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MODELING OF THE MICROCLIMATE OF A RESIDENTIAL COURTYARD DURING RENOVATION

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Abstract. The article provides an example of modeling the microclimate of a residential courtyard during renovation in conditions of high-density urban development. Modeling is carried out on the basis of a bioclimatic indicator - the environmental heat load index (TNS-index). The calculations are based on the method for analysis temperature radiation and determining the angel factors between a black glob temperature to the surrounding the given platforms of side of residential courtyard. The method shows a good reflection on changes in spatial planning, architectural and construction solutions, landscaping, aeration of the yard, etc. This allows to comprehensively assessing the degree of comfort of the microclimate of the courtyard for specific weather conditions.

Keywords: renovation, urban planning, microclimate of urban areas, radiation

МОДЕЛИРОВАНИЕ МИКРОКЛИМАТА ТЕРРИТОРИИ ДВОРА ПРИ РЕНОВАЦИИ

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Аннотация: В статье приводится пример моделирования микроклимата территории жилого двора при реновации в условиях высокоплотной городской застройки. Моделирование осуществляется на основе биоклиматического показателя - индекса тепловой нагрузки окружающей среды (ТНС-индекса). В основе вычислений используется метод расчета радиационной температуры с применением коэффициентов облученности с шарового термометра на окружающие приведенные площадки ограждений жилого двора. Метод расчета показывает хорошую рефлексию на изменения объемно-планировочных, архитектурно-строительных решений, способов озеленения, аэрации двора и др. Это дает возможность комплексной оценки степени комфортности микроклимата территории двора для конкретных метеоусловий.

Ключевые слова: реновация, градостроительство, микроклимат городских территорий, радиационная температура

1. INTRODUCTION

The program of Housing Renovation in Moscow, launched in 2017, is systemic and multi-purpose. The renovation should improve the living conditions of more than a million residents for the formation and development of a modern urban environment [1].

As a part of the environment-forming of open urban areas is its climate [2].

Interest increases to the quantitative and qualitative analysis of changes in the indicators of the microclimate of the courtyard area after renovation, for example, for the warm season with a significant increase in building density, and, if necessary, its

melioration by various methods to achieve comfort [3].
With an increase in building density, streets, squares, adjacent territories, courtyards, etc. sink to the bottom of "urban canyons". The visible part of the sky decreases. Therefore, the intense heat exchange with it, as with the coldest surface of the surrounding space, descends. Among other things, the result of this microclimatic process is an increase in radiation temperatures due to the surrounding surfaces. The increasing of radiation temperatures, the deterioration of the aeration of the urban active layer, air pollution and technogenic heat lead to the effect known as an urban heat island [4].
This article provides a number of simulation results for a bioclimatic indicator - the environmental heat load index (TNS-index) based on the method for analysis the radiation temperature using the irradiance coefficients obtained from a spherical bulb thermometer to the surrounding reduced areas of fences of a residential yard [5]. Based on the obtained simulation results, recommendations have been proposed to increase comfort in the courtyard of a residential building planned for renovation in Moscow.

2. PROBLEM FORMULATION

Simulation of the TNS-index was carried out for the space-planning solution of the residential yard, proposed by the Moscow Committee for Architecture, and was based on:
- variability of the use of materials in the decoration of the facade and their areas;
- variability of materials used in paving, landscaping;
- rational landscaping of yard areas and landscaping of vertical surfaces;
- changes in the aeration mode during the installation of "windows" in the perimeter (well) building.

2.1 ENVIRONMENTAL HEAT LOAD INDEX (TNS-INDEX)

According to SanPiN 2.2.4.548-96 "Hygienic requirements to occupational microclimate" TNS-index is calculated from the formula:

$$TNS=0.7\times tw+0.3\times tg, \qquad (1)$$

where
t_w is the wet bulb temperature, °C;
t_g is the spherical bulb temperature, °C.
Simulation of the microclimatic conditions of a residential court yard for the warm period of the year based on the TNS-index is not random, since the TNS-index has established itself as a universal tool for evaluation the environment indoors and outdoors during the warm season among other widely used bioclimatic indicators containing the radiation component. The TNS-index is easy to calculate. Many installations for field surveys using a spherical bulb thermometer determine these indicators automatically [6, 7].
As Figure 1 shows, the TNS-index has good compatibility with the WBGT index (ISO 7243) and the operational (equivalent) temperature, which is used to determine thermal comfort based on the predicted mean vote (PMV) according to ISO 7730. However unlike the latter one, it has no restrictions in its application with a significant local asymmetry of radiation temperatures.

