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Review

THE SIGNIFICANCE OF GREEN SPACES FOR PROTECTING HEALTH OF URBAN POPULATION

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Green spaces (green infrastructure, green areas) are important components of urban environment. They are able to mitigate health outcomes of climatic risks, exposure to urbanization and adverse environmental factors. Bigger areas covered with plants should increase their accessibility for people living in cities. Analysis of the results reported in foreign studies that addressed influence of green spaces on public health proves that they promote physical activity by urban citizens, sports included, development of interpersonal communication and social interactions, improve mental health, and reduce prevalence of diabetes mellitus and other diseases.

In some cases massive construction of residential housing and public buildings in Russian megacities and large cities led to reduction in green areas. The existing construction standards in Russia do not consider the recommendation of the WHO/Europe that requires accessibility of green spaces within a 15–20 minute walking distance and provision of 9 m^2 of green spaces per person. Utility of green spaces for public health depends on evenness of their distribution. In case their distribution is mosaic, their benefits for public health and protection capacities are reduced.

The present review shows the importance, needs and advantages of developing green infrastructure with continuous canopy that create potent green shading.

Keywords: *public health, mental health, obesity, health risks, diabetes, physical activity, green spaces, green infrastructure, city planning, urban studies, megacities.*

Creation of large green spaces in cities is one of few ways to protect health of people who are exposed to the aggressive urban environment. The issue has come into the limelight recently due to dynamic urbanization; this process causes a lot of concern that people in large cities are going to have reduced contact with natural greenness. Also, effective methods of remote sensing are available now; they allow better quantification of green spaces relying on values of the Normalized Difference Vegetation Index (NDVI) and this provides another incentive to investigate this issue. Green spaces protect health since they can function as places for recovery; places for social interaction and physical activity; they are also able to mitigate risks of harmful exposure to ambient air pollution, noise, and abnormally high temperatures.

The UN Sustainable Development Goals declare that by 2030 it is necessary to '*provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities*'[1]. Although there is common understanding that green spaces are

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[1] News UN in Russia. *United Nations in the Russian Federation*. Available at: http://www.unrussia.ru/en/un-in-russia/news (January 15, 2023).

necessary for protecting and improving public health, only one review has been published in Russian [1], which provides a general idea of basic trends in foreign research on the issue as well as some information about the significance of green spaces for public health published in 2022 [2]. However, this work does not provide any quantitative health risk indicators in a situation when necessary open green spaces or green infrastructure are either absent or barely accessible or when green spaces are located too far from residential areas. Therefore, we have set a task to provide healthcare workers, ecologists, constructors, urbanists, and experts in urban planning with necessary knowledge about the actual utility of green infrastructure, both existing and under development, and about reduction in public health risks evidenced by findings reported in outstanding epidemiological studies.

The concept of green infrastructure as an integral component of the ecological frame in any city has been described in detail in publications by Klimanova and others [3]. Instead of the traditional Russian term 'greenness, green plants', the authors of these works suggest using the term 'green infrastructure', which means 'integrity, connection, and hierarchy of green elements that provide stability of the environment thereby accomplishing the major function of green spaces'. This concept is in line with foreign publications where the term 'green infrastructure' as something more than just a green space is being used more and more often. The definition of green infrastructure which is widely cited now is as follows: '*green infrastructure is an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations*' [4]. Parks, boulevards, forests, city gardens and many other forms of public and private components of the natural landscape (greenness) taken together in one complex can also be considered green infrastructure.

However, architects point out that work with green infrastructure requires, first of all, knowledge of biology and ecology as its integral part and not of urban planning or considering the concept of 'green corridors' developed within this subject [5]. For example, L. Lunts[2], an architect, mentioned the necessity to consider a type of vegetation depending on climatic conditions in his manual on urban green development issued as far back as 50 years ago. This is especially vital at present due to climate change and occurrence of so called 'heat islands' in cities where public health risks are elevated.

Benign effects of greenness are associated, among other things, with overall improvement of urban residents' health including declining incidence of chronic diseases (for example, diabetes mellitus and cardiovascular diseases), development of cognitive functions in adults, mental health protection, and more favorable pregnancy outcomes (for example, normal birth weight) and a decline in premature deaths [6–13].

Most epidemiological studies with their aim to assess influence of green spaces on public health have relied on using cross-sectional or descriptive methods. Cohort studies, including prospective ones, are used significantly rarer; they can provide the best evidence but they are also the most complicated[3].

1. Basic characteristics of green spaces in cities. The system of indicators to assess green spaces in cities was first developed by the state authorities within the Development of Comfortable Urban Environment Federal project of the Housing and Urban Environment National project. Within the project, the basic target is to raise the index of urban environment quality by 30 points. Such indexes are based on 38 indicators that are distributed into

[2] Lunts L.B. Gorodskoe zelenoe stroitel'stvo [Urban green development]: the manual for higher education institutions. Moscow, Stroiizdat, 1974, 275 p. (in Russian).

