity index | WFP /D | Pantle-Buck saprobity index | |
| Beloye | 2,78 / 5 | 0,65 / 5 | <<1% | 2 / 4 | 1,66 / 8 | 5,5 |
| Vorobii | 3,14 / 5 | 0,67 / 3 | – | 3 / 9 | 1,52 / 1-2 | 3,9 |
| Turaveyskoye | 3,17 / 1 | 0,73 / 1 | – | 3 / 7 | 1,65 / 7 | 4,0 |
| Zolovskoye | 2,74 / 7 | 0,61 / 7-8 | <<1% | 2 / 5 | 1,67 / 9 | 7,1 |
| Tumskoye | 2,61 / 8 | 0,61 / 7-8 | – | 2 / 2 | 1,62 / 5-6 | 5,8 |
| Gubiza | 2,96 / 3 | 0,70 / 2 | – | 3 / 8 | 1,52 / 1-2 | 3,6 |
| Kayminskoye | 2,79 / 4 | 0,62 / 6 | <<1% | 2 / 6 | 1,62 / 5-6 | 5,4 |
| Golubino | 2,37 / 9 | 0,56 / 9 | – | 1 / 1 | 1,61 / 4 | 5,8 |
| Edi | 2,75 / 6 | 0,66 / 4 | – | 2 / 3 | 1,58 / 3 | 4,0 |

* Mean values for the phytoplankton, periphyton and zooplankton

Data analysis of the structural diversity was performed on the basis of calculation of Shannon and Piel indexes for phytoplankton, zooplankton and periphyton. It is need to specify that, in the rivers and the lakes, species wealh of phytoplankton and periphyton community is about the same (30-50 species in the sample), and several times greater than zooplankton (10-20). Considering the difference of species wealth of communities, the Shannon index values for the zooplankton community were obtained lower than for the phytoplankton and periphyton on the same stations observing at the same time.

The Shannon and Piel indexes in the community of phytoplankton in different rivers, compared with other communities, changed in a very narrow range - respectively 3,2-4,0 and 0,7-0,8 bits / individual. Compared to phytoplankton, the indexes calculated from periphyton samples showed a clear difference between the studied watercourses, as the level of species diversity of communities, and on eveness.

In lake ecosystems, periphyton community was characterized by the maximum difference of indexes, which indicates a higher potential for fouling the indicator.

The level of biodiversity in the lakes were not significantly different, the values of the Shannon and Piel indexes were slightly lower in the lake Golubino, the maximum - in lakes Turaveyskoye and Gubiza.

In general, in lakes, in comparison to river ecosystems, biodiversity indicators were slightly lower.

Indicators of primary production and decomposition have a quick response to changing environmental conditions, which allows using the ratio of production-destructive characteristics for rapid assessment of the aquatic environment. Thus, in areas of polluted waste water, the ratio of production and decomposition falls below 1, with high biogenic load – is much higher.

In rivers, the ratio of gross primary production of plankton in the decomposition (WFP / D) ranged from 3 to 9, the maximum values recorded for the rivers Viliya and Oshmyanka, minimum - for the river Stracha.

Unlike rivers, the ratio of the WFP / D in the lakes was lower, varying from 1 in Lake Golubino to 3 in the lake Vorobii, which indicates more balanced production-decomposition processes in lakes.

The calculation of the saprobity index in rivers and lakes was carried out for the phytoplankton, periphyton and zooplankton, and the calculated parameters were close enough to the different communities, varying within 1,5-2,0.

In general, the studied rivers and lakes can be attributed to β-mezosaprobic zone, while river Gozovka and lakes are at its border with oligosaprobic zone, which allows characterizing the quality of water in them as good enough.

The analysis of the rivers showed that they are all characterized by similar values of structural and functional indicators of biological communities and good quality water. The highest water quality characteristic were for the river Gozovka, then for the river Losha, Stracha and Viliya, the lowest - in river Oshmyanka.

The studied lakes are also a fairly homogeneous body. When analyzing the data no significant differences between them were revealed. Values of structural and functional indicators and saprobity indexes in different reservoirs are very close, while the average for the lakes was slightly lower than for rivers. The lakes Gubiza, Vorobii, Turaveyskoye and Edi are characterized by a little higher values. Lake Zolovskoye takes the last place among the studied lakes.

Thus, we can conclude that all the studied rivers and lakes are characterized by sufficiently good indicators of water quality.

The use of periphyton communities as an indicator of the state of the aquatic communities' structure is the most promising.

### *13.5.4 Springs*

There is a special type of aquatic ecosystems - the springs within the 30-km area of the nuclear power plant and adjacent territories, which play an important role in forming the overall biological diversity of water bodies of Belarus. A number of cryophilous species of freshwater invertebrates, those from rivers and lakes in the northern Europe and mountain reservoirs in Central Europe, can exist in the territory of Belarus only in pure and cold-water springs.The springs within the 30-km area are inhabited by at least by 25 rare, first detected in Belarus, aquatic invertebrates, not recorded previously in any type of water [90.91].

A very rare type of beetles that inhabit springs in Belarus is the Agabus guttatus. It can be assumed that this species is representative of aqueous glacial relict fauna. Among the crustaceans raznonogogo crustacean sinurellu Synurella ambulans Müller should be allocated, 1846 (fam. Gammaridae). Sinurella is ancient fresh water kind of North American origin, unique for the fauna of Belarus. As a relic of pre-glacial epoch in the fauna of Belarus S. ambulams has great scientific value. The springs are refugia for a number of relics of previous geological epochs, as well as a connecting link between the fauna of rivers and lakes of Northern Europe and fauna of the cool mountain waters of Central Europe. At the same time springs ecosystems, as compared with lakes and rivers, were the least resistant to human impacts. Thus, the ecological value of spring ecosystems on the one hand, and their vulnerability on the other hand, determine the need to provide special measures to preserve the springs. Among these measures may be adding of springs to nature monuments or sanctuaries with the appropriate regime for their protection.

In the northwest of Ostrovets District, Grodno region within Oshmyany hill near the village Varona, Kemeleshki, Bystritsa there is a number of spring and brook complexes, which are characterized not only by the peculiarities of the morphological characteristics, but also their inherent uniqueness of the fauna. In these water bodies there are rare species of benthic invertebrates and fish. It is the only region of Belarus for anadromous fish spawning - trout and salmon. This area is located in the basin of the river Viliya. Near the State Geodesic Station combined with the center of station Dugi Struve "Konrady" is situated. Altitude is 300 m.

Nine springs and brook complexes presented in figure 70 were examined:

1) No.1 – Spring and brook complex Boloshina;
2) No.2 - Spring and brook complex Porubye;
3) No.3 - Spring and brook complex Klevatishki;
4) No. 4 - Unnamed spring. The right bank of river Viliya. Bystritsa District;
5) No. 5 - Separate spring outlet. Stream untitled;
6) No. 6 - Separate spring outlet. Stream untitled;
7) No. 7 – Spring and brook complex Tartak. Before flowing into the river Viliya;
8) No. 8 - Spring marshland. The Upper Tartak;
9) No. 9 – Spring and brook complex Senkanka. Varona.

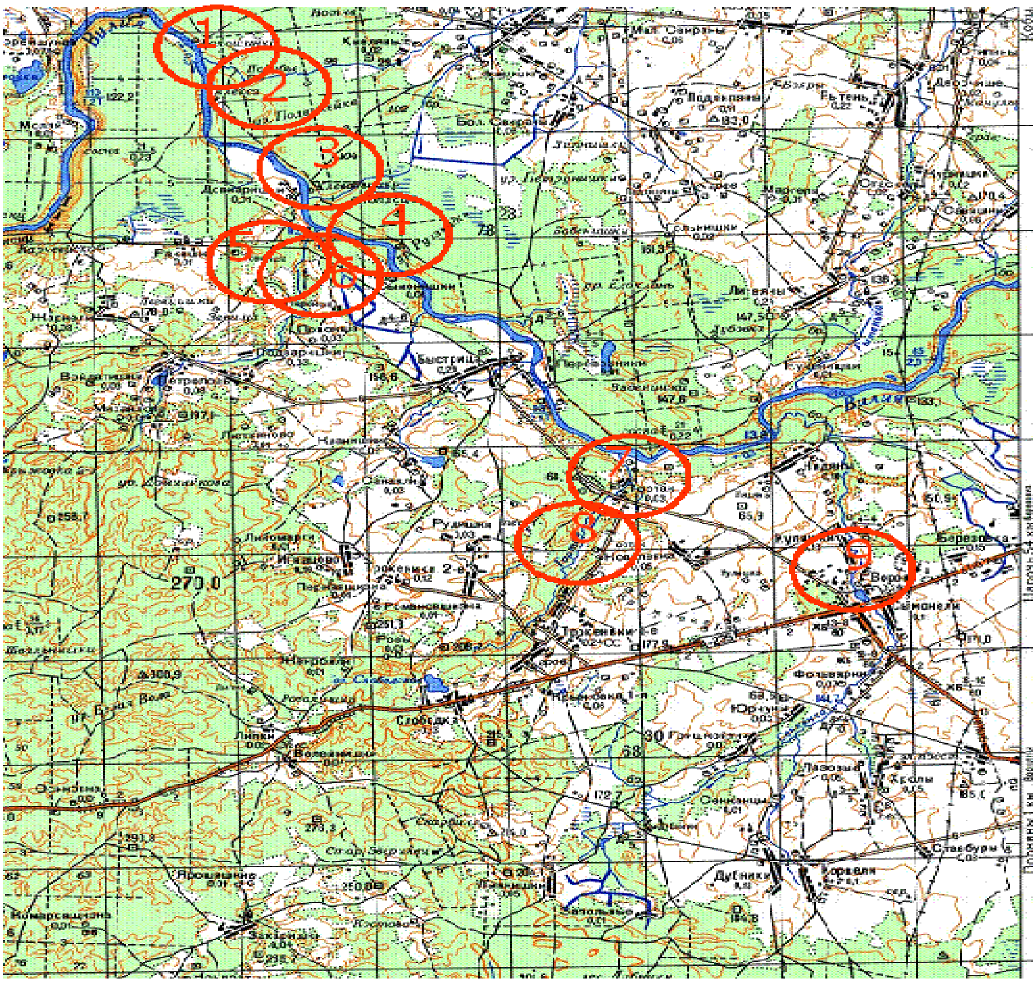



**Figure 70 - Schematic map of the localization of the studied spring and brook complexes in the villages Varona, Kemeleshki, Bystritsa**

Accept spring and brook complexes of the Oshmyany Upland there is information about the location of the spring "Krynichka lya bagini" on the right bank of the Vilja around the village Dubok (Smorgon District) within the 30-km area. Spring is encapsulated. Not protected. In its original form, probably is a limnokren. Main foresting species are birch, alder with noe assential admixture of spruce and pine. Spring with an artificial grotto, and is located approximately 500 meters away fro the Catholic chapel used for religious ceremonies. The anthropogenic contamination of adjacent territory is practically absent.

Location of the springs in the National Park “Narochanskiy" on the border with the 30-km area is shown in Figure 71. This group of springs is located on the territory of Svirskaya boundary glacial ridges and refers to a system of the river Stracha, right tributary of the Viliya (Neman basin) [92.93].


**Figure 71 - Schematic map of the localization of springs in the National Park "Narochanskiy". Yellow ellipse combines a group of springs Nos.1-6, located on the border of the 30-km area (marked in orange)**

## 13.6 Groundwater. Assessment of current state

### *13.6.1 Hydrogeochemical map*

As the main object for the construction of the hydro-geochemical maps of the 30-km area of the Belarusian nuclear power plant, Dnieper-Sozh aquifer was selected, which unlike all other aquifers has universal distribution on the studied territory and which are the main production aquifers equipped with the vast majority of water wells.

The basis for hydrogeochemical map made the following materials and information: materials of the hydrogeological and engineering geological survey, scale 1:200 000 and 1:50 000 performed in different years in sheet N-1935-VIII, N-1935-IX, N-1935-XIV and N -35-XV [89-93], materials of the Cadastre of underground water of Belarus [94-96], the results of hydrogeological studies undertaken in the exploration of underground water intakes in Ostrovets settlement, Oshmyany and Smorgon settlements, observations of the quality of groundwater for household and drinking purposes, which was carried out by the Centers of Hygiene and Epidemiology (CHE) of the Ostrovets, Smorgon, Oshmyany and Postavy Districts, as well as information on geochemistry of the groundwater obtained in the course of the integrated engineering-geological and hydrogeological survey made by the Unitary Enterprise “Geoservice" with a scale of 1:50 000 of the Ostrovetsstation (area 25 $km^2$) [94]

The chemical composition of groundwater in representative areas (more than 60 station) is characterized by a locus diagramm, in which the size of the color sector reflects the ratio of the concentrations of major anions ($HCO^{3-}$, $Cl^-$, $SO_4^{2-}$, $NO^{3-}$) and cations ($Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$), expressed in %-eq. The numbers of the water area sign indicate its catalogue number, total mineralization of water (g/$dm^3$) and the depth of sampling (m), and alphabetic indexes - on the geological age of the water sediments. When making a hydrogeochemical map, the intermorainal Dnieper-Sozh deposits (f, IgIId-sz) in the strata of Sozh (gIIsz) and Dnieper moraines overlying and underlying the aquifer were classified as closely related.

Areas with agricultural, communal and domestic pollution of groundwater of the Dnieper-Sozh aquifer were marked in relation to the content of the most typical components of this pollution in water ($NO^{3-}$, $Cl^{-}$, $SO_4^{2-}$, $Na^{+}$, $K^{+}$). As polluted we consider the water, in which the concentrations of these components was more than 5 times higher than in their natural geochemical background of $Cl^{-}$ 4,0 mg / dm $^3$; $SO_4^{2-}$- 6,2 mg / dm $^3$; $NO^{3-}$- 0.5 mg / dm$^3$; $Na^{+}$ - 4,6 mg / dm $^3$ and $K^{+}$ - 1,1 mg / dm $^3$ [98] in the pressured underground water of quaternary deposits of Belarus.

On most territories of the studies Quaternary deposits have underlain the Devon ($D_2$nr). The Devon aquifier contains mostly freshwater, but it hydrogeochemical anomalies were observed in some places, where the mineralization increase to 1,2-3,16 g/dm$^3$ and water takes up calcium sulfate and chloride-sulfate sodium-calcium composition. These sites are shown at the hydrogeochemical map sites of hydrogeochemical anomalies, formed by inflow of deep mineralized water and dissolution of gypsum-bearing deposits, limited to the rock mass of the Narovskiy aquifier of the Middle Devon ($D_2$nr).

Aquifer of the intermorainal Dnieper-Sozh deposits (f,lgIId-sz) on the research territories have universal development and is the first pressure aquifier in most parts. The depth of the aquifier top varies from 2,0 up to 100,0 m, being in average about 25-40 m. The thickness of the aquifier changes from 1,0 to 33,0 m, but in average is 8-15 m. Water-bearing deposits are primarily of fluvioglacial sands (from silt to gravel). There are often thicker layers of lake-glacial sandy loam and loam up to 5,2 m.

The aquifier crossed with the Sozh moraine (gIIsz) presented by dense sandy loam and loam with inclusions of gravel and pebbles. Rock mass capacity varies within 1 to 50 m, the highest is 20-30 m. Mostly the Sozh morain lies on surface.

The Sozh and Dnieper aquifier is underlain by the Dnieper moraine (gIId). It is represented by dense sandy loam and loam with inclusions of gravel and pebbles. Its rock mass thickness varies from 10 to 50 m, being in average about 20-30 m.

Lenses of sand can often be met (from silty to coarse) in the depth of the Sozh and Dnieper moraines, the capacity of which reaches 5-10 m.

Geochemical appearance of water in the Dnieper-Sozh aquifer and closely related sporadic distribution of water in the moraine deposits of the the Dnieper and Sozh age are predominantly bicarbonate magnesium-calcium. Their mneralization varies from 0,15 to 0,73 g/dm$^3$, being in average 0,30-0,40 g/dm$^3$. The pH varies in the range from 6,6 to 9,46, being in average about 7,4-7,7. Higher contents of Fe - to 1,4-5,6 mg / dm $^3$ is often observerd in the water of the aquifier which exceeds the level of MPC by 0,3 mg/dm$^3$, set for drinking water [95]. In some instances it exceeds the acceptable level of total water hardness (MCL – 7,0 mg/dm$^3$). In general, it varies in the range from 0,8 to 16,3 mg-eq./dm$^3$.

The following rules in the distribution of groundwater with different levels of mineralization are typical for the territory studied. For example, areas where groundwater mineralization is minimal (0,15 – 0,3 g/dm$^3$), they are usually limited to watersheds and uplands. As an example, the watershed area of the rivers Gozovka, Viliya, Oshmyanka and Losha should be mentioned, where the site of potential nuclear plant construction is situated. Moreover, similar sites are located on watersheds of the rivers Gozovka and Senkanka, Oshmyanka and Ustizerki, Viliya and Klevel, as well as in the south and south-west part within the Oshmyany ridge. This location is determined because these uplands is a area of nutrition of the Dnieper Sozh aquifer. Here the levels of groundwater are at marks considerably exceeding the piezometric levels of groundwater of the Dnieper-Sozh aquifier that provides its own recharge due to overflowing of the undergraound water table. Low mineralization of groundwater at such sites is formed due to a high washing of surficial sediments, and relatively small residence time of water in the aquifier. It should be noted that the relation of sites with minimal mineralization of groundwater to recharge areas on watersheds is also observed in other areas of Belarus, in Polesie particularly [96].

### *13.6.2 Existing anthropogenic contamination*

The Dnieper-Sozh aquifer is the first from the surface of the pressured aquifers in the most of the researched territory. Traces of anthropogenic contamination, mainly agricultural and household, are often observed because of its relatively shallow occurrence (25 - 40 m) in the waters of the aquifer. This appear in the growth of ions in groundwater content $NO^{3-}$, $Cl^{-}$, $SO_4^{2-}$, $Na^{+}$ and $K^{+}$ to the levels many times higher than their natural geochemical background of fresh groundwater in Belarus [97]. At high levels of contamination geochemical type of water may vary. For example, the most intensive contamination of groundwater in the Dnieper-Sozh aquifer was found in hydrogeological well No. 72 near the village Staraya Rudnya of Smorgon Sistrict. Here, at a depth of 36,2-42,0 m water with $NO_3$- equal to 98,0 mg/dm$^3$ were found (levels of MCL for nitrate in drinking water is 45 mg/dm $^3$ [101]. Water also has higher concentrations of $Cl^{-}$37,0 mg/dm$^3$, $SO_4^{2-}$ 33,3 mg/dm$^3$, $Na^{+}$ - 22,0 mg/dm$^3$ and $K^{+}$ - 12,7 mg/dm $^3$. These content are below acceptable levels in drinking water, but many times higher than levels of natural geochemical background. In general, the water had dramatically abnormal chloride-nitrate sodium-calcium composition.

This cartographic generalization of hydrogeochemical materials of the Dnieper-Sozh aquifer revealed the confidness of sites with traces of contamination of underground water to the recharge areas of the given aquifier. It is obvious that the dominateng downward movement of groundwater in these areas, including in the groundwater, promotes the transfer of contamination from the surface zone to the deeper layers of groundwater. Territorial coincidence is typical for the majority of sites where contamination detected in areas with groundwater with minimal mineralization (0,15 – 0,3 g/dm$^3$) which as mentioned before also comply to the areas of recharge of the Dnieper Sozh aquifer.

As an important additional information on the hydrogeochemical map the position of hydrogeochemical anomalies that are limitedo the first surface of the aquifer pre-Quaternary sediments - Devon ($D_2$nr) is shown. This aquifier has spread throughout the most territory of the studies, contains mostly fresh water and is among the most important used aquifers. However, in the least northern area of the studied territory in a broad area from village Mostyany to village Losi of Ostrovets district, mineralized water is spread (from 1,2 to 3,16 g/dm$^3$) in the Devon aquifer. They were opened here at depths from 61 to 102 m, which characterize them as hydrogeochemical anomalies. In the mineralization term from 1,2 to 2,7 g/dm$^3$ these waters are bicarbonate-sulphate and sodium-calcium and with the mineralization of 3,16 g/dm$^3$ acquire chloride-sulfate magnesium-sodium-calcium composition. The formation of these hydrogeochemical anomalies is apparently associated with the processes of underground dissolution of gypsum-bearing deposits, limited to the depth of Narovskiy aquifier of the Middle Devon ($D_2$nr). Limit distribution of gypsum-bearing packets of the Narovskiy aquifier in this area can be traced on the right bank of the river Viliya [98]. Its presence is probably the main reason for heave decrease of capacity of fresh water in the area - from 300-350 m and 100-150 m. The existence of hydrogeochemical anomalies of the sulfate-calcium type indicates, on the one hand, the processes taking place in the underground dissolution of gypsum-bearing deposits, and on the other hand - related dissolution of karst processes. The evidence of such processes is proved, in particular, by collapse breccias encountered by the Devon sediments.

Formation of hydrogeochemical anomalies could be influenced by Berezovskiy rift which is allocated on this territory according to the geophysical data. The area with hydrogeochemical anomalies [99] (from village Mostyany to village Losi) is paralleled to the line of the rent. Excessively high content of $Cl^-$ and $Na^+$ in the water of the Devon aquifier in the well at the village Zhukoyni Zhelyadskiye may be due to inflow of the deep mineralized water along the rent.

### *13.6.3 Usage*

As a result of the performed hydrogeological studies it was revealed that the Ostrovets district is adequately resourced with fresh groundwater. As of 01.01.2008 5 deposits of fresh water located at a distance of 20 to 40 km from the site are explored on the territory of the studied area for industrial development and are limited to the Quaternary, Proterozoic and Cambrian sediments, Ordovician carbonate complex, Silurian carbonate complex. Currently the following water abstraction are active in Ostrovets – “Ostrovets”, Oshmyany - "Vaygeta", Smorgon - "Koreni", resort area Naroch "Malinovka-1, Lake Naroch -" Baloshi "(Figure 72). For drinking water in rural regions, single departmental wells are used. Wells used the aquifers of the Quaternary, Devon, Silurian and Ordovician sediments.

In rural regions, residential population tradifionally use underground wells for household needs along with centralized water supply.

Analysis of previously performed studies at this territory shows that the use of groundwater can be increased substantially.

Natural resources represent the total flow rate of underground water, drained by the river network and provided by infiltration of precipitation. The total value of the natural resources of the Grodno region is 7158 thousand.$m^3$/day. Within the territory of the Ostrovets District, module of natural resources varies from 0,6 (Myadel district) to 4,45 l/s * $km^2$ (Ostrovets district) taking in consideration civil division.

The uneven distribution of natural resources is related primarily to the nature of the terrain, lithology of the mantle rock and water-bearing rocks. Total natural resources within the given territory are 662,2 thousand $m^3$/day. Their distribution within individual administrative districts is given in Table 114.