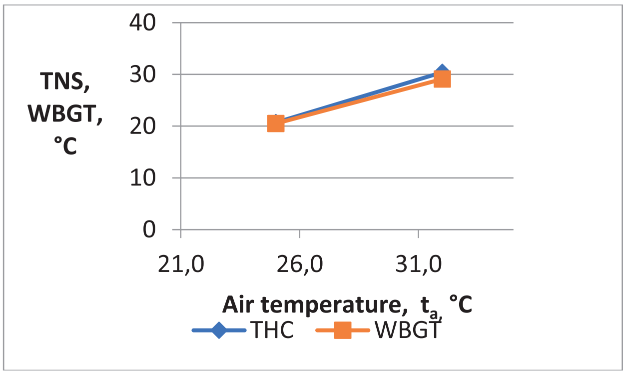


Figure 1. Graphs for TNS-index and WBGT-index under the same meteorological conditions.

3. ALGORITHM FOR ANALYSIS

3.1. Step 1. Calculation of radiation temperatures (tr) for i point of the yard at a height of 1.5m

Based on the determination of the average radiation temperature inside the room, in accordance with the formula (12) ISO 7726:1998 “Ergonomics of the thermal environment — Instruments for measuring physical quantities" and earlier numerical results, confirmed by field studies, an equation has been proposed for determining the average radiation temperature of the environment using the irradiance coefficients from a spherical bulb thermometer to the surrounding reduced areas of fences of a residential court yard [5].

The formula for the average radiation temperature of the environment for the *i* point of a residential court yard from the influence of all six fences looks like this:

$$t_{ri} = \sum_{1}^{6} \sum_{n=1}^{N} t_{\text{пл.}} \times \varphi_{\text{сф}-\text{пл.}} \quad (2)$$

where $\varphi_{sph-y.}$ is the irradiance coefficient from a spherical bulb thermometer towards the reduced area of a particular fence;

$t_{пл.}$ is the temperature of the reduced area, °C;

N is the number of reduced areas on the fence.

3.2. Step 2. Calculation of the indication of a spherical thermometer (tg) for the i point of the yard

According to ISO 7243, the relationship between the temperature of a bulb thermometer and the radiation temperature of the environment during natural convection, i.e. $\bar{\upsilon} <$ 0.15 m/s is defined as:

$$t_g = \frac{t_R + 2.44 \times t_a \times \sqrt{\bar{\upsilon}}}{1 + 2.44 \times \sqrt{\bar{\upsilon}}}, \quad (3)$$

where t_R is the ambient radiation temperature, °C; t_a is the air temperature, °C; t_g is the spherical bulb thermometer readings, °C; $\bar{\upsilon}$ is the wind velocity, m/s.

3.3. Step 3. Calculation of the TNS index for the i point of the yard

The TNS-index is calculated according to formula 1.

Field studies of new residential microdistricts have shown that the average values of the wet thermometer readings (tw) amounted to +18.0 ° C at an average relative humidity of 46% [7] for the absence of tree and shrub plantations or their insufficiency, as well as the absence of water surfaces at an outdoor temperature of +26.0 ° C. Formula 1 takes the form:

$$THC_i = 0{,}7 \times (+18°C) + 0{,}3 \times t_{gi}$$

3.4. Step 4. Construction of areas of the TNS-index of a residential yard and determination of the level of comfort/discomfort according to Table 1

Table 1. Working conditions in terms of TNS-index (°C) for working premises with a heating microclimate, regardless of the period of the year and open areas in the warm season (upper limit)

Category of work *	Working conditions					
	Permissible *	Harmful				Dangerous (extreme)
		3.1	3.2	3.3	3.4	
Ia	26,4	26,6	27,4	28,6	31,0	31,0
Ib	25,8	26,1	26,9	27,9	30,3	30,3
IIa	25,1	25,5	26,2	27,3	29,9	29,9
IIb	23,9	24,2	25,0	26,4	29,1	29,1
III	21,8	22,0	23,4	25,7	27,9	27,9

* According to app. 1 SanPiN 2.2.4.548-96 "Hygienic requirements to occupational microclimate"

4. OBJECT OF SIMULATION

The object of the study was two identical residential courtyards planned for placement in zones 18.1 and 22.1 in accordance with the Planning Project for the Perovo district of Moscow, proposed by the Moscow Architecture Committee under the renovation program

(Figure 2). The building density is 52.59 thousand sq. m/ha (super dense) [8].

