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## Ash Content of Ornamental Plants in Urban Environment (Through the Example of the Cities of the Novosibirsk Region)

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### Abstract

The results of determining the ash content of perennial and annual plants growing near industrial zones, roads and in the urban environment of the administrative centres of the Novosibirsk Region (Iskitim, Berdsk, Novosibirsk) are presented. These plant habitats differ in the degree of anthropogenic impact on the environment, with the greatest pollution in the city of Iskitim. It is noted that the ash content of the leaves of plants of different systematic groups is determined by many factors, including species and varietal belonging, anthropogenic pollution of the environment, and the features of the growing season. A decrease in the content of ash substances in the leaves of herbaceous plants belonging to the families Hemerocallidaceae > Asteraceae > Iridaceae > Hostaceae > Laminaceae was established.

**Keywords:** leaf, ash content, herbaceous plants, urban environment, Novosibirsk Region

### INTRODUCTION

The Novosibirsk urban agglomeration is distinguished by a large network of industrial zones that are situated in the suburbs or in small towns of the Region. The zone with the highest urbanization is the town of Iskitim and its vicinities, where more than 15 industrial facilities are situated, in particular the largest plant in the Novosibirsk Region (SC Iskitimtsement) and three large enterprises mining mineral resources. In 2018, the environmental monitoring and ecological control services recorded 39 cases of extremely high and high pollution of atmospheric air (excess over the MPC by a factor of 10 and more) in the cities of Siberia and Transbaikalia. Among them, there are Iskitim and Novosibirsk, where the permissible level of carcinogenic benz(a)pyrene was exceeded by a factor of 17 and 21, re-

spectively [1]. The major effect on the state of vegetation in Novosibirsk is caused by the industrial and road complex [2, 3]. The urban forestry in small towns is insufficient, especially in the territories near industrial zones. The ecological medium in the system of urban and industrial complex causes a specific effect not only on the growth and development of herbaceous plants but also on the accumulation of the compounds of ash-forming elements (K, Ca, Mg, Fe, Mn, Zn, etc.), which are present in the ash after the removal of the organic substances from the phytomass. It is known that the ash content of leaves depends on many factors including the special and varietal diversity, and on the quality of the environment in which the plants are grown [4–9].

The goal of the work was to carry out a comparative analysis of the ash content of the leaves of flowering decorative plants growing near

the industrial zones and motor roads in the town of the Novosibirsk Region (Berdsk, Iskitim, Novosibirsk).

## EXPERIMENTAL

In the work, we studied the plants that were grown in plant gardens: *Hemerocallis hybrida* (Hemerocallidaceae family), *Iris hybrida* (Iridaceae family), *Hosta lancifolia* Engl. (Hostaceae family), *Salvia splendens* (Lamiaceae family), *Malva hybrida* (Malvaceae family), *Tagetis patula* (Asteraceae family), *Senecio cineraria* (Asteraceae family), *Tussilago furfara* L. (Asteraceae family), *Leucanthemum vulgare* Lam. (Asteraceae family), *Alyssum hybrida* (Brassicaceae family).

The plant raw material was collected during the vegetation period of the year 2018 under the conditions of the urban environment:

1) near motor roads at a distance of 50–100 m in plant gardens of Novosibirsk (the Central district: Chelyuskintsev str., Krasniy avenue; the Sovetskiiy district: Zolotodolinskaya str., Rossiyskaya str., Shaturskaya str.), Berdsk (Rogachev str., Rossiyskaya str., Krasnaya Sibir), Iskitim (Sovetskaya str., Komsomolskaya str.);

2) near the industrial zones of Iskitim (Zavodskaya str. – SC Iskitimtsement, PC Concrete Products Plant No. 13; Kommunisticheskaya str. – SC EPM-Novosibirsk Electrode Plant, Yuzhbiy Mikrorayon str. – SIBIT plant of PC Glavnovosibirskstroy, Berdsk (Klyuchevaya str., – PC Berdsk Brick Plant).

