



(RESEARCH ARTICLE)



Trade-offs in the process of enrichment of tree plantations in sanitary protection zones of enterprises regarding the peculiarities of potential accumulation of toxicants in the leaves of trees

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Abstract

Plants serve as a versatile filter that is capable of purifying the atmospheric air from various toxic substances. In this study we investigate the green areas of sanitary protection zones of PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises in the city of Zaporizhzhya, Ukraine. The forest stands growing in these zones were surveyed using the route method and the level of accumulation of water-soluble phenolic compounds, sulfur and fluorine in the leaves of plants was determined. On the basis of the data obtained during our investigation, compromise plans were proposed for enriching the tree flora growing in the area of green spaces of sanitary protection zones of PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises, taking into account both their current and potential gas absorption capacity. Taking into account the environmental conditions and the natural resistance of plants, as far as protective plantations of the PrJSC "Ukrgrafit" enterprise and the species composition of forest belts of the Zaporizhzhya Aluminium Plant PJSC, the second and the fifth variants in the first case, as well as the fifth and the sixth variants in the second case, were determined as being the best options available for the purpose of tree flora enrichment.

Keywords: Accumulation; Fluorine; Industrial enterprises; Phenolic compounds; Plantation options; Species composition of trees; Sulfur dioxide; Tree flora

1. Introduction

Air pollution, which is a major problem in the civilized world, has a serious toxicological impact on the environment and is a threat to public health, causing cardiovascular [1–4], respiratory [5, 6] and various other diseases. Industrial processes are regarded as the main contributor to air pollution. Harmful pollutants that originate from the aforementioned sources include sulfur oxides [7–9] carbon oxides, fluorine, phenolic compounds, nitrogen oxides etc. [10, 11].

Contaminants can cause leaf tissue destruction (necrosis) [12–14]. Under the influence of chlorine gas, the following acute morphological and physiological effects on species of coniferous plants were described and assessed: chlorosis, necrosis, decreased photosynthetic efficiency, damage to chloroplast membranes [14–16]. Trees growing near industrial enterprises suffer from a decrease in the average leaf area with a higher percentage of said area being damaged [17]. Changes in the content of assimilation pigments under the influence of industrial pollution are observed [18, 19] and the rate of photosynthesis decreases [20]. Emissions of dangerous pollutants, which include fluorine, phenolic compounds and sulfur, can lead to contamination of agricultural land in Zaporizhzhya region, where grains and oilseeds are being grown. This will weaken Ukraine's food security and prevent international export commitments as a result of agricultural products rapidly deteriorating in quality [21].

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Green plantations of the sanitary protection zones of industrial enterprises act as a natural filter that retains solid particles [22–26], reduces the amount of dust [27, 28]. Plants are capable of accumulating harmful toxicants [13, 17, 29–30], whereby their concentration in the leaves increases during the growing season [31]. This limits the spread of ingredients of industrial emissions not only to the city's living areas but also to the surrounding crop fields.

The aim of the study is to offer compromise plans for the enrichment of green spaces of sanitary protection zones of PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises, taking into account their potential gas absorption capacity.

2. Material and methods

Research was carried out in the areas of sanitary protection zones of a number of enterprises in the city of Zaporizhzhya (47°49'22" N.L., 35°11'25" E.L.): Zaporizhzhya Aluminium Plant PJSC (ZALK) and «Ukrainian Graphite» PJSC (Ukrgrafit). Inspection of the forest stands of the sanitary protection zones of the investigated enterprises was carried out by the route method, taking into account all of the trees growing in each specific forest belt. The study of the species composition of the tree flora was performed according to [32] using reference publications [33]. Plant names were given by [34].

Water-soluble phenolic compounds were detected from an aqueous extract of phytomass by the method of [35], using a Folin-Ciocalte reagent. Fluoride content was determined by L.A. Khazemova et al. [36]. Determination of sulfur content was performed spectrophotometrically by the method of A.D. Mochalova (1975) [37].

