Formation of an ecological framework of the urban environment in arid conditions

E A Amikova1, G E Nastinova2, M M Sangadjiev3

1 Department of General biology and physiology, Kalmyk State University named after B. Gorodovikov, 11, Pushkin Street, Elista, 358000, Russian Federation
2 Department of General biology and physiology, Kalmyk State University named after B. Gorodovikov, 11, Pushkin Street, Elista, 358000, Russian Federation
3 Department of construction, Kalmyk State University named after B. Gorodovikov, 11, Pushkin Street, Elista, 358000, Russian Federation

E-mail: uni@kalmsu.ru

Abstract. The article scientifically substantiates the formation of the ecological frame of the urban area in arid conditions. The object of research is the greening system of the city of Elista, the capital of the Republic of Kalmykia. The main methods of the study are analytical, cameral and comparative geographical methods. The study shows that the intensity of traffic, physical, geographical and meteorological conditions and the condition of streets affect the gas content of the city's air basin. The zones of active pollution by emissions into the air are intersections and stops of public transport. The dust-collecting capacity of leaves of certain types of vegetation does not adequately ensure the sanitary and hygienic state of the city's atmospheric air. Based on the principle of a systematic approach to the problem, ecological-functional zoning of urban landscapes, as the basis of the ecological framework, has been carried out. The structure and its main elements that can act as "cores" and "corridors" of the ecological framework are presented. The study found that open, unconverted spaces account for about 26% of the city's area. The implementation of the principles of forming an ecological frame and the broader use of conifers for landscaping in Elista is aimed at solving an urgent problem, namely, improving the ecological situation in the city and providing a favourable, comfortable environment for the population in arid conditions.

1. Introduction

Urbanization is a global multidimensional process associated with the active development of industry, all types of transport, a constant acceleration of the pace of urban life and changes in the ability to support ecosystem services (Pickett, Cadenasso, 2004).

A favourable, comfortable living environment is an essential condition for ensuring environmental safety and achieving sustainable socio-economic development of society. This fact actualizes the most crucial problem, namely, the creation and provision of favourable, comfortable living and recreation conditions for the townspeople (Yarmosh, Mikhina, 2014).

Arid (arid) territories of the South of the European part of Russia are mainly represented in the Republic of Kalmykia. Elista, being the administrative and industrial centre of the republic, belongs to the category of medium-sized cities experiencing anthropogenic impact, which affects the ecological state. This process, along with the hot climate, has a significant impact on the health and mental state of the city's population (Nastinova, Emelianenko, 2013).
Greening is one of the main factors in creating a favourable ecological environment in the city. The development of greening projects should be carried out with maximum consideration of the general situation for a specific urban area.

Based on world and international experience, it is the "green" strategies based on the concept of the ecological frame of the urban area that can act as a helpful direction in optimizing the architectural and landscape planning and territorial management of urban greening (Tilman et al., 1997; Nabeeva et al., 2018; Klimanova et al., 2018).

According to E. Yu. Kolbovskiy's definition: the ecological frame of an urban area is "a medium-stabilizing territorial system, purposefully formed to improve the ecological situation in the city, consisting of elements of the cultural landscape of various types, dimensions and functional purpose, spatially connected into a single "living" network from "cores" (areal blocks of the ecological frame) and "corridors" (linear blocks)" (Kolbovskiy, 1999).

The development of principles for the formation of the ecological frame of the urban area will provide a solution to the problem of optimizing the greening system and creating a favourable urban ecological environment for the population of medium-sized cities in the arid territory of Russia on the example of Elista.

2. Formulation of the problem

2.1 Research concept.
Compliance with the principles of forming the ecological frame of the urban area, as a way to solve the problems of greening urbanized areas, most fully meets the modern requirements for ensuring the quality of the urban environment. The basis for the formation of the ecological frame of the urban area is the ecological and functional zoning of architectural and landscape elements of the city territory.