[3] Revich B.A., Avaliani S.L., Tikhonova G.I. Ekologicheskaya epidemiologiya [Environmental epidemiology]: the manual for higher educational institutions. In: B.A. Revich ed. Moscow, Akademiya, 2004, 384 p. (in Russian); Vlasov V.V. Epidemiologiya [Epidemiology]: the manual, 3rd ed., revised and supplemented. Moscow, GEOTAR-Media, 2021, 496 p. (in Russian); Briko N.I., Pokrovskii V.I. Epidemiologiya [Epidemiology]: the manual for higher educational institutions. Moscow, GEOTAR-Media, 2017, 368 p. (in Russian).

six groups describing six types of urban spaces. ‘Green spaces” is one of them; it, in its turn, consists of six indicators. The most significant indicators describe reduction in health risks caused by exposure to ambient air pollution and noise and growth in urban residents’ mobility and levels of their physical activity. Such indicators include ‘the share of public green spaces in the whole area of green spaces’; ‘level of greenness’, that is, the share of the city area covered with greenness in the whole city area; ‘effectiveness of management’, that is, the share of urban residents who have access to public green spaces.

In 2020, the indexes of urban environment quality were estimated for 1116 cities in Russia, including 15 cities with population exceeding one million people. Among these megacities, the lowest values as per the ‘green spaces’ indicator were established in Omsk, Yekaterinburg and Volgograd; the highest ones, in Moscow, Saint Petersburg, Ufa, Perm, Kazan, and Nizhniy Novgorod [14]. In our opinion, the values established in Moscow and Saint Petersburg require some clarification since green spaces are very heterogeneous in these two cities.

Unfortunately, the ‘green spaces’ characteristic within the aforementioned Federal project does not include the most informative indicator of greenness levels in cities, the Normalized Difference Vegetation Index (NDVI)[4]. Still, the index was applied in the fundamental study conducted by experts from the Geographical Department of M.V. Lomonosov Moscow State University [3, 15]. The term ‘open green spaces’ is used in urban planning documents and multiple medical articles and it seems much more suitable when considering designs for new urban areas.

Green infrastructure is becoming more and more significant these days when microclimate in cities gets warmer and more and more soils and grounds are ‘closed’ in centers of Russian cities, that is, it is very hard to find land spots with open soils not covered with asphalt. Most studies describe green spaces and their areas relying on remote sensing and the Normalized Difference Vegetation Index (NDVI)[4]. Some publications provided much more detailed descriptions of green spaces with such data as exact numbers of trees, squares of greenness, and squares of canopy cover. The descriptions were provided specifically for forests, trees, shrubs, grass, arborous marsh plants, agricultural lands and gardens [16]. Green spaces are described with different values such as the ratio of the area covered by tree vegetation to the whole city area; provision with greenness in square meters per one resident; peculiar configuration of an ecological frame with greenness (mosaic, along a river, peripheral, and some others) [3].

These teams of geographical experts assessed green infrastructure in 15 largest cities in Russia using the share of territories covered by tree vegetation and provision with canopy cover. As a result, they divided these 15 cities into several groups. Two of them, Volgograd and Omsk, have small shares of areas covered with trees, 16 and 18 % accordingly; Yekaterinburg and Perm have the biggest areas covered with forests, 59 and 61 % accordingly. The medium values were established in Voronezh, Kazan, Krasnoyarsk, Rostov-on-Don, and other cities. The other indicator was the square of the whole tree vegetation per one resident; its minimal values were established in four cities (Chelyabinsk, Perm, Rostov-on-Don, and Volgograd); the maximum ones, in Yekaterinburg and Novosibirsk [3]. It is obvious from the analysis of this work and the study by Dyachkova [14], that green spaces and their quantity can be assessed quite differently depending on indicators used in this assessment.

At present, there is no standard in urban planning that specifies the mandatory greenness on a territory; but some construction standards and rules that had been valid until 2016 stipulated that the share of greenness should be equal to 40 %. When it comes down

[4] This index is calculated as per a specialized formula and shows the ratio of sunlight reflection coefficients in infrared and red spectral zones.

to how useful green spaces are for urban residents' health, we should remember that greenness should have an even structure and not a mosaic one since the latter weakens its protective properties. Another important indicator that describes utility of green spaces is their location within walking distance, which, according to the recommendation of the WHO/Europe, should not exceed 15–20 minutes and provision should equal 9 m^2 of green spaces per person [17]. This large-scale review by the WHO/Europe covers different systems of indicators that support urban planning in order to provide sustainable health and provides some of them that describe the environment in cities. These indicators are used in such UN programs as UN-Habitat, ISO (the International Organization for Standardization) and some others. They are applied within risk-based urban planning, which should consider levels of ambient air pollution based on average annual concentrations of fine-dispersed particles ($PM_{2.5}$ and PM_{10}) as well as excessive mortality caused by ambient air pollution, insufficient provision with green spaces per one person etc.