The size of the space of the residential yard after renovation is 104.4 × 122.4 m; h=10-55-65-95 m.

4.1. Initial data:

The residential group is assumed to be latitudinal (Figure 2.).

- period of the year: July
- time period: 11.00-13.00 hours
- air temperature +26.0 °C - with a security of 0.98;
- wind speed up to 0.06 m/s;
- clear.

The solar component coming to the spherical bulb thermometer is +21.5 °C

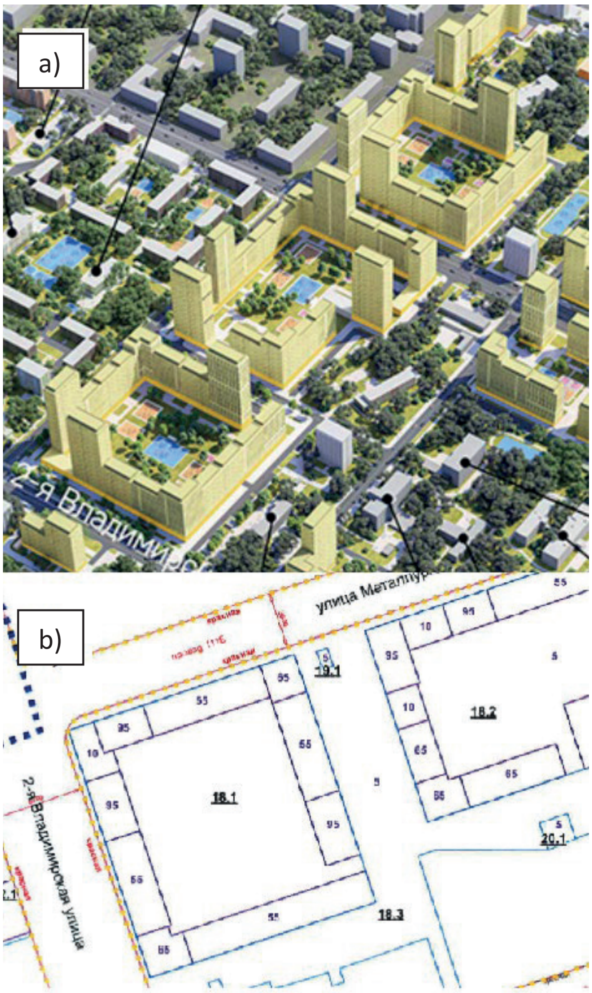


Figure 2. urban planning solution a) 3D vizualization; b) scheme

On the basis of field studies of similar objects (Table 2) [7], the surface temperatures of various coatings (t_{melt}) corresponding to the above mentioned meteorological conditions were obtained:

Table 2. Surface temperatures of urban planning solution coating for air temperature +26,0°C.

No	Coating	Surface temperature, C
1	2	3
1	Facade "light" - concrete surface painted in light colors	+30.0
2	The facade is dark	+36.0
3	Window	+28.0
4	Concrete pavers "light"	+36.0
5	Concrete pavers "dark"	+38.0
6	Rubber coating, brown, recreation and sports grounds	+40.0
7	Lawn	+32.0

The temperature of the sky was calculated by formula 4 [9]:

$$T_{sky}=0.0552\times T_{air}^{3/2} \quad (4)$$

$$T_{sky}=0.0552\times(273+26.0)^{3/2}=285{,}4°K \text{ or } +12{,}4°C$$

Specifically, for the area under consideration, the equation for calculating the radiation temperature of the environment for the i point considering the irradiance coefficient from the sphere bulb thermometer towards the given sites after its renovation (104.4×122.4×95.0 m), takes the following form:

$$t_{ri}=\sum_1^{3654} t_{av.ar.ins.f.}\times \varphi_{sph-ar.ins.f.}+\sum_1^{3654} t_{av.ar.shady.f.}\times \varphi_{sph-ar.shady.f.}++\sum_1^{4284} t_{av.ar.right.f.}\times \varphi_{sph-ar.right.f.}+\sum_1^{4284} t_{av.ar.left.f.}\times \varphi_{sph-ar.left.f.}+ +\sum_1^{3944} t_{av.ar.land.f.}\times \varphi_{sph-ar.land.f.}+\sum_1^{3944} t_{av.ar.sky.f.}\times \varphi_{sph-ar.sky.f.} \quad (5)$$

where
$t_{av.ar.f.}$ is the average surface temperature of the reduced area of a particular fence of an imaginary yard space;
$\varphi_{sph-ar.f.}$ is the irradiance coefficient from a sphere bulb thermometer in the direction of the reduced areas of a specific fence of an imaginary yard space