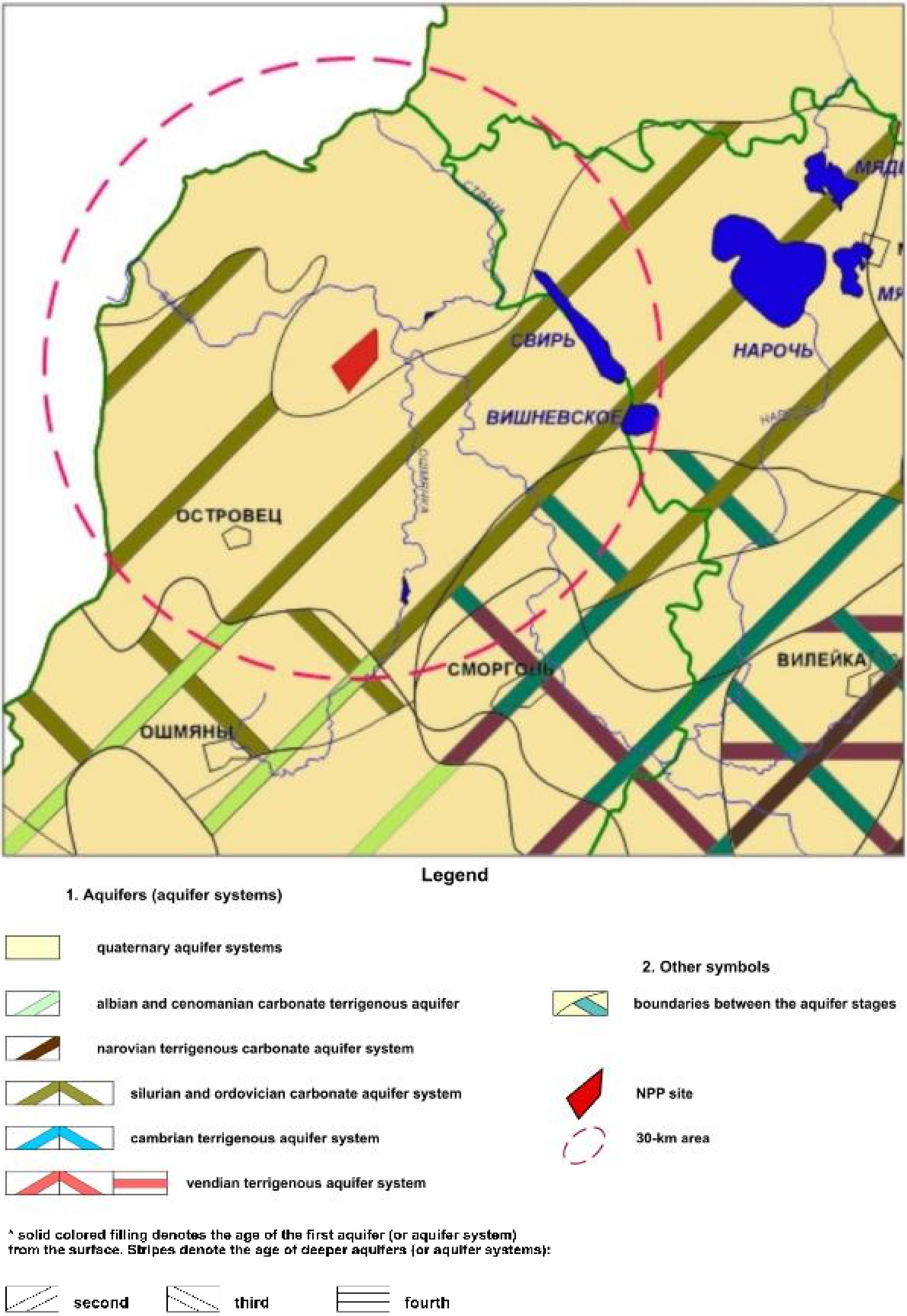



**Figure 72 - Map of major aquifers (complexes), prospective for use in house-hold and drinking water supply. Scale 1:500 000**

**Table 114 - Distribution of natural resources in the administrative districts**

| District | Total area, km$^2$ | Area within the site, km$^2$ | Natural resources module, l/s km$^2$ | Natural resources, thousand m$^3$/day |
|---|---|---|---|---|
| 1 Ostrovets | 1560 | 1549,34 | 4,45 | 595,7 |
| 2 Postavy | 2079 | 49,97 | 2,5 | 10,8 |
| 3 Myadel | 1956 | 215,44 | 0,6 | 11,2 |
| 4 Smorgon | 1490 | 272,27 | 1,17 | 27,5 |
| 5 Oshmyany | 1207 | 45,7 | 4,32 | 17,0 |
| Total | | 2132,7 | | 662,2 |

Groundwater recharge is better insured within the Ostrovets district. The maximum value of natural resources is fixed – 595,5 thousand m$^3$/day. The value of the module is 4,45 l/s.km$^2$. Territory of Postavy and Myadel District are characterized by slow water exchange: a generalized power module is 0,6 and 1,17 l/s.km$^2$, values of natural resources are about 11 l/s.km$^2$.

Prospective useful resources characterize the possibility of use of groundwater. They are estimated by the amount of groundwater of the estabslished quality and target purposes, which can be obtained within the hydrological area, river basin or a civil division of the Republic of Belarus and show the potential use of groundwater.

Modules of the useful resources and total prospective resources across the territory of the administrative districts, being a part of the territory studied are presented in Table 115.

**Table 115 - Distribution of the prospective resources within the administrative districts**

| District | Total area, km$^2$ | Area within the site, km$^2$ | Module of the useful resources, l/s km$^2$ | Prospective useful resources , thousand m$^3$/day |
|---|---|---|---|---|
| 1 Ostrovets | 1560 | 1549,34 | 5,19 | 694,7 |
| 2 Postavy | 2079 | 49,97 | 3,90 | 16,8 |
| 3 Myadel | 1956 | 215,44 | 2,96 | 55,07 |
| 4 Smorgon | 1490 | 272,27 | 5,4 | 127,97 |
| 5 Oshmyany | 1207 | 45,7 | 4,79 | 18,9 |
| Total | | 2132,72 | | 913,5 |

Discovered useful reserves are determined by the amount of groundwater, which can be obtained by rational, technical and economical water abstraction stations under predetermined running regime, as well as water meeting the sanitary requirements during the estimated period of water consumption.

Data on the total resources and reserves of the underground water on the site are shown in the table 116 and 117.

The territory of the Ostrovets district is extremely heterogeneous according to the ratio of the values of the performance of useful resources to the natural ones. The areas with equal or close to each other running and natural resources are characterized by favorable supply (Ostrovets and Oshmyany Districts). The least favorable conditions for ground water recharge are in Myadel and Smorgon district, where the prospective useful resources exceed the natural almost in 5 times, and recharge of aquifers by meas of the last varies from 20 to 45 %.

The degree of knowledge of the prospective resources (relation of the useful reserves to prospective resources) in the studie territory is very low and is about 4%. Thus, there is a significant reserve to meet the demand for drinking water, and there are opportunities for exploration in order to meet the needs of farmlands and villages.

It is necessary to explore a place that can meet the needs defined (550 - 650 $m^3$/h) of drinking quality water in order to choose a concrete site for placing the water abstraction station.

**Table 116 - Information of the explored deposits of underground waters**

| District | Town | Water abstraction station | Index of the running aquifer | Available reserves of underground water, A+B, thousand $m^3$/day | Deposit state | % of the approved reserve usage |
|---|---|---|---|---|---|---|
| Ostrovets | Ostrovets | Ostrovets | S | 5.3 | Running | 25 |
| Smorgon | Smorgon | Koreni | V+E | 28.3 | Runnin | 40 |
| Total | | | | 33.6 | | |

**Table 117 - Resources and reserves of groundwater**

| District | | Ground water resources thousand $m^3$/day | | Ratio of the useful resources to natural ones, % | Explored available reserves in categoaries A+B, thousand $m^3$/day | Ratio of the avalanle reserves to the useful resources, % |
|---|---|---|---|---|---|---|
| | | Natural | Prospective useful | | | |
| 1 | Ostrovets | 695,2 | 694,7 | 100 | 5,3 | 0,8 |
| 2 | Postavy | 10,8 | 16,8 | 155 | | |
| 3 | Myadel | 11,2 | 55,07 | 492 | | |
| 4 | Smorgon | 27,4 | 127,97 | 467 | 28,3 | 22 |
| 5 | Oshmyany | 17,0 | 18,9 | 111 | | |
| | Total | 761,6 | 913,5 | 120 | 33,6 | 3,8 |

### *13.6.4 Ground water protection*

#### *13.6.4.1 Protection assessment criteria*

The natural protection of ground waters is determined by a set of parameters, the main ones being:

- depth of occurrence, ion-salt and gas composition of ground waters;
- aerated zone capacity, capacity of the composing soils and lands;

- soil pattern (soil type, soil texture, mineralogical composition of soil, its hydrophysical condition) and sorption characteristics;
- capacity, behavior and composition of hydrometeors (rain, snow);
- filtration parameters of grounds and soils;
- pollutant types and physicochemical properties.

In the stage of the first EIA examinations it is justified to use some of the following types of information listed below: Data concerning the depth of occurrence of the most vulnerable groundwater and its quality; characteristics of soil mantle as a medium of radionuclide migration; migration process characteristics and distribution of $^{90}Sr$ and $^{137}Cs$ in the soil mantle of the Chernobyl fallout area as sample ones. Despite the limited information we have at our disposal, however it is enough for making up a general model of ground water protection within the 30-km area of the Ostrovets site for possible NPP construction.

*13.6.4.2 $^{137}$ Cs and $^{90}$Sr migration parameters*

The analysis of $^{137}$ Cs and $^{90}$Sr redistribution through the depth of soil profile showed [100,101] that:

- even after 15-20 years passed since the Chernobyl NPP accident, 95-98 % of $^{137}$ Cs storage is concentrated in the upper 0-5 cm layer, in some cases in 0-20 cm layer in the majority of soil types, regardless the density of $^{137}$ Cs fallouts. The main storage of $^{90}$Sr (same 95-98 %) is concentrated in the 0-15 cm layer, in some cases in 0-25 cm layer (Krasnoselye, sand dune, 21 km from the Chernobyl NPP);
- linear migration speed of $^{137}$Cs (V) and quasidiffusion coefficient (D) are varied in wide range: V – 0,11-2,66 cm/year, D – 0,01-1,40 cm$^2$/year. For $^{90}$Sr the same parameters of vertical migration through the soil profiles are given 0,14-7,14 cm/year and 0,01-19,00 cm$^2$/year

A statistically valid tendency of decreasing of $^{137}$ Cs migration parameter values (V, D) in time was determined for mineral automorphic soddy-podzolic soils (Podzoluvisol) of second bottoms and terraces above the flood-plain being accounted for the irreversible $^{137}$ Cs sorption by soil solid substratum as a result of diffusion and isotope demobilization in an interlayer space of clay minerals [106,107]. The tendency is valid for the rest soil types - hydromorphic, peat-bog and semihydromorphic fluvial soddy soils (Histosol and Fluvisol). Semihydromorphic waterlogged soddy-podzolic soils of lake catchment basins are the only exceptions, on the contrary being characterized by increasing of the parameters in time due to the high percolation mode and convective mass transfer overlapping on the diffuse flow as a result.

$^{90}$Sr migrates in automorphic mineral soddy-podzolic sandy soils (Podzoluvisol) actively. A growth of migration parameters in time was detected for the type of soil ($R^2$=0,7-0,9). A tendency of migration parameter growth in time was also determined for semihydromorphic soddy-fluvial sandy loam soils (Fluvisol) of bottoms and second bottoms. The decrease or constancy of migration parameters in time was determined for hydromorphic highly organic peat-bog soils (Histosol).

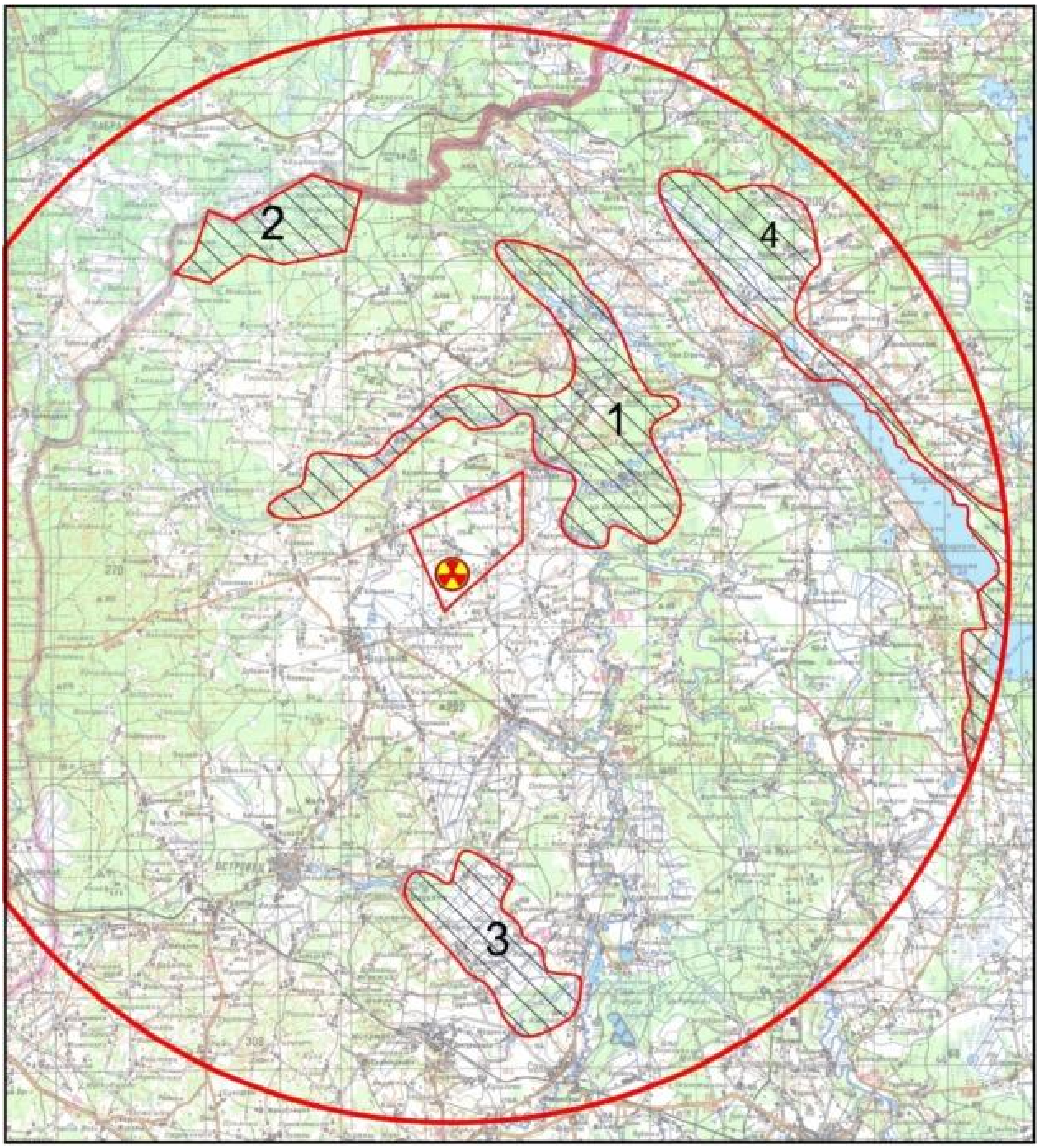
Thus, *localization of main storage* of the Chernobyl radionuclides $^{137}$Cs и $^{90}$Sr at the depths below 5-25 cm of soil profiles indicates a rather effective, in general, shielding role of the Belarusian lands and soils in the processes of vertical redistribution of *main storage* of radionuclides to the level of ground waters even after 15-20 years passed since the accidental fallout.

*13.6.4.3 Radioactive pollution protection*

The radiation condition analysis of ground waters occurring at the depths down to 2 m in the areas of the Chernobyl fallouts [104,105] actually showed relatively low levels of its current (as of 2002-2007) $^{137}$Cs and $^{90}$Sr pollution (0,02-0,58 and 0,012-2,206 Bq/dm$^3$, respectively). However if one compares the activities listed with the pre-accident radiation pollution levels of the river Prypiat (0,006-0,066 Bq/dm$^3$ of $^{137}$Cs and 0,003-0,018 Bq/dm$^3$ of $^{90}$Sr), that were (mainly) connected with global fallouts as a result of nuclear tests in atmosphere, they (activities) appear to be rather high in the context of nonthreshold impact on human body. With that one should take into account that in the regions of agricultural industry and application of ions $NH^+_4$ and $K^+$ competitive with radiocesium during fertilization of soil mantle the threat of additional $^{137}$Cs-pollution of ground waters is increased. In the same regions the intensity of $^{90}$Sr migration processes to the ground water level increases due to the mineralization of soils' organic matter.

Summing up it should be noted that in the regions with the depth of ground water occurrence down to 2 m the soil mantle isn't capable of forming an effective pollution protection from surface pollution sources, including “plane” surface source of radionuclides ($^{137}$Cs, $^{90}$Sr and etc.). Areas with thick (more than 2 m) aeration zone should be considered as regions with rather effective soil shielding of ground waters.

This statement is depicted by a radiation protection sketch map (figure 72) of the 30-km area of the Ostrovets site showing the areas with low depth of ground water occurrence, within a broad background of relatively fine $^{137}$Cs and $^{90}$Sr protection of ground waters, as the most sensitive to pollution by such radioisotopes.




**Legend:**

1, 2, 3, 4 - areas with maximum rates of migration of $^{137}Cs$ and $^{90}Sr$ through the soil and maximum probability of ground water contamination

**Figure 73 – Location on the sketch map of the chosen typical areas being the most vulnerable to the natural factors determined**

## 13.7 Soils. Agriculture. Risk assessment of radiation exposure on agricultural ecosystems

### *13.7.1 Risk assessment of radiation exposure on agricultural ecosystems. Purposes and objectives*

Ensuring the radiation safety of population and environmental protection from radioactive pollution is one of the most important objectives of nuclear energy program implementation. Despite almost half-century experience of NPP operation indicates small levels of radioactive pollution within the 30-km area of observation [108], this issue remains to be actual as the way from entering radioactive matters into the atmosphere to dose-formation in biota and human body is very complicated. There is an extremely broad range of natural conditions, physicochemical properties of radionuclides, agricultural ecosystem features defining significant uncertainty of NPP radiation impact assessments and necessity of complex solution of problem in every particular case.

Therefore assessment of radioactive pollution levels of environment and products used by human, firstly, agricultural products is extremely important. Finally, within a very small probability of NPP incidence one can't help considering the peculiarities of radioactive pollution and biota radiation dose formation within such an unfavourable development of events that will be a ground for making up a range of protective measures.

Thus a complex assessment of radiation impact on agricultural ecosystems was the purpose of research scientific work implementation.

To reach the objectives the following research tasks are set:

- characteristic analysis of the radionuclides intake into agricultural ecosystem within regular and emergency fallouts;
- verification of radionuclide distribution models in agricultural ecosystems and prediction of radionuclide content in agricultural products based on the models;
- separation of agricultural ecosystems' components being critical to ionizing irradiation impact, predictive assessment of external radiation dose for biota and possible radiation-induced effects;
- development of suggestions concerning local radio ecological monitoring system of agricultural ecosystems;
- preparation of proposals in relation to the protective measures in agricultural industry in case of NPP's emergency pollution.

### *13.7.2 General mechanisms of radionuclide intake*

Radioactive pollution of plant complexes and values of radiation dose for biota and human body connected with it are determined by [109-112]:

- activity of radionuclides emitted into environment;
- peculiarities of travel and deposition of radioactive fallouts;
- physical and chemical properties of radionuclides;
- properties of land cover.

In the most common case the value of radionuclide concentration in main ecosystem components and the corresponding radiation doses are directly relative to emission activity of radioactive source (emergency or normally operated NPP reactor).

Travel of radioactive agents and intensity of deposition are determined by the fallout considerations [109,110]:

- within normal operation: there is a constant emission of a certain amount of radioactive agents into the environment along with accumulation of long-life radionuclides in various agricultural ecosystem components;

- within radiation accident: there is possible a short-term high activity emission of radioactive materials with a broad range of physicochemical properties from completely or partly depressurized active zone. Three-dimensional pollution distribution and intensity of deposition are determined by meteorological conditions at the moment of the maimum radionuclide concentrations in atmosphere [113].

As a rule, a smaller extent of distribution and a greater value of deposition on adjacent area are noted within prevalence of unstable categories of atmosphere condition and influence of atmospheric precipitation [114,115]. The roughness of the underlying terrain determined by terrain relief, economic activity features, presence of certain natural complexes plays an important part in deposition. Distribution of radioactive fallouts is directly relative to the height of its rise determined by the difference of temperatures in source and environment.

Throughout the reactor operation a formation of a broad range of radionuclides (fission products, activation products and transuranium elements) with various physicochemical properties occurs in the reactor fuel. Inert radioactive gases make the main contribution to the activity of both regular and emergency emissions [116]. However owing to its chemical properties they are slightly stopped by filtration protective systems, do not participate in migration across the components of agricultural ecosystem and in formation of internal radiation dose due to its alimentary intake [117]. With that they are capable of defining the additional external biota irradiation.

Radioactive isotopes of iodine make a significantly greater contribution to internal irradiation dose, dose formation and endanger the thyroid body of animals and humans at the initial moment of emergency fallouts (first of all $^{131}I$ and $^{132}I$ with parent $^{132}Te$) [117].

When considering the radionuclide migration in the components of agricultural ecosystems and food chains a special attention should be paid to long-life radioactive isotopes of biogenic chemical elements or to those which possess similar biogenic elements [109,110,117]. First of all $^{137}Cs$ (chemical analogue of potassium) and $^{90}Sr$ (analogue of calcium) should be concerned as such elements. A long half-life period determines a gradual accumulation in environment due to regular emissions or a long-lasting migration between ecosystem components along with addition in food chains as a result of emergency pollution. At the same time various chemical properties of such radionuclides determine significantly different redistribution mechanisms in ecosystems [118]. So, a relatively high fugacity in radioactive emissions, a significant foliar accumulation in plants, a non-exchangeable absorption type in fine soil fraction, a prevailing accumulation in plant root systems and a relatively uniform distribution inside the body of animals and humans is typical for $^{137}Cs$ being an alkaline metal. A smaller foliar intake in plants, an exchangeable sorption type by soil mineral matter and a non-exchangeable type by organic matter is established for $^{90}Sr$ being an alkaline-earth metal. A prevailing accumulation in aboveground biomass of plants and an osteotropic type of distribution in body of animals and humans is typical for the radionuclide.

*Properties of land cover* determine the deposition value of radioactive emissions on the ground since one of the most important ground characteristics for distribution of impurities in atmosphere, its roughness, is connected with the properties [119]. Forest range plays a special part here. Depending on the wind speed the deposition of radionuclides in forest can be 6-12 times higher than in meadow vegetation within equal meteorological conditions and the depletion rate of radioactive cloud is 3,7-5 times faster when it moves above the forest-covered terrain rather than open grass vegetation covered spaces.

It important to note that a character of radionuclide distribution across the components of agricultural ecosystems accompanied by corresponding biota irradiation doses and radionuclide accumulation in agricultural products are determined by intensity and duration of radioactive emission so radionuclide redistribution in the biogeocenoses under consideration should be considered separately for both regular radioactive emissions within normal reactor operation mode and pollution as a result of maximum credible accident.