The total mass of leaves obtained from studying the model tree was determined by the formula given by V.G. Nesterov and B.M. Bobilev (1967) [38]:

$$P = \frac{\pi}{4} \rho \left(l \sum D_j^2 + \frac{1}{3} l_1 D_{j+1}^2 \right),$$

where P – total mass of tree leaves, kg; ρ – the weight of leaves per 1 m³ of the crown, kg/m³; D_j – diameters of the crown, m; l – the distance between the cross-sections, m; l_1 – length of the apex, m.

The average content of a particular toxicant in the leaves of tree plants was then calculated.

H.M. Il'kun (1978) [39] is credited with the idea of using woody plants to purify the atmospheric air from pollutants, namely the idea of a balanced method, which assumes not only the content of pollutants in the leaves but their potential outflow to other organs or its removal by precipitation (a certain percentage depending on a given month of a growing season). This approach makes it possible to assess the potential filtering role of plants and not just the end result of the accumulation of pollutants in the leaves of tree species.

Environmental purification role in the absorption of sulfur by tree plantations was assessed using the formula by S. A. Sergeychik (1997) [40]:

$$P = K * Y \frac{T_B}{T_y}$$

P – absorption capacity of 1 ha of plantations per growing season, kg/ha; Y – dry phytomass of leaves and/or needles, kg; K – coefficient of physiologically acceptable accumulation of sulfur (hardwood – 0,002, coniferous – 0,0001); T_B – the duration of the growing season; T_y – period of time needed for the removal of sulfur from leaves and/or needles (10 days).

Creating a multicriteria optimization model was carried out in the following sequence. Biodiversity is provided by N species of trees. In the conditions of sanitary protection zones of such enterprises as PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC 20 species of trees are being grown.

But in specific contexts, it is advisable to choose the most efficient and naturally resistant species, depending on the level of contamination with certain toxicants, which makes specific the value of N .

Let x be the number of new trees of the i -th species to be planted $i = 1 \dots N$. Adhering to the content, all entered unknowns accept only non-negative integer values, that is, $x_i \geq 0$.

The composition of the tree flora of protective forest strips is described by known quantities (except for trees that are to be replaced):

y_i^1 – number of young trees of the i -th species,

y_i^2 – middle age trees of the i -th species,

y_i^3 – mature trees of the i -th species, $i=1 \dots N$.

Then let A_1 and A_2 determine the needs of supplementing the quantitative composition of the trees growing in the green zones, taking into account the condition of the existing plantations and the area of the territory of the sanitary protection zone without plantations. From this we obtain our restrictions here:

$$\sum_{i=1}^N x_i \geq A_1, \quad (1)$$

$$\sum_{i=1}^N x_i \leq A_2. \quad (2)$$

Species diversity requirements (no less than B tree species) are taken into account by the ratio:

$$\sum_{i=1}^N \text{sign}(x_i) \geq B. \quad (3)$$

Let's denote by a_i the basic fluorine accumulation (g), b_i – basic accumulation of phenolic compounds and c_i – baseline sulfur accumulation depending on the level of pollutant concentration around a given enterprise per phytomass (kg), produced by one tree of the i -th species, $i=1 \dots N$.

The production of plant leaf phytomass in the sanitary protection zones of PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises is averaged for all species in each age category and amounts to:

for young trees $k_1 = 3$ kg,

for middle-aged trees $k_2 = 10$ kg,

for mature trees $k_3 = 6$ kg,

The total amount of uptake of pollutants in the protective forest strips of these enterprises was calculated by the formulas given below:

$$\text{for fluorine: } F_1 = \sum_{i=1}^N (x_i \cdot k_1 + \sum_{j=1}^3 y_i^j \cdot k_j) \cdot a_i, \quad (4)$$

$$\text{for phenolic compounds: } F_2 = \sum_{i=1}^N (x_i \cdot k_1 + \sum_{j=1}^3 y_i^j \cdot k_j) \cdot b_i, \quad (5)$$

$$\text{for sulfur: } F_3 = \sum_{i=1}^N (x_i \cdot k_1 + \sum_{j=1}^3 y_i^j \cdot k_j) \cdot c_i. \quad (6)$$

Alternating selection in the models from (1)–(6) as the maximized criterion of the functions from (4)–(6) will allow to find the optimal arrangement for the enrichment of green zones by the tree species with a maximum absorption capacity for fluorine, phenolic compounds and sulfur on the yet unused territory and to realize the replacement of the dead-wood.