5. NUMERICAL RESULTS AND CONCLUSIONS FOR THE MOSCOW ARCHITECTURE OPTION

The TNS index calculation grid is 1.8 × 1.8 m.
In accordance with Table 1, three areas of the TNS-index were built on the yard plan (Figure 3.):
- in the sun above +25.1°C;
- in the sun in the range of +24.2°C <……≤ +25.1°C
- in the shade less than +24.2°C.

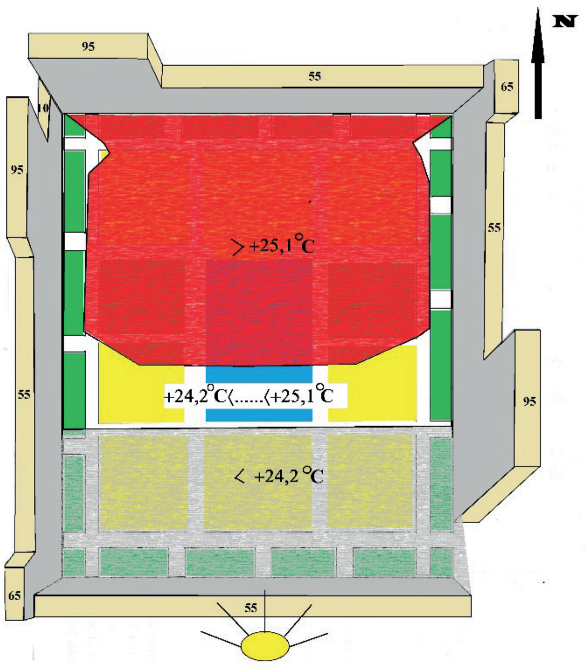


Figure 3. Areas of the TNS-index (°C) for the projected urban planning solution

Using the obtained TNS-index (Table 1.) (R 2.2.2006-05 "Occupational health. Guidelines for the hygienic assessment of factors of the working environment and the labor process. Criteria and classification of working conditions"), we can draw the following conclusions about the bioclimatic impact on a person from due to such urban planning solutions for specific weather conditions:
1. Throughout the yard it is comfortable to be in a state of rest and unhurried walks with an intensity of energy consumption up to 200 Kcal / h.
2. Fast walking (>5 km/h), carrying a grocery bag (more than 1 kg), light jogging, etc. with energy consumption up to 220 Kcal/h will cause uncomfortable heat sensations such as: slightly warm - warm in half of the yard.
3. Physical activity with energy consumption over 220 Kcal / h, for example: volleyball, gymnastics, badminton, will cause uncomfortable heat sensations such as: warm-hot in half of the yard.

6. CLIMATOMELIORATIVE MEASURES, SIMULATION RESULTS

6.1. Coating materials, paving

Calculations of radiation temperatures and field studies show the surface-ground provides main “contribution” to the resulting radiation temperature from the surrounding surfaces (42÷46%), regardless of the height of the yard building [5]. Since the degree of heating of materials in the sun is related to the absorption coefficient of short-wave radiant energy (Equation 5.), It should be noted that the materials of coatings, paving must have absorption coefficients (a_p) of no more than 0.5, for example: white sand; yellow brick; polished marble. Well-maintained lawns can also be used to reduce the resulting radiation temperatures.
Additional sun heating of surfaces (ti), according to IEC 60721-2-4:1987 “Classification of environmental conditions. Part 2: Environmental conditions appearing in natural. Solar radiation and temperature" is determined by the formula:

$$t_i = t_a + (a_p \times E)/h_{to}, \quad (6)$$

where t_a is the air temperature, °C;
a_p is the absorption coefficient of radiant energy;
E is the solar flux density, W/m²;
h_{to} is the heat transfer coefficient of the surface, W/m²×C°.

6.2. Facade finishing materials

The previous section also applies to the issue of finishing insolated facades. As you approach the sunlit facade, its synergistic effect on the resulting radiation temperatures increases to 35% of the total "contribution" (Figure 4).