#### *13.7.3 General characteristics of agricultural compex of the Belarusian NPP's location area, made using materials of surveying works at the stage of site selection*

All the territory of Ostrovets district as well as part of Smorgon and Oshmyany districts is included in the 30-km area of the Belarusian NPP site. The amount of soil resources of the mentioned areas in Grodno region is 215,37 thousands ha., including:

- lands for agricultural organizations - 86,31 thousands Ha (40,1 %);
- private lands -10,42 thousands ha (4,8 %);
- lands for state forestry organizations -109,37 thousands ha (50,8 %);
- lands for industries, transport, communication, power engineering, military defense and other purposes – 5,15 thousands ha (2,4 %);
- lands in general use in townships - 3,19 thousands ha (1,5 %);
- reserve lands – 0,66 thousands ha (0,3 %);
- lands for environmental, rehabilitation, recreation and historical-cultural purposes – 0,27 thousands ha (0,1 %).

So as it appears from the mentioned data, the main part of the territory under consideration is occupied by forest ranges and agricultural lands (nearly 90 %) where the intensive economic activity is carried out at the present time.

*Agricultural industry.* Agricultural organizations situated on the territory given are specialized in cereal crops, flax, sugar beet, rape, potato, feed crops, milk and meat production.

In 2008 agricultural enterprises on the territory under consideration produced crop and livestock production in comparable prices to the amount of 66,3 bln. roubles. Livestock production makes 52,7 % of the whole output, crops production - 47,3 %. Households produce 3,4 % of the agricultural production in the given region.

*Crops production.* Plough lands take up 62,5 % of the whole agricultural land area, meadows - 37,4 % (2/3 of them is improved). Nearly 3,5 % of plough lands are subjected to wind erosion, 11 % - to water erosion, 6,4 % - obstructed by stones. Ploughed up lands occupy 63 %.

Quality score attributed to agricultural lands is 28,8 and to plough lands – 30.

Productivity of cereal and leguminous crops has increased from 30,8 to 39,6 dt/ha, flax-fiber – from 6,2 to 6,8, rapeoil seeds – from 12,8 to 27,3 dt/ha. Sugar beet - 342 dt/ha.

In 2008 the croppage of cereal and leguminous crops by weight after processing was 70718 t., flax-fiber – 336 t., sugar beet – 21191 t., rapeoil seeds – 3799 t., potatoes – 4648 t., vegetables – 61 t.

In 2006 the amount of manufactured products in terms of feed units (f.u.) was 133,3 thousands t., in 2007 - 181,2 thousands t., in 2008 - 200,9 thousands t., including plough lands – 112,3, 155,4 and 175,3 thousands t. respectively.

Averagely in 2006 24,1 dt. of f.u. were harvested from every 1 ha of agricultural lands, in 2007 - 32,7 and in 2008 - 37,3 dt. of f.u. The productivity of plough lands reached 33,3, 46,1 and 52,0 dt. of f.u. respectively. From ballohectare of plough lands the output increased from 1,11 dt. of f.u. to 1,73 dt. of f.u. in 2008.

Averagely in 2008 37,3 dt. of f.u. were harvested from every 1 ha of agricultural lands. The productivity of plough lands reached 52,0 dt. of f.u. respectively. From ballohectare of plough lands the output increased from 1,11 dt. of f.u. to 1,73 dt. of f.u. in 2008.

In 2009 cereal and legominous crops are planned to be farmed on the area of 17,9 thousands ha (53,2 % of plough land structure) including 9,3 thousands ha of winter cereal crops sown in autumn 2008.

Feed crops are planned to be located on the area of 13,1 thousands ha (38,7 %).

*Livestock production.* In 2008 the produced amount of milk reached 34011 t., raised livestock and poultry – 7105 t. Average milk yield from a cow in 2008 reached 4677 kg, 477 kg more than in 2007. The average daily gain in weight of cattle stock on raising and fattening increased from 626 g in 2007 to 653 g in 2008 (values for region from 522 g to 549 g), swine – from 573  g to 595 g (values for region from 522 g to 549 g) respectively. On January, 1 2009 the livestock in households reached 27621 heads, including cows – 7341, swine – 14526 heads. All types of fodder were procured in the amount of 86356 t of feeding units for state-owned livestock, including bundle feed – 40564 t of feeding units per one animal unit – 20,2 dt of feeding units.

In livestock industry it is planned to produce 35110 t of milk, breed 7580 t of livestock and poultry to be processed for meat.

### *13.7.4 Radioecological assessment of current condition of agricultural ecosystems and agricultural production*

Pollution density of soil by $^{137}$Cs is less than 2 kBq·m$^{-2}$, $^{90}$Sr – less than 2 kBq·m$^{-2}$. According to these values the region is comparable with the rest territory of the Republic polluted only by global emissions from nuclear tests (pollution density for $^{137}$Cs is less than kBq·m$^{-2}$ and for $^{90}$Sr is less than 1,8 kBq·m$^{-2}$ [113]). The exposure dose in the air is less than 0,15 µSv·h$^{-1}$ and determined by natural radiation environment.

On the territory of Ostrovets district monitoring of $^{137}$Cs content in agricultural production is implemented at the expense of Ostrovets laboratory of veterinary-sanitary examination. In 2008 determination of the radionuclide content was implemented in a broad range of plant and livestock production manufactured on the territory of the district.

There were examined 2474 t of rye seeds from 9111 t stored, 10113 t of wheat from 21156, 7793 t of triticale from 16402, 8844 t of barley from 19273, 3827 t of oat from 8882, 215 t of leguminous crops from 3225, 25 t of rape from 3798 and 670 t of fodder grain from 41438. All the examined production possesses specific activity of $^{137}$Cs less than Bq·kg$^{-1}$. Approximately the same specific activity of the radionuclide was noted in the examined samples of corn, millet, flax seeds. Specific activity less than 50 Bq·kg$^{-1}$ was established for haylage and herbage (additional feeding). The amount of the types examined was 19740 and 740 t from 70257 and 91058 t respectively.

In 2009 the members of Radiology Institute accomplished an additional sample selection of agricultural production manufactured in public and private households.  There were selected 31 samples of milk, 33 samples of cereals, 18 samples of root and tuber crops and 53 samples of fodder production. Specific activity of $^{137}$Cs in the samples examined was determined with γ-spectrometric complex Canberra. Radiochemical extraction of $^{90}$Sr was performed according to standard methodology CINAO with radiometric completion on α-β counting-tube Canberra-2400. Measurement instrumental error was below 20 %.

As it was stated by examinations performed, the specific activity of $^{137}Cs$ in milk and market products is at the level of global emissions and in a number of cases lower than MDA (minimum detected activity is equal for γ-spectrometric complex Canberra 2,6 $Bq \cdot kg^{-1}$). Specific activity of $^{137}Cs$ in hay is below 10 $Bq \cdot kg^{-1}$.

$^{90}Sr$ pollution levels of milk were below 0,6 $Bq \cdot kg^{-1}$ that is at least 5-6 times lower than standard values (3,7 $Bq \cdot kg^{-1}$). Specific activity of $^{90}Sr$ in hay is below 18,7 $Bq \cdot kg^{-1}$. In general, average values for all the inhabited localities of $^{90}Sr$ content in samples examined may be placed in the following line of decreasing of radionuclide concentration.

- hay - 5,54±3,78 $Bq \cdot kg^{-1}$;
- grain (rye, oat, wheat, barley) – 1,81±0,85 $Bq \cdot kg^{-1}$;
- grain (corn) - 0,95±0,38 $Bq \cdot kg^{-1}$;
- beet - 0,76±0,23 $Bq \cdot kg^{-1}$;
- potato - 0,70±0,32 $Bq \cdot kg^{-1}$;
- carrot - 0,59±0,3 $Bq \cdot kg^{-1}$;
- milk - 0,45±0,11 $Bq \cdot l^{-1}$.

Consequently, the values of specific activities received are tens of times lower comparing with actual standard values. Particularly, according to level of $^{137}Cs$ and $^{90}Sr$ content accepted in the Republic in agricultural raw materials and fodder specific activity of $^{137}Cs$ in grain for food needs shouldn't exceed 90 $Bq \cdot kg^{-1}$, and for $^{90}Sr$ – 11 $Bq \cdot kg^{-1}$, in milk for processing to whole milk products, cheese and cottage cheese - 100 and 3,7 $Bq \cdot kg^{-1}$, respectively [120,121].

Generally, the values of $^{137}Cs$ and $^{90}Sr$ content in agricultural ecosystem components on the territory examined are similar to the values on adjacent regions polluted only by global emissions as a result of nuclear tests.

## 13.8 Landscapes, flora, fauna

### *13.8.1 Landscapes*

The region of NPP construction is entirely located in the range of one landscape province – Poozerskaya province of glaciolacustrine, moraine- and hilly-moraine-lacustrine landscapes. For their altitudinal location the region's landscapes are referred to all of the three groups of landscapes present on the territory of the Republic of Belarus – elevational, medium-altitude and low. Elevational landscapes occupy its marginal parts - north-eastern and south-western. When moving to center the landscape changes to medium-altitude and low [122,123].

#### *13.8.1.1 Landscape potential*

Natural soil fertility for the majority of landscapes is relatively low. Quality score attributed to the lands is lower than the region average value. A high relief roughness determines small outlines of the lands. For these reason the development level of the 30-km area is not much of intensity. Natural complexes remain here to a wide extent with the forests prevailing. Agricultural lands occupy approximately half of its area.

Comparatively low economical development of the 30-km area in combination with its natural properties – great amount of lakes and favorable environmental condition – provides bright background for recreation usage of the given territory. According to regionalization scheme of the Belarusian territory for sanatorium-resort and recreation development there are three landscape-climatic regions within the 30-km area under consideration: Narochansko-Glubokskiy (north-eastern part), Molodechnensko-Vileika (central part) and Oshmyany (south-western part). Its adequacy for resorting purposes was assessed according to three private criteria: landscape esthetic quality, its ecological condition, bioclimatic conditions as well as integral criterion of opportuneness based on the synthesis of these conditions

Among the three regions assessed one of them – Narochansko-Glubokskiy – has the most favorable resorting conditions, with the rest two also possessing favorable conditions. So generally, the region possesses high recreation natural resources potential. A part of the largest state recreation area in Belarus created on the base of "Narochanskiy" national park is located within this region. In addition recreation areas and local objects are also located here. All of them are situated overa distance of 20 km from the site. Sanatoriums, preventoriums and children's recreation camps located here are designed for simultaneous rest of 600 persons.

Specially protected territories located in the region such as the republican and local wildlife reserve, can also be considered as potential recreation objects. They are considered to be perspective for ecological tourism development.

Mineral resource potential of the territory under consideration is formed by deposits of construction raw materials, peat and sapropel. 7 deposits of construction raw materials are located within the given territory [124]. These are deposits of building sands, sandy gravel and clays. Only two of them are being developed: one – building sands and the other – clays.

There are 11 deposits of peat [125]. Its area is small in the majority of cases and equals from 100 to 700 ha. And only two largest of them occupy more than 1 thousands ha. The average occurrence depth of peat varies from 1,1 to 2,7 m, and its geological reserves - from 60 to 2500 thousands t. Total reserves of peat are relatively small. All the large peat beds are dried and used generally as agricultural lands.

The region possesses significant sapropel resources. There are 46 lakes with putrid mud in total. 88,5 mln. $м^3$ of raw sapropel are located here. Siliceous and calcareous types prevail.  At the present time there is no sapropel production.

*13.8.1.2 Landscape pollution resistance*

Migration of chemical substances on the territory is determined by its landscape geochemical conditions. Its carry-overprevails in eluvial landscape type, and its carry over in combination with accumulation prevails in eluvial accumulative type and they are accumulated in superaqual (swamped) landscape type [126, 127].

Approximately 50 % of the total area is occupied by eluvial landscapes along with eluvial accumulative landscapes occupying nearly 90% within the 30-km area. Superaqual landscapes account for 7 % of the total. Natural ecosystems have a similar landscape structure.

Sandy loam soils on loose powdery psammitic and psammitic sand loams occupying nearly 52 % of the whole 30-km area prevail in grain-size texture. Sandy soils occupying 58 % of its total area prevail in natural ecosystems.

Soil-forming materials are of non-uniform structure and often there are bi- or trinomial structures of soil profile. Specific weight of sandy loam soils possessing binomial structure (sandy loam-sandy clay) is rather high and reaches 35 %. Uniform soil profile structure is typical to a greater extent for sandy types occupying 34 % of the 30-km area;

Typomorphic elements of landscapes are hydrogen ion ($H^+$) and ferric ions ($Fe^{2+}$) and to a smaller extent calcium ions ($Ca^{2+}$) forming the following landscape classes depending on oxidation-reduction conditions: sour – 38 %, sour-fen clayed – 18 %, fen clayed – 1 %, sour calcareous – 23 % and sour calcareous fen clayed – 20 %;

Sour eluvial landscapes with forests (mostly coniferous) on sandy deposits are the most common within the 30-km area. They are widespread along the valley of the river Viliya, in western part of the 30-km area, in interfluve area of the river Oshmyanka and river Viliya and also in the northern and north-western parts.

Within the 5-km area the sour landscapes occupy 18 %, sour fen clayed – 7 %, fen clayed – 8 %, sour calcareous – 40 % and sour calcareous fen clayed – 26 %. Sour calcareous eluvial and transeluvial landscapes on sandy loam deposits underlain by moraine sandy clay are the most common. Practically everywhere the given landscapes are developed for agricultural needs. Forest sour eluvial landscapes on sands are present as small lots mostly in the northern part.

Generally, natural ecosystem conditions of the 30-km NPP site are contributed to formation of acid soil reaction that leads to high mobility of chemical elements in landscapes and encourages its carry-over from soils with infiltration waters and its transfer into plants;

Practically everywhere within the 30-km and 5-km areas radial geochemical barriers are indicated. Biogeochemical forest, internal soil sorption and temporary fen clayed barriers are the most common for the 30-km area, the most typical ones being biogeochemical forest – temporary fen clayed, internal soil sorption – temporary fen clayed, biogeochemical forest – internal soil sorption. For natural ecosystems biogeochemical in combination with temporary fen clayed barrier is the most typical. Within the 5-km area sorption internal soil and temporary fen clayed barriers as well as their combinations are the most common. In the context of chemical element (sorption) accumulation (including atmospheric fallouts) biogeochemical barrier plays the most important part.

Generally on an aggregate basis of natural factors landscapes resistant to chemical pollution prevail in the region. They occupy 57 % of the total area; in natural ecosystems – 64%. It means that the processes of chemical element carry-over with water flows (due to land runoff and internal soil infiltration) are typical for the leading automorphic eluvial landscapes developed on light deposits according to grain-size texture.

The assessment of the present heavy metal content (Pb, Zn, Cu, Ni, Cr) in mineral and peat soils nearby to the territory of the NPP site showed that its concentrations are of significant variability (Table 118). A higher average content of zinc, copper and nickel and a lower data scattering for all the examined elements are typical for peat soils comparing with mineral soils.

**Table 118 – Heavy metal content in soils of the 30-km area, mg/kg**

| Factor | Pb | Zn | Cu | Ni | Cr |
|---|---|---|---|---|---|
| Minimum content, mg/kg | 6,9 | 5,2 | 0,9 | 1,4 | 6,7 |
| Maximum content, mg/kg | 42,0 | 65,5 | 10,3 | 10,9 | 91,4 |
| Average for selection, mg/kg | 14,7 | 20,9 | 3,8 | 4,9 | 41,3 |
| Occurrence of values above MAC/APC, % | ind. sample | ind. sample | – | – | – |
| Maximum ratio of exceeding MAC/APC | 1,3 | 1,1 | – | – | – |
| Background content | 6,0 | 28,0 | 11,0 | 15,0 | 30,0 |

Lead content is varied from 6,9 to 42,0 mg/kg. Its average value equals to 15,2 mg/kg that is 2,5 times higher than background level. Exceeding of the allowed concentration occurs in one case. It equals to 1,3 times and is observed in the sample taken in forested area on the bank of the river Oshmyanka (figure 74).

Zinc concentration values in the majority of soils examined are close to background values and vary from 5,2 to 65,5 mg/kg within average content of 22,9 mg/kg. Content of the element being higher than APC is observed in two areas both of them being situated in the bottomland of the river Gozovka.

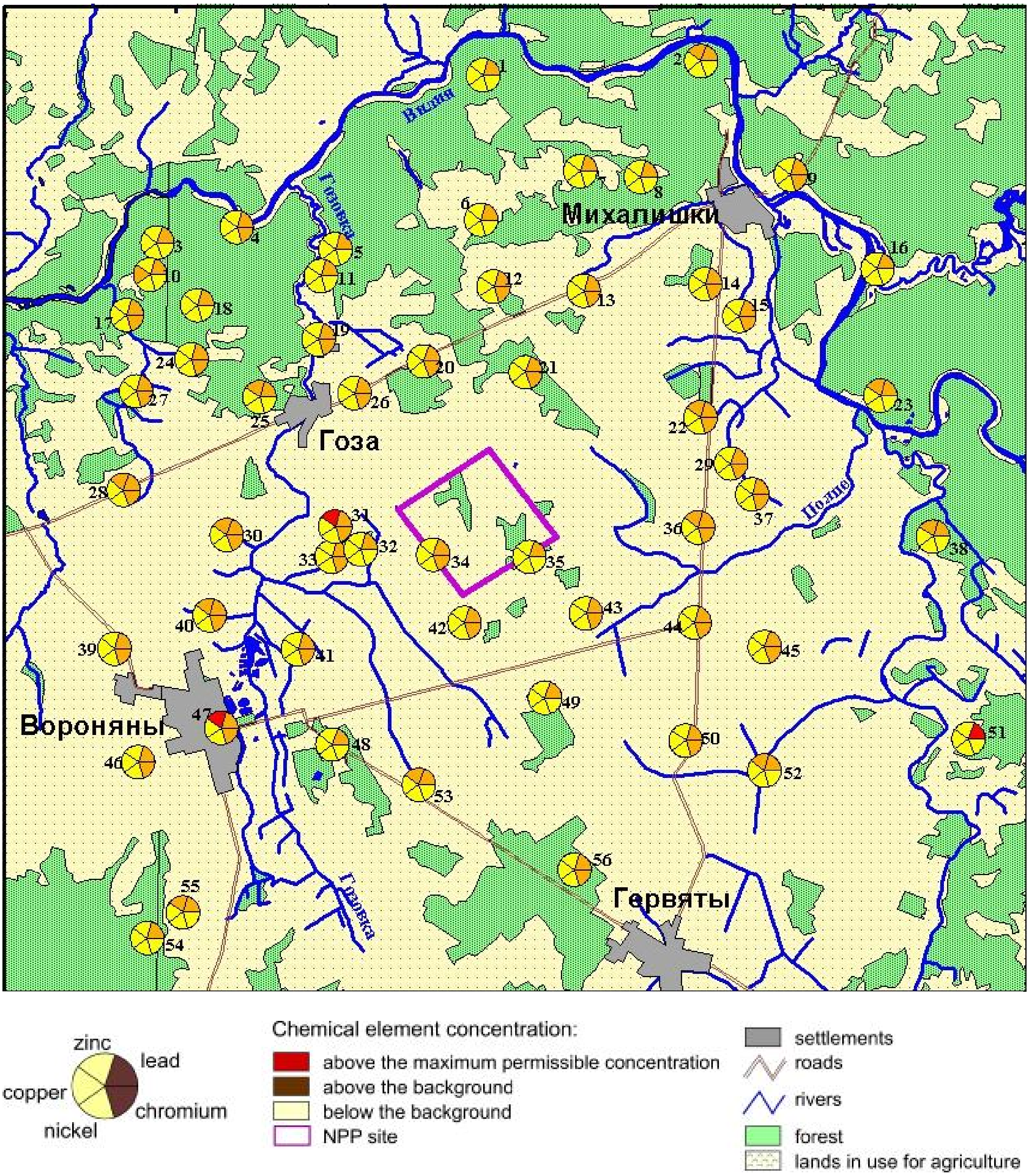



**Figure 74 – Heavy metal contamination of soils on the territory nearby to the NPP site**

Copper concentration in the soils of natural ecosystems is averagely 3,8 mg/kg of soil and varies from 0,9 to 25,3 mg/kg. In comparison with background for soils of the Republic of Belarus, the examined soils are depleted by the element. A similar situation is for nickel with its average content being 2,8 times lower than background values and equal to 5,3 mg/kg, varying from 1,4 to 14,0 mg/kg.

Chrome content in examined soils lies between 5,0 mg/kg and 91,4 mg/kg with average value of 40,3 mg/kg of soil. The excess of background being equal to 1,5-3,0 times is observed in 41 % of selected samples. No APC excesses were indicated.

The given heavy metal concentrations in soils of the region prove its ecological purity. The excess of the allowed levels was determined only in single cases being of a small value (1,3 times for lead and 1,1 times for zinc).

To predict the soil pollution in future there was performed a modeling [128] of lead and cadmium content in the soil for a 40-year prediction period according to two scenarios: within present level of emissions and with its 2 times increasing. The data obtained states that concentration of the elements will either remain on the present level or be slighty increased (up to 1,2 times) but in every case they will not exceed MAC/APC and also will not be higher than critical loads on natural ecosystems they are causing.

### *13.8.2 Natural flora structure*

Natural flora within the territory under consideration occupies nearly a half of the area (figure 75). Forests appear to be its dominant type occupying 37,7 %. Swamps, natural meadows and water ecosystems taken together occupy 10,6 %.

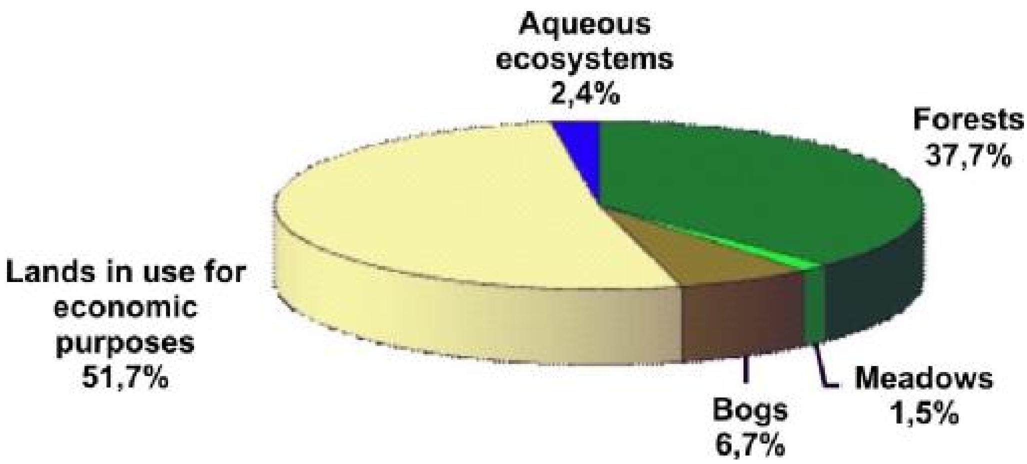



**Figure 75 – Land structure of the 30-km area of NPP site**

Formational-typological structure of forests is determined by a complex of natural and anthropogenic factors. As a result of poor sandy soil prevalence, pine forests dominate among other forest types (68,1 % of forested area). Spruce forests (12,1 %) and nodding birch forests (13,4 %) occupy relatively large area. Sticky alder forests, gray alder forests, pubescent birch forests and broad-leaved (oak, lime, ash) forests occupying 6,4 % of forested area are present fragmentarily. Plantations of mossy (35,2 %), adder-spitted (15,9 %), wood-sorrel (9,8 %) ericetal (7,4 %) series of forest types prevail in the spectrum of typological variety.

