The study of the environmental impact of radioactive discharges from an atomic power plant is a problem, which must be solved if nuclear power development is to have a future. Forest biogeocenoses are among the natural objects most vulnerable to the effect ionizing radiation because of the high radiosensitivity of forest vegetation (especially conifers) and its increased capacity for retaining radionuclides and slowly ridding itself of the nuclides when radioactive substances arrive as fallout [1-3]. After such major radiation accidents as that in the Southern Ural in 1957 and the Chernobyl Atomic Power Plant in 1986, forest ecosystems were the only natural communities (cenoses) where pronounced radiation damage was detected [4, 5]. Following the Chernobyl disaster the area of pine forests damaged entirely was 500-600 ha and the area of pine stands with a high or intermediate degree of damage was 3000 and 12,000 ha, respectively [6].

Up to the present time, however, insufficient information involving specific estimates of the impact of an atomic power plant on the forest stands in the vicinity, estimates of the dose burdens on the forests, and the radiation under the conditions of normal operation of an atomic power plant and in various kinds of accidents has been accumulated. In view of this it is desirable to consider possible radiation effects from the discharges of the Novovoronezh Atomic Power Plant since the region around contains large forests, predominantly with diverse species, including coniferous stands, in the nearest proximity (at a distance of roughly 2 km). This makes it possible to assess the range of possible situations when the forest is affected by the operation of the Plant, which in many respects can be considered as typical situations for most atomic power plants on the territory of Russia and the Ukraine as well as other countries.

**Assessment of Normalized Discharges on Forest Stands.** The dose burdens on forest biogeocenoses, lying within a 30-km zone, were calculated with data on the concentration of the most significant radionuclides (90Sr, 106Ru, 131I, 137Cs, 144Ce, etc.) in the surface layer of the atmosphere near this power plant during normal operation [7]. The effective rate of 131I deposition was assumed to be 0.01 m/sec and that of other radionuclides, 0.08 m/sec. When the content of radionuclides in the crown of the forest stands is estimated along with processes determining the retention and redistribution of radionuclides in the above-ground part of the trees, taking into account phenomena associated with the self-purification of forest biogeocenoses. The effective period of half-purification of the arboreal layer was assumed to be the same for all radionuclides, namely, 90 days, which is in keeping with a conservative estimate of this quantity. In the calculations of the dose burdens on the arboreal layer along with the radiation dose from radionuclides distributed in the crown of the trees we determined the contribution from the radiation of radionuclides that enter the forest floor. In both cases we estimated the contribution to the total radiation dose from the forest vegetation, both $\gamma$ and $\beta$ rays.

On the basis of data obtained by examining the forests in a 30-km zone, the phytomass density was assumed to range from 5 to 25 kg/m². The dose was calculated for each part of the forest (both young and open stands, constituting a tiny fraction of the forest lands, as well as mature forests with closed crowns). Moreover, in the calculations we took into account the predicted change in the radionuclide content in the surface layer of the atmosphere near the atomic power plant as a result of the decommissioning of energy units (12th in 1990, 3rd in 1996, 4th in 1997, and 5th in 2005) and some other engineering equipment (ILK in 1966) and the commissioning of the 6th (in 1996) and 7th (in 1997) power units.

The dose burdens on the forest stands is to decrease substantially in the period from 1990 to 2027. The maximum radiation dose of the arboreal layer of forests in the 30-km zone in 1990 was $1.8 \times 10^{-8}$-2-10⁻⁶ Grd/yr. From 1991 to 1996
it will decrease down to $9 \cdot 10^{-9} - 7 \cdot 10^{-7}$ Grd/yr. From 1997 to 2005, after the decommissioning of the 3rd and 4th power units and the ILK and the commissioning of the 6th and 7th power units, the dose burdens will be roughly at the same level and will begin to decrease in 2006, after the decommissioning of the 5th power unit ($2.9 \cdot 10^{-10} - 2.4 \cdot 10^{-8}$ Grd/yr).