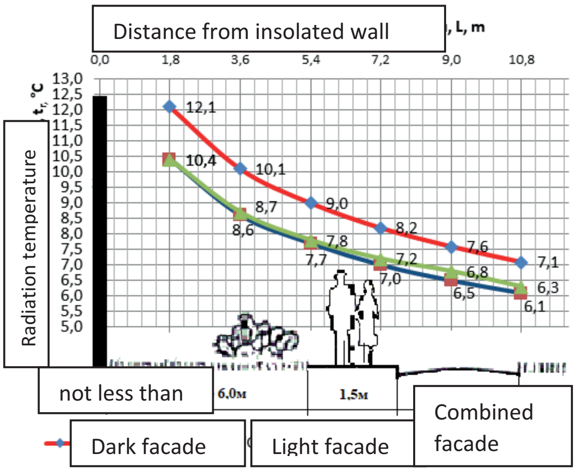


Figure 4. Graphs of radiation temperatures generated by an insulated facade with various architectural and construction solutions

This means the pedestrian paths fall into the zone of active influence of the insolated facade. There are cases when, in the absence of an extensive pavement-path network, a person is experienced the maximum thermal load while moving along a fire-prevention passage along a multi-meter wall illuminated by the sun. It is recommended to provide shortest paths to the entrances to the building and objects in the yard when planning it (Figure 5).

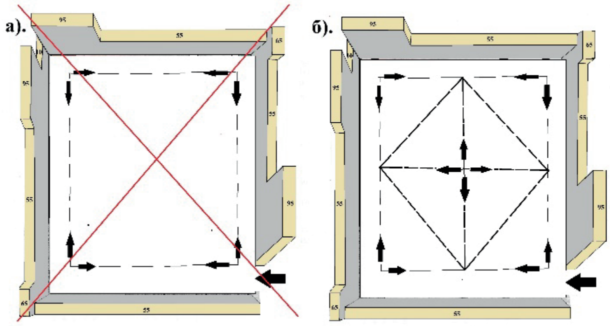


Figure 5. a). in the planning structure of the yard only fire lanes with sidewalks; b). in the planning structure of the courtyard, a developed sidewalk and path network

If it is necessary to use "dark" (radiant energy absorption coefficient of the material ~ 0.8) facade elements in architectural and construction solutions, it is advisable to make the facing of the first five floors from "light" material (radiant energy absorption coefficient is not more than 0.6). At the same time, at least 50% of the thermal radiation generated by the insolated facade falls on the first five floors (Figures 4, 6).

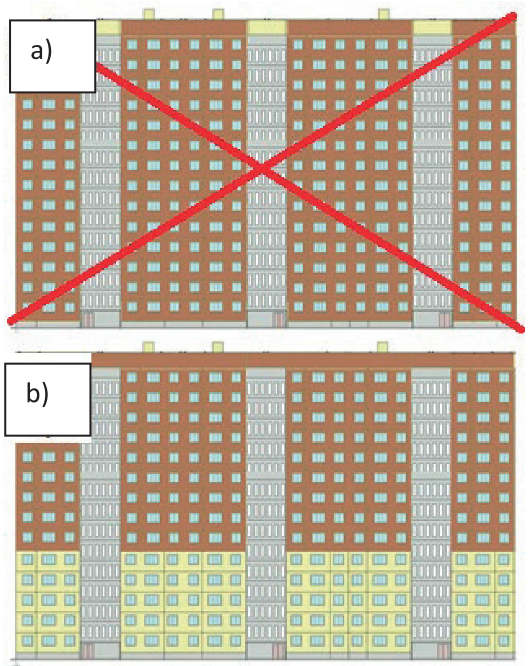


Figure 6. Variants of the architectural and construction solution for the insolated facade: a) "dark"; b) "combined" with the first floors of "light" cladding

6.3. Landscaping area

Since 2020, the planning structure of the adjoining and courtyard areas of residential buildings has been standardized including landscaping area. However, these requirements are only quantitative.

Simulation of the thermal load of the environment to residential yard shows the green areas should be quantitative and applied nature. For example, the even distribution of green areas allows you to evenly distribute the heat load isotherms of the yard. In the future, individual trees or groups of trees can be grown in these areas, which will improve the microclimate in the warm season (Figure 7) [10].