Let's mark in our plans F_j^{min} and F_j^{max} – the largest and smallest total accumulation of pollutants.

In order to determine the compromise plans for the enrichment of sanitary protection zones of PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises, it is possible to determine the absorption values in the range $[F_j^{min}, F_j^{max}]$ according to the level of accumulation of each of the toxicants and also to obtain alternative models of the quantitative composition of tree species growing near the industrial enterprises.

The quantitative assessment of woody plants did not take into account the number of the self-seeding species growing in the area of sanitary protection zones of the PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises.

3. Results and discussion

The practical implementation of the proposed multicriteria optimization model according to formulas (1)–(6) was realized using the MS Excel spreadsheet environment for two enterprises in the city of Zaporizhzhya – PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC.

We have examined the green plantations of sanitary protection zones of PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises for which the species composition of the tree flora amounts to $N = 20$ species [41, 42]. The quantitative characteristics of the uptake of pollutants such as sulfur, phenolic compounds, fluorine and the quantitative composition of the forest stands of the protective forest strips of enterprises (except for the trees that are described as dead-wood and are to be replaced) are contained in Tables 1 and 3.

Table 1 Input parameters of the protective plantation of the "Ukrgrafit" enterprise

Nº	Tree species	Number of trees	a_i , g/kg	b_i g/kg	c_i , g/kg	y_i^1	y_i^2	y_i^3	Moribund
1	<i>Acer negundo</i>	2	0,06762	0,4344	3,8	2	0		
2	<i>Acer platanoides</i>	13	0,08137	0,2412	4	7	5		1
3	<i>Ailanthus altissima</i>	53	0,09928	0,4395	3	5	48		
4	<i>Catalpa bignonioides</i>	1	0,08549	0,3962	4,1		1		
5	<i>Elaeagnus angustifolia</i>	1	0,14971	0,4938	2,8		1		
6	<i>Fraxinus lanceolata</i>	37	0,09928	0,2706	4	21	16		
7	<i>Juglans regia</i>	9	0,08562	0,4395	4,1	6	3		
8	<i>Malus domestica</i>	4	0,09928	0,4395	4,1		4		
9	<i>Morus alba</i>	116	0,09774	0,2388	2,7		115		1
10	<i>Populus alba</i>	70	0,12475	0,7422	6,1		60	10	
11	<i>Populus nigra</i>	3	0,12781	1,0333	4,9			3	
12	<i>Populus pyramidalis</i>	1	0,11596	0,5664	4,1			1	
13	<i>Populus simonii</i>	4	0,13232	0,8172	4,5		4		
14	<i>Pyrus communis</i>	1	0,09928	0,4395	4,1		1		
15	<i>Robinia pseudoacacia</i>	365	0,06136	0,3030	5,1	14	285	61	5
16	<i>Salix alba</i>	2	0,11074	0,2922	4,2		2		
17	<i>Thuja orientalis</i>	4	0,09928	0,4395	4,1	3	1		
18	<i>Tilia cordata</i>	7	0,0628	0,2172	5	4	3		
19	<i>Ulmus laevis</i>	61	0,10534	0,2418	4,1	2	35	24	
20	<i>Ulmus carpinifolia</i>	183	0,09956	0,3054	2,9	3	134	42	4

The green area of the protective forest strip of the PrJSC "Ukrgrafit" enterprise consists of 937 trees. The assessment of the need to supplement the quantitative composition of trees, to replace the dead-wood in the sanitary protection zone of this enterprise and to ensure the biodiversity is characterized by the following values: $A_1 = 73$, $A_2 = 88$, $= 7$.

The compromise plans of supplementing the trees in order to fill the gaps in rows and empty regions of land and replacing the dead-wood are outlined in (Table 2).