When making a conservative estimate, it is desirable to compare the possible radiation effects at the calculated maximum dose ($1.8 \cdot 10^{-6}$ Grd/yr) absorbed by the arboreal layer at the western boundary of the pine forest area closest to the atomic power plant, at a distance of approximately 2 km from the plant, with the observed radiation damage from results of studies carried out on the most radiosensitive form of forest vegetation, the pine *Pinus sylvestris*. Conifers (in the given use the *Pinus* species) have an exceptionally radio-sensitivity, close to that of humans. According to the data of various workers [1, 2, 8], the 100% lethal dose ranges from 6 to 100 Grd for individual species of pine. In the region of the Chernobyl disaster four years after the discharge pine forests have been observed to die out completely at a dose of 80-100 Grd [6]. Since even the minimum of this dose range (6 Grd) is more than 10^6 times the calculated radiation dose of forest near the Novovoronezh Plant, one should not expect any somatic effects due to inhibition of the growth and development of vegetation in the 30-km zone. Many years of studies [9] have shown that the mass and quality of the seeds do not change when conifer stands receive a chronic radiation dose of 0.73 Grd/yr. This enables us to conclude that the ability of even the most radiosensitive species of trees to reproduce fully is not affected at the given levels of irradiation.

Under the conditions of normal operation from the standpoint of the effect on the nearest forest stands the Novovoronezh Plant meets the requirements of ecological safety.

**Assessment of the Potential Consequences of Accidental Discharges on Forest Ecosystems.** To assess the possible effect of accidental discharges on forest stands we used calculated data on the density of radioactive fallout in the 30-km zone for various variants of possible accident situations: the maximum possible design-basis accidents with a discharge height of 15 and 50 m and other accidents with a discharge height of 15, 50, and 750 m. The total discharges with regard to the main dose-forming radionuclides ($^{90}$Sr, $^{131}$I, $^{137}$Cs) for the maximum possible design-basis and other accidents with a discharge height of 15 and 50 m are several tens of times smaller than the discharges of these radionuclides from the Chernobyl disaster and correspond to the design documentation of the Novovoronezh Plant. The total amount of $^{90}$Sr, $^{131}$I, $^{137}$Cs entering the environment in the case of the most serious non-design-basis accident is comparable to the total amount of these radionuclides discharged by the Chernobyl disaster [4]. The discharge from a major accident of this kind is equivalent to the discharge from the accident in the southern Urals (1957) only in regard to $^{90}$Sr. A significant difference between the southern Ural accident and the accident situations under consideration is that $^{131}$I was absent from the southern Ural discharge [9].

The range of accident situations analyzed thus makes it possible to assess all possible cases involving the action of radioactive discharges on forest biogeocenoses from nuclear power plant accidents of various degrees of severity. In calculating the dose burdens we took into account the same processes of radionuclide migration in forests as when estimating the absorbed dose for the case when the Novovoronezh Atomic Power Plant functions normally. The radiation damage to the arboreal layer was predicted with allowance for the absorbed dose formed in the first year after the accidental discharge.

On the basis of the scenarios considered the radioactive discharge occurs in a short interval at a time when the wind direction may differ markedly from the seasonal average; accordingly, we calculated the consequences from the effect of the accidental discharges for four or five directions, determined from an analysis of the spatial structure of the location of the forest areas in the 30-km zone of the Novovoronezh Plant. These directions were chosen so as to adequately estimate the range of possible consequences from the effect of the accidental discharges on the forest stands. Considering the calculated dose burdens in the first year after the maximum possible, design-basis accident (discharge height 15 and 50 m), we must note that although the total amount of radionuclides entering the environment in both scenarios is the same ($2.0 \cdot 10^{11}$ Bq $^{90}$Sr, $1.5 \cdot 10^{13}$ Bq $^{131}$I, and $2.2 \cdot 10^{12}$ Bq $^{137}$Cs), their spatial distribution in the 30-km zone, as well as the composition of the fallout, and as a result the dose burdens on the forest areas in the region of the Novovoronezh Plant differ substantially. The maximum radiation dose (0.1 Grd/yr) on the forest stands is observed in the case of the maximum possible, design-basis accident with radionuclides discharges to a height of 15 m at a distance of 2 km from the power plant with the radioactive cloud spreading eastward (Fig. 1). With distance from the power plant for the given accident scenario the dose burdens on the forest ecosystems decrease abruptly and the possible range of dose burdens in the first year after the accident on the arboreal layer of the forests (in all directions) is $2.7 \cdot 10^{-6} - 1.0 \cdot 10^{-1}$ Gy/yr. At a discharge height of 50 m the radionuclides are distributed more uniformly over the territory of the radioactive track, which is responsible for the narrower range of absorbed dose $5.0 \cdot 10^{-4} - 5.6 \cdot 10^{-3}$ Grd/yr. The maximum dose burdens on the forest stands are found at a distance of about 5 km from the power plant ($5.6 \cdot 10^{-3}$ Grd/yr). For both variants under consideration the maximum possible design-basis accident is characterized by a wide radioactive track.