The reference samples were the plants from the bioresource scientific collection of the Central Siberian Botanical Garden SB RAS (CSBG SB RAS; “Collection of living plants growing outdoors and indoors”, UNU No. USU 440534), grown under conditions with minimal technogenic load at the ground of the laboratory of decorative plants. Leave samples after washing from dust were dried to the air-dry state, ground to the fine fraction, sieved through a sieve with the mesh size of 1 mm. Determination of ash content (total ash, % of the mass of the dry substance) was determined by means of dry ashing based on the combustion of the organic substances in a muffle furnace according to GOST 24027.2–80 [10]. Analyses were repeated three times for each sample. Mathematical processing was carried out with the Statistica 6.1 and Microsoft Office Excel 2007 software.

## RESULTS AND DISCUSSION

Different degrees of the technogenic load had definite effects on the accumulation of ash elements in the leaves of herbaceous plants from different systematic groups (Table 1). Diverse data were obtained with respect to industrial zones. The highest ash content in the leaves of *S. splendens* (7.93–8.03 %) and *T. patula* (7.72–7.96 %) is observed in the vicinity of the Berdsk Brick Plant (Klyuchevaya str., Berdsk) and the Concrete Products Plant No. 13 (Zavodskaya str., Iskitim). The high ash content of the leaves of *H. hybrida* (8.81–

TABLE 1

Ash content in the leaves of decorative plants near the roads or urban environment and industrial zones of the Novosibirsk Region (% of the mass of dry matter)

Plant species, family	Sampling site			
	1	2	3	4
<i>Iris hybrida</i> (Iridaceae)	7.74 ± 0.26	7.07 ± 0.16	9.74 ± 0.13	7.70 ± 0.26
<i>Hemerocallis hybrida</i> (Hemerocallidaceae)	7.37 ± 0.10	9.85 ± 0.21	8.07 ± 0.13	8.81 ± 0.29
<i>Hosta lancifolia</i> (Hostaceae)	8.52 ± 0.20	8.56 ± 0.23	9.63 ± 0.10	— <sup>a</sup>
<i>Salvia splendens</i> (Lamiaceae)	8.03 ± 0.13	7.33 ± 0.26	7.44 ± 0.23	7.93 ± 0.21
<i>Tagetis patula</i> (Asteraceae)	7.96 ± 0.13	7.15 ± 0.27	7.15 ± 0.10	7.72 ± 0.16

Note. 1 – Berdsk (Klyuchevaya str., Plant); 2 – Iskitim (Sovetskaya str., road); 3 – Novosibirsk (Sovetskiiy district, Shaturskaya str., road); 4 – Iskitim (Zavodskaya str., industrial zone).

<sup>a</sup>No data.

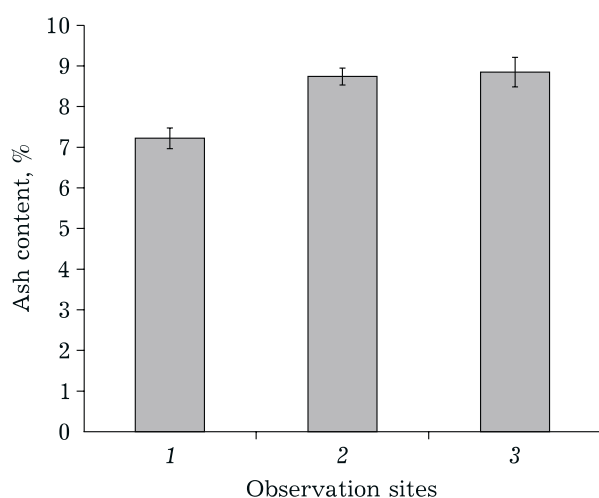


Fig. 1. Ash content of the leaves of *Senecio cineraria* depending on growing site: 1 – Kommunisticheskaya str. (Iskitim, EPM-Novosibirsk Electrode Plant), 2 – Krasniy ave. (Novosibirsk, road), 3 – Sovetskaya str. (Iskitim, road).