Anthropogenic impact on silva within the 30-km area is insignificant and consists, generally, in final felling and improvement felling, artificial forest creation involving, generally, pine monocultures on the place of natural sometimes complicated spruce-pine plantations. Such plantations occupy 20,3 % of state forest reserves within the area. The greater part of artificial plantations was created from wood species not corresponding to the habitat conditions (mainly spruce). This leads to simplifying of the forest composition and structure, degradation of forest regeneration, floristic composition depletion and elimination of economically valuable as well as rare and relic species from it, formation of unstable plantations. Thinning of moss cover, forming gramineous green mossy and gramineous digressive groupings is observed in pine forests.

Swamps are introduced mostly by bottom type (78 %). Upper swamps occupy 20% of the total area with transitional swamps occupying 2%. As a result of drainage melioration in 1960-1970 the most part of large swamp areas was dried. Its remaining parts are small outlined.

Eutotrophic grassy swamps are associated with negative relief factors in river valleys and on watersheds. Presence of grass cover consisting of hydromesophilic and mesohydrophilic species with prevailing sedges, horsetails, cereals and species of swamp herbs is typical for them. Mesotrophic swamps are formed in the kettle of interfluve area on the territories with depleted mineral feeding and well-developed peat deposit. Upper oligotrophic swamps are typical for domination of *Sphagnum magellanicum* in the moss cover. The tree layer is absent or is introduced by thinned or strongly oppressed *Pinus sylvestris* f. Litwinowii.

Meadow lands are most widely introduced in the bottom of the river Viliya and its tributarys Oshmyanka, Stracha, Losha and also in valleys of a number of lakes. Productivity (yield capacity) of communities' plant formations correlates with the soil richness. Communities of swampy, fallow and moist meadows possess its highest value.

There are 44 species of higher plants (tracheophyte) (183 of them are on the territory of the Republic of Belarus) including 24 species of true aquatic, 20 of aero-aquatic and semi-aquatic plants in water bodies and constant stream flows on the territory under consideration. The number includes 1 rare relic species entered the Red Book of the Republic of Belarus (saw grass - Cladium mariscus (L. Pohl), Lake Glubelka) and 18 species of economically valuable resource-forming plants, 2 species (sweet flag, Canadian pondweed) being stranger and denizen species. Lakes Svir, Vishnevskoye and lakes from Sorochanskaya group are notable for its flora richness with less various flora being in the rivers Viliya and Stracha. There is a poor flora of water plants in shallow rivers of the second order.

Grade of water overgrowing in lakes and rivers of the territory and quantitative development of higher aquatic plants there correspond to the mode of overgrowing in general for Belarus. The main quantity of lakes and rivers of the territory are typical for low and moderate grade of overgrowing from 10 to 40 % of aquatic area (the number includes nearly 70 % of water bodies for Belarus). Only lake Vishnevskoye and separate parts of the rivers Stracha, Oshmyanka with streaming flow are referred to strongly or fully (40-80 % of aquatic area) overgrown water bodies (progression of such lakes is 30 % for Belarus). The great majority of water bodies (55 % of the total examined) possess a low biomass of higher aquatic plants (less than 0,2 kg/m$^2$) with only 5 % of water bodies possessing high biomass (more than 0,4 kg/m$^2$).

In the structure of land reserves of the near 5-km area as well as the site itself agricultural lands take up a dominating position – more than 80 %. Forests occupy 10 % and 20 % respectively. Spruce forests prevail in the forested area of the site (86 %).

The average age of the region's forest plantations is 49 years. Young forests (I-II age classes) occupy 22,6 % of forested area, middle-aged forests (III class) – 36,4 %, ripening (IV class) – 27,1 %, mature (V-VI class) – 13,4 %, overmature forest stands (VII class and higher) – 0,4 %.

The average forest stand normality is 0,70. Forests of medium normality (0,6-0,8) prevail occupying 88,9 % of forested lands. Forest stands of low (0,3-0,5) and high normality occupy 5,3 % and 5,8 % of forest area respectively.

The average quality class of plantations is 1,6. Highly productive (1,6-1 quality class) forests occupy 49,6 % of forested area and are located on the region's periphery, especially in western and north-eastern parts and also along the whole length of river Viliya. Middle-aged and ripening plantations of the forests possess 210-230 $m^3$/ha of forest yield. Middle (II-III quality classes) and low-productive (IV-V) plantations occupy 47,4 % and 3,0 % respectively. The forest yield of middle-aged and ripening plantations is 160-190 (for middle-aged) and 60-100 $m^3$/ha (for ripening).

Total forest yield in forests of the region as of 01.01.2006 is worth 17677 thousands $m^3$. The basic tree species here is coniferous forming more than ⅔ part of the total reserve with hardwood accounting for the remainder. Forests are used intensively enough though violated age structure doesn't allow using the forest resources to the full.

According to natural fire protection, forests are divided into 5 classes. In the 30-km area 22,8 % of forests are referred to I class, 0,4 – to II class, 41,9 – III, 30,7 – IV and 4,2 % to V class. Generally, forest fire danger is moderate its average class being equal to 3,0.

Forests of very high natural fire danger (I class) are spread relatively uniformly across the 30-km area and are combined with the forests of medium and low natural fire danger. The greatest aggregation of forests of high natural fire danger is noted to be located to the east and south-east of the NPP site. Some forest areas of high natural fire danger are located closely to the site (at the distance of 1,5 km from the site).

**Chemical and radioactive pollution of flora.** To assess the present radioactive and chemical pollution of flora within the 30-km area, samples of various plant components were selected and analyzed for the content of cesium-137 and heavy metals. Selection of the latter was performed taking into account the emission amounts of these matters into environment, its toxicity and ability to accumulate in life forms and included 9 elements: cadmium, lead, zinc, chrome, cobalt, nickel, copper, vanadium, manganese. Forest and meadow ecosystems were the objects of examination.

Radioecological situation in the forest ecosystems was assessed according to accumulation of cesium 137 in tree layer, undergrowth shrub layer, shrub layer, live ground layer, mushrooms, soil, and underlayer. Within common low content of the given element in all the silva components its highest levels of content were indicated in traditional radionuclide accumulators: forest underlayer and plants of grass-shrub-moss layer. The largest accumulation among them was indicated in green mosses and epiphytic lichens.

In the structure of tree and grass-shrub layers the highest levels of radiocesium content were obtained for red bilberry and blackberry, the lowest – for wood.

In various production types of secondary forest use the content of cesium-137 is many times lower than value defined in technical regulations. Thus in mushrooms (the main accumulator of the given element) it turned out to be 6,9 times less than stated standards, in berries of blackberry and red bilberry – 22 times, in drug raw material (springs of blackberry and red bilberry) – 5-8 times.

In swamp and meadow plant formations the dominants of plant cover and grass sod were analyzed. The results obtained showed that its radiocesium content is 16-55 times lower than allowable level.

The obtained data on the present cesium-137 content in greenery components show its correspondence with the background values. The data can be used as input parameters when organization and performing of long-term radioecological monitoring of plants in the region of NPP construction.

The content of heavy metals in plants of forest biogeocenoses is within the background level in the great majority of cases. Lead is the main element with stable excess of background concentrations being observed. Apparently such situation is the result of a higher lead content in soils comparing with the background (2,4 times higher).

The excess content of lead is indicated practically in all the components of flora. In pine needles it is equal to 1,7 times, in the pine bark – 1,8 times, in epiphytic lichen – 2,1 times, in ground biomass of blackberry – 2,2 times. The higher concentrations in comparison with background values were obtained for other elements – chrome, vanadium, copper, nickel – in various plant components.

In all the cases a low level was detected for values of integral plant pollution index. Such assessment depicts a favorable ecological situation established in the region concerning chemical pollution index.

### *13.8.3 Protected plant species*

Directly on the site of NPP construction there are no species entered into the Red Book of Republic of Belarus (2005) or species from the "List of plants and mushrooms requiring preventive protection”. This is associated with the fact that agricultural lands are widely introduced here when forest areas are mostly small outlined and young in its age.

Within the 5-km area around the site one species of protected plants Trollius europaeus L. – European globe flower – was noted. The plant grows 2,2 km to south-west from the village Goza. The planned construction works may influnence negatively on it. In order to protect the species in the present ecotope it’s necessary to support the existing ecological regime. It’s important to replant the species to the nearest suitable ecotope in case of necessity of building or laying communication. It transplants well.

4 species from the "List of plants and mushrooms requiring preventive protection” were also found in the nearest area. However it will not be seriously affected by the planned works. It’s popularity and variety in the region under consideration and on the adjacent areas are rather high. It is typical for a rather high reproductive capacity.

30-km area examinations revealed the presence of 11 protected plant species in its range besides those that grow in wild life reserves and in "Narochanskiy" national park and are protected. Majority of them (7 species) is referred to IV protection category, 1 – to III, 2 – to II and 1 – to I category. The most representative ecotopes for growing of the discovered rare plant species turned out to be valleys of rivers and streams, lake kettles and large forest areas.

Practically all the discovered populations of the protected plant species are distant enough from the NPP site construction and the planned works will not be able to affect its existence directly. However a possible indirect influence is associated with water depression or on the contrary with water raising, high anthropogenic pressing and etc.

### *13.8.4 Specially protected natural areas (SPNA), protected forests, valuable plant communities*

There are situated “Sorochanskiye ozera” national landscape wildlife reserve, a part of forests of “Narochanskiy” National Park and 3 local landscape wildlife reserves (“Golubye ozera”, “Serzhanty”, “Lake Byk”) as well as 3 local natural monuments

("Lipovaya alleya s tremia dubami" and "Starazhytny dub") within the 30-km NPP site.

Large SPNA are located mostly in north-eastern parts of the area. There is located "Sorochanskiye ozera" National wildlife reserve with a total area of 13 thousands ha containing a separately allocated "Starazhytny dub" local natural monument as well as a part of "Narochanskiy" National park territory (7748,8 ha of forested area).

"Lake Byk" and "Serzhanty" local landscape wildelife reserve and "Lipovaja alleja s tremia dubami" local natural monument are situated in south-western part of the 30-km area. In south-eastern part of the territory "Golubyje ozera" local landscape wildlife reserve is situated.

Summarily the specially protected natural areas occupy nearly 15 % of the 30-km NPP site that stands for the high index of the region's protected natural object saturation and requires special attention to supporting of their functioning stability in conditions of the anthropogenic press increasing as a result of the NPP construction and operation.

Forests of the I group in the 30-km area occupy 62,5 % of the forested area and include forbidden (water protection) shelterbelts, shelterbelts along the roads, shelterbelts along the railways, forests of the national park, forests of the national wildlife reserves, forest-park parts of green belts, forestry parts of green belts. According to average taxational indices and formation structure they aren't different from all the forests of the territory under consideration.

The special distribution of the I group forests is determined by location features of developed and urbanized territories, specially protected natural territories and water ecosystems. Particularly water protection forests are concentrated generally along the river Viliya. Protective forests along the automobile roads and railroads occupy relatively large areas in south-western, southern and northern parts of the 30-km area. Forests of "Narochanskiy" National Park and "Sorochanskiye ozera" landscape wildlife reserve are located in the north-eastern part of the territory under consideration. Forests of green belts are mostly located around the town Ostrovets and town Oshmyany.

The central part of the 30-km NPP site is sparsely forested and includes small areas of water protection and merchantable forests.

Within the 30-km area a set of categories of valuable plant communities was selected. The set includes areas of the following forest communities: less damaged by economic activity; old-growth; complicated in its composition and structure of plantations or forest stands with single trees of previous generations; rare and endangered forest types; with populations of rare or endangered species of flora and fauna; with presence of rare broad-leaved species in the tree layer (maple, lime, wych elm, elm); in natural river bottoms, around the river sources and springs; With limited accessibility (islands on the lakes, mineral islands on the open swamps). They occupy 7,1 % of region's forested area. There were also selected 17 categories of rare and unique meadow ecosystems requiring protection.

Generally natural flora of the region is of high nature-oriented value. To minimize the influence on it, the following measures are necessary to consider during NPP construction and operation:

- data recording on location of valuable plant communities and rare protected species and also resource-important areas when designing of station construction project and accompanying infrastructure.
- detection and organization of protection of rare plants and valuable plant communities, monitoring of state;
- system creation and monitoring of natural flora state (forest, meadow, swamp, coastal vegetation) within the NPP impact area.

- strict adherence of fire-fighting measures, including organization of fire-fighting forest management, arrangement of fireproof breaks and mineral belts, creation of operative supervision system of forest fire beds (observation towers, remote monitoring), secondary flooding of abandoned dried peats;

- plan development and implementation for special forest management of recreation forests visited by the campers.

### *13.8.5 Fauna*

According to zoogeographical regionalization of the Republic of Belarus, the region of NPP is situated in the western zoogeographical region. Geobotanically the territory is located in the area of taiga forests being typical for its faunal complexes.

#### *13.8.5.1 Ground invertebrata*

Ground invertebrata fauna of coniferous (pine and spruce) forests prevailing in the composition of region's natural flora is generally typical for its poor species composition and small population. Most of the insects in forest ecosystems are bounded with soil and underlayer as well as with wood plants.

Insects-xylobinotes inhabiting under the bark and in the wood of coniferous and broad-leaved trees comprise a special large group of forest ecosystems. It, generally, includes beetles, hymenopteran and dipteran butterflies. The discovered coleopterous represent a complex consisting of the main trophic groups: xylophages actually feeding with wood and not associated with certain types of mushrooms, saproxylophages eating wood injured by mushroom mycelium, mycetophages using mycelium or mycothallus as a feeding substrate.

Coleopterans also dominate in shrub and undergrowth of coniferous forests. Families of weevils, leaf beetles and elaters are the largest of them.

#### *13.8.5.2 Ichthyofauna*

Ichthyofauna of water bodies and water runoffs of the 30-km area is very rich in species. It is represented by 42 species of fish being referred to 13 families [129,130]. It also includes 8 from 11 present on the territory of Belarus species of fish-like vertebrates and fish entered into the Red Book of the Republic of Belarus [131]. Besides 3 of them are salmon, salmon trout and river lamprey can be found only in those parts of the river Viliya and its tributarys being located within the 30-km area.

Along with the river Viliya, its tributarys of the first order are also referred to the main fishery water bodies of the territory - rivers Oshmyanka and Stracha. They are typical for its various species composition and relatively large fish reserves.

Ichthyofauna of the river Viliya includes 42 species of fish within rheophilic species dominating. Both conventional species represented in many water bodies of the Republic of Belarus – bream, orfe, chub, asp, pike-perch, burbot, pike, tench, carp, crucian carp, Prussian carp, with less valuable – roach, dace, perch, ruff, lookup, silver bream, redeye, gudgeon and some others and "specific" ones – anadromous salmons (salmon and salmon trout), sabrefish – inhabit here. Rare fish species entered into the Red Book of the Republic of Belarus (2004) – brown trout, grayling, vimba, barb and sneep inhabiting in channel, flinty-pebble, semigravel areas are met in the area of the given river within the Ostrovets District. In the river Viliya, a fish-like vertebrate rare for Belarus – river lamprey - can possibly be met too.

There are commercial species of fish such as bream, silver bream, roach, perch, pike, asp, pike-perch and orfe within catfish and eel sometimes being met there. Carp, prussian carp, crucian carp, tench and loach inhabit back waters and adjacent water bodies. The total fish stock of the river Viliya is 138 kg/ha. In the present time there's no fish cropping on channel areas of the river Viliya as it is fished by amateur fishermen.

The river Viliya is the only water flow on the territory of the Republic of Belarus with its channel having no regulating stanch and providing a natural way to the Baltic sea that is extremely important for migrating of fish species. Valuable migratory salmon fish species such as Atlantic salmon and salmon trout appear in the given river and its tributarys for a spawning season there also remaining a possibility of entrance the spawning areas for other migrating species of fish-like vertebrates and fish:

- river lamprey;
- sea whitefish.

There also a possibility of occupying the nursery grounds for valuable migrating species – freshwater eel.

Ichthyofauna of the rivers Stracha and Oshmyanka compared with rivers the similar in dimensions of other river basins is typical for its variety of fish species composition (from 13 to 26 species on different areas) owing to the species entering them for spawning from the river Viliya (sneep, vimba, grayling, brown trout). In the ichthyofauna composition of the given rivers as well as of the river Viliya, rheophilic fish species prevail:

- dace;
- chub;
- lookup;
- gudgeon;
- char;
- minnow;
- riffle minnow;
- burbot;
- bullhead.

There also are met conventional freshwater species – pike, eel, roach, redeye, silver bream, tench, crucian and prussian carp, loach, spined loach, perch, ruff, three-spine stickleback and some others.

The total fish stock of the rivers Stracha and Oshmyanka is 71 kg/ha. In the present time there is no fish cropping in the rivers being fished only by amateur fishermen.

Due to the NPP construction the maximum effect should be given to the river Gozovka. It is referred to small rivers. The ichthyofauna of the river is not typical for a great variety of species (5-8 fish species) and a fish stock amount (50 kg/ha). With that it includes the rarest and the most protected species. There are habitats and spawning areas of brown trout, its population condition being assessed as good and spawning areas of two migrating from the Baltic Sea salmon fish species – salmon trout and salmon. In the r. Gozovka from 2002 to 2006 there was noted a passage for spawning of 7-13 spawners of salmon trout and creation of 4-8 spawning redds (“nests”) of the species.

*13.8.5.3 Toadfish- and herpetofauna*

Toadfish- and herpetofauna of the region is relatively typical for Belarusian Poozerye species composition (12 species of amphibian – 92 % of Belarusian fauna and 5 species of reptiles 71 % of Belarusian fauna) [132,133].

The most dominating in frequency of occurrence are brown frog and common toad as well as edible frog subdominant being common newt and common and sand lizards.

The rest species are relatively rare – green toad, crested newt, running toad, deaf adder, fire-bellied toad which localities occurring individually.

Central part of the territory under consideration within the 5-km area of the site is inhabited by only 4 species typical for open developed in agricultural relation territories with spiked forest cover. The area of forests and density of hydrographic network is increased moving to its periphery. These factors provide increasing of reptiles and amphibian variety from 4 to 17 species. There are also 2 species entered into the Red Book of the Republic of Belarus (*Triturus cristatus, B. calamita*) and 2 species entered into the Red Book of IUCN (*T. cristatus, Bombina bombina*).

*13.8.5.4 Bird fauna*

Region's bird fauna is represented by 151 species of nesting and migrating birds taking up 48,1 % of country's bird fauna. Owing to the presence of various biotopes on the examined territory, members of practically all the orders registered in Belarus were detected on this territory. Majority of bird species are referred to perching birds (48,3 %) [134].

As soon as the territory is typical for its dense amount of forests, more than half of bird fauna here is represented by species referred to *forest* and *tree-shrub* ecological complexes. They take up 45 % and 12 % of all the noted species respectively (figure 76).

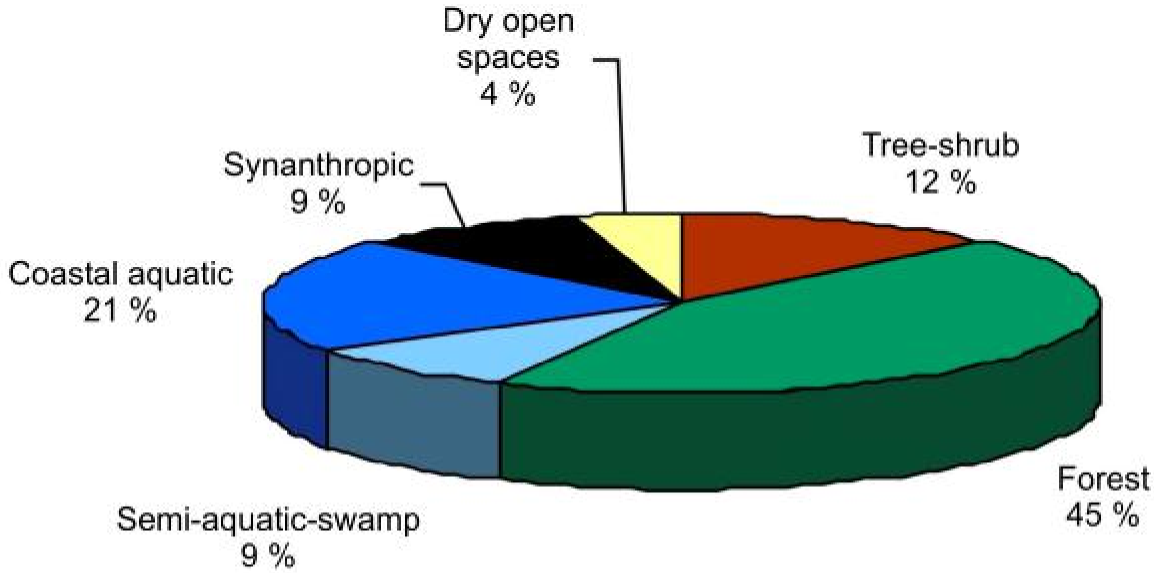



**Figure 76 – Relation between bird species of different ecological complexes**

Owing to the presence of such large lakes like Svir and Vishnevskoye as well as the group of lakes Sarochanskiye and a set of other smaller water bodies, river bottoms, channels, ponds, swamp areas species referred to coastal aquatic and semi-aquatic swamp ecological complexes are widely represented in the region. They take up 30 % of the examined bird fauna.

In total there were determined 41 species of aquatic and semi-aquatic birds from 9 orders. The greatest variety of representation is typical for anseriformes – 18 species. Main places of the largest geese concentration in the period of spring migration (end of March – first half of April) are located at the lakes Svir and Vishnevskoye and also at the agricultural lands within the 3-8-km of the NPP site. For the latter, its construction can be a factor of disturbance.

There were registered habitats of 23 bird species entered into the Red Book of the Republic of Belarus within the 30-km area of the NPP site.

- black-throated loon (*Gavia arctica);*
- bittern (Botaurus stellaris);
- white egret (Egretta alba);
- black stork (Ciconia nigra);
- smew (Mergellus albellus);
- buff-breasted merganser (Mergus serrator);
- merganser (Mergus merganser);
- white-tailed eagle (Haliaeetus albicilla);
- marsh harrier (Circus cyaneus);
- lesser spotted eagle (Aquila pomarina);
- osprey (Pandion haliaetus);
- merlin (Falco columbarius);
- little crake (Porzana parva);
- corncrake (Crex crex);
- gray crane (Grus grus);
- curlew (Numenius arquata);
- mew gull (Larus canus);
- gnome owl (Glaucidium passerinum);
- great gray owl (Strix nebulosa);
- kingfisher (Alcedo atthis);
- green woodpecker (Picus viridis);
- white-backed woodpecker (Dendrocopos leucotos);
- three-toed woodpecker (Picoides tridactylus).

