Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 11th International Scientific and Practical Conference. Volume I, 235-239

The Dependence of Morphological and Physiological Indicators of the Leaves of Woody Plants on the Degree of Technogenic Pollution

Aleksandr Rostunov, Tatyana Konchina, Elena Zhestkova, Dmitriy Gusev, Svetlana Kharitono

Lobachevsky State University of Nizhny Novgorod (Arzamas branch). Address: K.Marx 36, Arzamas, 607220, Russia.

Abstract. Plants of modern urban ecosystem suffer from negative effects of a series of technogenic pollution which leads to changes in their morphological and physiological state. The reason for this is the penetration of phytotoxicants into plant organs, primarily, into leaves, thus distorting the structural components of cells and their functioning. In various species the degree of this reaction is manifested differently, so this fact must be taken into consideration when creating environmentally effective plantations. For this purpose the integrated study of the impact of pollutants on the morpho-physiological state of deciduous trees was conducted. Some morphological, physiological and biochemical indicators of leaves of Tilia cordata Mill., Populus tremula L., Salix fragilis L., Salix alba L. from different urban areas, characterized by different levels of technogenic pollution, were also studied. It was found out that the increase of technogenic load led to the decrease in the size of leaves, the increase of their necrotization and the total ash content of the tissues of these organs as well as the reduction of the photosynthetic pigments concentration with increase of relative portion of carotenoids which is the most significantly revealed in the leaves of the lime-tree, brittle willow and, to a lesser extent, in the white willow. At the same time the increased relative portion of carotenoids in the photosynthetic organs in case of strong pollution by pollutants indicates an increase of the protective role of the yellow pigment. Besides, the increased ratio of chlorophyll a/b characteristic for the resistant plant species was established in the leaves of these trees, which is a sign of a higher potential photochemical activity of leaves and the rate of photosynthesis.

All the studied morpho-physiological indicators characterize a greater resistance to pollutants of Tilia cordata, Salix fragilis, Salix alba, which can be recommended for the reconstruction of the sanitary and protective plantations of Arzamas. The studied tree species have a great capacity of gettering harmful technogenic substances with a further effective ability to accumulate them in the tissues of the leaves.

Keywords: technogenic pollution, woody plants, size of leaves, degree of necrosis, water content and ash content of leaves, concentration of photosynthetic pigments, species resistance.

I. INTRODUCTION

Modern cities are the source of all kinds of technogenic pollution, which have a negative impact on the morphological and physiological condition of plants of urban ecosystems [3; 12; 15].

Phytotoxicants penetrate into plants and distort structural components of cells and their functioning. Depending on the strength and duration of exposure, the chemical composition of pollutants and the general physiological state of the plant body, the degree of this reaction is manifested in various species in different ways [3]. Woodland in the urban landscape performs a number of important functions – recreational, environmental, aesthetic; it neutralizes harmful harmful gases, accumulating pollutants in the tissues of the leaves [2; 6; 8; 10; 23; 24]. At the same time, changes in morphological and functional processes in the conditions of urban environment have not been properly studied. In this regard, the creation of eco-efficient plants without taking into account ecological and biological characteristics of plants is impossible.

Under the conditions of technogenic pollution indicators of physiological state of woody plants can be: the size of the lamina, the degree of damage and water content, the amount of mineral salts in them, as well as the functioning of the photosynthetic organ, which is very susceptible to external factors [3; 5; 17; 22; 23].

At the same time, in our city the integrated studies of the influence of pollutants on the physiological condition of deciduous trees were carried out for the first time [18; 19; 20]. The purpose of this work is a comparative analysis of several morphological

ISSN 1691-5402

http://dx.doi.org/ 10.17770/etr2017vol1.2516

exponents such as a leaf size and the degree of necrotic deterioration; physiological and biochemical features: amount of water, ash and photosynthetic pigments, of different tree species growing under different levels of man-made pollution.