2.2. Purpose of the study.
The main goal is to substantiate the need to form the ecological framework of the city of Elista based on an assessment of the ecological state of the urban environment and ecological-functional zoning of architectural and landscape elements of the study area.

2.3 Research objectives:
2.3.1. Describe the history and natural conditions of the city of Elista.
2.3.2. Assess the level of atmospheric air pollution in the urban environment.
2.3.3. Determine the dust-collecting ability of leaves of tree-shrub species.
2.3.4. To carry out ecological-functional zoning of the urban environment as the basis for the formation of the ecological frame of the urban environment.

3. Materials and methods.
The object of the research is the greening system of the urban area of Elista city. The main methods are analytical, cameral and comparative geographic. The initial data for the work were the indicators collected during peak hours from 8 am to 10 am and from 5 pm to 7 pm in the summer period of 2017-2019 in key areas of the city (central highways, city streets, crossroads, public transport stops and territory). The traffic intensity of vehicles and the assessment of air pollution in the urban environment were carried out by the calculation method (Methodology of calculation, 1999). For assessing the dust-collecting ability of the studied plant species, ten normally developed whole leaves were selected at the same time. The dust settled on the leaves, after washing and subsequent filtration through a paper filter, was dried, and the weight was determined by weighing on an analytical balance. An analysis of the architectural, planning and functional structure of urban landscapes based on the principle of consistency has become the basis for the ecological and functional zoning of the city territory (Kalmanova, 2015).

The adequacy of the research methods used for the tasks set, sufficient volume (n = 300) and representativeness of the sample ensured the validity of the results obtained. Statistical processing of the data obtained was carried out on a computer using the EXCEL program. The reliability of the results
was confirmed by the correct use of the parametric Student's t-test (Borovikov, 2003). Differences in arithmetic mean values were considered significant at a 95% (p ≤ 0.05) probability threshold.

4. Discussion
4.1. History and natural conditions of the city of Elista.
Elista is the capital of the Republic of Kalmykia, located in the very centre of the vast Kalmyk steppes, in the southeastern part of the Ergeninskaya Upland. The climate of Elista is characteristic of the steppes and is sharply continental with dry, hot summers and little snow in winters. The climate is characterized by an abundance of sun and wind, frequent dust storms lasting up to 40 days a year, with a wind speed of 16 m/s or more. The average July temperature is +24.4°C, and the maximum temperature reaches +44.0°C. Temperatures above +30°C are observed from April to October inclusive.

Elista is home to about 110 thousand people, which is 40% of the total population of the republic. The total area of the city is 210.45 km².

Complex natural and anthropogenic geosystems represent the modern landscape of Elista. The protective role of the “green belt” around the city limits has been lost. The expansion of the city's territory, especially in the western, south-western and northern parts, led to the almost destruction of forest stands (former forest belts). The general ecological situation cannot be assessed as favourable.

4.2. Assessment of the level of atmospheric air pollution in the urban environment.
Because there are no extensive industrial facilities in Elista, the primary source of environmental pollution in the city is road transport.

Accounting for the traffic intensity in key areas of the city showed that the maximum traffic load falls on the central highways of the city, street intersections and public transport stops. On the streets of the city, where there is no public transport, the traffic intensity is somewhat less. In the adjacent territories, the traffic load is less noticeable (Fig. 1).

![Figure 1. Traffic intensity of different types of vehicles in Elista](image-url)

The zones of active pollution by emissions into the air are intersections and stops of public transport, where the level of gas pollution significantly exceeds the maximum permissible concentration of pollutants (Fig. 2). A lower level of emissions of gaseous toxicants and vehicle soot on main streets (slightly exceeding the maximum permissible concentrations of pollutants) and streets...
(significantly lower than the excess of maximum permissible concentrations of pollutants) is associated with dispersion under the influence of wind. In the surface layer of the atmosphere, in places with the highest traffic load (at pedestrian crossings, stops), city residents are most affected by air pollution. Residents of multi-storey buildings, despite the lower traffic load on the adjacent territories, also experience the harmful effects of polluted air due to low dispersion.