The role of different greenness including vertical one ('green parking lots', gardens on roofs, and other objects) has been described in many Russian publications, for example, in the review by Weber, Kucherov and Lylov [18]; but these studies did not consider influence exerted by greenness on public health using methods of evidence-based medicine. There has been a drastic growth in the number of foreign publications in the sphere starting from 2000. Our search in the Library of the US National Institute of Health (PubMed) has revealed more than 405 articles following the search request 'green place and health' published by January 01, 2023 including more than 10 reviews published between 2017 and 2022 [6–13].

Most studies rely on various indicators to estimate influence of green spaces on health; predominantly, they use the Normalized Difference Vegetation Index (NDVI) but it cannot be applied to estimate heterogeneity of greenness. For example, green spaces differ as per their objectively measured benign properties (such as tree canopy, pedestrian walkways, and sitting places) and other, more subjective ones (emotional or spiritual bond between an object and a person). At the same time, proximity to motorways with intensive traffic or absence of easy access can make visit to green spaces more difficult.

2. Green spaces and mental health. Availability of many evidence-based epidemiological studies prompted the WHO to initiate a review [19] to sum up their findings including those addressing effects produced by green spaces on children's mental health. Some reviews have also focused on studies that investigated influence of green spaces on children's physical health [20, 21]. This new knowledge on children's mental state (as regards any issues with peers, hyperactivity or inattention symptoms, behavioral or other issues) has been obtained by using computerized neuropsychological tests aimed at estimating children's cognitive development. All the studies mentioned at least one indicator that described a socioeconomic status, that is, a family income, parents' education and / or employment, access to green spaces for walks, and housing costs. The evidence provided in 21 studies consistently suggested a beneficial association between green space exposure and children's and adolescents' emotional and behavioral difficulties [22].

Low levels of physical activity raise a lot of concern regarding children's mental health; this is also typical for Russia. For example, according to the study conducted in Kaunas (Lithuania), every additional hour of time spent in parks was associated with decreased sedentary behavior and a lower risk of poor health; shorter park usage was associated with the risk of poor health and the general risk of mental difficulties in 4–6-year-old children [23]. The medical expert society in Russia acknowledges the problem; in 2020, the National Medical Center for Children's Health together with the Russian Society for the School Healthcare Development published the article with evidence that '*informatization of the social processes with use of electronic teaching*

aids that has been growing steadily over the last years has already deteriorated children's health'[5] [24].

A major issue in assessing influence of green spaces on a child's mental health is the necessity to isolate effects produced by this very factor after adjusting (considering) those produced by many other ones. Great attention has always been paid to the role played by socioeconomic factors since a place where a child' family lives depends exactly on them. Patients who lived in the greenest areas had many physical or mental disorders much less frequently (after the adjustment for most probable socioeconomic and demographic factors) than their peers who lived in areas where greenness was minimal. It is remarkable that the most significant deviations in mental development were identified in children with mental disorders who lived in areas with scarce greenness.

In 2009, the findings of a remarkable study were published; it established associations between green spaces near housing and medical diagnoses put by healthcare organizations for primary medical and sanitary aid for approximately 345 thousand Dutch patients from various age groups. Patients, who lived in the greenest areas, after considering socioeconomic and demographic factors, were much less frequently diagnosed with certain physical or mental disorders in comparison with patients who lived in areas with the poorest greenness [25]. Since then, more and more studies have been estimating associations between greenness and children's and adolescents' mental health. The authors of the study that involved meta-analysis of 21 publications highlight these associations between green spaces and adolescents' mental health [22]. According to them, children who live near green spaces have fewer problems with their peers and are rarer diagnosed with 'hyperactivity' [26].

Positive effects produced by green spaces on mental health have also been evidenced for other age groups; for example, urban citizens were more likely to have depression [27] or suicidal indicators in case they lived in areas with the smallest number of parks and green zones [28]. There is evidence of an association between frequent visits to parks and a person's emotional state and their satisfaction with life [29]. Peculiarities of the design and upkeep of parks are also significant [30].