II. MATERIALS AND METHODS

The objects of the study were the tillet (*Tília cordáta Mill.*), aspen or *Pópulus trémula L.*, brittle willow (*Sálix fragílis L.*) and white willow or common willow (*Sálix álba L.*) from four habitats in the gray forest soils, which are characterized by different levels of pollution. Arzamas is an industrial city of Nizhny Novgorod region with the developed sectors of mechanical engineering and instrument-making, production of construction materials and others. The least polluted city area – a pedestrian Karl Marx street – was chosen as the zone of control (ZC). The sectors under the research were the territories adjacent to: 1) Arzamas Engineering Works (AEW) (average degree of pollution); 2) Plant for the production of building mixtures “Arzamix"; 3) the old landfill of solid domestic wastes (SDW). The level of pollution in the last two sections was higher compared with the territory of AEW. The content of heavy metals in soil samples of the studied areas was determined by atomic absorption spectroscopy with the help of the technical detector MGA-915 MD.

The research was carried out in August, during two vegetative periods. We selected leaves of the middle size at the annual vegetative growth from the lower third of the crown of trees of the southern exposure. In each sample at least one hundred leaves were analyzed. We determined the size of the leaf area, the degree of necrotization [1], the amount of water by drying to constant weight at 50 – 60 ° C and ash after combustion in a muffle furnace at 600 – 800ºS t [9], the contents of photosynthetic pigments with the help of a spectrophotometer PE 5400VI "Ekohim" [7]. The analyses were performed in 3 of biological and chemical 2 replicates. The results obtained were processed statistically [13], the validity of differences between control and experimental variants was assessed by Student’s-test with the program BioStat 2008 Professional 5.2.5.0 for Windows.

III. RESULTS AND DISCUSSION

The degree of pollution can be indicated by the analysis of soils for the accumulation of heavy metals in the studied areas (Table. 1). It was revealed that most polluted territory was the one adjacent to "Arzamix" because of a high concentration of lead and zinc and SDW for all studied elements.

It was found that the leaf size of all the studied species of woody plants in the polluted areas of the city was less than in the ZC (Fig. 1). Moreover, the rate of the lamina reduction depends both on the place of growth, and the type of the plant. By far the smallest leaf size is characteristic of the more polluted areas - SDW and "Arzamix". The inhibitory effect of toxicants on leaf growth manifests itself in a much lesser extent in the area adjacent to the AEW (Fig. 1). Aspen leaves suffer most severely from pollution.

Table 1
The content of heavy metals in the soils of the studied areas

exponent, mcg/g	Studied area			
	ZC	AEW	Arzamix	SDW
Cu	7,3 ± 0,7	11,5 ± 1,1	9,8 ± 0,9	45,6 ± 2,3
Pb	25,0 ± 1,3	36,8 ± 2,5	48,1 ± 3,2	56,0 ± 4,5
Ni	6,8 ± 0,6	10,9 ± 1,0	7,9 ± 0,4	20,2 ± 2,0
Zn	10,2 ± 0,9	14,5 ± 1,3	22,1 ± 2,8	34,3 ± 2,3

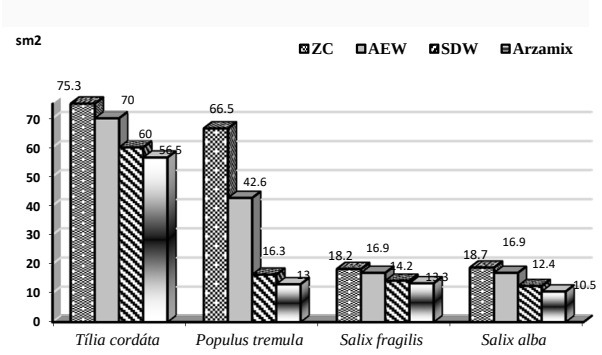

Fig. 1. The leaf size (sm^2) of deciduous trees in Arzamas habitats polluted to a different degree

With increasing degree of pollution of the territory all species of plants have a growing number of leaves damaged by necrosis (Fig. 2).

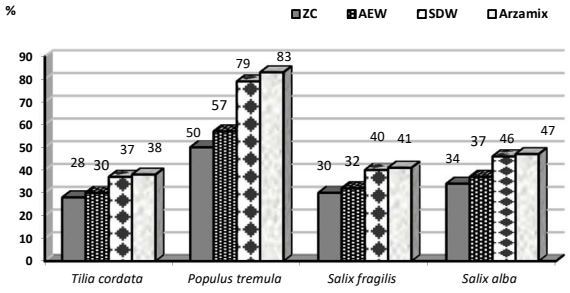

Fig. 2. The proportion of necrotic leaves (% of the sample) of deciduous trees in habitats with different degree of pollution in Arzamas

As is in the case with growth ratio, the study of the degree of necrotization showed that aspen leaves were exposed to the most severe damaging effect of pollutants. These changes can be explained by impaired regulatory mechanisms under the effect of toxicants - inhibition of ATP synthesis and reduction of enzyme activity [3], resulting in the inhibition of growth of cells, tissues and organs [8; 22].