The main habitats of the protected bird species are concentrated at least 10 km away from the site and are associated mostly with large lakes and forest areas with water bodies. So the construction itself will not make any influence on them. An increasing intensity of recreating territory usage due to population growth associated with the NPP construction will be a disturbance factor.

*13.8.5.5 Hunting species*

Hunting animal species in the region are notable for being rather various. Elk, roe, wild boar are typical and royal stag and fallow deer are imported in the places. Brown hare inhabits the farm lands. Typical forest species are blue hare, squirrel, common marten. Water bodies are inhabited by otter, mink, beaver having rather large population.

There are bird species on farm lands such as partridges, quails. In forests, mostly in coniferous, there are wood grouses, hazel grouses; in mixed forests – black grouses, wood pigeons, woodcocks. Gray geese, dabbling and diving ducks, bald coots are nesting at water bodies.

7 hunting entities are fully or partly located on the territory under consideration. The population of hunting species inhabiting there is mostly medium. In the group of the most valuable species – hoofed – roe has the largest population followed by boar, elk and deer. The hunting capacity is varied in the following sequence: boar – 49 % of the total population, roe – 11 %, elk – 4 %, deer - is not hunted.

A complicated mosaic structure of various lands - forests, open spaces, water bodies, swamps - typical for the 30-km area, creates favorable conditions for nesting of birds of prey. There were noted 13 such species. Common species for diurnal birds of prey are common buzzard, marsh and Montagu's harriers. In the vicinity of large lakes there inhabit two species of fish-eating birds of prey - osprey and white-tailed eagle being rather rare on the territory of Belarus but in the region under consideration they are *nesting rather often.*

Among vespertinal birds of prey there were found 4 of 10 owl species nesting in the country. The most typical of them are boreal owl and tawny owl.

A group of woodpeckers is represented fully enough in the region. There were found 8 species of 10 inhabiting in Belarus. Greater spotted woodpecker is the most common representative of woodpeckers having the larges population. The given species besides all the rest provides favorable conditions for habitats of small species of nesting cavity birds - tomtits, flycatchers, some of owls and etc.

***Wildlife of agricultural ecosystems.*** Species composition of insects in agricultural ecosystems is significantly depleted in comparison with natural biocenoses and is typical for domination of some species. Ground beetles are dominating in the ground layer. Representatives of snout-beetles, lady-bugs, cicadas and some other dipterous insects are typical for field layer. Population of ground insects on developed fields is not large as its associations are exposed to influence as a result of chemical processing.

The same poorness of species composition is typical for the variety of amphibian and reptiles. Edible frog, brown frog, common toads are dominating in agricultural ecosystems. The two latters being typical for forests are found only within the borders of deforested areas of agricultural lands.

Bird fauna of agricultural ecosystems is not typical for a large amount of species and a comparatively large bird population either. Skylark is dominating on the fields developed for cereals. Winchat can also be referred to dominating species on the areas of lands with perennial artificial herbs. The number of habiting bird species is increased from 12 to 32 on perennial hayfields with small swamps, shrub curtains and low forests.

***Hunting species*** of animals in the region are typical for its significantly large variety. Elk, roe, wild goat are typical and royal stag and fallow deer are imported in the places. Brown hare inhabits the farm lands. Typical forest species are blue hare, squirrel, and common marten. Water bodies are inhabited by otter, mink, and beaver having rather large population.

There are bird species on farm lands such as partridges, quails. In forests, mostly in coniferous, there are wood grouses, hazel grouses; in mixed forests – black grouses, wood pigeons, woodcocks. Gray geese, dabbling and diving ducks, bald coots are nesting at water bodies.

Relative populations of majority of hunting species of mammals in the region is medium, for birds - it is low (Table 119). Among mammals deer, stone-marten, common squirrel, musk beaver, blue hare are referred to species with relatively small population. Among birds – gray goose, mallard, gadwall, shoveler, widgeon, garganey teal, green teal, snipe, black grouse, gray partridge, quail, moorhen, rail

The usage of separate hunting species including all the hoofed is standardized. Some beasts of prey such as wolf, red fox and raccoon dog in their present population are classified as nuisance.

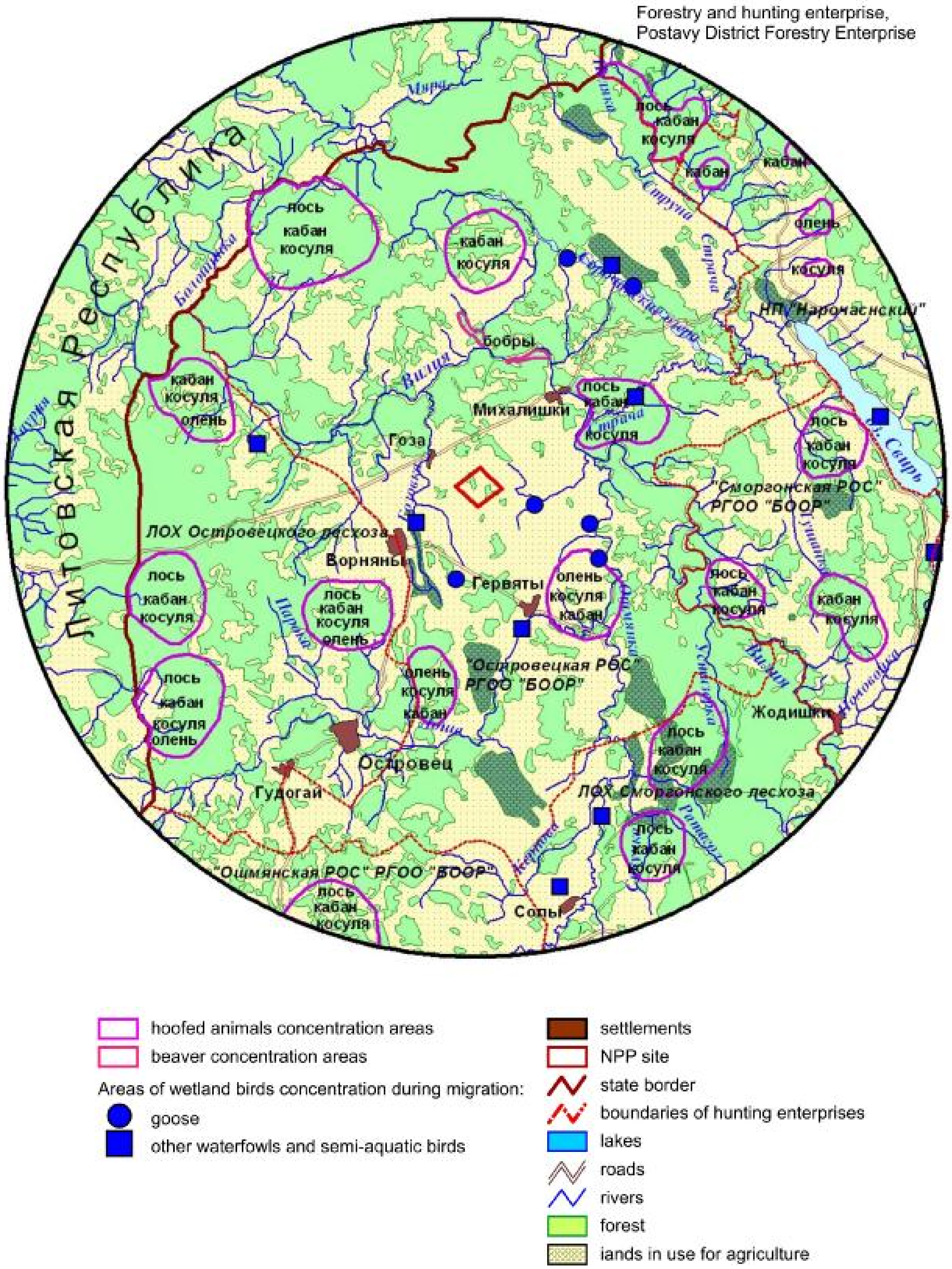
7 hunting entities are fully or partly located on the territory under consideration. In the structure of hunting lands, forest lands play the main part. They occupy 48 % of these land area. Meadow lands occupy 46 % of area and wetlands – 6 %.

In the group of the most valuable hunting species – hoofed – roe has the largest population followed by boar, elk and deer. The hunting capacity is varied in the following sequence: boar – 49 % of the total population, roe – 11 %, elk – 4 %, deer - is not hunted.

**Table 119 – Relative population and habitation character of hunting species within the 30-km NPP site**

| Species | Relative population | Habitation character | Species status |
|---|---|---|---|
| MAMMALS (animals) | | | |
| *Cloven-hoofed mammals* | | | |
| Elk | Meduim | Permanently | Standartized |
| Deer | Low | Permanently | Standartized |
| Roe | Meduim | Permanently | Standartized |
| Boar | Meduim | Permanently | Standartized |
| *Beasts of prey* | | | |
| Wolf | Low | Permanently | Nuisance |
| Red fox | Meduim | Permanently | Nuisance |
| Raccoon dog | Meduim | Permanently | Acclimatized, nuisance |
| Common marten | Meduim | Permanently | Hunting |
| Stone marten | Low | Permanently | Hunting |
| Ermine | Meduim | Permanently | Hunting |
| American mink | Meduim | Permanently | Acclimatized |
| Polecat | Meduim | Permanently | |
| True otter | Meduim | Permanently | Standartized |
| *Rodents* | | | |
| Squirrel | Low | Permanently | Hunting |
| European beaver | Meduim | Permanently | Standartized |
| Musk beaver | Low | Permanently | Acclimatized |
| *Double-toothed rodents* | | | |
| Brown hare | Meduim | Permanently | Hunting |
| Blue hare | Low | Permanently | Hunting |
| BIRDS | | | |
| *Anseriformes* | | | |
| Gray goose | Low | Passing | Hunting |
| White-fronted goose | Meduim | Passing | Hunting |
| Bean goose | Meduim | Passing | Hunting |
| Mallard | Low | Nesting | Hunting |
| Gray duck | Very low | Nesting | Hunting |
| Shoveler | Very low | Nesting | Hunting |
| Widgeon | Low | Passing | Hunting |
| Garganey teal | Low | Nesting | Hunting |
| Green teal | Low | Nesting | Hunting |
| *Charadriiformes* | | | |
| Snipe | Low | Nesting | Hunting |
| Woodcock | Meduim | Nesting | Hunting |
| *Galliformes* | | | |
| Black grouse | Low | Permanently | Standartized |
| Hazel grouse | Meduim | Permanently | Hunting species |
| Common partridge | Low | Permanently | Hunting |
| Quail | Low | Nesting | Hunting |
| *Gruiformes* | | | |
| Moorhen | Low | Nesting | Hunting species |
| Bald coot | Meduim | Nesting | Hunting |
| Rail | Low | Nesting | Hunting |

Main concentration areas of hoofed animals are associated with large forest areas. They are located far from the NPP construction site (figure 77).



| | |
|---|---|
| Лось | Elk |
| Кабан | Wild boar |
| Косуля | Roe deer |
| Олень | Deer |
| НП «Нарочанский» | Narochanskiy National Park |
| Сморгонская РОС РГОО «БООР» | Smorgon District Organizational Structure, Belarusian Nature Protection Society Republican State Public Organization |
| Островецкая РОС РГОО «БООР» | Ostrovets District Organizational Structure, Belarusian Nature Protection Society Republican State Public Organization |
| ЛОХ Сморгонского лесхоза | Forestry and hunting enterprise, Smorgon District Forestry Enterprise |
| Ошмянская РОС РГОО «БООР» | Oshmyany District Organizational Structure, Belarusian Nature Protection Society Republican State Public Organization |
| ЛОХ Островецкого лесхоза | Forestry and hunting enterprise, Ostrovets District Forestry Enterprise |
| Литовская Республика | Lithuanian Republic |

**Figure 77 – Hunting entities and the most valuable hunting species of animals within the 30-km of the NPP site**

***Wildlife of the nearby 5-km area*** is not rich in species and comparatively low in population considering majority of animal classes. Hunting value of the given territory is not high either. No ecosystems – places of habitation of the protected animal species – were detected in its range. The river Gozovka make the only exclusion where valuable and rare fish species inhabit.

*13.8.5.6 Chemical and radioactive animal pollution*

To determine chemical and radioactive pollution of animals within the 30-km area there were selected the samples of muscular tissue of mammals, birds and fish. There was performed an analysis of radioactive element content for: strontium-90 and cesium-137 as well as for heavy metals: copper, zinc, ferrum, cobalt, manganese, lead, cadmium, tin, aluminum, antimony, nickel.

The objects of examinatin were mammals (murine rodents, common shrew, and also hoofed: roe, elk, boar), birds (mallard, woodcock, wood pigeon, crow), amphibian (brown frog), fish (northern pike, river perch, bream, chub, prussian carp, silver bream).

Based on the analysis performed the content of radioactive elements in all the examined animals was determined to be low. So for cesium-137 it is less than 6 and 2 % of the permitted level for fish and hunting animals respectively.

There were detected excesses of sanitary standards concerning heavy metal content for two elements – lead and cadmium in tissues of commercial mammals and birds. The maximum lead concentration excess was equal to 16,8 times for mallard and cadmium excess – 7,6 times for roe. Presence of the indicated chemical pollution proves that even in the 30-km area under consideration being an ecologically clean region there is a possible danger of a high heavy metal build-ups in muscular tissues of animals.

## 13.9 Population and demography

### *13.9.1 Demographic situation within the 30-km of the Belarusian NPP site*

When locating Belarusian NPP at the Ostrovets site, there will be located settlements of the Republic of Belarus and Lithuania within its 30-km area. The demographic situation analysis was performed for the population living within the 30-km area of the site on the territory of the Republic of Belarus.

Within the 30-km area, there are situated the settlements of Ostrovets, Oshmyany, Smorgon districts of Grodno region; Myadel district of Minsk region; Postavy district of Vitebsk region.

Totally as of 01.01.2007 within the 30-km area of Ostrovets settlement there are 35682 persons living, 6191 of them (17,3 %) being younger than working age, 19571 persons (54,9 %) being at working age, 9920 persons (27,8 %) being older than the working age. Population density in the region under consideration is 15 pers./km$^2$ (without considering Lithuania). In the settlement structure small villages prevail in amount (less than 100 persons), the specific weight of it being equal to 85,6 % [137].

There are no settlements within the 1,5-km area of the Ostrovets site, 765 persons live within the 5-km area, 122 of them (15,9 %) being younger than working age, 361 of them (47,2 %) - at working age, besides 195 persons of them live within the 3-km area of the site, with 29 persons (14,9 %) being younger than working age, 88 persons (45,1 %) being referred to labor force (figures 78, 79) [138].

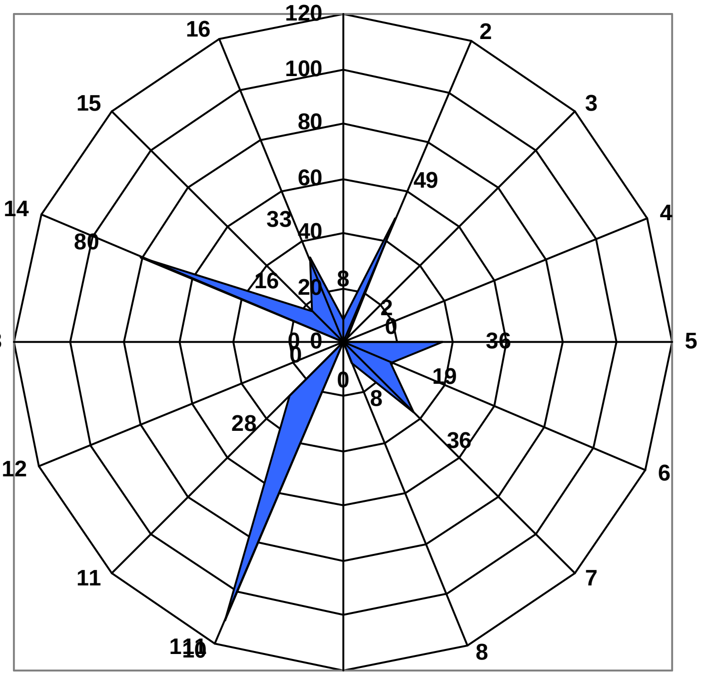



**Figure 78 – Diagramm of population distribution living within the 5-km area of the Ostrovets site**

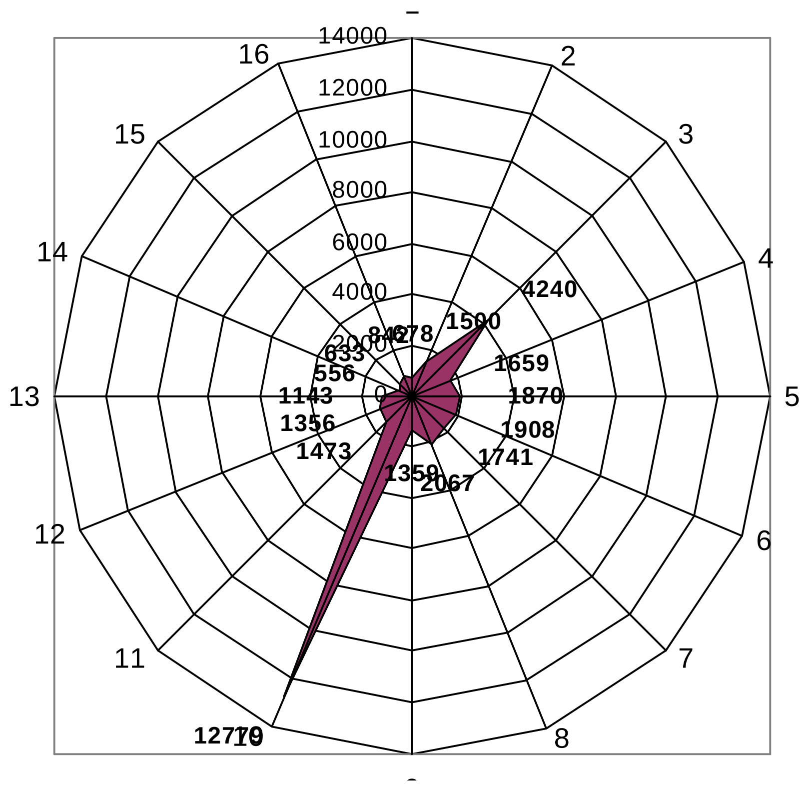



**Figure 79 – Diagramm of population distribution living within the 30-km area of the Ostrovets site**

### *13.9.2 Comparative analysis of primary disease incidence of adult population in Grodno, Vitebsk and Minsk Regions in 2004-2008*

A comparative analysis of disease incidence of population for five-year period was performed based on data of annual statistical reports made by medical and preventive treatment institutions of the republic. The data were obtained from Ministry of Health of the Republic of Belarus.

The primary disease incidence analysis of population of the Republic of Belarus was performed in terms of 13 main disease classes in accordance with ICD-10. There was determined a structure of disease incidence in 2004 and in 2008. A comparative structure analysis of primary disease incidence of adult population in cases of diseases diagnosed for the first time showed no significant changes in 2008 compared to 2004 concerning the analyzed disease classes (figures 80,81) [139,140].

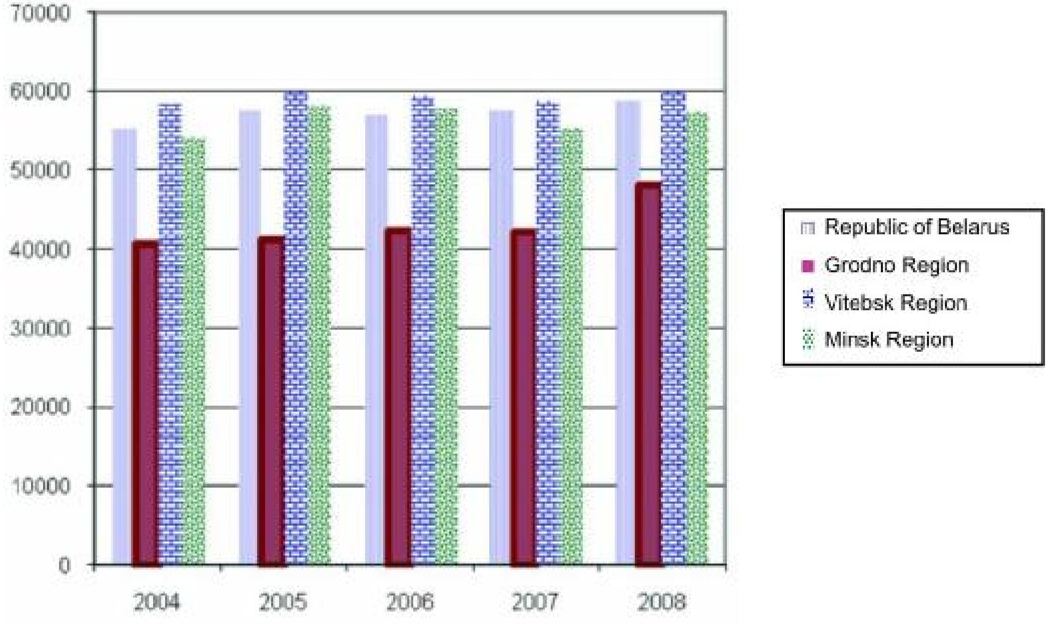
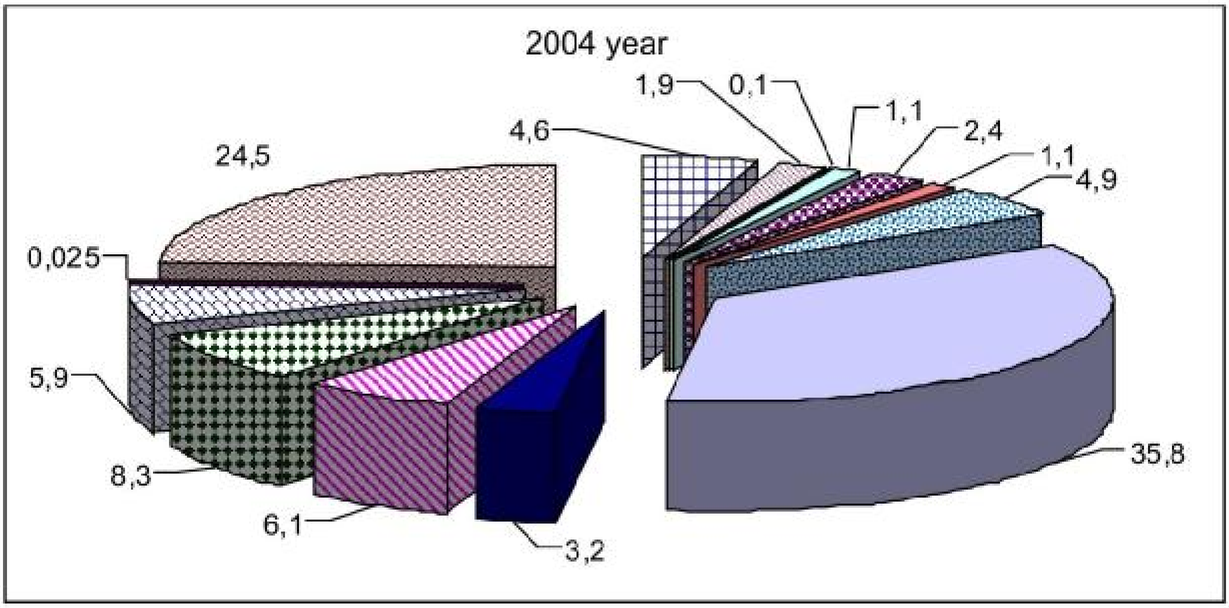