There is increasing attention and evidence for a positive relation between the amount of green space in the living environment and people's health and well-being, especially for low-income and poor urban residents [25]. Proximity to parks was associated with more frequent physical activity and weight loss (for example, [31]), lower incidence of ischemic heart disease (for example, [25]). Some studies also report the association between influence of green spaces and benefits for mental health occurring regardless of physical activity due to such effects as perceived availability of green spaces for rest and recovery (for example, [32]). These benefits include better spirits and higher self-esteem, lower levels of stress and cognitive fatigue, greater attention focusing and promotion of emotional recovery [33]. Greenness provides a safe space for social interactions and this can lead to lower social isolation, creation of social capital, a rise in social solidarity, sense of belonging and more solid trust between residents living in the same area. Therefore, urban green spaces are directly associated with life quality of urban residents.

When discussing better mental health of urban residents who live near parks, we should mention the role that belongs to sports; parks with sport grounds create favorable conditions for such activities [27] (the minimal time that should be spent on physical exercises is 20 minutes; the optimal time, 90 minutes). On the other hand, criminal risks, crime rates, and

[5] Kuchma V.R., Selova A.S., Stepanova M.I., Barsukova N.K., Aleksandrova I.E., Aizyatova M.V., Grigor'ev O.A., Komarov D.B. [et al.]. Gigienicheskie normativy i spetsial'nye trebovaniya k ustroistvu, soderzhaniyu i rezhimam raboty v usloviyakh tsifrovoi obrazovatel'noi sredy v sfere obshchego obrazovaniya [Hygienic standards and specific requirements to the organization, maintenance and modes of work in the digital educational environment in general education]: guide. Moscow, National Medical Research Center for Children's Health of the RF Ministry of Health, 2020, 20 p. (in Russian).

anti-social behavior are likely to grow on blighted green areas [34].

The systemic review of publications aimed at identifying and generalizing findings about how effective green spaces were for improvement of adults' mental and physical health revealed that mental health indicators were much more likely to improve than physical health ones. The analysis of findings reported in 16 studies confirmed the hypothesis that greenspace exposure promoted lower incidence of depression in urban citizens [21].

A study on the analyzed subject with a highly unusual design was conducted in Denmark. In this small country, experts investigated associations between mental health and living near greenness in childhood for more than 940 thousand people. The control group was made of people born between 1985 and 2003. Green space presence was assessed at the individual level using high-resolution satellite data to calculate the Normalized Difference Vegetation Index within a 210 × 210 m square around each person's place of residence from birth to the age of 10. Risk for subsequent mental illness, such as depression, anxiety, and use of psychoactive substances, was up to 55 % higher for those who lived with the lowest level of green space during childhood compared with those who lived with the highest level of green space. The association between mental disorders and greenspace exposure remained authentic even after adjusting for socioeconomic factors, parental history of mental illness, and parental age [35, 36]. In addition, proximity of public parks to places of residence (400–8000 meters) contributed to better mental health of women and reduced prevalence of depression among them (especially in young women and homemakers) [37].

The issue of green spaces and health of megacity residents, which we are considering in this review, is also extremely vital in the South-East Asia. Several studies have been conducted in China to assess influence of green spaces on mental health of megacity residents, one of them in Shenzhen (17 million people). It is noteworthy that this study relied not only on the aforementioned Normalized Difference Vegetation Index (NDVI), but also Quick Bird – 2 high-resolution remote sensing image data; mental health was assessed using specifically designed questionnaires. The study findings are authentic and indicate the significance of creating larger green spaces in megacities [38].

Having compared the results of studies that address effects produced by greenness on people's mental health in such countries as South Korea and Iran (with drastic differences in their socioeconomic conditions), we observed quite a similar situation. In Korea (169 thousand examined participants), depression and suicidal ideation was 16–27 % higher in areas with minimal greenness after adjustment for all the potential variables. People without moderate physical activity had higher odds for self-reported depression and suicidal ideation than those with moderate physical activity [28]. In Iran, frequent visits to parks also made for better emotional state of a person [29].

Studies with their focus on estimating influence of green spaces on mental health are gradually switching from using questionnaires or psychological tests to instrumental examinations, MRI included [39]. Nevertheless, a few studies do not give evidence of positive effects produced by greenness on health; on the contrary, they concentrate on probable deterioration of a criminal situation in green spaces [34, 40]. It is also reported in some studies that additional green spaces in some city areas can result in higher housing costs and property values; this, in its turn, leads to displacement of people with a lower socioeconomic status into other areas with less greenness in them [41].

Loneliness can be another reason for mental ill-being. Psychological problems associated with loneliness in a city, a megacity in particular, are an extremely important challenge for contemporary healthcare, sociology, urban studies, and other disciplines that investigate the issue of 'a person in a city'. Loneliness is widespread in the contemporary society and this raises a lot of concern in healthcare workers, sociologists, psychologists and experts in other areas. Persistent loneliness trou-

bles people across the life span, with its prevalence being as high as 61 % in some groups of elderly people [42].