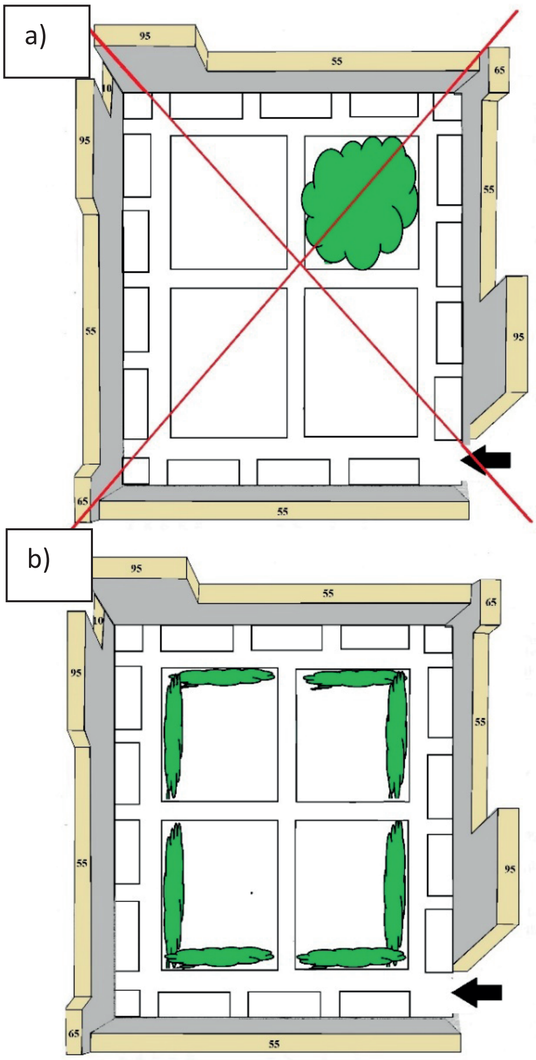


Figure 7. a) quantitative nature of landscaping; b) applied nature of landscaping

For landscaping vertical insolated surfaces, climbing grapes were chosen as the most common fast-growing plant of medium latitude with well-studied properties (Figure 8) [11]. Moreover, a plant height of 6 to 8.0 meters is sufficient, because a further increase in the height of vertical gardening does not lead to significant changes in the heat load (calculation data).

The calculation of the TNS-index for wall landscaping showed that it becomes more comfortable on the walking route (Figure 9). The shift of the increased area of the TNS-index (> +25.1°C) to the central part of the yard is due to the use of molded rubber coating with a high absorption coefficient of solar energy (~0.8) in the coating of playgrounds, recreation and sports grounds. It is recommended to replace the coating material of the sites with materials with a solar energy absorption coefficient (0.5÷0.6).

Figure 8. The example of green facade of building

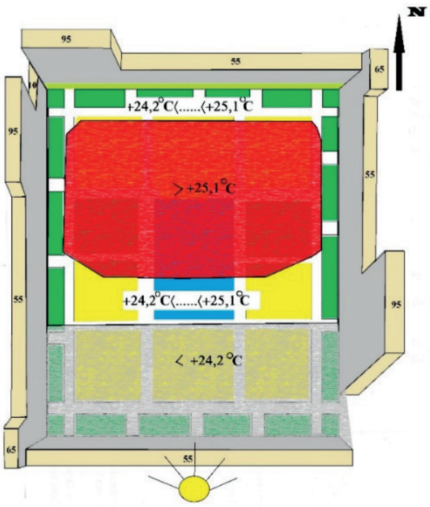
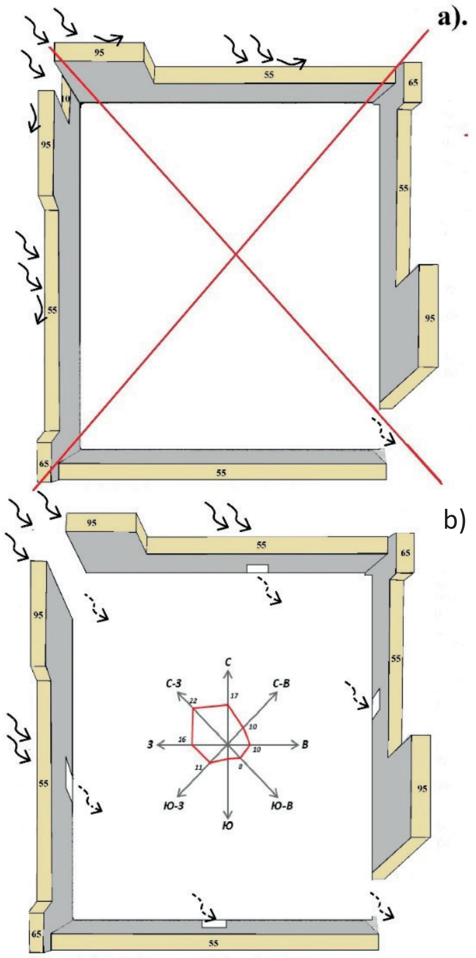