**Figure 80 – Dynamics of primary disease incidence in all the disease classes of adult population in the regions of the Republic of Belarus in 2004-2008 (per 100 thousands of population)**



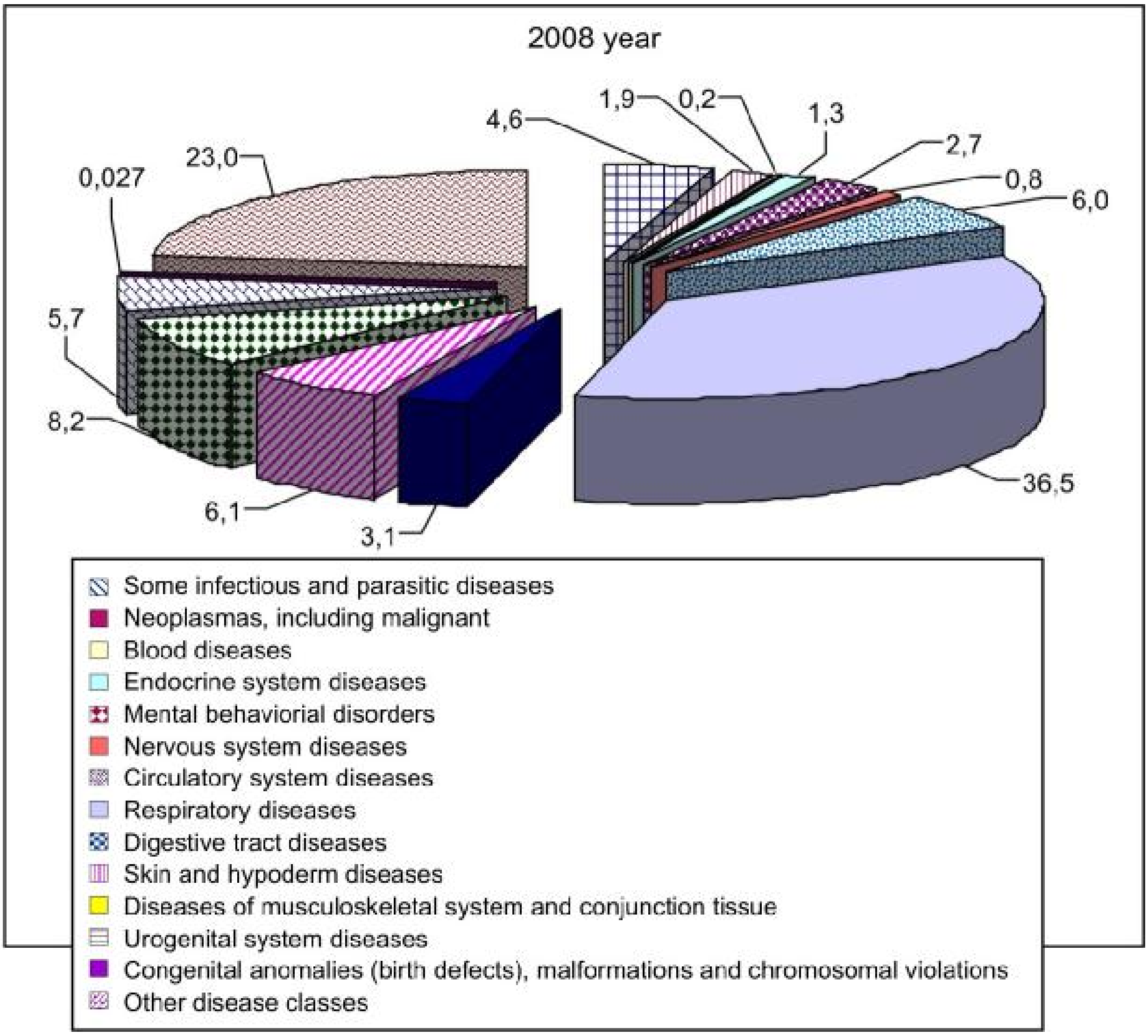



**Figure 81 – Structure of primary disease incidence of adults in the Republic of Belarus in 2004 and 2008, %**

The first rank place both countrywide and regionwide was taken by respiratory diseases – from 33,9 % in Grodno region to 40,5 % in Vitebsk region in 2004, from 32,9 % in Grodno region to 41,8% in Vitebsk region in 2008. This disease class made 35,8 % to 36,5 % countrywide respectively.

The second rank place was taken by diseases of musculoskeletal system and connective tissue – from 6,6 % in Grodno region to 10,6% in Minsk region in 2004 and from 6,7 % in Vitebsk region to 9,1 % in Minsk region in 2008. The given disease class made 8,3 % to 8,2 % countrywide respectively.

The third rank place was taken by skin and hypoderm diseases – from 6,4 % in Minskaja and Grodnenskaja regions to 7,7 % in Vitebsk region in 2004 and from 5,3 % in Grodnoregion to 8,1 % in Vitebsk region in 2008. The disease class made 6,1 % countrywide both in 2004 and in 2008.

The fourth rank place was taken by blood circulatory system diseases - from 5,0 % in Vitebsk region to 6,1 % in Grodno region in 2004. and from 5,0 % in Vitebsk region to

9,2 % in Grodno region in 2008. There should be noted an increasing of specific share of the disease class in Grodno region – from 6,4 % to 9,2 % and in Minsk region – from 5,8 % to 7,8 % over a period of 2004-2008. The share of given class diseases has been increased from 4,9 % in 2004 to 6,0 % in 2008 countrywide.

The fifth rank place in the structure of primary disease incidence of adult population was taken by urogenital system diseases its interest varying from 4,2 % in Grodno region to 5,6 % in Minsk region in 2004 and from 4,2 % in Grodno and Minsk regions in 2008. This disease class made 5,9 % to 5,7 % countrywide respectively.

The sixth rank place was taken by class of infectious and parasitic diseases, its percentage varying from 4,0 % in Minsk region to 6,0 % in Vitebsk region in 2004 and from 3,5 % in Minsk region to 5,3 % in Vitebsk region in 2008. The percentage infectious and parasitic diseases hasn't changed through the mentioned period being equal to 4,6 % countrywide [141-144].

Percentage of the mentioned six disease classes in the primary disease incidence structure amounted to 65,6 % in 2004 and 67,1 % in 2008 [140].

For a five-year period there is observed an increasing of primary disease incidence in all the disease classes both among adult population of the republic in general (6,4 % higher) and among population of the region analyzed: from 2,5 % in Vitebsk region to 18,4 % in Grodno region.

The following disease classes are notable for the greatest increase of the disease incidence level [141-144]:

- blood diseases,
- endocrine system diseases,
- blood circulatory system diseases,
- congenital anomalies (birth defects), malformations and chromosomal violations,
- mental behaviorial disorders.

In the rest disease classes there were noted both increasing and decreasing of primary disease incidence levels for adult population region wide and countrywide. It should be noted that disease incidence concerns revealed, registered cases of disease, i.e. a complex of diseases being the reason for population to seek medical treatment for the first time in the given year. This limited understanding should always be kept in mind as the level of registered disease incidence is determined by such objective factors as accessibility of medical institution, amount and specialization of medical assistance, security of health care workforce in general and functional specialists in particular, availability of the necessary medical equipment [141-144].

### *13.9.3 Comparative analysis of primary disease incidence of children and adolescents (0-17 years inclusively) in Grodno, Vitebsk and Minsk regions in 2004-2008.*

Comparative analysis of primary disease incidence of children and adolescents showed insignificant ratio variations of main disease classes for a five-year period.

The first rank place in overall disease structure was taken by respiratory diseases – from 69,0 % in Grodno region to 71,2 % in Vitebsk region and 68,0 % countrywide in 2004 and from 73,5 % in Minsk region to 77,2 % in Vitebsk region in 2008 within the interest of respiratory diseases being equal to 72,4 % countrywide in 2008. The percenttage of the rest 5 classes is much smaller.

The second rank place was taken by infectious and parasitic diseases – from 4,0 % in Minsk region to 6,4 % in Vitebsk region and 4,7 % countrywide in 2004 and from 3,5 % in Minsk region to 3,9 % in Grodno region and 3,7% countrywide in 2008.

The third rank place was taken by skin and hypoderm diseases – from 3,8 % in Vitebsk region to 4,7 % in Minsk region and 4,3 % countrywide in 2004 and from 2,6 % in Vitebsk region to 4,5 % in Minsk region and 3,9 % countrywide in 2008.

The fourth rank place was taken by digestive tract diseases – from 2,5 % in Vitebsk region to 3,4 % in Minsk region and countrywide in 2004 and from 2,5 % in Grodno region to 2,8 % in Vitebsk region and countrywide as well.

The fifth rank place was taken by diseases of musculoskeletal system and connective tissue – from 1,0 % in Vitebsk region to 1,4 % in Minsk region. Generally countrywide the ration of this disease class was equal to 1,3 % in 2004. There is noted a decreasing of the ratio in 2008 - from 0,7 % in Grodno region to 1,0 % both in Minsk region and countrywide.

Having low ratio, urogenital system diseases were on the sixth rank place – from 1,1% in Grodno and Vitebsk regions to 1,4 % in Minsk region and 1,2 % countrywide. in 2008 ratio of the disease class was equal to 0,9 % in all the three regions and 1,1 % countrywide [141-144].

The interest of diseases taking first six rank places in the disease structure was 82,9 % in 2004 and 84,9 % in 2008.

The lowest rate of disease incidence increase in all the disease classes among all the regions was determined in Minsk region - 7,9 %, the highest being in Grodno region - 15,6 %, in Vitebsk it was equal to 12,8 %.

The highest rate of disease incidence increase was determined in:

– class of respiratory diseases,

– class of congenital anomalies (birth defects), malformations and chromosomal violations,

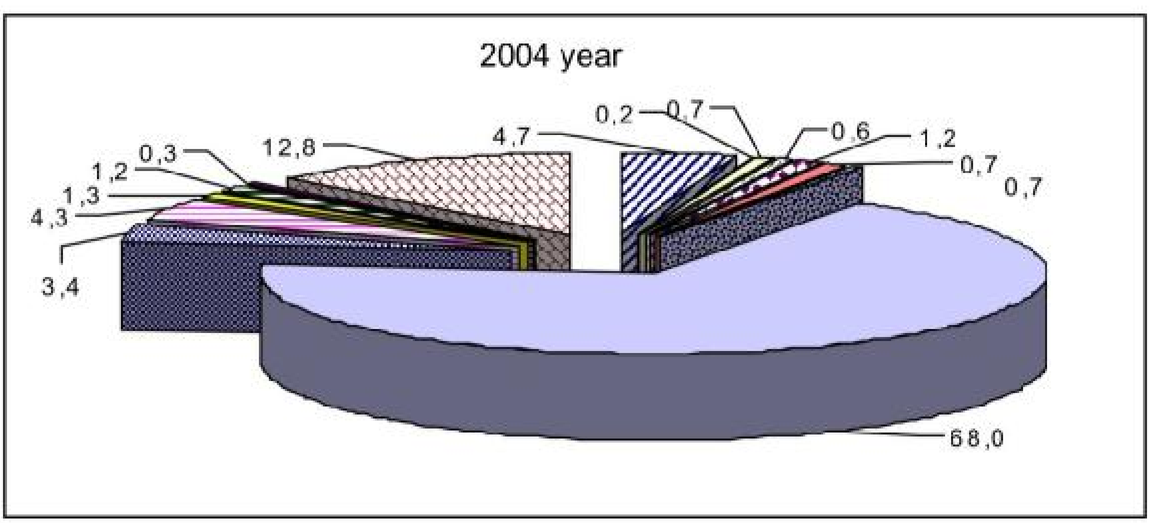
– class of neoplasms.

The most significant disease incidence decrease in 2008 in comparison with 2004 was determined in:

- class of blood circulatory system diseases,
- class of endocrine system diseases,
- class of mental disturbances and behaviorial disorders,
- class of diseases of musculoskeletal system and connective tissue,
- class of digestive tract diseases.

The disease incidence decrease was 8,5 % countrywide [141-144].

Structure of primary disease incidence of children and adolescents is represented in diagram (figure 82).



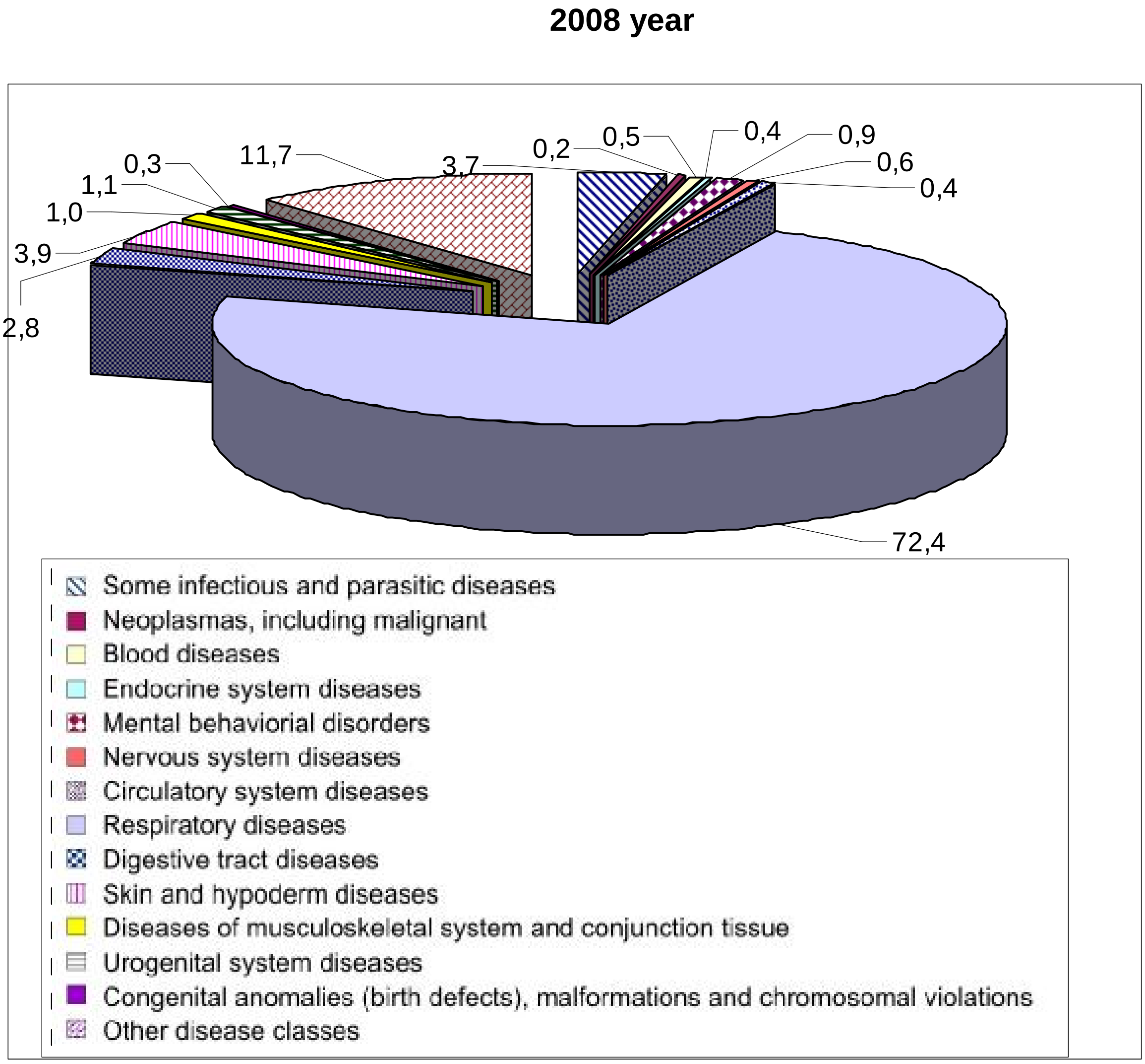



**Figure 82 - Structure of primary disease incidence of children and adolescents (0-17 years inclusively) in the Republic of Belarus in 2004 and 2008, %**

### *13.9.4 Analysis of primary disease incidence associated with malignant neoplasms of population in Grodno, Vitebsk, Minsk regions and separate districts of these regions in 2004-2008*

Neoplastic processes are typical for extraordinary variety of its clinical and morphological evidences. The malignant neoplasms attacking the different organs and systems is not similar not only for different countries but for separate areas of one country (regions and districts). The tendencies of disease incidence dynamics are varied in time as well as its structure is changes depending on etiological factors inducing cancerogenese in separate organs.

Assessing the dynamics of primary oncological disease incidence of the Republic's population for the period of 2004-2008, an increase of disease incidence should be noted countrywide by 6,9 % and in Grodno, Minsk and Vitebsk regions the increase was varied from 2,8 % to 8,8 %. Concerning separate districts of the regions there was a decrease in Oshmyany district by 13,8 %, in Smorgon district - by 13,5 %, in Postavy district – by 5,3 % In Oshmyany district there was an increase by 10,6 % and there was a significant increase of disease incidence in Miadel district by 55,8 % [141-145], being the most worrying. Dynamics of primary disease incidence associated with neoplasms of adult population as well as of children and adolescents in the regions of the Republic of Belarus for a period of 2004-2008 are given in Figures 83 and 84.

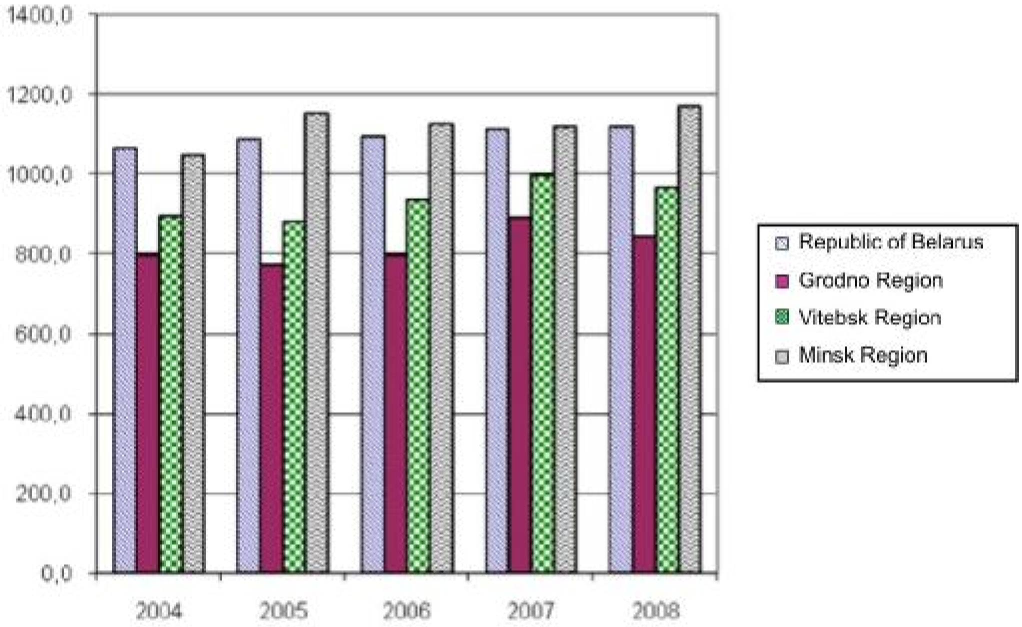



**Figure 83 – Dynamics of primary neoplasm disease incidence of adult population in the regions of the Republic of Belarus in 2004-2008 (per 100 thousands of population)**

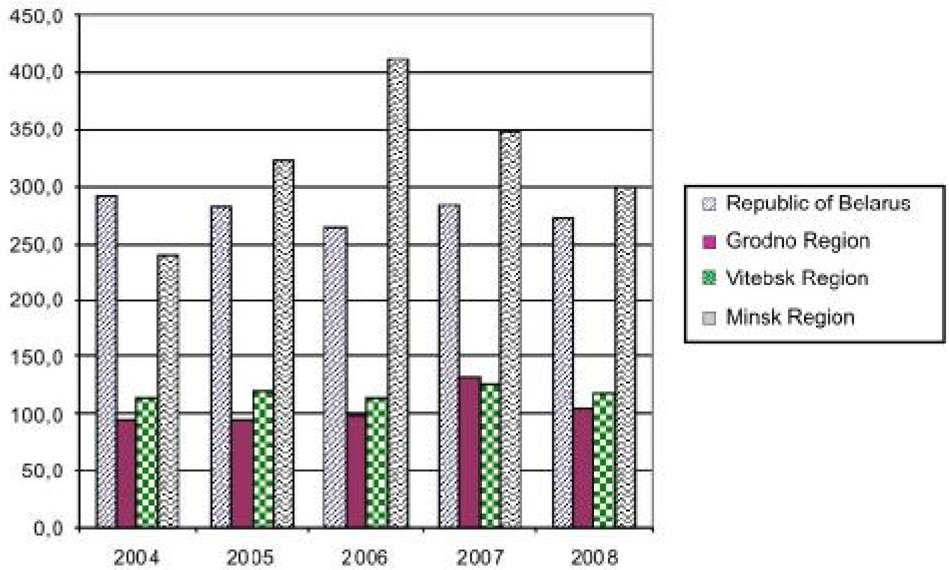



**Figure 84 – Dynamics of primary neoplasm disease incidence, including malignant, of children and adolescences (0-17 years inclusively) in the regions of the Republic of Belarus in 2004-2008 (per 100 thousands of population of the given age)**

Average indices of disease incidence for a five-year period in the regions and districts were varied from 320,3 cases to 392,8 cases per 100,0 thousands of population and only in Miadel district the index was equal to 469,1 per 100,0 thousands of population significantly exceeding the republican and regional levels.

In 2004 the indices of disease incidence were higher than average republican level in Vitebsk region, Postavy district and Minsk region; the indices of desease were lower than republican level in all the districts of Grodno and Vitebsk regions in 2008. The index of disease incidence in Minsk region exceeded the republican level by 2,9 %, in Miadel district being higher than republican level by 33,1 % (figure 85) [141-145].