Loneliness as a social phenomenon has been examined in detail within the famous study entitled the Russian Monitoring of Economic Status and Public Health performed by the Higher School of Economics National Research University and Demoskop LLC with the participation of the Carolina Population Center at the North Carolina University [43]. The study findings indicate that 3 % of Russians feel lonely all the time and 40 % feel lonely periodically. According to sociologists, women more often feel lonely and they suffer more from this state than men. This is also related to the fact that women remain single more frequently than men and loneliness can be observed in various age groups, including young people. In elderly people, loneliness can lead to poor health and exacerbation of chronic diseases.

Green spaces in residential areas or in proximity to them promote better physical and mental health of lonely people; 22 studies have provided evidence of it over the last years and 11 out of them have been cross-sectional. According to the review of these studies, of 132 associations, 88 (66.6 %) indicated potential protection from green space against loneliness, with 44 (33.3 %) reaching statistical significance ($p < 0.05$). Most of the studies in this review were conducted in high-income countries [42]. Over the last five years, a new state policy has been developed in the USA, Spain, Singapore, Australia and some other countries; its specific aim is to create more green spaces in cities as a part of the strategy to reduce loneliness.

3. Green spaces and obesity, diabetes. Over the last forty years, the number of obese people worldwide has almost tripled. The issue has become so serious for public healthcare that experts in prevention medicine consider it a world epidemic [44]. Obesity is a recognized factor of early deaths and declining life expectancy at birth. The number of obese people older than 18 years has reached almost 2 billion all over the world and prevalence of the disease is expected to grow; according to the WHO estimates, by 2025 the shares of obese people can reach 18 % among men and 21 % among women [45]. Up to 3.5 million deaths worldwide are associated with obesity, which often involves poorer life quality and shorter life expectancy. Obesity is a serious health issue not only in developed countries: prevalence of overweight and obesity grew from 5 to 13 % in developing countries as well over the period between 1980 and 2013 [46]. In the USA, total public healthcare spending associated with overweight and obesity is expected to double each decade and reach 16–18 % of the total public healthcare expenses.

Overweight is becoming a more and more vital issue in Russia as well; our country is among those where prevalence of obesity is the highest. The literature review that addresses prevalence of obesity and elevated body mass index (BMI) among adults in Russia provides the results of several projects (WHO MONICA Project, 1985–1995; HAPIEE 2003–2005 and some others) [47]. Thus, obesity was diagnosed in 10.7 million men and 18.7 million women in 2014 [48] or, according to the WHO data, in 18.1 % men and 26.9 % women[6]. A growth in the number of people with elevated BMI is also evidenced by findings of the epidemiological study conducted in Moscow (random samples in several districts in 1975–2014); this growth is close the world trends but is still not so significant [49]. According to the WHO study, obesity is growing not only among adults but among adolescents as well [50].

Obesity is a basic risk factor able to cause many non-communicable diseases including cardiovascular and oncological ones, strokes, diabetes, cancer and asthma as well as mental disorders. Obesity turned out to be a risk factor

[6] Prevalence of obesity among adults, BMI >= 30 (age-standardized estimate) (%), 1975–2016, Both sexes. *WHO*. Available at: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-obesity-among-adults-bmi-=-30-(age-standardized-estimate)-(-) (February 13, 2023).

of COVID-19 mortality. Prevalence of obesity is a huge financial burden for a government, public healthcare system, and people. To prevent obesity is a serious challenge for practitioners and researchers dealing with healthcare issues.

More and more studies accept the fact that prevalence of obesity is caused by social and environmental factors. Urban design peculiarities can promote obesity by limiting opportunities for people to have any physical activity [51]. Green spaces in cities are considered a crucial factor for health improvement including maintenance of healthy weight.

Many studies report a negative relation between access to green spaces and obesity, time spent on watching TV, BMI and children's weight. A distance to the closest green space measured by using a GIS in 10 studies was often used to estimate access to the closest green space. In addition, indicators of greenness levels included the average NDVI value at different distances from a place of residence, the number of green spaces, tree density at a 0.5-km distance from a residential area, a distance to the closest park or any other green space and some others [52].

The large-scale study (700 thousand people) was conducted in two American cities with different climate, Phoenix with low greenness levels and Portland with sea climate and vast green spaces. In this study, cause-effect relations between access to green spaces and urban residents' weight were estimated. Greenness along city streets was proven to be a predictor of healthy weight. Each 10 % of growth in such greenness within 2 km was associated with 18 % lower risks of overweight or obesity (odds ratio (*OR*) = 0.82, 95 % CI: 0.81–0.84 in Phoenix; 0.82, 95 % CI: 0.81–0.83 in Portland). Prevalence of overweight or obesity was 18 % lower in greener areas (*OR* = 0.87 for Portland, 95 % CI: 0.81–0.92) [16]. Similar relations were established in New York. A higher density of street trees (at the 75th vs 25th percentile) was associated with 12 % lower prevalence of obesity [53]. Similarly in Spain, residential proximity to forests was associated with 39 % and 25 % lower relative prevalence of excessive screen time and overweight/obesity accordingly [54]. Many studies reported a positive correlation between healthy weight and green spaces within 500 m radius from home [55, 56].