Figure 9. TNS-index areas (°C) for the designed urban planning solution

6.4. Aeration mode

The variant of urban planning proposed by the Moscow Committee for Architecture is a semi-closed morphotype of the yard [12]. There is practically no aeration in such yards, the temperature fields are more stable than in sparse buildings. Simulation of the TNS-index shows that in order to improve the thermal conditions of the yard, it is enough to increase the air velocity in the surface (active) layer up to 0.1 m/s. The TNS-index will drop to a favorable +24.8 °C. To aerate the residential yard, it is proposed to make an additional gap in the perimeter building and several through arches, considering the wind rose of the warm period of the year (Figure 10).



<u>Figure 10.</u> a). there is not aeration of the yard; b). aeration of the yard

7. CONCLUSIONS

The possibility of the radiation temperatures' calculation for the environment of the yard in regard with the urban planning solution of the surrounding buildings, allows to simulate the microclimate of its territory and assess the degree of its comfort based on the bioclimatic indicator of the TNS-index.

This simulation allows you give a comprehensive recommendation for improving the microclimate for typical meteorological conditions during the warm season in the renovation area of Moscow, such as follows:

- development of the system of sidewalk and footpath network of the yard;
- rational placement of landscaping areas on the territory of the yard and landscaping of the insolated facade;
- thermal performance of materials used in coatings, paving and facade cladding;
- space-planning solution in order to improve the aeration of the yard.

REFERENCES

1. **Telichenko V.I.** Renovatsiya - sozdaniye sovremennoy gorodskoy sredy [Renovation - creating modern urban environment] // Vestnik MGSU. – 2020. – T. 15. – No 1. – P. 11. – EDN JXFWEE.
2. **Myagkov M.S., Gubernskiy YU.D., Konova L.I., Litskevich V.K.** Gorod, arkhitektura, chelovek i klimat [City, architecture, human and climate] //Arkhitektura-S. Moscow, 2007.
3. **Myagkov M.S.** Normirovaniye i normativy mikroklimaticheskikh usloviy territoriy gorodskoy zastroyki. Realizatsiya trebovaniy bioklimaticheskoy komfortnosti v proyektnoy podgotovke stroitel'stva [Rationing and standards for microclimatic conditions in urban areas. Implementation of the requirements of bioclimatic comfort in the design preparation of construction] //