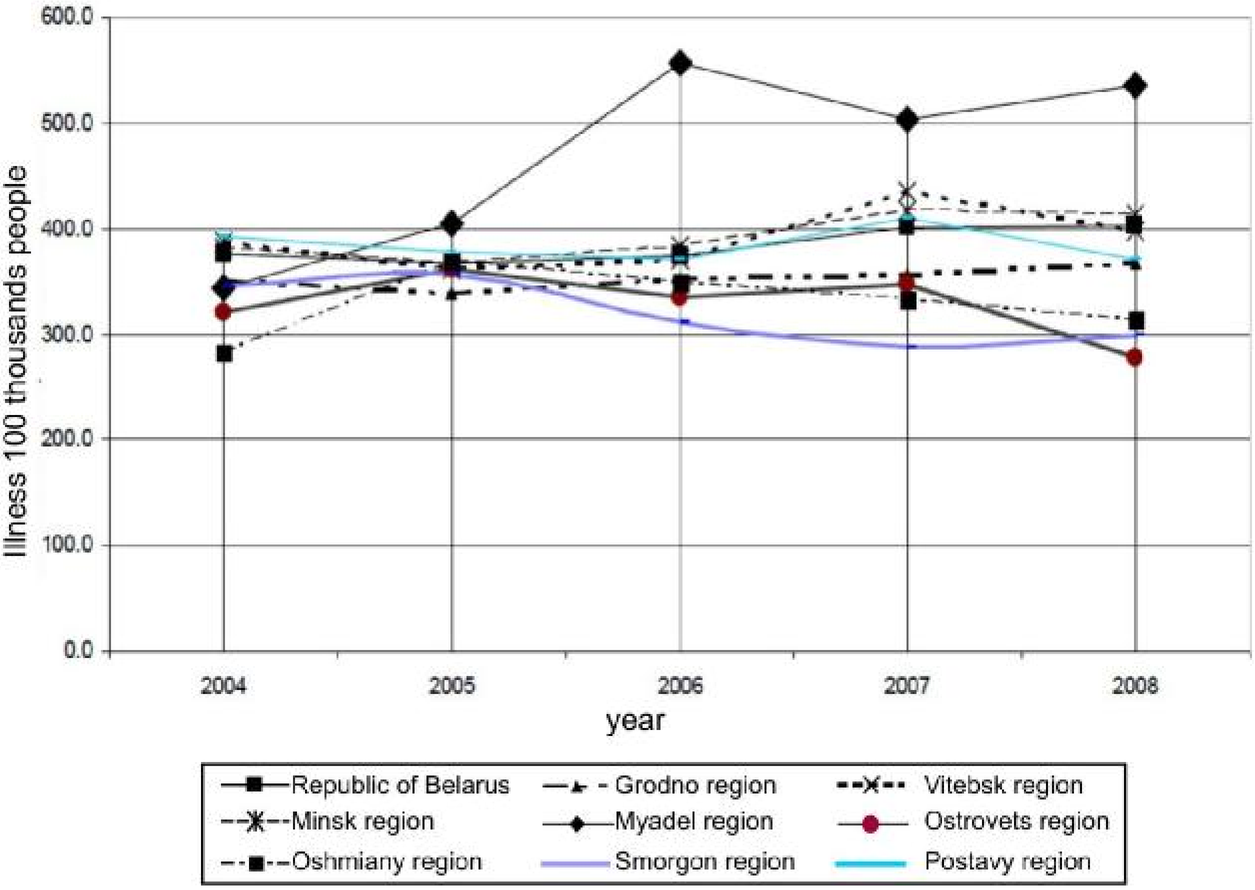



**Figure 85 – Dynamics of primary oncological disease incidence in the regions of the Republic of Belarus in 2004-2008 (per 100 thousands of population)**

The average republic thyroid carcinoma incidence hasn't changed significantly for the period analyzed (2004-2008). The average indices of thyroid carcinoma incidence of the analyzed regions' population were lower than republican level for a period of 2004-2008 and only in Smorgon district the disease incidence was equal to 13,6 cases per 100,0 thousands of population being insignificantly higher than the average republican value - 11,2 per 100,0 thousands of population. The increase of disease incidence in Ostrovets and Smorgon districts can be considered statistically uncertain and the increase rate calculated for these districts should be assessed with a certain extent of care due to a small number of cases of registered thyroid carcinoma in the examined districts for a period of last five years (141-145).

## 13.10 Historical and Cultural Heritage of the Ostrovets District

The list of the historical and cultural heritage of the Ostrovets District of Grodno Region is given in Table 120 [146].

**Table 120 – Historical and Cultural Heritage of the Ostrovets District**

| Name of the Heritage | Year of origin | Location of the Heritage | Number |
|---|---|---|---|
| Geodesic Arch Struve: place “Konrady” | XIX century | Ostrovets district; 2,8 km to the north-west from the Kandraty village | 1 |
| Site of the Mesolithic Period | 7-6 thousand years BC | Akartely village; 0,5-km to the south-east from the village | 2 |
| Catholic Church of the Ascension of the Holy Cross | Year 1760 | Village Bystritsa | 3 |
| Burial Mound of the Earlier Medieval Period | The end of the 1st thousand years BC | Budrany village; 0,7 km to the south-west from the village | 4 |
| Architectural Ensemble of the village Vornyany | Year 1770; XVII – XIX century | Vornyany village | 5 |
| St. George Catholic Church | The middle of the XVIII century | Vorona village | 6 |
| Site of Ancient Settlement | XI – XIII century | Gury village; 2 km to the north-east from the village | 7 |
| Site of Ancient Settlement | XI – XIII century | Ignatovo (Ignatsovo) village; 1,5-km to the west from the village | 8 |
| Site of Ancient Settlement | XI – XIII century | Koronyaty (Korenyaty) village; 1,8 km to the north-west from the village | 9 |
| Burial Mound Cemetry | 1-2 thousand years of AD | Katsenovichy village; 1,5-km to the north-west from the village | 10 |
| Catholic Church | Year 1900 | Kemelishki village | 11 |
| Burial Mound Cemetry | The end of the 1st thousand years of AD | Malye Sviryanky village; 1,1 km to the north-east from the village | 12 |
| Burial Mound Cemetry | The end of the 1st thousand years of AD | Motski (Matski) village; 1,5-km to the north from the village | 13 |
| St. Mikhail Catholic Church | XVII century | Mikhalishky village | 14 |
| Site of Ancient Settlement | XI – XIII century | Nidzyany village; 1 km to the south-west from the village | 15 |
| Burial Mound Cemetry | The end of the 1st thousand years of AD | Podkostelok village; 0,5-km to the east from the village | 16 |
| Trinity Church of the Old Believers | XVIII – XIX century | Podolskiy village soviet; natural landmark Strypishky | |
| Burial Mound Cemetry | The 2nd half of the 1st thousand years of AD | Polushky village; 0,6 km to the south-east from the village | |
| Burial Mound | The 1st thousand years of AD | Perevozniky village; 1 km to the west from the village | 17 |
| Burial Mound Cemetry | The 2nd half of the 1st thousand years of AD | Pilviny village; 1,3 km to the south from the village | 18 |
| Burial Mound Cemetry | the 1st thousand years of AD | Savishky village; 1,2 km to the south from the village | 19 |
| Site of Ancient Settlement | XI-XIII century | Sorochye village; 0,5-km to the west from the village | 20 |
| Burial Mound of the Iron Age | V-VI century | Andreevtsy village; on the right shore of Viliya river | 21 |

| Name of the Heritage | Year of origin | Location of the Heritage | Number |
|---|---|---|---|
| Burial Mound | IV-VII century | Vygolenenty village; 1,5-km to the east from the village | 22 |
| Site of Ancient Settlement of the Iron Age | The 1st thousand tears BC – V century of AC | Garony village; 1,5-km to the north-west from the village | |
| Holly Trinity Catholic Church | Year 1612 | Zhodishki village | 23 |
| Former Country Estate | XVII century | Zhodishki village | 24 |
| Water Mill | Year 1871 | Zhodishki village | 25 |
| Settlement of the Mesolith Period | 7-6 thousand years BC | Zaozertsy village; between the center of the village and the north-east bank of the lake Ryzheye | 26 |

Map of the Ostrovets District with all cultural and historical places of heritage are showed below (Figure 86):

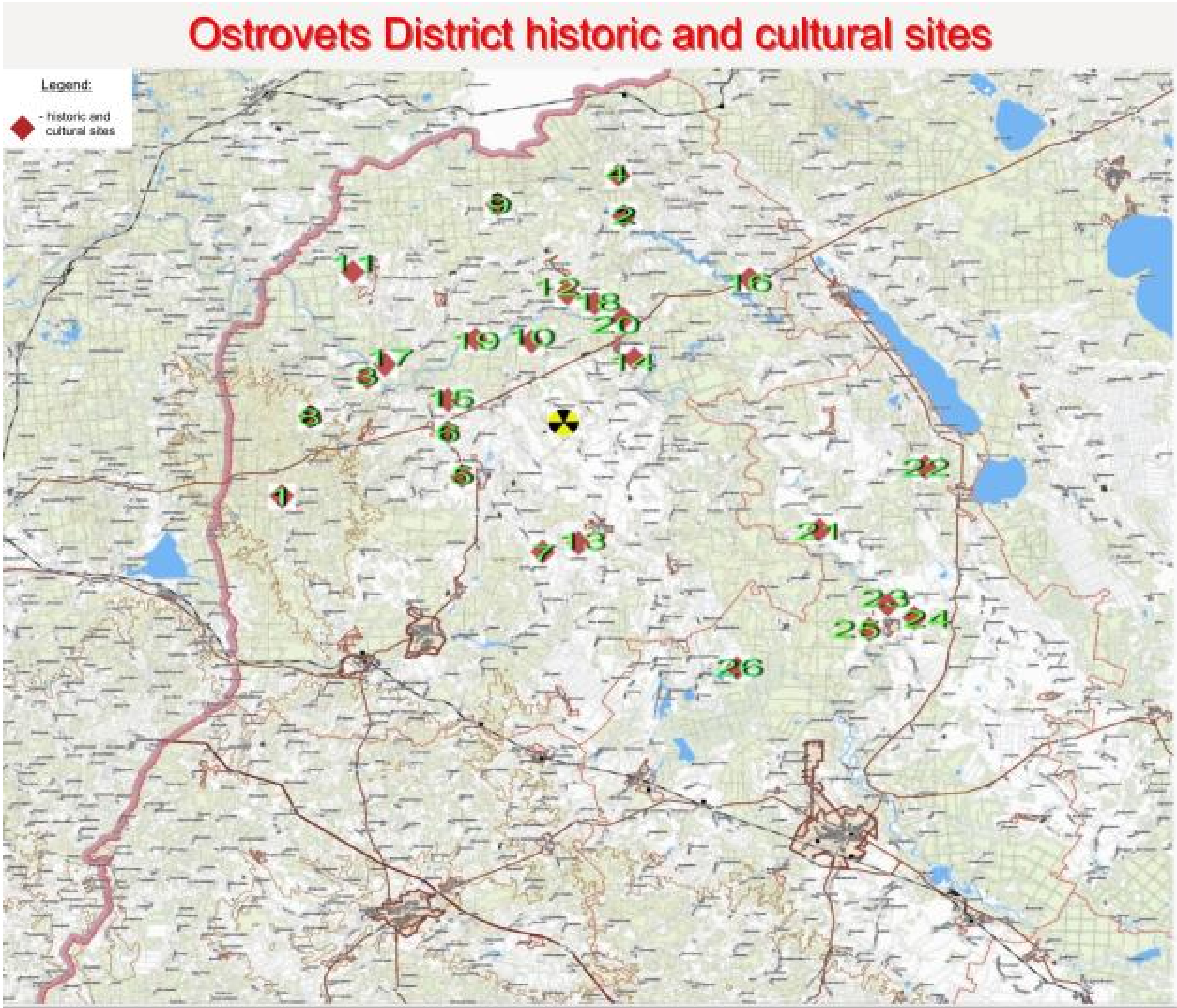



**Figure 86 – Ostrovets district map**

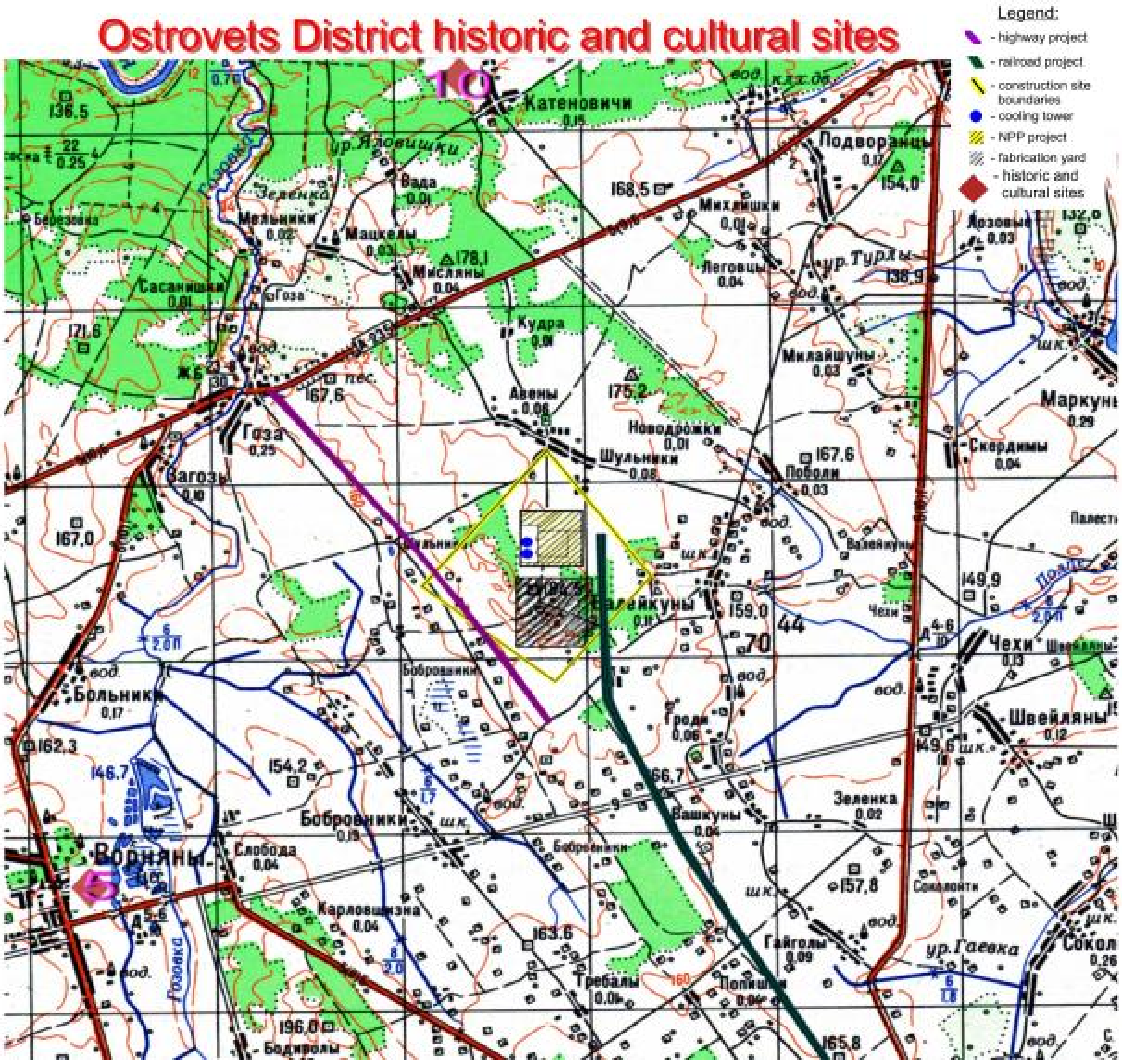



**Figure 87 – The plan of the 5-km area around the NPP site**

There is the plan of the 5-km area around the NPP shown at Figure 87. As we can see, the road planned is going to be at the distance near to 3 km from “The Architectural Ensemble of the Center of the Village Vornyany” and “The Burial Mound” in the Katsenovichy village. At the same distance from these cultural monuments will also be a railway.

### 13.11 Summary

In this part there is a short characteristic of the main elements of the environment, which will be influenced by the NPP in the process of the vital cycle. To sum up all the results we can say the following.

### *13.11.1 The Geological Environment.*

The geological environment of the 30-km area is described by the certain differences within the range of of this or that part of the territory. In particular, the geological structure of the NPP site differs from the 30-km area.

#### *13.11.1.1 The 30-km area of the NPP*

The main elements of the structure of the surface are: the valley of the river Viliya, flat-undulating plain Vileika on the both sides of the valley and moraine elevation, such as Svirskaya at the north-east and Oshmyany at the south-west. In geological and tectonic point of view this territory is located on the Baltic monocline, in its middle part that is located between the Vileika buried nose of the crystalline base and distant wing of the Baltic sineclise. In the structure of sedimentory cover of the examined region were found deposits of four structural-substantial complexes: Upper Sorbian – Lower Cambrian (Late Baikal), Lower Cambrian – Lower Devone (caledone), Middle Devone –Middle Triassic (gertsin), Middle Triassic - Quaterial (Cimmerian-Alpian). In geological structure of quaternary deposits dominate moraine formations of the Sozh's glaciation, in the west and south-west combine northern and nothern-eastern hills of the Oshmyany elevation. In the north-east with high details were examined 2 final-moraine ridge – Svirskaya and Konstantinovskaya, streched from the north-west to the south-east in the form of 2 strips of moraine formations of 4-6 km wide.

#### *13.11.1.2 The NPP site*

As for geomorphology the site is situated within the moraine plain with its flattened terrain, at the watershed of the river Viliya, between its left tributarys – Oshmyanka and Gozovka. The absolute points of surface are 176-185 m., at the extreme western and eastern parts limited to the slopes of watershed – 160-175m. The location of the site at the watershed provides the superficial flows, there are no signs of bogginess. The surface of the watershed is enough plain, that is why there is no need in large volume of land planning. As for stratigraphic geology, the geological complex (from the bottom to the top) is represented by the deposits of the Upper Agnotozoic era, Lower and Middle parts of the Cambrian, Ordovician Period, Silurian, Middle part of the Devon, Lower Neogene and Quaternary's deposits. The site is located on the solid block of the crystal base. By the preliminary results of the geophysical research, the absolute marks of crystal base's roof is minus 340-410 m. The power of the quaternary's deposits – 71,7-102,8 m. They are represented by 3 horizons of moraines (final and main moraines of the Sozh's horizon, moraine of the Dnieper horizon), by the divided rockmass of the final-moraine's sands, aqueo-glacial formations of Dnieper and Sozh horizons.

There are the possibilities to build the main structures on the natural base (the most economical option). The conditions of the construction will be dry, the separate lenses of water- saturated sand in moraine (sporadic spreading waters) may be drained by the landing drainage from the foundation pits.

The exogenous geological processes outside of the site can not influence on the stability of the NPP because of theirs distance. On the site itself there were no signs of the dangerous geological processes, such as landslides, karsts, subsoil erosion, boggings, etc.

The seismic activity of the NPP site:

- strength level earthquake (the probability is 1 time in 100 years), Richter magnitude – 6 points;
- maximum strength level earthquake (the probability is 1 time in 1000 years) Richter magnitude – 7 points.

The degree of influence of the exogenous geological natural factors on the stability of the buildings and structures of the NPP depends on characteristics and stability of the geological environment. The Belarusian NPP site's geological environment is characterizes by the sufficient stability and in this connection does not show any negative influence on the operation of the NPP's structures.

### *13.11.2 Chemical and Radioactive Pollution*

The analysis of the structure of the superficial waters of the rivers Gozovka (Goza village), Losha (Gervyaty village), Viliya (Mikhalishki village), Oshmyanka (Velikiye Yatsyny village) shows that the examined rivers belong to the rivers with little and average mineralization, the maximum value (dry rest) is 324 mg/dm$^3$. The general rigidity in the rivers has not have very high value, but the maximum value is 4,90 mg-eqv/dm$^3$ (river Oshmyanka – Velikiye Yatsyny village). Among the amount of the main ions (macro-components) the main are hydrocarbonated ions and calcium ions.

Among the main polluted components in the rivers were found oil products in the river Goza – 1,0 km higher the village Gozovka– 0,06 mg/dm$^3$ (more than 1 MPC), the total values of phenols are from 0,002-0,004 mg/dm$^3$. The maximum value of BCO's (Biological Consumption of Oxygen) index was received in the river Viliya in the range ofary of Mikhalishki village – 5,93 mg$O_2$/dm$^3$ (near 2 MPC) which shows that there is an increased content of unstable organic components in the water. The maximum values of the ammonia nitrogen were received in the rivers: Gozovka (1,0 km upper the village Goza) – 0,41 mgN/dm$^3$ and Viliya (in the range of of Mikhalishki vilage) – 0,39 mgN/dm$^3$ (more than 1,0 MPC). Maximum values of total iron – 0,17 mg/dm$^3$ (more than 1 MPC) were detected in the rivers: Goza – Gozovka village and Oshmyanka – Velikiye Yatsyny village. That is why, it is necessary to provide measures in the given NPP's project for removing iron from the natural waters, which will be used in the technological NPP's cycle.

In the rest indexes and substances determined in water objects that are located in the immediate vicinity of the proposed place of the construction of the Belarusian NPP, exceeding values of MPC were not fixed.

The content of chemical polluted substances and heavy metals in the samples of coil selected within the Ostrovets district, do not exceed the maximum permissible values.

According to the information of the filed work and the information about the middle levels of radioactive pollution of the villages and settlements of the Republic of Belarus, registered in the database of the Department of Hydrometeorology of the Ministry of Nature among 251 locations situated within the 30-km area around the proposed place of the NPP construction, 17 locations have the average density of pollution of $^{137}$Cs, insignificantly exceeding the level of global fall-outs. The maximum value of content of $^{137}$Cs was found in Sailyuki village of Murovano-Oshmyany rural soviet, Oshmyany District – 0,26 Ci/km$^2$ (9,6 kBk/m$^2$). The average density of pollution of $^{90}$Sr within the 30-km area of the villages and settlements are in the range of 0,01-0,02 Ci/km$^2$ (0,37-0,72 kBk/m$^2$) hat correspond to the level of global fallouts of this radionuclide.

The level of activity of natural radionuclide in the selected samples of soils and bottom sediments correspond to the levels of middle activity of these radionuclides that is typical for soddy-podzolic and podzolic soils.

The results of the carried generalization of soil based on the intensity of the migration processes show that near 10 % of the Belarusian territory within the 30-km area of the NPP are soils with low intensity of migration of $^{137}$Cs, a little bit more than 60 % are the soils with moderate migration ability of this radionuclide; 4,4 % are the soils with increased migration ability and 25,2 % are the soils with relatively higher mobility of $^{137}$Cs.

The moderate mobility of $^{90}$Sr is typical for the most territories of the 30-km area of the Belarusian NPP (85,4 % from all the Belarusian territory). The area of soils with increased mobility of $^{90}$Sr are 9,4 % and the soils with high mobility of radionuclide – 5,2 %. According to the soils map, it can be said that there are almost no soils with low mobility of $^{90}$Sr on the examined territory.

Thus, more than 70 % of the territory within the 30-km area around the Belarusian NPP is the soils in which the mobility of $^{137}$Cs and $^{90}$Sr are low and moderate, that is the positive fact during the assessment of the alternative site according to the point of view of its suitability for allocation of the NPP. The territory of the Belarusian NPP site occupies for all purposes the soils with moderate migration ability of radionuclide.

The analysis of actual distribution of radionuclides based on vertical soil's type show that even in soils with relatively high migration ability of radionuclide, the main reserve $^{137}$Cs is in the upper 15 cm of the soils.

### 13.11.3 Meteorological and Aerological Conditions

The territory of the 30-km area of the Belarusian NPP is located on the north-west of Belarus in Grodno Region on the territory of Narochano-Vileika flatlans. The territory of the site is located in moderate climatic zone, where the air masses of the middle latitudes dominate.