For normal existence the cells and tissues of plants must have a sufficient water content [3]. Lack of water leads to the distortion of a number of physiological processes, and first of all the

photosynthesis, that causes a decrease in the growth of plant organs [5]. It was found that in the polluted areas the quantity of water compared with ZC significantly decreased only in aspen leaves (Fig. 3). Moreover, with the increasing degree of pollution, the figure becomes smaller.

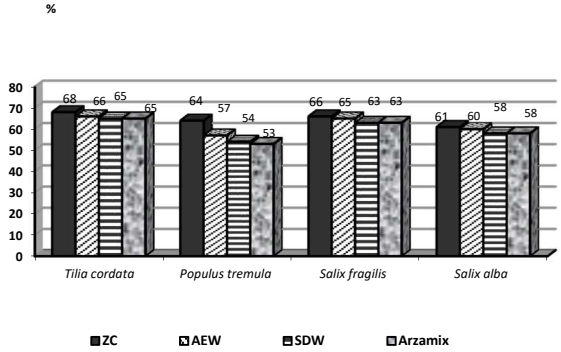

Fig. 3. Water content in the leaves of deciduous trees in the habitats of Arzamas with different degree of pollution

It is known that the amount of water in the cells influences the resistance to adverse environmental factors, and can serve as a criterion for evaluating the resistance of plants [17]. The fickle species increase the of cell membranes in case of environmental pollution, which naturally causes a rapid loss of water by cells [5].

When pollutants are accumulated, leaves stock up mineral elements, which also serves as an indicator of state of the environment. It was revealed that in case of anthropogenic impact the total ash content of the leaves of all the studied species of woody plants, with the exception of aspen leaves in AEW area significantly increased (Fig. 4).

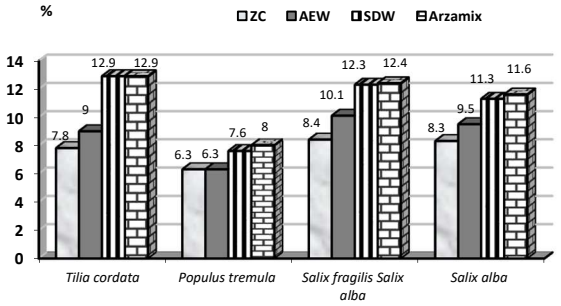

Fig. 4. Ash content in leaves (%) of deciduous trees in habitats with different degree of pollution in Arzamas

Similar results in other kinds of woody plants were noted by a number of authors [11; 14]. Our findings are not associated with a favorable mineral nutrition, and most likely these are the consequences of the accumulation of pollutants by leaves, or metabolic disorders.

Comparison of species by accumulation of pollutants showed that in the situation of pollution of the territory there are several trees whose leaves have greater accumulative capacity (linden and brittle willow), and a slightly lesser – the white willow. At the same time the aspen leaves have the least accumulation of mineral elements in a highly-polluted area. Accumulating activity of different leaves of the studied species of woody plants, apparently, is a consequence of their physiological state.

Moreover, in a much polluted environment a high ability to accumulate contaminants by leaves of linden and brittle willow may be due to the greater resistance of these species thanks to more active absorption of pollutants by these species cells [23]. This, in turn, leads to the removal of the technogentic pollutants from the air.

In addition, another important indicator of the physiological state of woody plants in the urban environment can be photosynthetic system; one of which main components is a pigment system. Photosynthetic activity is an indicator of the general state of the plant body, as a series of man-made gases have an impact on the structural and functional activity of chloroplasts inhibiting the process of photosynthesis [3; 8]. It was found in our experiments that the increase in the degree of an anthropogenic impact on the territory leads to a significant distortion in the pigment complex in the leaves of all the studied species of woody plants. There was a decrease in the content of photosynthetic pigments (chlorophylls and carotenoids) compared to ZC in all the areas of research. Besides, there was no credible decrease in carotenoid content only in the linden leaves in the area adjacent to the plant «Arzamix» (figure 5; 6; 7).