9.85 %) was detected in Iskitim near the road (Sovetskaya str.) and near the industrial zone of Iskitim. For the plants of *I. hybrida* and *H. lancifolia* near the roads of the Sovetskiy district of Novosibirsk, the ash content of leaves was higher by 1.12–2.03 % in comparison with the samples from Berdsk and Iskitim. In general, the ash content of the leaves in the regions under investigation depended on the families to which the species belonged (see Table 1) and, as a rule, decreased as a sequence: Hemerocallidaceae > Iridaceae > Hostaceae > Laminaceae > Asteraceae.

It was established that the ash content of the leaves of *S. cineraria* (Asteraceae family) depended on the site where the plants grew (Fig. 1). Near the main roads of the Central district of Novosibirsk and Iskitim, ash content was 9.23–9.44 %, which is higher by 2.44 % than the ash content of the plants grown near EPM-Novosibirsk Electrode Plant (Iskitim).

Among annual and perennial plants growing under the same conditions near SIBIT plant in Yuzhniy Mikrorayon str. (Iskitim), the ash content is higher in the plants of the Asteraceae family (*T. furfara*, *L. vulgare*) than in the plants of the Brassicaceae family (*A. hybrida*) (Fig. 2). The dominating ash content was determined by the authors of [6, 7] also in woody plants from the Asteraceae family. The ash content of the leaves of plants growing at a distance of 50 m from the road in Rossiyskaya str. (Sovetskiy district, Novosibirsk) is somewhat higher for *H. hybrida* (9.89 %) than in *M. hybrida* and *I. hybrida* (Fig. 3). It should

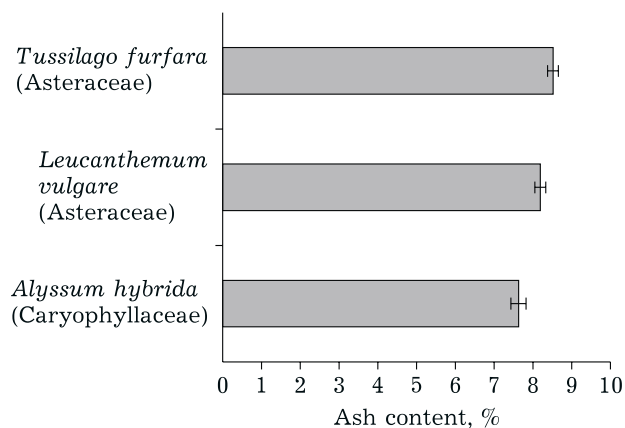


Fig. 2. Comparative ash content in the leaves of annual (*Alyssum hybrida*) and perennial (*Tussilago furfara*, *Leucanthemum vulgare*) plants growing near the SIBIT plant (Iskitim).

be noted that the accumulation of ash substances in the leaves of *H. hybrida* depended on the growing site. For instance, near the Berdsk Brick Plant, the ash content was 7.42 %, while near the road along Krasnaya Sibir str. it was 8.81 %.

It was established by comparing ash content in different organs of *H. lancifolia* that within the third decade of July the ash content of the leaves ( $7.37 \pm 0.20$  %) and rhizomes ( $7.04 \pm 0.15$  % and  $7.41 \pm 0.16$  %, collected in Shaturskaya str. (Novosibirsk) and Rogachev str. (Berdsk), respectively) are comparable and are practically independent of the growing site. The ash content in the leaves of this species decreased by the end of vegetation in the urban environment in comparison with the plants growing under favourable ecological conditions at the territory of the CSBG SB RAS (reference, Zolotodolinskaya str., Novosibirsk, Fig. 4). The same trend was recorded for ash content in the leaves of *H. hybrida* growing in plant gardens in Chjelyuskintsev str. (Novosibirsk), for which these parameters are comparable:  $9.44 \pm 0.39$  % (12.07.18) and  $9.30 \pm 0.27$  % (26.07.18). It should be noted that by the end of the vegetation period (27.09.18) the plants of *H. hybrida* growing under different conditions of the urban load had a different ash content of leaves, which was evidence of different adaptation degrees. In particular, the ash content of leaves decreased in the following order, %:  $9.19 \pm 0.13$  (Shaturskaya str., Sovetskiy district, Novosibirsk),  $8.81 \pm 0.10$  (Krasnaya Sibir str., Berdsk),  $7.07 \pm 0.16$  (Sovetskaya str., Iskitim). In this situation, the plants were adapt-