Evidence of a relationship between children's BMI and green spaces is not so apparent. The review that addressed the issue considered research articles published prior to January 01, 2019. Sample sizes ranged between 108 and 44,278 cases. The authors of the review believe that it still remains difficult to draw a clear conclusion on the association between access to green space and BMI and it is necessary to conduct further prospective studies on the matter [57]. The necessity of such studies has also been mentioned by some other authors [25, 58, 59].

Obesity as a health issue is to a certain extent related to physical activity and this indicator is mentioned in the documents issued by the Rosstat[7] and The Ministry of Sports of the Russian Federation. According to these sources and questionnaires, the share of people who systematically do sports and/or physical exercises does not exceed 30 % in Russia. Therefore, it has become extremely vital to install more equipment for doing sports or everyday exercises in green spaces. The role of green spaces as an important factor able to motivate people to have physical activity and to prevent type 2 diabetes has been investigated in a large-scale study of urban population conducted in the USA. This prospective cohort study included 5574 people. Its aim was to investigate a relation between green spaces and type 2 diabetes. Green spaces were estimated as per the normalized difference vegetation index identified from satellite imagery within 1 km radius from participants' homes; type 2 diabetes was diagnosed by a doctor relying on

[7] Dolya grazhdan, sistematicheski zanimayushchikhsya fizicheskoi kul'turoi i sportom [The share of citizens who systematically do sports and physical exercises]. *EMISS: gosudarstvennaya statistika [state statistics]*, 2020. Available at: https://fedstat.ru/indicator/59266 (January 18, 2023) (in Russian).

fasting glucose levels, use of insulin, and use of hypoglycemic medicine. Of the 5574 study participants with no prevalent diabetes at baseline, 886 (15.9 %) developed incident diabetes over the study period. For each IQR increase in NDVI, the risk of developing diabetes was 21 % less among those with higher neighborhood NDVI compared to lower, controlling for individual characteristics, neighborhood-level covariates, and diabetes risk factors (*OR* = 0.79; 95 % CI: 0.63–0.99) [60].

4. Green spaces, mortality and incidence among urban residents. Ambitious projects are being implemented in many cities worldwide with their aim to create vaster green spaces with a closed tree canopy cover. These expensive measures have been substantiated, among other things, by findings of some longitudinal studies evidencing relationships between access to green spaces and mortality. Thus, some quantitative indicators were calculated to identify a relationship between green spaces and mortality risks for 1645 people who had a stroke between 1999 and 2008. It turned out that the hazard was lower for patients living in locations in the highest quartile of green space compared to the lowest quartile. This association remained statistically significant after adjustment for residential proximity to a high traffic road [61]. Lower cardiovascular mortality was identified for hospitalized patients with type 2 diabetes and myocardial infarction [62].

Longitudinal studies with more than 8 million people participated in them involved using the Normalized Difference Vegetation Index NDVI calculated from a space image with spatial resolution 30 × 30 meters. The findings were estimated using meta-analysis and as a result it was established that the NDVI was associated with air temperatures. The retaliate risk value *OR* = 0.96 (95 % CI: 0.94–0.97) indicates that it is trees, and not grass-plots or lawns, that ensure a decrease in high air and soil temperatures thereby creating more comfortable conditions. Trees also promote a decline in public health risks caused by exposure to extremely high temperatures; that is, they help reduce mortality among urban residents [63], including that caused by circulatory diseases [64]. The same has been proven in other studies [33, 65]. Their authors applied such an indicator as ‘the square of tree cover or a share of ground covered by tree canopy’ based on aerospace images made by LIDAR [66].

For example, municipal authorities in Philadelphia (1.6 million) have set a strategic goal to be achieved by 2025. The goal is to increase the total forest area in the city and to achieve the 30–40 % tree canopy cover, a level recommended for all the American cities. The necessity to implement such a program is caused by Philadelphia being drastically different from 10 other largest US cities as per such indicators as population incomes (the lowest level) and higher mortality (the applied all-cause mortality rate for the city’s adult residents in 2015 was 887 deaths per 100,000 people compared with 733 deaths per 100,000 people in the USA overall) [67]. Therefore, together with some other healthcare programs aimed at reducing mortality, the greenness program is also about to begin. It is largely based on a hypothesis that such high mortality rates would be prevented in case tree canopy cover increased by 30 %. The plan was to reduce excessive mortality among the city residents by 2025, first of all, in areas with low socioeconomic status. In 2015, the overall number of premature deaths associated with scarce greenness reached 403 cases in Philadelphia (95 % CI: 298–618), of which 244 (95 % CI: 180–373) occurred in districts with lower socioeconomic indicators. Squares of green spaces in the city were estimated using the LIDAR.