The selection of plants for the purpose of enrichment (supplementation) should also take into account the environmental conditions of growth and resistance of plants to pollutants produced by these enterprises. In the first, fourth and last (sixth) embodiment, the trees of the *Salicacea* family appear to be quantitatively dominant. In the third variant, the largest number of trees proposed for planting in the sanitary protection zone of the "Ukrgrafit" enterprise belongs to the *Acer negundo* specimens. This species is characterized by high self-healing ability, which affects negatively the structure of the plantation. Natural seed renewal of *Acer negundo* is commonly observed on the fringes of the objects of landscaping, parkways, degraded communities, and the like. Species that spontaneously propagate in natural and artificial ecosystems pose a threat to their stability and natural resistance [43]. In the second and fifth variants, *Ailanthus altissima*, *Morus alba*, *Robinia pseudoacacia* and representatives of the *Ulmaceae* family predominate. The species proposed in these variants are characterized by their considerable resistance to the ecological conditions of the Ukrainian Steppe but also to the significant concentrations of toxicants.

Table 2 Compromise variants of enriching the plantations of sanitary protection zones of the "Ukrgrafit" enterprise are assessed using the models (1)–(6)

Values	Tree species	Alternative variant					
		1	2	3	4	5	6
x_1	<i>Acer negundo</i>			38			1
x_2	<i>Acer platanoides</i>						
x_3	<i>Ailanthus altissima</i>		28		16	17	1
x_4	<i>Catalpa bignonioides</i>						
x_5	<i>Elaeagnus angustifolia</i>	27					3
x_6	<i>Fraxinus lanceolata</i>					5	
x_7	<i>Juglans regia</i>					5	1
x_8	<i>Malus domestica</i>						1
x_9	<i>Morus alba</i>		20		12	12	
x_{10}	<i>Populus alba</i>	14	4	16	13		13
x_{11}	<i>Populus nigra</i>	15		18	17		24
x_{12}	<i>Populus pyramidalis</i>	9		10	9		6
x_{13}	<i>Populus simonii</i>	18					38
x_{14}	<i>Pyrus communis</i>						1
x_{15}	<i>Robinia pseudoacacia</i>	0	27		1	23	
x_{16}	<i>Salix alba</i>	1		1	1		
x_{17}	<i>Thuja orientalis</i>						
x_{18}	<i>Tilia cordata</i>		2		12		
x_{19}	<i>Ulmus laevis</i>	3	5	3	3	12	
x_{20}	<i>Ulmus carpinifolia</i>		2			12	
	F_1	745,9	734,1	736,4	737,7	734,3	744,5
	F_2	2902,3	2811,7	2882,1	2859,7	2803,1	2935,2
	F_3	35388,0	35277,8	35441,3	35363,4	35258,5	35515,5

Remark: F_1, F_2, F_3 – the content of toxicants (fluorine, phenolic compounds and sulfur, g) in the leaves of tree species that are growing in the green area of the enterprise, taking into account the factor of enrichment of green plantations.

Tree plantations of the sanitary protection zone of the "Ukrgrafit" enterprise, which amount to 937 specimens, produce 8230 kg of phytomass. Each year, 0.7 kg of fluorine, 2.7 kg of phenolic compounds and 34.3 kg of sulfur are concentrated in the leaves of tree plants. However, the actual forest absorption potential is much higher. In general, the protective plantations of the enterprise absorb 296.3 kg of sulfur or 592.6 kg of sulfur dioxide, 7.9 kg of phenolic compounds and

1.9 kg of fluorine. In case of enrichment and replacement of deadwood with new breeds, the sanitary protection zone of the "Ukrgrafit" enterprise will absorb 0.3 kg more phenolic compounds from the atmospheric air as well as 10 kg more sulfur. In 10 years' time, the forest belt of the "Ukrgrafit" enterprise will absorb 328.0 kg of sulfur (656.0 kg of SO₂), 8.8 kg of phenolic compounds and 2.0 kg of fluorine (Fig. 1).