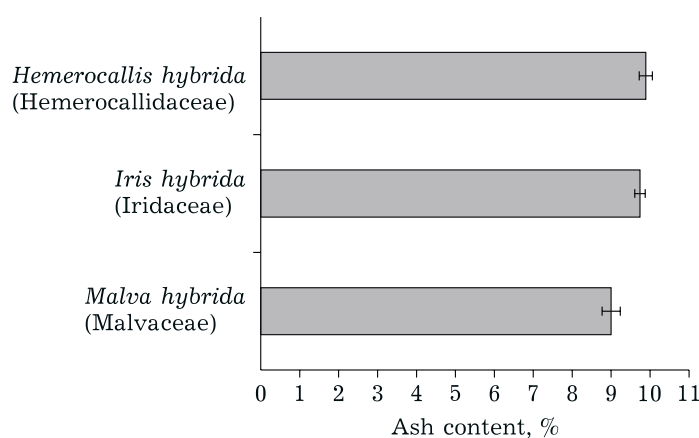


Fig. 3. Ash content in the leaves of plants growing at a distance of 50 m from the road in Rossiyskaya str. (Sovetskiy district, Novosibirsk).

ed to the conditions of the urban environment but had smaller habitus and lower decorative characteristics.

It is known [5] that ash content depends on the species and variety specificity of plants and is possesses individual significance. For instance, it was established during collection and analysis of samples chosen as reference (Zolotodolinskaya str., CSBG SB RAS) during the second decade of July (13.07.18–18.07.18) that the ash content of the leaves of *H. lancifolia* and *Hosta albo-marginata* are comparable and equal to  $9.63 \pm 0.13$  and  $9.78 \pm 0.17$  %, respectively. In *H. hybrida* of Sea Gould variety ( $8.04 \pm 0.16$  %), it was lower by 1.5–2.8 % than in *H. lancifolia* and *H. hybrida* of Regal Air variety ( $10.85 \pm 0.10$  %).

In spite of the fact that the industrial zone in Iskitim includes the objects causing stronger environmental pollution than in Sovetskiy district

of Novosibirsk, the ash content of *T. patula* leaves during the period of mass blossoming (20.08.18–20.09.18) was equal to, %:  $7.52 \pm 0.20$  (Zavodskaya str., Iskitim),  $7.11 \pm 0.29$  (Sovetskaya str., Iskitim) and  $7.44 \pm 0.13$  (Shaturskaya str., Sovetskiy district, Novosibirsk). Comparison of ash content in the leaves of *T. patula* in the industrial zone and near motor roads of Iskitim revealed an insignificant increase within the error limit in Zavodskaya str. (Fig. 5).

Thus, the content of ash-forming elements in the leaves under the conditions of urban environment and industrial zones of the towns of the Novosibirsk Region depends on the species, which is evidently connected with the ecological and biological features of plants. Results obtained on the ash content of leaves may serve as a bioindicator of atmospheric pollution, which was previously reported by the authors of [11–14] for

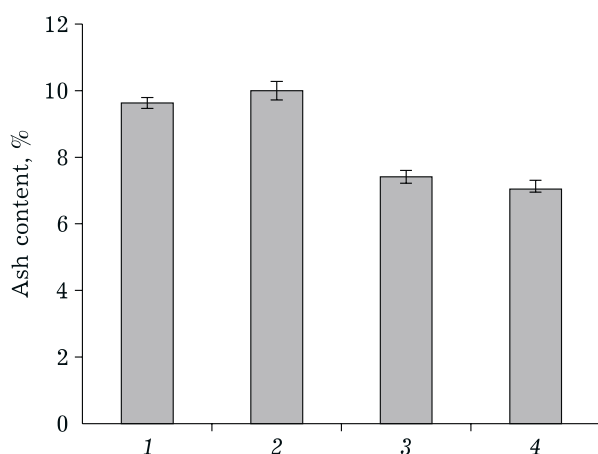


Fig. 4. Distribution of the ash content in the leaves of *Hosta lancifolia* during vegetation period in 2018 (Sovetskiy district, Novosibirsk): 1 – reference (Zolotodolinskaya str., CSBG SB RAS, 22.07); Shaturskaya str.: 2 – 10.06, 3 – 22.07, 4 – 20.08.