The authors used quite an interesting technique for dividing the city territory into zones. It was divided into 384 tracts and socioeconomic status of each tract was identified as well as the existing and necessary squares of closed tree canopy covers. Of 384 census tracts in Philadelphia, 80 already meet or exceed the 30 % tree canopy cover goal, and 103 census tracts could meet the goal by planting trees in areas currently covered with grass or shrubs. Average household incomes in the

city coincided with the total greenness in the city districts; as a rule, there were fewer trees or greenness in districts with lower socioeconomic status than in richer ones. Increases in tree canopy cover were estimated to provide a decrease in population mortality and, consequently, considerable health and economic benefits [11].

In Moscow, a similar method for dividing the city territory into zones was applied by N.B. Barbash, Candidate of Geographical Sciences from the Moscow Institute for the General Town Planning Scheme. This was done to identify micro-districts with elevated population density, elevated levels of ambient air pollution, and proximity to green spaces[8]. Later, the cross-sectional epidemiological study with its focus on prevalence of bronchial asthma in children identified locuses of areas with the highest values of this indicator [68]. The findings of this study (of course, together with economic, ecological, and some other reasons) were used by the Moscow Institute for the General Town Planning Scheme to substantiate the necessity to relocate some enterprises and to reinforce the pulmonologic service for children.

The largest European project aimed at assessing influence of greenness on mortality was implemented in 2015 in 49 large cities located in 31 European countries. Square areas of greenness were estimated as per the Normalized Difference Vegetation Index (NDVI) and the percentage of green area was estimated at a fine grid-cell level 250 × 250 meters. The project established that annual mortality was by 43 thousand cases lower in cities where green areas were located within 15–20 minute access for population. This accounted for 2–3 % (95 % CI: 1.7–3.4) of the total natural-cause mortality; 245 cases (95 % CI: 184–366) of lost years of life per 100 people. Among European capitals, Athens, Brussels, Budapest, Copenhagen, and Riga showed some of the highest mortality burdens due to the lack of green space [69].

Relationships between access to green spaces and incidence have not been studied as profoundly as it was with mortality rates. Still, the issue has been investigated in more than 60 publications in English where green spaces are described with the Normalized Difference Vegetation Index (NDVI) and indicators reflecting qualitative parameters of tree cover [70]. For example, higher land-cover diversity promoted a decline in prevalence of chronic diseases [71] and bronchial asthma in children [72]. Higher density of trees in parks was associated with lower prevalence of cardiovascular diseases [73, 74] and better life quality [75, 76]. Health is also influenced by a scale of 'green spot', that is, closed tree canopy cover in a city. Most studies found certain evidence of a relationship between various health indicators and large green areas, including body mass index [77, 78], mortality caused by circulatory diseases [64], depressions [79], all-cause mortality including cardiovascular one [12], obesity, prevalence of type 2 diabetes, osteoporosis, and other health disorders [33]. Access to green spaces can promote lower cortisol levels, pulse rate and blood pressure [52].

Recently, some studies have provided evidence of multisensory influence exerted by park vegetation including visual, hearing and tactile feelings that ensured a recovery effects produced by a visit to a park [80]. Higher density of trees among park vegetation had an association with lower prevalence of cardiovascular diseases [73].

Discussion. The issue of green spaces in cities has been given more and more attention not only by architects, constructors, or experts on creation of urban green spaces but healthcare researchers as well. The necessity to create green infrastructure with tree ranges is confirmed by epidemiological studies conducted in many countries. The COVID-19 pandemic and post-pandemic issues have also attracted additional interest to the subject since people started to spend more time in green spaces willing to overcome the consequences of strict

[8] Barbash N.B. Metodika izucheniya territorial'noi differentsiatsii gorodskoi sredy [The methodology for investigating territorial differentiation of the urban environment]. Moscow, Institut geografii AN SSSR Publ., 1986, 180 p. (in Russian).

quarantine and resulting psychological problems [81–83].

Mechanisms that underlie effects of green spaces on health have not been studied completely; still, there is solid evidence that visits to green spaces contribute to eliminating negative outcomes of stress and exposure to ambient air pollution, noise, high temperatures; they improve cognitive functions; they promote social interactions and higher levels of physical activity. The analysis of research results reported in many countries worldwide proves that it is necessary to develop urban green spaces. We have found solid confirmation of hypotheses that when green spaces are within a walking distance, this leads to greater mobility of urban residents, lower prevalence of diabetes and cardiovascular diseases among them. Green spaces are a vital component of the urban environment; they play a key role in mental well-being of urban residents, produce positive effects on people suffering from depression. Health risks tend to go down in areas with green spaces with closed tree canopy cover.