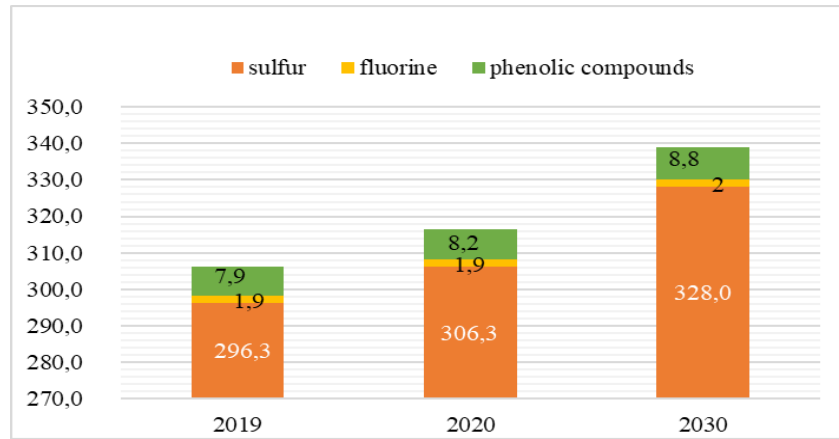


Figure 1 Actual (2019) and projected (2020, 2030) absorption capacity of plantations of the sanitary protection zone of "Ukrgrafit" enterprise, kg.

Plantation of the sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC industrial enterprise consists of 954 trees in total.

Table 3 Input parameters of the protective plantation of the Zaporizhzhya Aluminium Plant PJSC industrial enterprise

Nº	Tree species	Quantity	a _i , g/kg	b _i g/kg	c _i , g/kg	y _i ¹	y _i ²	y _i ³	Moribund
1	<i>Acer pseudoplatanus</i>	2	0,44308	0,3456	3,5	1	1		
2	<i>Aesculus hippocastanum</i>	11	0,60026	0,1284	3,6		11		
3	<i>Ailanthus altissima</i>	27	0,43326	0,6192	2,7	2	25		
4	<i>Betula pendula</i>	2	0,28071	0,3718	5		2		
5	<i>Catalpa bignonioides</i>	16	0,49721	0,3012	3,9	6	10		
6	<i>Fraxinus lanceolata</i>	57	0,42083	0,2184	3,4	9	42		6
7	<i>Morus alba</i>	9	0,5226	0,1692	1,9	3	6		
8	<i>Picea pungens</i>	13	0,44308	0,3718	3,5	4	9		
9	<i>Platanus acerifolia</i>	1	0,2891	0,3718	3,5		1		
10	<i>Populus alba</i>	29	0,64267	0,6870	4,5		24	5	
11	<i>Populus nigra</i>	5	0,67011	0,9264	3,7		4	1	
12	<i>Populus Simonii</i>	1	0,57936	0,6798	3,7		1		
13	<i>Quercus robur</i>	3	0,44308	0,3718	3,5	3	0		
14	<i>Robinia pseudoacacia</i>	348	0,2756	0,2610	4,2	14	325	5	4
15	<i>Salix alba</i>	15	0,6029	0,2304	3,2		9	6	
16	<i>Sorbus aucuparia</i>	2	0,44308	0,3718	3,5		2		
17	<i>Thuja orientalis</i>	6	0,44308	0,3718	3,5	1	5		
18	<i>Tilia cordata</i>	14	0,26031	0,1830	4	6	6		2
19	<i>Ulmus laevis</i>	32	0,27071	0,2568	3,5	2	25	4	1
20	<i>Ulmus carpinifolia</i>	361	0,31054	0,1992	2,1	6	329	21	5

Plans to supplement the quantitative composition of the green space of the Zaporizhzhya Aluminium Plant PJSC were outlined using the MS Excel spreadsheets environment. The assessment of the need for the renewal of the quantitative composition of the trees in the sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC, while ensuring the biodiversity is characterized by the following values: A₁ = 64, A₂ = 82, B = 7. Compromise plans for the enrichment

(supplementation) of protective forest belts of the Zaporizhzhya Aluminium Plant PJSC industrial enterprise are demonstrated in Table 4.