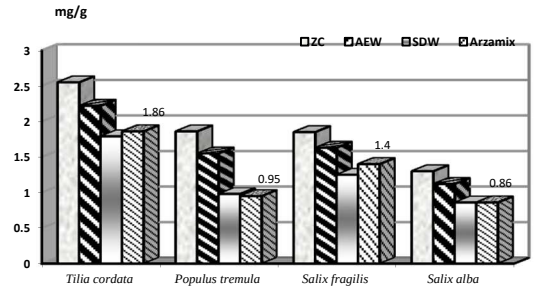

Fig. 5. The content of chlorophyll "a" (mg / g green weight) in the leaves of deciduous trees in habitats with different degree of pollution in Arzamas

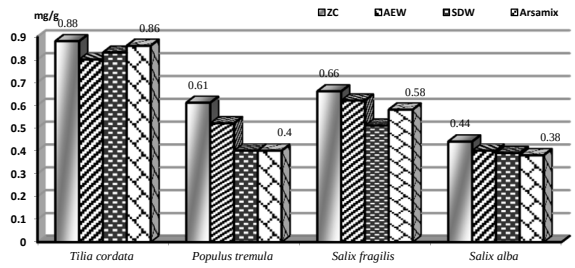

Fig. 6. The content of chlorophyll "b" (mg / g green weight) in the leaves of deciduous trees in habitats with different degree of pollution in Arzamas

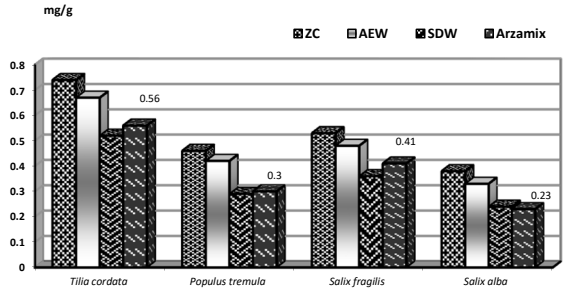

Fig. 7. The content of carotenoids (mg / g green weight) in the leaves of deciduous trees in habitats with different degree of pollution in Arzamas

For example, in the brittle willow leaves in the moderately polluted area adjacent to AEW the concentration of chlorophyll "a", decreased by 12%; while in the more polluted areas around the waste dump SDW and «Arzamix» plant this figure decreased by a greater degree, namely 32% and 24%; concentration of chlorophyll "b" decreased by 9%, 32% and 23%. At the same time, there were no significant changes in the ratio of the above forms of chlorophyll. The only exceptions are aspen leaves, in which the increasing pollution of the territory causes the change in the exponents *a / b* in the direction of increase of the concentration of *chlorophyll b* (Table 2).

Table 2
The ratio of the content of pigments in the leaves of deciduous trees in habitats with different degree of pollution in Arzamas

Species	Habitat			
	ZC	Near the territory of AEW	Near the waste dump SDW	Near the «Arzamix » plant
a/b				
Linden	3,4	3,3	3,4	3,3
Aspen	4,0	3,7	3,4	3,2
Brittle willow	3,5	3,4	3,4	3,4
White Willow	3,4	3,4	3,6	3,6
a + b / carotenoids				
Linden	3,8	3,6	2,8	2,8
Aspen	3,8	3,8	3,2	3,1
Brittle willow	3,6	3,4	2,4	2,3
White Willow	3,8	3,6	2,8	2,8

Such a change may be an adaptation of the most affected by pollution and therefore less resistant to high concentrations of pollutants species of woody plants [14].

Similar results on resistance to pollutants have been identified in other plant species [4; 16]. According to the authors, the increased correlation of *chlorophyll a / b*, which was observed in resistant species and the reduced one in unstable and moderately stable species, characterizes a higher potential of photochemical activity of leaves. At the same time, the increased value of *chlorophyll a / b* may be a sign of the greater potential intensity of photosynthesis, that, along with the studied parameters (leaf size, necrosis, water content and mineral elements), characterizes a higher resistance to industrial pollutants of such species of trees as linden, white willow and brittle willow.