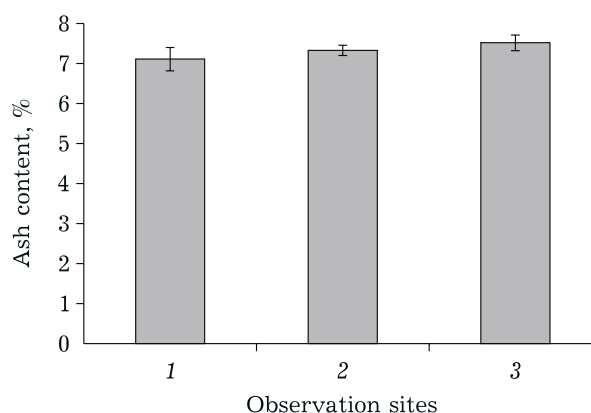


Fig. 5. Ash content in the leaves of *Tagetis patula* depending on growing site in Iskitim: 1 – Sovetskaya str.; 2 – automobile gas filling station at the road off the town; 3 – Zavodskaya str., 1a.

plants of other families. It was established that in heavily polluted sites (Iskitim) the parameters of ash content in the leaves of decorative plants were 7.07–9.74 %; in the sites with a medium level of pollution (Central and Sovetskiy districts, Novosibirsk) – 9.21–9.42 and 7.15–9.47 %, respectively; in slightly polluted sites (Berdsck) – 7.37–8.81 %. In our opinion, the Sovetskiy district (Novosibirsk) occupies an intermediate position in the parameters of ash content of plants between the territories with medium and low pollution levels. However, it should be noted that the effect of technogenic pollution is not the only significant factor forming a definite level of chemism in plants. Thus, in spite of the fact that there are industrial plants including the Brick Plant in Berdsck, the parameters of ash content in the leaves of plants are generally lower than in the industrial zone of Iskitim. An evident reason is the larger number of green zones in Berdsck. The effect of motor roads in urban environments also enhances plant metabolism. It was stressed that ash content is higher in the urban environment in such plants as *S. cineraria*, *H. hybrida*, which are permanently used for planting near the roads in Novosibirsk, Berdsck and Iskitim, in comparison with the industrial zones of Iskitim and Berdsck.

## CONCLUSION

Results of the determination of ash content of plant samples from the territories of an industrial zone and motor roads of urban environments in the Novosibirsk Region (Berdsck, Iskitim, and Novosibirsk) provide evidence of the dependence of the degree of the accumulation of ash-forming elements on the conditions in growing sites, species specificity and the dynamics of seasonal development. Among the species dominating in ash content, there are the representatives of Hemerocallidaceae (9.85–10.85 %) and Asteraceae (7.76–8.85 %). It was established that at heavily polluted territories (Iskitim) the maximal ash content of the leaves of decorative plants was 9.74 %; in the territories with the medium level of pollution (Central and Sovetskiy districts, Novosibirsk) – 9.47 %; in slightly polluted sites (Berdsck) – 8.81 %. During the period of seasonal development, a decrease in the content of ash-forming elements was detected in *H. lancifolia* by September, especially in heavily polluted sites. This may be connected with an increase in the fraction of organic assimilants participating in the formation of the leaves. At the same time, high ash content is ob-

served in *I. hybrida* and *H. lancifolia* in the weakly polluted sites of the Sovetskiy district of Novosibirsk and in Berdsck, which is evidence of good adaptation of plants to the environment. The degree of adaptation of plants as the accumulators of ash-forming elements from the environment to growing conditions may be evaluated from the ash content parameter.

The use of flower decorative annual plants (*S. splendens*, *S. cineraria*, *T. patula*) and perennials (*I. hybrida*, *H. hybrida*, *H. lancifolia*) as the accumulators of ash-forming elements from the environment may be recommended for the zones of industrial enterprises.

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