4.3. Dust-collecting ability of leaves of trees and shrubs of plants in the city of Elista.
Kalmykia is one of the most deflationary dangerous territories. Therefore, in Elista, there is often a significant dustiness of the atmospheric air.

The functional significance of greening in the city consists of cleaning the air from dust, various pollutants, ensuring gas exchange, regulating the ratio of carbon dioxide and oxygen, and reducing city noise. The filtration capacity of plant leaves is the mechanical retention of atmospheric dust and chemical compounds from the environment.

Figure 2. The level of emissions of some pollutants from motor transport in Elista

An assessment of the dust-collecting ability of leaves of the main objects of greening in the city at different key sites showed statistically significant differences in their filtration function, depending on the biological characteristics of the plant species. The best dedusting ability is in elm, poplar, ash, maple, lilac, thuja and pine (Table 1).

In Elista historically along the highways, there are mainly perennial plantings (50-60 years) of elm, maple, and poplar. Possessing functional filtration capabilities, they are also capable of phytoremediation. Phytoremediation as a method of reclamation of soils contaminated with heavy metals is gaining more and more interest, and understanding of the physiological responses of plants to heavy metals (Radwanski at al., 2019).

Many plants, including elm, poplar, maple, intensively absorb elements from the soil, including arsenic, cadmium, chromium, mercury and lead, which are known to be toxic even at low concentrations, accumulate them, and thus, exclude entering the food chain (Peralta-Videa et al., 2006).

Elista, as well as other small towns in the South of Russia, is characterized by low biodiversity of green spaces. The limiting factors for the growth and development of landscaping species are moisture deficit, high temperatures and soil salinity.
Table 1. Dust collecting capacity of the main types of trees and shrubs of the city of Elista

| Types of tree and shrub vegetation | Key site |  |  |
|-----------------------------------|---------|---|---|
|                                   | Crossroads | Stops | Highways |
| Balsam poplar                     | 65.0±1.3 | 41.2±1.4 | 18.8±0.91 |
| Ash-leaved maple                  | 60.0±3.2 | 48.2±2.1 | 13.5±0.56 |
| White acacia                      | 51.3±2.3 | 45.3±1.2 | 15.3±0.23 |
| Narrow-leaved elm                 | 65.5±2.3 | 50.3±2.2 | 19.3±1.2 |
| Cherry oak                        | -        | -     | 10.3±0.2 |
| Common lilac                      | 48.0±3.2 | 45.3±1.2 | 11.3±0.4 |
| Gleditsia vulgaris                | 45.3±1.2 | 30.3±1.1 | 12.3±0.4 |
| Loch narrow-leaved                | -        | 45.3±1.2 | 11.3±0.2 |
| Common pine                       | 60.3±2.2 | 40.2±1.5 | 10.3±0.1 |
| Catalpa the beautiful             | -        | 45.6±2.2 | 12.3±0.5 |
| Thuja western                     | 65.6±2.2 | 38.3±2.2 | 15.3±0.5 |
| Common juniper                    | 68.6±2.2 | 40.2±1.9 | 16.3±0.7 |

Coniferous plantations (thuja, pines, junipers) are the best means of increasing the comfort of the environment. They, with their high evaporative capacity, reduce the temperature and increase the humidity of the urban environment during hot periods. In the cold season, they provide wind and snow protection, create obstacles to the movement of cold air, regulate its movement and, as a result, a suitable microclimate in the territories. Conifers, possessing high filtration, sanitary and hygienic and aesthetic characteristics, fit well into the architectural and planning structure of the city of Elista.

The architectural, planning and functional structure of the city of Elista has been formed for no more than 100 years. Landscaping was carried out without scientific and environmentally sound design.