However, in the heavily polluted areas (waste dump SDW and «Arzamix») in the leaves of plants of all the studied species the degree of the decrease of carotenoids, in comparison with chlorophylls, is significantly less. It is particularly noticeable in the leaves of the linden and white willow. So if linden total *chlorophyll (a + b)* in the SDW waste dump areas decreased by 30%, near "Arzamix" – by 27%, the carotenoid concentration in the leaves at the waste dump is reduced by 6%, and in the enterprise zone «Arzamix» it remains on the level of control.

In the white willow *chlorophyll* content decreased by 35% and 37%, and *carotenoids* – only by 11% and 14%. At the same time the aspen has a significantly smaller difference in decrease in the amount of green and yellow photosynthetic pigments. Thus, if the chlorophyll content of the waste dump areas of SDW and "Arzamix" respectively decreased by 45% and 46%, the carotenoids in both cases decreased by 33%.

As a result, all the studied species of plants on the highly polluted sites had an increased ratio of *chlorophyll a + b / carotenoids* (Table 2). This implies that the relative proportion of carotenoids in the photosynthetic organ in the polluted areas substantially increases in comparison to ZC. Most significantly it is evident in the leaves of the brittle willow and, to a lesser extent, linden and white willow. Similar data, indicating the increase in carotenoids due to the increase of environmental pollution, is given on the leaves of other woody species [4; 14]. At the same time, the increased relative proportion of carotenoids in the photosynthetic apparatus in case of a strong pollution is an indication of the enhanced role of the protective yellow pigments. In this regard, it is believed that basing on this indicator, the white willow, linden, and particularly brittle willow in comparison with aspen, can be named as species which are more resistant to man-made pollution.

Also, the obtained data on the decreasing chlorophyll amounts and relative increase in yellow pigments in leaves, in the situation of anthropogenic pollution growth, to some extent correlates with the reduction in their water content. Similar results were obtained by other authors in the studies of various kinds of plants [14; 22].

IV. CONCLUSION

Thus, air pollution in Arzamas, caused by industrial wastes, has a negative impact on the anatomical, morphological, physiological and

biochemical parameters of the leaves of the trees growing in urban areas. All the studied species of plants manifested the decrease in the size of the lamina, water content of cells, concentration of photosynthetic pigments along with the increase in the relative proportion of carotenoids that perform a protective function against pollutants. Besides, there is an increase in such indicators as total ash content of leaf tissue and the number of leaves exposed to necrotization. With the increasing degree of technogenic pollution in urban areas all the studied species of woody plants manifested the results of the negative impact of harmful substances on the morphological and physiological characteristics of leaves.

On the basis of the obtained results, we may use some of the studied species of woody plants in Arzamas for the purpose of reconstruction of sanitary and protective plantations, as they combine a higher gas resistance and leaves with the capacity to absorb pollutants. The most suitable in this respect are the linden, brittle willow, and to a lesser extent the white willow. The leaves of these trees in heavily polluted areas have less, compared with aspen, decrease of morphological and physiological parameters, namely, leaf size, water content of tissues, the concentration of green and yellow pigments, the incidence of necrosis, and high content of ash elements.

REFERENCES

[1] Bioindication of pollution of terrestrial ecosystems / ed. R. Schubert. Moscow, 1988, 350 p.

[2] Bulygin N.E. Dendrology / N.E. Bulygin. – Moscow, Agropromizdat, 1985, 280 p.

[3] Bukharin I.L. Bioecological features of herbaceous and woody plants in urban plantings / I.L. Bukharin, A.A. Dvoeglazova. Izhevsk, Publishing House of Udmurt. University Press, 2010, 184 p.

[4] Bukharin I.L. Analysis of the content of photosynthetic pigments in leaves of woody plants in the urban environment (for example, the city of Naberezhnye Chelny) / I.L. Bukharin, P.A. Kuzmin, I.I. Gibadulin // Bulletin of Udmurt University. 2013, Vol. 1, pp. 20 – 25.

[5] Volzhanina E.M. Estimation of stability of introduced species of pines in terms of water-holding capacity of needles / E.M. Volzhanina // Vestn. Nizhegorod. Univ. – №8, Vol. 2, 2004, pp. 94 – 99.

[6] Vorobeichik E.L. Reaction of forest communities in to technogenic pollution: dose-effect / E.L. Vorobeychik, E.V. Hantemirova // Ecology, 1994, № 3, pp. 31 – 43.