Table 4 Compromise variants of enriching the plantations of the sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC are assessed using models (1)–(6)

Values	Tree species	Alternative variants					
		1	2	3	4	5	6
x_1	<i>Acer pseudoplatanus</i>						
x_2	<i>Aesculus hippocastanum</i>	12	10				
x_3	<i>Ailanthus altissima</i>			5		17	14
x_4	<i>Betula pendula</i>						
x_5	<i>Catalpa bignonioides</i>		1				
x_6	<i>Fraxinus lanceolata</i>			45	26		1
x_7	<i>Morus alba</i>	3	1			9	
x_8	<i>Picea pungens</i>						
x_9	<i>Platanus acerifolia</i>						
x_{10}	<i>Populus alba</i>	17	15	6			6
x_{11}	<i>Populus nigra</i>	20	18	1	1	4	1
x_{12}	<i>Populus Simonii</i>	10	8				
x_{13}	<i>Quercus robur</i>						
x_{14}	<i>Robinia pseudoacacia</i>			20	10	27	37
x_{15}	<i>Salix alba</i>	19	11				
x_{16}	<i>Sorbus aucuparia</i>						
x_{17}	<i>Thuja orientalis</i>						3
x_{18}	<i>Tilia cordata</i>					1	
x_{19}	<i>Ulmus laevis</i>				42		
x_{20}	<i>Ulmus carpinifolia</i>					18	
	F_1	3065,8	3037,8	3011,1	2994,0	3010,3	3021,2
	F_2	2427,4	2410,9	2369,7	2359,4	2389,8	2377,4
	F_3	29171,4	28992,2	29112,3	29101,2	29022,1	29192,6

Remark: Same as Table 2

The proposed plans for supplementing the plantations of the sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC are somewhat different, but the difference in the accumulated toxicants is not significant. When selecting species of woody plants, resistance to pollutants and the ability to grow in accordance with the given environmental conditions should be taken into account. In the first and second variants, considerable preference is given to *Aesculus hippocastanum* and *Populus alba*. In the third and fourth embodiment – *Fraxinus lanceolata* and *Robinia pseudoacacia*. In the last two, the maximum number of proposed trees is attributed to such species as *Robinia pseudoacacia* and *Ailanthus altissima*. V.P. Bessonova and O.A. Ponomaryova (2016), in their works pointed out that plantations of *Robinia pseudoacacia* in the southern regions of Ukraine appear to be the most dominant and perform protective, purifying functions and are characterized by a high level of vitality [44]. The same characteristics are applicable to *Ailanthus altissima*. Therefore, the most promising are the last two variants of supplementing the protective forest belts of the sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC.

Provided the young trees are to be planted, the leaves of woody plants growing in the area of plantations of the sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC industrial enterprise will accumulate almost 3.0 kg of fluorine, 4.4 kg of phenolic compounds and approximately 29.1 kg of sulfur.

Taking into account the loss of phytotoxicants through leaves (as described in the calculation of their accumulation for the trees growing in the sanitary protection zone of the "Ukrgrafit" enterprise for the entire period of the growing season) and outflow to other organs (Il'kun, 1978), 316.3 kg of sulfur, i.e. 632.6 kg of sulfur dioxide, is absorbed, as well as 8.6 kg of fluorine and 7.3 kg of phenolic compounds. As new trees are being planted and deadwood is being replaced, the role of sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC will increase with time. In all of the plans proposed (1-6), the accumulation potential will increase by 9 kg in the case of sulfur and will equal 325.2 kg of sulfur or 650.4 kg of sulfur dioxide. The absorption of fluorine and phenolic compounds will increase by 300 grams each. And only in 10 years' time the enriched plantation of the sanitary protection zone will absorb 9.6 kg of fluorine, 8.0 kg of phenolic compounds and 345 kg of sulfur (or 690 kg of SO₂) (Fig. 2).