To improve the greening system of the urban environment in arid territories, the use of modern methods of landscaping and improvement based on the formation of an ecological frame has excellent prospects.

4.4. Ecological-functional zoning of the urban environment as a model of the ecological framework of the city of Elista.

The total area of ”green” zones in Elista, with natural landscapes adjacent to residential buildings, is 67.3 km$^2$, the level of greenery is 32% of the total area of the city, with a norm of 50%. In the conditions of the South of Russia, this is entirely insufficient.

The main principle of the "green strategy" is the continuity of the ecological framework of the city. For fulfill these requirements, it is necessary to connect areal objects ("cores") by linear objects ("corridors"). The development of such projects should be strictly individual for each city, taking into account all the features of a particular territory and the principles of designing an ecological framework (Nabeeva, 2018; Klimanova et al., 2016; Nastinova, Amikova, 2020).

By ranking the urban landscapes of the city of Elista from the standpoint of their sustainability, four ecological-functional zones have been identified, united by the performed ecological functions, and their areas have been established (Table 2).

The city of Elista has a relatively large area of environment-forming (20%) and environment-stabilizing zones (12% of the total area of the city). Among the urban landscapes, there is a significant area of the environmentally destabilizing zone (vulnerable areas of the city) (12%). They require the closest attention and the development of special measures to transform them into cultural landscapes for the ecological and geographical component.

Along the city highways, there are non-transformed territories devoid of tree and shrub vegetation with a total area of 26%. They can act as promising areas for environmental planning for green building.
Table 2. The structure of the ecological-functional zoning of Elista city

| Eco-functional zone                              | Structural elements of the ecological-functional zone                                                                 | Functions performed                                                                 |
|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Environment-forming zone – 20% of the total area of the city. | Landscape and recreational areas: Druzhba Park, Victory Park, City Park, Heroes Alley, boulevards, public gardens, sanitary protection and green areas of enterprises, educational, municipal and state institutions | Biodiversity conservation; aesthetic; sanitary and hygienic functions; microclimate formation; preservation of natural ecosystems, soil biota |
| Environment-stabilizing zone – 12% of the total area of the city. | A park near the monument to O. Gorodovikov, protection zones along highways, a water protection zone along the Elistinka River, adjoining and inner-quarter green zones | Aesthetic, erosion-stabilizing functions; ensuring a normal hydrological regime; stabilization of gas exchange in air; regulation of temperature and wind conditions |
| Environmentally destabilizing or vulnerable zone – 12% of the total area of the city. | Ravines, eolotards, wastelands, industrial wastelands, dumps, quarries, areas of occurrence of talus and landslides | Destruction of natural and natural-anthropogenic complexes as a result of erosion and geological processes; dust formation |
| Anthropogenic-technogenic zone – 26% of the total area of the city. | Residential, industrial, agricultural areas; linear and nodal systems of urban infrastructure. Among them are open non-transformed spaces - 26% | Ensuring the life of citizens. Prospective reserve territories for ecological planning of the landscaping system |

Elista does not meet the mandatory requirements for the greening system: uniformity and continuity. The ecological-functional zoning of the urban area, as the basis of the ecological frame of the urban area, made it possible to assess the functional significance of the identified zones, to highlight the elements that can act as "cores" and "corridors" of the ecological frame. The main "cores": Druzhba Park, City Park, Victory Park. Druzhba Park with perennial tree and shrub plantations of the mid-late 19th century requires serious reconstruction, renovation and streamlining of urban development of public recreation areas. Improvement of existing streets and alleys is to be done as linear landscaping objects ("corridors" of the ecological frame), as they connect the "cores".

The creation of a comfortable and environmentally safe urban environment can be ensured by preserving the already functioning green spaces in the city, improving the greening system of the urban...
environment, expanding the species diversity of trees and shrubs within the framework of implementing the strategy of forming the ecological frame of the urban area of Elista.