[7] Gavrilenko V.F. Large workshop on plant physiology / V.F. Gavrilenko, M.E. Ladygina, L.M. Handobina. Moscow, Higher School, 1975, 392 p.

[8] Goryshin T.K. Plant photosynthetic apparatus under medium / T.K. Goryshin. Leningrad, Leningrad State University, 1989, 202 p.

[9] Ermakov A.I. Methods of biochemical studies of plant / A.I. Ermakov, V.V. Arasimovich, N.P. Yarash. – Leningrad, Agropromizdat, 1987, 400 p.

[10] Ivanov A.A. Bioindication stress Betula pendula Roth in the conditions of anthropogenic pollution / A.A. Ivanov, V.K. Velikova // Plant Physiology. – 1990. – V. 16. – № 3 – pp. 76 – 82.

[11] Kavelenova L.M. About the specific content of mineral elements in the leaves of woody plants in the urban environment in the conditions of forest-steppe (on the example of Samara) / L.M. Kavelenova, A.G. Zdetovetsky, A.Y. Ognevenko // Chemistry of plant materials, 2001, №3, pp. 85 – 90.

[12] Kulagin A.A. Woody plants and biological preservation of industrial pollutants / A.A. Kulagin, Yu Shagieva. Moscow, Nauka, 2005, 190 p.

[13] Lakin G.F. Biometrics. / G.F. Lakin. Moscow, Higher School, 1990, 352 p.

[14] Maracayev O.A. Technogenic stress and its effects on deciduous woody plants (for example, parks in Yaroslavl) / O.A. Maracayev, N.S. Smirnova, N.V. Zagoskina // Ecology, 2006, №6, pp. 410 – 414.

[15] Neverov O. Environmental Assessment of woody plants and pollution of the industrial city (on an example of Kemerovo): Abstract. Dis. ... Dr. biol. Sciences. M., 2004, 36 p.

[16] Nicholas B. C. Biological Basis of gas resistance of plants / B. C. Nicholas. – Novosibirsk: Nauka, 1979. – 275 p.

[17] Polovnikova M.G. Changes in the water regime of lawn grass in the urban environment / M.G. Polovnikova, O.L. Voskresenskaya // Individual and population – life strategy: Coll. Materials IX All-Russia population seminar (Ufa, 2 – 6 October 2006), Part 1, Ufa, Wiley Oksler 2006, pp. 398 – 402.

[18] Rostunov A.A. Influence of technogenic pollution on physiological characteristics of leaves of woody plants on an example of Arzamas / A.A. Rostunov, T.A. Konchina // Bulletin of Irkutsk State University. Series: Biology. Ecology, 2016, V. 15, pp.68 – 79.

[19] Rostunov A.A. The research project in the studies of the ecological state of the various areas of Arzamas / A.A. Rostunov, S.S. Kharitonov, M.V. Molkova // Young scientist. 2016, № 8 – 7 (112), pp. 27 – 29.

[20] Rostunov A.A. Research project activity of the future teachers in determining the degree of anthropogenic pollution of the various highways of Arzamas by methods of bioindication / A.A. Rostunov, S.S. Kharitonov, E.I. Norkina // Young scientist, 2016, № 8 – 7 (112), pp. 29 – 33.

[21] Tarchevsky V.V. Influence of smoke and gas emissions of the industrial enterprises of the Urals on vegetation / V.V. Tarchevsky // Plants and industrial environment. Sverdlovsk, 1964, pp. 5 – 9.

[22] Chukparova A.W. Study of state of pine plantations in terms of aerotehnichal pollution / A.U. Chukparova // Forest management, ecology and protection of forests: fundamental and applied aspects: Proceedings of the international scientific-practical conference. Tomsk, 2005, pp. 208 – 210.

[23] Shenher E. Penetration into the leaf, and the accumulation of organic compounds in the cuticle of plants / E. Shenher, M. Riderer // Pollution and Toxicology. Moscow, Mir, 1993, pp. 11 – 83.

[24] Zhestkova E.Specifics of educational activity antimotivation in future teachers subject to the training period / Assel Bakirovna Akpayeva, Natalia Valentinovna Ivanova, Tatiana Ivanovna Luchina, Elena Viktorovna Minaeva, Elena Alexandrovna Zhestkova // International Review of Management and Marketing. – 2016. - №3. – p.265-259.