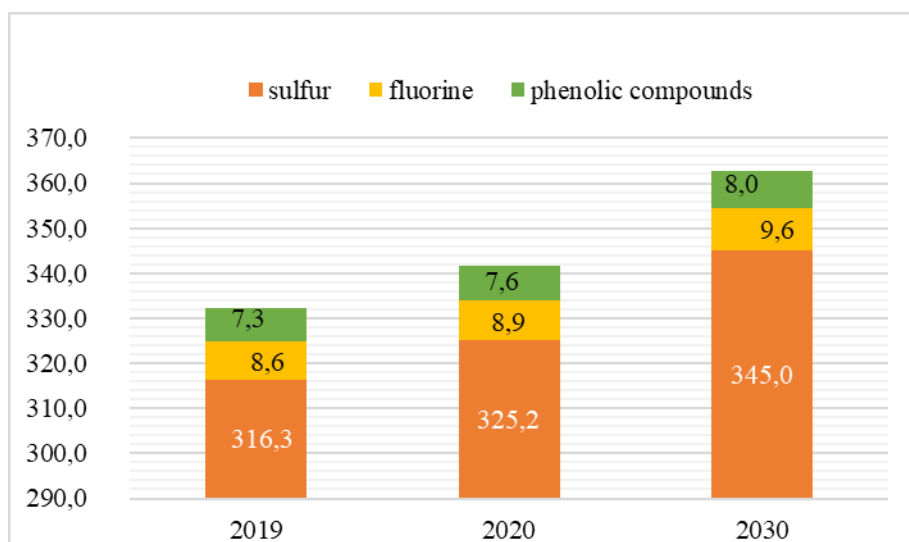


Figure 2 Actual (2019) and projected (2020, 2030) absorption capacity of plantations of the sanitary protection zone of the Zaporizhzhya Aluminium Plant PJSC, kg

In terms of 1 ha of permeable dense forest shelterbelt, the potential absorption capacity will be as follows: sulfur – 160 kg (or 320 kg sulfur dioxide), fluorine – 1.0 kg, phenolic compounds – 4.3 kg; and for the Zaporizhzhya Aluminium Plant PJSC it will be: sulfur – 166.5 kg (or 333 kg sulfur dioxide), fluorine – 4.6 kg, phenolic compounds – 3.9 kg. For comparison, the data from other authors on the purifying role of plantations of woody plants is listed below.

According to P.P. Yavornytskyi (2014) [45], 0.4 ha of sulfur gas and 0.1 tonnes of chlorides are absorbed by 1 ha of forest plantations. V.P. Tarabrin (1985) [46] indicates that one plant is able to absorb and neutralize 150 g of heavy metals, 900-1000 g of gaseous substances and 1 ha of green plantations of (500 - 700) trees inactivate 700-800 kg of gases during the growing season.

According to the estimates by W. H. Smith (1985) [47], 1 ha of forest absorbs 748 kg of SO₂, or 374 kg of sulfur. In this case, the green phytomass of woody plants (856 kg) will contain 2.2 g of sulfur per 1 g. O.V. Chernyshenko (2010) [48], however, describes the figures given to us by W.H. Smith that are meant to estimate the capacity of plants to absorb gaseous substances as being overstated.

4. Conclusion

We have devised the compromising plans of replacing deadwood and enriching the protective plantations of PrJSC "Ukrgrafit" and Zaporizhzhya Aluminium Plant PJSC industrial enterprises. The aim is to improve the purifying role of woody plants growing in the green area of these enterprises. Considering environmental conditions and the natural resistance of plants, the second and the fifth in the case of protective forest belts of the "Ukrgrafit" enterprise as well as the fifth and sixth variants in the case of species composition of the Zaporizhzhya Aluminium Plant PJSC appear to be the best options for the purpose of enrichment (supplementation) of the aforementioned green plantations.

Implementation of variants of compromise plans for the renewal of green areas will contribute to the growth of the role of protective forest strips in purifying the environment. Leaves of woody plants of the sanitary protection zone of the "Ukrgrafit" enterprise will absorb 160 kg of sulfur (or 320 kg of sulfur dioxide), 1,0 kg of fluorine and 4,3 kg of phenolic compounds. Whereas in the case of Zaporizhzhya Aluminium Plant PJSC, 166.5 kg of sulfur (or 333 kg of sulfur dioxide), 4.6 kg of fluorine and 3.9 kg of phenolic compounds will be absorbed.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares no conflicts of interest.

Statement of ethical approval

'The present research work does not contain any studies performed on animals/humans'.

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