In Russia, some singleton articles have been published with their focus on influence of green spaces on health; one of these studies has been conducted in Ufa where green infrastructure has 30 scores and the Normalized Difference Vegetation Index (NDVI) is high as well; that is, green infrastructure is quite developed in the city [3]. Individual carcinogenic risks were assessed in this city based on data about benz(a)pyrene levels in ambient air provided by the Bashkortostan Office for Hydrometeorology and Environmental Monitoring. The risks turned out to be within their permissible levels. For comparison, similar study was conducted in Arkhangelsk where industries and energy production were not so well developed and greenness levels were lower than in Ufa where the Normalized Difference Vegetation Index (NDVI) identified well-developed vegetation. The authors of this study believe that high greenness in a city reduces risks created by benz(a)pyrene in ambient air [84]; health risks are predominantly caused by levels of fine-dispersed particles. People living in another Russian megacity, Chelyabinsk, were questioned in order to identify any psychological problems; the questioning revealed more apparent effects produced by stress-factors in a district in the city where green areas were scarce [85].

Urban green infrastructure is considered by economists a most significant element of ecosystem services. Intensive urban development has already made urban areas unstable in some cities [86, 87] and, consequently, created green space deficiency. It is especially true for rapidly developing Krasnodar where the water-green city frame is absent, trees are not preserved systematically, and the number of existing parks and public gardens is not sufficient. The newly developed general town planning scheme stipulates about 400 green areas different in their sizes but they are not combined into unified green infrastructure [88]. On the other hand, we can mention some very successful town planning solutions aimed at creating a large green infrastructure in a district in Kazan (20 thousand people). A three-time growth in the conventional greenness level, that is, up to 60 % of the total area, will make the district much more comfortable. According to the nature capital model developed by the Dutch National Institute for Public Health and the Environment, in summer, air temperatures will go down by 2 $^{\circ}$C and the average wind speed will decrease by 8 m/sec in this district; the number of people satisfied with air temperature will grow by 6 % in winter and by 8 % in summer against the traditional scenario [86].

The state policy as regards comfort provided by the urban environment has started to change in our country as well. For example, the issue is given a lot of attention in the Program for Development of Recovery Potential of Public Green Spaces included in the Green Spaces section of the Comfortable Urban Environment Federal project. Within this Program, green spaces were estimated in Yekaterinburg using several indicators including shares of public green spaces in the total square area of green spaces (%), level of greenness (%), quality of greenness, attraction

of green spaces. Recommendations have been developed on how to achieve proper quality of the urban environment in Ekaterinburg; they include various recovery activities and measures aimed at making sport grounds more accessible for people with limited mobility [89]. However, healthcare workers also need to know what percentages of people from different age group have green areas within 15–20 minute walking distance from the total population as per separate districts.

The scales of researches aimed at assessing quality of green spaces and their influence on health are growing steadily. The results indicating their utility have been more apparent for people living in areas with large tree canopy. There is a demand for additional prospective studies that include estimating quality of green spaces and consider factors able to distort analysis. Investigations that concentrate on assessing quality of green spaces have practical significance for urban planning.

Cities with high population density tend to face some challenges in renovation; in particular, it is often difficult to preserve green areas and easy access to them for population groups with different socioeconomic status. Therefore, it is necessary to search for compromises between town developers, constructors, municipal authorities, on the one hand, and healthcare experts, ecologists, and experts in green infrastructure, on the other hand. In addition, it would be advisable to give responsibility over planning and managing green spaces as well as control of their quality to town planning authorities, offices for architecture and planning or any other managerial structures responsible for creating a comfortable urban environment. This issue should be supervised by them and not by housing and communal services or offices responsible for improvement of city areas. Since space is limited in any city, changes in quality of existing green areas can help maintain and even improve quality of life in urban societies, especially given the ongoing climate change.

Protection of urban residents' health requires development of green spaces as well as planning of city landscapes considering health risks and developing new recommendations on optimal population density. Economists believe that 'the complex approach to creating the urban environment with emphasis on residents' health and well-being not only satisfies the demands of a modern urban resident but is also beneficial for urban economies and the country economy as a whole' [88]. Further development of green spaces requires closer coordination between town planning organizations and relevant municipal services responsible for territorial improvement. Parks, public gardens, boulevards and other green spaces are too important for creating a more comfortable urban environment and protecting urban citizens from harmful environmental exposures. Therefore, it is advisable to take responsibility over them from municipal authorities on territorial improvement and assign it to structures responsible for rational use of natural resources and environmental protection.

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