The average annual air temperature of the Belarusian NPP's 30-km area is in the range of 5,2-5,4 ºC, absolute maximum – in the range of of 34,0 – 34,6 ºC, absolute minimum – in the range of minus 31,8 – minus 39,8 ºC. As for the NPP site the rated average annual air temperature is 5,4 ºC. The air temperature in July vary from 16,9 to 17,0 ºC, and in January – from minus 6,5 to minus 6,7 ºC. As a rule, the period when there are no frosts lasts for 140-149 days. Maximum twenty-four hours amplitudes on this territory can be seen in summer and vary from 10.6 to 11,1 ºC.

The average annual tempreture of soil surface at the territory under consideration is 6-7 ºC, which is a little bit higher than the average annual air temperature (5,2-5,4 ºC). The absolute peak of the temperature of the soil surface is in the range of 54-60 ºC and absolute minimum is minus 36 ºC.

The average annual relative humidity is 80-81%, average annual partial pressure of water steam is 8,2 gPa, the shortage of saturation is 2,7-2,8 gPa.

The annual amount of cloudiness in the range of the examined territory is 6,7-7.1 points, according to the general cloudiness and 5,1-5,4 points according to the lower.

According to the precipitation felt, the examined region, as the whole Republic of Belarus, belongs to the area with sufficient humidity. There are all types of precipitations here: rain percipitation, solid and combined. The precipitations fall irregular during the year. The total amount of precipitations during the winter are just 17 % of the annual amount, during the spring – 21 %, during the summer – 37 % and during the autumn – 25 %. The annual amount of precipitations in the northern area are 741mm; in the southern – 645mm. During the cold period within the 30-km area of the Belarusian NPP can fall only 29-32 % from the annual amount of precipitations and in warm period the number is 68-71 %. The maximum total annual amount of precipitations at the Belarusian NPP's area is 1075 mm in the north and 828 mm in the south. The maximum monthly amount of precipitations, 215-322 mm, falls to August. The smallest annual amount of precipitations on the territory changes from 445 mm in the southern part of the area to 527 mm in the northern. The biggest twenty-four hours maximum of precipitations in the southern part of the examined territory was in May, in the northern part in June. What is more, the twenty-four hours maximum of the southern part (101 mm) exceeds the twenty-four hours maximum of the northern area (80 mm). The average number of days with precipitations during the year within the given area varies from 184 to 193 days, the greatest – from 206 to 235 days. The largest amount of days with precipitations is in June – about 15 days.

The amount of days with snow cover within the 30-km area of the Belarusian NPP is 111-120 days. The average decadic snow cover depth at the end of February within the examined territory is 19-26 cm; the highest among the average – 25-34 cm. The maximum snow cover depth during the winter was 58-72 cm and was noted at the first decade of March. The annual density of the highest snow cover depth is 0,24-0,25 g/cm$^3$. The largest reserve of water of the snow cover during the winter was 195 mm.

The annual amount of soil surface vapour (the total vapour) during the warm period within the examined territory is 370 mm., the biggest monthly amount – 83 mm – in July.

During the year within the 30-km area of the Belarusian NPP there are winds from the south-western quarter of horizon. What is more, for the southern part of the area more frequent is eastern direction (11 %), in northern – southern (12 %).

The biggest amount of zero wind during the year is in the northern part of the area (9%), the smallest – in the southern (3%). Among the separate seasons the main amount of zero wind are in summer. There are 5% of calms in the southern part and 14% in the northern.

The average annual velocity of wind (disregarding directions) within the examined territory is increased from 2,5 m/s in the northern part of the area to 3,7 m/s in the southern. During the winter period the average monthly velocity of wind is in the range of 2,8-2,9 m/s in the northern part and 4,0-4,3 in the southern.

The frequency of zero wind or gentle breeze is in the range of permissible conditions for locating the NPP. As a whole, it can be nearly 30 % during the year and nearly 24% during the cold period (from October to March).

In average there are 67 foggy days in the northern area and 70 days in the south at the territory of the 30-km area of the Belarusian NPP. During the warm period there are 20 foggy days in the northern area and 22 days in the south. During the cold period the number of foggy days changes from 47 days in the north to 48 days in the south.

During the year the average number of stormy days at the examined territory is 21-23, the biggest – 37-38 days. The biggest thunder activity is during the summer period (May-August), sometimes there can be winter storms.

The dangerous weather phenomenon be significant for the 30-km area of the Belarusian NPP can be determined on the whole territory of the Republic of Belarus. In that case we examine the territory of the administrative regions: Grodno, Vitebsk and Minsk. As for the dangerous meteorological phenomena at the examined territory, heavy rains took place (the amount of precipitations ≥ 50 mm during 12 hours and less); big hail (diameter ≥ 20 mm.); the wind with the velocity of ≥ 25 m/s, hurricanes, squalls and tornados; heavy snowstorms (with the wind velocity ≥ 15 m/s); snowfalls (the amount of precipitations ≥ 20 mm for 12 hours and less); heavy fogs (visibility less than 100 m.);

heavy black ice (diameter of deposits ≥ 20 mm.). In the individual cases these phenomena inflicted damage to the agriculture located at the examined territory.

It should be noted that the dangerous meteorological phenomena influence on the nuclear power plant in many ways – from additional load to the station's structure (stormy wind, tornado, black ice, snowfall) to conditions forwarding to pollutant ventilation as well as its transport at considerable distance (heavy precipitation, stormy wind).

Distribution of the average wind velocity has a seasonal character: high speed at the attitudes of 100, 200, 300 and 500 meters were registered in autumn and winter and come to winds of western, southern and northern quarter – vary from 6-7 m/s on the attitude of 100 meters to 12-13 m/s on the attitude of 500 meters. The increase of zero wind and ligh breeze during the cold seasons within the area of the Belarusian NPP can assist the development of the winter maximum of the air pollution in several years.

The ground inversions of temperature are evenly distributed by the seasons of the year. Slightly raised temperature inversions in winter happens in 2 times often, than in spring, and almost in 3 times often than in summer. In autumn their parts are also considerable. The maximum frequence of the ground inversions are during the warm period of the year, slightly raised – during the cold period.

The average capacity of the inversion layers is the smallest in summer and do not exceed 0,30 km. The ground inversion as well as the raised inversion reaches the maximum value in winter months and makes 0,58 and 0,45 km accordingly. At special weather conditions the capacity of the ground inversion can exceed 2,0 km in single cases, raised inversion – 1,8 km.

### *13.11.4 Assessment of the Conditions of Aquatic Ecosystems within the 30-km area of the Belarusian NPP*

The assessment of the conditions of water streams of the basin of the river Viliya within the 30-km area of the Belarusian NPP shows the normal operation of theirs ecosystems. Community of phytoplankton, phytoperiphyton, zooplankton and macrozoobenthos are characterized by high species resources. The quantity of biotic index were in the range of 7 to 10 (I-II types of contamination), the values of the EPT index also reached 6-15 points. The quantity of saprobity index calculated by phytoplankton varied from 1,33 to 2,08; by zooplankton – from 1,34 to 2,31; by phytoperiphyton – from 1,60 to 2,07, that corresponds to II-III classes of contamination and let refer this water streams to the β-mesosaprobic zone.

There were no essential changes of trophic status of shallow lakes of Sarochanskaya group during the 11-years period passed between the complex explorations of lakes in the years 1980 and 1991. The beginning of harsh shortage of oxygen in by-beds layers in summer 1991 in the lakes Beloye, Podkostelok, Turoveyskoe, show the considerable roles of bottom sediments in forming oxygen conditions in lakes, that can attest on actuality of beginning of dead phenomena in winter period.

The track down tendency of worsening of ecological condition of the lake Tumskoye from the group of mid-water Sorochankiye lakes. In this way, the water transparency of the lake in 1957 was 2,7 m, in 1980 – 1,9 m and in 1991 was only 1,3 m. In 1991 it was noted a considerable oxygen supersaturated of the upper water layers (177 %) and its harsh decreasing with increasing of depth. This fact has not noted earlier. The common biomass of phytoplankton increased from 2,5 in 1980 to 7,0 g/m$^3$ in 1991. The observed changes show the increasing of the lake trophicity and worsening of the water quality. There are no essential changes in the conditions of the lake Gubeza in comparation with 1957.

There is a trophicity of the lakes Edi and Golubino of the group of deep Sarochanskiye lakes.

The lakes Svir and Vishnevskoye are characterized as a eutrophic water body. The water quality in these lakes according to the saprobic index is classified as III class (moderate-polluted waters).

Thus, generalization and analysis of the results of the researches carried out within the limits of this project as well as available materials of the last years let conclude, that water steams ads water bodies within the 30-km area of the Belarusian NPP are situated on the different levels of the eutrophic process, however, work in normal regime, are characterized by high species variety, considerable biological self-purification potential and meet requirements of the the basic conditions of the ecosystems of the appropriate biolimnic type.

### *13.11.5 Subterranean Water*

According to hydrogeologic zoning, the territory of the 30-km area of the Belarusian NPP is associated with the western slope of the Belarusian hydrogeologic solid mass. Its hydrogeologic conditions are determined by the geological structure and climatic peculiarities of the moderate continental area with excessive moistening.

Considerable capacty of the sedimentary deposits, the absence of secure staunched waterproofs and predominance of the amount of precipitations above the total vapours create favorable backgrounds for accumulation of fresh subterranean waters and theirs active circulation under existing waterexchange. The capacity of the fresh water area varies from 70,0 m in the north of the territory to 300,0 m and more in the south. The fresh subterranean waters contain in the deposits of the quaternary, low-water, devone, Silurian, ordovic and Cambrian periods.

In the range of the Belarusian NPP, the hydrogeologic conditions of the quaternary deposits are characterized by almost full absence of subterranean waters up to the depth of 10-24,4 m at the main part of the site. Beneath these depths the quaternary sands (the final sozh's moraines, middle-moraines dnieper-sozh's, and also sand lens in the main sozh's, dnieper's and berezina's moraines) are fully water-saturated.

In general, for the subterranean waters within the 30-km area of the Belarusian NPP is typical the straight vertical hydrogeochemic zoning: fresh hydrocarbonate calcium water; mineralized sulfate-calcium; sodium chloride waters. The power of fresh water area - 100-300 m. The intensive hydrogeochemic anomaly can be found on the site to the north-western part of the planned NPP site. At the region of Losi village, Zhukoyni village, Zhelyadskiye village and Mostyany village in the thickness of the devone's deposits, the roof of which lies here on the depth of 61-103 m, chloride-sulphate and hydrocarbonate-sulphate, sodium-calcium and sodium-magnesium-calciium water with the mineralization of 1,2-3,16 g/dm$^3$ can be detected. Evidently, the forming of this hydrogeochemic anomaly is connected with processes of dissolving of gypsum deposits of Narov's horizon of the middle devone ($D_2$nr), and also with the flows of deep mineralized water of chloride sodium composition across the area of Berezovskiy break. At present this indicate to the opportunity of karstification in the gypsum deposits of devone and to the availability of tectonic weakened zones in this region, through which the deep mineralized water flows can appear.

As a rule, the fresh subterranean water within the 30-km area of the Belarusian NPP are hydrocarbonate sodium-calcium; their mineralization changes in the range from 0,15 to 0,76 g/dm$^3$. The grounds of spreading of the subterranean water with minimal mineralization (0,15-0,30 g/dm$^3$) are inlined towards high watershared areas, being the regions of supply for this horizon. Ostrovets point (between Gozovka, Viliya, Oshmyanka and Losha rivers) is situated in the range of of one of those watershared areas.

The subterranean water of shallow underground reservoir is exposed to anthropogenic pollution (agricultural and public-domestic).

Now there are no tracks of the anthropogenic pollution in fresh subterranean water of the by-quaternary deposits (cretaceous, devone, Silurian, ordovic and Cambrian underground reservoir).

The mineral waters spread within the examined territory are not extracted; however, there are good perspectives for using them as medical and medical-table water.

Nowadays, the subterranean water is used as drinking water supply through water intake in township Ostrovets – “Ostrovets”, township Oshmyany – “Vaygeta”, township Smorgon – “Koreni”, public resort Naroch “Malinovka-1”, Naroch Lake – “Baloshi”, the single departmental downholes are used in rural locations. The used underground reservoir is underground reservoir and complexes of quaternary, devone, silurian and ordovic deposits.

The available information of the prediction recourses (relation of the used reserves to the prediction recourses) on the territory under consideration is very low and is only 4 %. Thus, there is an essential reserve for the satisfaction of needs in drinking water.

### *13.11.6 The grounds. Agriculture*

The main part of the examined territory within the 30-km area around the Belarusian NPP is occupied by forests and agricultural plantations (near 90 %), on which, an intensive economical work is taking place now. The agricultural works specialize in cultivation of cereals, flax, sugar beet, rapes, potatoes, fodder crops, production of meat and milk.

The density of ground pollution of $^{137}$Cs on this territory is from 0,7 kBk/m$^{-2}$ to 2 kBk/m$^{-2}$, the capacity of the equivalent doze in the air – 0,10-0,15 µSv/h$^{-2}$ and according to these indexes it is comparable to the rest of the territory of the Republic polluted only by the global fallouts from the nuclear weapon tests.

The content of $^{137}$Cs in the agricultural products does not exceed the value of minimum detected activity (<2,7 Bk/kg$^{-1}$), $^{90}$Sr amounts to the tenth part of Bk·kg$^{-1}$ and by these indexes does not differ from the rest of the territory.

### *13.11.7. Landscapes, flora and fauna*

The NPP construction site within the 30-km area of the Belarusian NPP locates in the range of Poozerskaya province of glaciolacustrine, moraine and undulating-moraine-lakes landscapes and according to their aesthetic, bioclimatic and ecologic characteristics has a high recreation and health potential. The landscape-geochemical conditions of the natural ecosystems of the region are characterized by high migration activity of chemical elements on the one hand stipulated by the predominance of acid environment reaction and by practically universal spreading of geochemical barriers on the other hand, on whom their elements can accumulate.

The degree of economic assimilation of the territory is moderate. Its woodiness is 37,7%, that is on the middle level for the country and is enough for maintenance the ecological balance in the region. Among the forests are the pineforests, the part of which occupies about 70% of the forests and the same situation is with timber reserves. The forests productivity is high, the half of them has the first class of bonitate. The anthropological influence on the forests is relatively slight, their ecological conditions are satisfactory. The deforestation of small areas within the NPP site construction influence on the conditions of the ecological balance in the region.

The ichthyofauna of waterway and reservoirs of the region are differs by high species variety and has 42 types of fishes. The river Viliya with its tributarys is the only one river basin in the Republic of Belarus, in which there are 8 protected types of fish and fish-like vertebrates, including 2 types of salmon.

The avifauna of the territory is represented by 162 typesof birds that is the half of the species of the avifauna of Belarus. The density of valuable types of the hunting mammal (hoofed) in the hunter keeping region is mainly middle.

The chemical pollution of the territory of natural ecosystems is negligible. The concentration of heavy metals in the soils and plant production are practically at the level of the background values. The excess of MPC is registered in single cases and for insigniacant value. The pollution of commercial animals is a little bit higher.

The 30-km area of the Belarusian NPP has an essential value for conservation of the biological and landscape varieties at the national and international level. The special protected natural areas occupy here near 15 % of the area, exceeding in 2 times the similar index for the whole country. They all are situated at the distance of more than 7 km from the site and the construction itself does not influence on them.

The index of the first group forest within the 30-km area is 63 %, that is almost in 1,3 times higher than the middle level for Belarus and is the evidence of increased nature-protecting significance of that territory. The largest massive of the protected forests lay along the river Viliya and make a complete ecological passage, joining the secial protected natural areas of the Republic of Belarus and protected nature objects of the Republic of Lithuania.

Places of growth of rare types of plants were found in the Region, the tenth part from their total amount in Belarus. There were also found 45 types of the protected animals. The areal of concentration of the rare types of plants and animals are far enough from the site, except the river Gozovka, where salmons dwell.

### *13.11.8 Population and Demography*

#### *13.11.8.1. Primary desease incidence of the adults*

As the result of analysis of the primary desease incidence of the adults in Grodno, Vitebsk and Minsk Regions of Republic of Belarus in 2004-2008, the main classes of deseases (there are 13 main classes of deseases according to the MCD-10) were determined the followings:

The first rank place both countrywide and regionwide was taken by respiratory diseases – from 33,9 % in Grodno region to 40,5 % in Vitebsk region in 2004, from 32,9 % in Grodno region to 41,8% in Vitebsk region in 2008. This disease class made 35,8 % to 36,5 % countrywide respectively.

The second rank place was taken by diseases of musculoskeletal system and connective tissue – from 6,6 % in Grodno region to 10,6% in Minsk region in 2004 and from 6,7 % in Vitebsk region to 9,1 % in Minsk region in 2008. The given disease class made 8,3 % to 8,2 % countrywide respectively.

The third rank place was taken by skin and hypoderm diseases – from 6,4 % in Minskaja and Grodnenskaja regions to 7,7 % in Vitebsk region in 2004 and from 5,3 % in Grodnoregion to 8,1 % in Vitebsk region in 2008. The disease class made 6,1 % countrywide both in 2004 and in 2008.

For a five-year period there is observed an increasing of primary disease incidence in all the disease classes both among adult population of the republic in general (6,4 % higher) and among population of the region analyzed: from 2,5 % in Vitebsk region to 18,4 % in Grodno region.

The following disease classes are notable for the greatest increase of the disease incidence level: blood diseases, endocrine system diseases, blood circulatory system diseases, congenital anomalies (birth defects), malformations and chromosomal violations, mental behaviorial disorders.

*13.11.8.2 Primary Disease Icidence of Children*

As the result of analysis of the primary disease incidence of the children in Grodno, Vitebsk and Minsk Region of the Republic of Belarus in 2004-2008, the main classes of diseases (there are 13 main classes of diseases according to the MCD-10) were determined the followings:
- Comparative analysis of primary disease incidence of children and adolescents showed insignificant ratio variations of main disease classes for a five-year period.
- The first rank place in overall disease structure was taken by respiratory diseases – from 69,0 % in Grodno region to 71,2 % in Vitebsk region and 68,0 % countrywide in 2004 and from 73,5 % in Minsk region to 77,2 % in Vitebsk region in 2008 within the interest of respiratory diseases being equal to 72,4 % countrywide in 2008.
- The second rank place was taken by infectious and parasitic diseases – from 4,0 % in Minsk region to 6,4 % in Vitebsk region and 4,7 % countrywide in 2004 and from 3,5 % in Minsk region to 3,9 % in Grodno region and 3,7% countrywide in 2008.
- The third rank place was taken by skin and hypoderm diseases – from 3,8 % in Vitebsk region to 4,7 % in Minsk region and 4,3 % countrywide in 2004 and from 2,6 % in Vitebsk region to 4,5 % in Minsk region and 3,9 % countrywide in 2008.
- The highest rate of disease incidence increase was determined in the class of respiratory diseases, class of congenital anomalies (birth defects), malformations and chromosomal violations,

*13.11.8.3 The oncological diseases*

The analysis of oncology diseases of population in Grodno, Vitebsk and Minsk regions of the Republic of Belarus shows the following:

- during the 5-years period there was an increase of oncological diseases in the Republic by 6,9 % and in regions this increase was in the range of from 2,8 % to 8,8 %, as to the separate regions, it is necessary to pay attention to an essential increase of diseases in Myadel District by 55,8 %;

- aqverage indices of disease incidence for a five-year period in the regions and districts examined were varied from 320,3 cases to 392,8 cases per 100,0 thousands of population and only in Miadel district the index was equal to 469,1 per 100,0 thousands of population significantly exceeding the republican and regional levels.

- As for the primary diseases of lung cancer, it can be mentioned that during the 5-years period there were no any special changes in the structure of this disease among the population of the examined regions. As a positive moment it is necessary to mention the decrease of increase rates countrywide by 1,1 %, in Grodno Region by 9,0 %, in Vitebsk Region by 10,3 % and only in Minsk Region there was an increase by 10,1 %. During the 5-years period, the average level of lung cancer in the Republic was 44,5 cases for 100 000 population, in all examined regions the level of diseases was higher than the republican and only in Grodno Region it was lower than the republican (44,0 cases for 100 000 population);

- the average level of stomach cancer during 5 years was 53,5 cases for 100 000 population, in Vitebsk Region was 38,8 cases, in Minsk Region – 39,4 cases for 100 000 population. As to the other regions, in Postavy and Myadel Districts this index was a little bit higher than the republican one. The stomach cancer in the general structure of oncological diseases in 2008 in the Republic was 8,6 %, in Grodno Region – 8,6 %, in Vitebsk Region – 9,1 %, in Minsk Region – 9,8 %. Among the regions this index changes from 7,9 % in Myadel District to 13,0 % in Smorgon District. From 2004 to 2008 there was a reduction of the increase rates in the Republic in general by 3,6 %, in Grodno Region – by 4,6 %, in Vitebsk Region by 12,5 % and almost without any changes in Minsk Region.

- there is also an increase of the primary diseases incidence of skin cancer among the population in the mentioned regions during 2004-2008 from 14,6 % to 16,4 %. The rates of increase of skin cancer in the Republic and regions varied during the examined period from 11,3 % in Vitebsk Region to 40,9 % in Minsk Region, there was also an increase of this disease in Smorgon and Myadel districts. In all regions and five districts the average indexes of skin cancer were lower than in the Republic in general.

- in all examined regions the indexes of breast cancer were lower than middle-republican level. The increase rates of breast cancer significantly rise in the Republic of Belarus and regionwide, especially in Minsk Region and in Postavy District. The amount of women with this disease in the structure of all diseases during 2004-2008 is stable and is 9,4 %, according to the examined regions this indexes have a little bit changed in 2008 in comparison with 2004. According to the examined regions these indexes have not changed essentialy, except Myadel district, where the part of sick people has come down from 10,3 % to 5,5 % in 2008 in general structure of diseases;

- there were no essentil changes in thyroid gland cancer among the population in the examined regions during the last 5 years. The average index of the thyroid gland cancer among the population in Grodno, Vitebsk, Minsk Region and Myadel, Ostrovets, Oshmyany, Postavy DistrictS during the period from 2004 to 2008 was lower than the republican index, and the average index of this disease was a little bit higher only in Smorgon District than in the Republic of Belarus as a whole;

- the average incidence of leukaemia during 2004-2008 in the Republic was 11,4 cases for the 100 000 population, in all examined regions the average incidence of leukaemia has not exceed the republican level, and only in Grodno Region this index has been higher than the republican and has been 13,2 cases for 100 000 population;

- there was an increase of leukaemia in the districts by the year 2008 in the general structure of diseases in Ostrovets district by 5,9 %, in Smorgon district by 0,6 %, in Postavy district by 0,2 %, in Myadel District by 1,3 %. The average incidence of leukaemia during the mentioned 5-years period was higher than the republican (11,4 cases for 100 000 population), only in Grodno Region – 13,3 cases for 100 000 population, including the following districts of this Region:

- in Ostrovets district – 12,8 cases for 100 000 population;

- in Oshmyany district – 17,0 cases for 100 000 population.