https://marhi.ru/kafedra/techno/phisics/myagkov_climat.pdf (available on 01.08.2022).
4. **Oke T.R**. The urban energy balance / T.R. Oke//Progress in Physical Geography 1988; 12; 471 DOI: 10.1177/030913338801200401 https://www.researchgate.net/publication/275590257_The_urban_energy_balance_Prog_Phys_Geogr (accessed 10.07.2022) (In Russian).
5. **Sumerkin YU.A.** Raschet radiatsionnoy temperatury okruzhayushchey sredy gorodskoy zastroyki [Calculation of the radiation temperature of the urban development environment] // Promyshlennoye i grazhdanskoye stroitel'stvo. 2020. No 4. P. 34-40. DOI: 10.33622/0869-7019.2020.04.34-40.
6. **Fedorovich G.V.** Otsenka teplovoy obstanovki s pomoshch'yu sharovogo termometra [Assessment of the thermal situation using spherical bulb thermometer] // Bezopasnost' i okhrana truda. 2011. No 1. P. 68-71.
7. **Sumerkin YU.A.** Naturnoye obsledovaniye zhiloy zastroyki na predmet energeticheskogo vliyaniya zdaniy na mikroklimaticheskiye usloviya dvorovogo prostranstva [Field Surveys of Residential Development on the Subject of Energy Impact of Buildings on Microclimatic Conditions of Courtyard Space] // Promyshlennoye i grazhdanskoye stroitel'stvo. 2017. No 5. P. 76-80.
8. Moskomarkhitektura. Proyekt planirovki territorii mikrorayonov 11-12, 21-22, 23-24, chasti mikrorayonov 29, 68 rayona Perovo goroda Moskvy [Moscow Architecture Committee. Draft planning of the territory of microdistricts 11-12, 21-22, 23-24, parts of microdistricts 29, 68 of the Perovo district of Moscow] URL:https://www.mos.ru/authority/documents/doc/44599220/ (available on 05.07.2022)
9. Metodika rascheta soprotivleniya teploperedachi ograzhdayushchey konstruktsii zdaniya s uchetom pokrytiya «mikrosfera-svyazuyushcheye» [Method for calculating the heat transfer resistance of the building envelope, taking into account the "microsphere-binder" coating] //URL:http://inoteck.net/metodika_rascheta_soprot (available on 10.07.2022)
10. **Berezin D.V.** Snizheniye peregreva na pridomovoy territorii putem ratsional'nogo razmeshcheniya zelenykh nasazhdeniy [Reduction of overheating in the local area by rational placement of green spaces] / D.V. Berezin // Vestnik YUUrGU. Seriya «Stroitel'stvo i arkhitektura». – 2013. – Vol. 13, No 2. – P. 16-21.
11. **Sandifer S., Givoni B.** Thermal effects of vines on wall temperatures- comparing laboratory and field collected data // https://www.sbse.org/sites/sbse/files/attachments/scholarships/Sandifer.pdf (data obrashcheniya 10.05.2022).
12. **Kozhayeva L.YU.** Morfotipy zastroyki v teorii i na praktike [Building morphotypes in theory and practice]. Arkhitekturnyy vestnik, No 4. - 2011. - P. 43-47.

СПИСОК ЛИТЕРАТУРЫ

1. **Теличенко В.И.** Реновация – создание современной городской среды // Вестник МГСУ. – 2020. – Т. 15. – № 1. – С. 11. – EDN JXFWEE.
2. **Мягков М.С., Губернский Ю.Д., Конова Л.И., Лицкевич В.К.** Город, архитектура, человек и климат //Архитектура-С. Москва 2007.
3. **Мягков М.С.** Нормирование и нормативы микроклиматических условий территорий городской застройки. Реализация требований биоклиматической комфортности в проектной подготовке строительства // https://marhi.ru/kafedra/techno/phisics/myagkov_climat.pdf (дата обращения 01.08.2022).
4. **Oke T.R.** The urban energy balance / T.R. Oke//Progress in Physical Geography 1988; 12; 471 DOI: 10.1177/030913338801200401

https://www.researchgate.net/publication/275590257_The_urban_energy_balance_Prog_Phys_Geogr (accessed 10.07.2022) (In Russian).

5. **Сумеркин Ю.А.** Расчет радиационной температуры окружающей среды городской застройки // Промышленное и гражданское строительство. 2020. № 4. С. 34–40. DOI: 10.33622/0869-7019.2020.04.34-40.
6. **Федорович Г.В.** Оценка тепловой обстановки с помощью шарового термометра // Безопасность и охрана труда. 2011. № 1. С. 68–71.
7. **Сумеркин Ю.А.** Натурное обследование жилой застройки на предмет энергетического влияния зданий на микроклиматические условия дворового пространства // Промышленное и гражданское строительство. 2017. № 5. С. 76-80.
8. Москомархитектура. Проект планировки территории микрорайонов 11-12, 21-22, 23-24, части микрорайонов 29, 68 района Перово города Москвы URL:https://www.mos.ru/authority/documents/doc/44599220/ (дата обращения: 05.07.2022)
9. Методика расчета сопротивления теплопередачи ограждающей конструкции здания с учетом покрытия «микросфера-связующее» //URL:http://inoteck.net/metodika_rascheta_soprot (дата обращения 10.07.2022)
10. **Березин Д.В.** Снижение перегрева на придомовой территории путем рационального размещения зеленых насаждений / Д.В. Березин // Вестник ЮУрГУ. Серия «Строительство и архитектура». – 2013. – Том. 13, №2. – С. 16-21.
11. **Sandifer S., Givoni B.** Thermal effects of vines on wall temperatures- comparing laboratory and field collected data // https://www.sbse.org/sites/sbse/files/attachments/scholarships/Sandifer.pdf (дата обращения 10.05.2022).
12. **Кожаева Л.Ю.** Морфотипы застройки в теории и на практике. Архитектурный вестник, № 4. – 2011. – С. 43–47.

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