5. Conclusion
The presented structure of the ecological framework of the city of Elista is aimed at preserving the already functioning green spaces in the city, improving the greening system of the urban environment, expanding the species diversity of trees and shrubs. The implementation of the "green" strategy based on the ecological framework of the urban area will contribute to the creation of a favourable, comfortable environment for the city population-based on modern architectural and environmental standards, taking into account the forecast of the future situation.

References
[1] Picket TS, Cadenasso M L, Grove J M 2004 Resilient cities: meaning, models, and metaphor for integrating the ecological, socio-economic and planning realms J. Landscape and urban planning 69 (4) pp 369-384
[2] Yarmosh TS, Mikhina OV 2014 Socio-cultural principles of designing a living environment Vestnik BGTU named after V.G. Shukhova (5) 254-258
[3] Nastinova GE, Emelianenko DA 2013 Impact of atmospheric air pollution with suspended solids on the health status of the population of the Republic of Kalmykia Geology, geography and global energy 51 (4) 113-120
[4] Tilman D, Knops J, Wedin D, Reich P, Ritchie M, Siemann E 1997 The Influence of Functional Diversity and Composition on Ecosystem Processes Science 277 pp. 1300-1302,
[5] Nabeeva E G., Yupina G A., Zamaletdinov R I, Zahvatova A A., Mingazova N M 2018 Ways of Environmental Improvement of Urban Recreational Zones on the Example of the Uritsky Park The Journal of Social Sciences Research Special Issue 5 pp 340-344
[6] Klimanova OA, Kolbovsky EY, Illarionova OA 2018 Ecological framework of the largest cities of the Russian Federation: modern structure, territorial planning and development problems Bulletin of St. Petersburg University. Geosciences 63 (2) 127-146
[7] Kolbovskiy EY Urban landscape and construction of the ecological framework of the city 1999 Engineering geography. Ecology of urbanized territories Yaroslavl: Publishing house of YAGPU named after K.D. Ushinsky 78-83
[8] Methodology for calculating the determination of vehicle emissions for the summary calculations of air pollution in cities for determining vehicle emissions 1999 (M: State Committee of the Russian Federation for Environmental Protection)
[9] Kalmanova VB 2016 Ecological-functional zoning of urbanized territories (on the example of Birobidzhan) Regional problems 18 (4) 66-69
[10] Borovikov VP 2003 Statistica The art of data analysis on a computer 2nd edition (SPb .: PETER)
[11] Radwanski D, Gallagher F J, Vanderklein D W, Schafer K V R. 2019 Physiology and carbon allocation of two co-occurring poplar species (Populus 1 deltoides and 2 Populus tremuloides) in an urban Brownfield Environ. Pollut. 28 (1) pp 92-102
[12] Peralta-Videa J R, Lopez M L, Narayan M, Sauge G, Gardea-Torresdey 2006 The biochemistry of environmental heavy metal uptake by plants: implications for the food chain J. Biochem. Cell Biol. pp. 1665–1677
[13] Nabeeva E G., Yupina G A, Zamaletdinov R I, Zahvatova A A, Mingazova N M 2018 Ways of Environmental Improvement of Urban Recreational Zones on the Example of the Uritsky Park The Journal of Social Sciences Research Special Issue 5 pp 340-344
[14] Klimanova O A, Kolbovskii E, Yu, Kurbakovskaya A V 2016 Assessing the geocological functions of the green infrastructure in cities of Canada Geography and Natural Resources 37 (2) pp 165-173.
[15] Nastinova G E, Amikova E A 2020 Ecological and Functional Zoning of the Urbanized Environment of Arid Territory as the Basis of Ecological Framework *International Scientific and Practical Conference Anthropogenic Transformation of Geospace: Nature, Economy, Society’* (ATG 2019) Advances in Engineering Researc ed. V V Novochadov (Volgograd, Russia: Volgograd State University) 191 pp 193-198.