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Strategic Planning and Ecological Safety Evaluation of University Campuses on Green Marketing Principles

Oleksii Kofanov[1*], Olena Kofanova[1], Oksana Tverda[1], Kostiantyn Tkachuk[1], Andrii Huzan[2], Oleksandr Borysov[3]

[1] Igor Sikorsky Kyiv Polytechnic Institute, National Technical University of Ukraine, Ukraine

[2] National Aviation University, Ukraine

[3] LLC 'NIuPRYM-LTD, Ukraine

***Corresponding author:** aleckof@gmail.com

Strategic planning of university campuses (UC) aims to harmonize nature, humans, and architectural complexes, enhancing the positive university image through specialized green and recreation zones. Highly urbanized UC areas, particularly with nearby roads, encounter increased technogenic load and pose additional health hazards. The purpose of the paper is the evaluation of the environmental safety level of the UC recreational territories on the example of campuses of Kyiv universities, located nearby highly loaded roads, using a complex of express methods of analysis, mathematical modeling and criterion-based approach, considering the main green economy principles. The scientific novelty of the paper and the authors' contribution is in the assessment of the environmental safety level of city-type UC recreational territories being under the significant technogenic load from vehicle emissions. Such express analysis methods as densimetry, viscometry, stalagmometry, conductometry, potentiometry and optical methods, and in particular, refractometric studies have been used to assess the impact of vehicle emissions. The mathematical modeling and computational experiment have been carried out for dispersion fields of the main vehicle emissions pollutants. Ecologically acceptable distances from the road considering the specifics of recreational territory have been determined using the integral index of technogenic load. Propositions for minimizing human health hazards and improving the system of environmental monitoring of such territories have been provided and substantiated. The study also confirms the positive effects of environmental management and green marketing principles synergy, benefiting both nature and humans as well as the university image. Obtained results can be used for the design and reconstruction of UC and their recreational areas, as well as for planning roads located nearby the campuses, improving traffic on them. It is also convenient to foresee the enhancement of the environmental activities in the student research work and create student communities for monitoring the UC environmental state and the development of eco-startup projects.

Keywords: ecological safety, vehicle pollution, dispersion fields of toxicants, green (circular) economy, green management and marketing.

Introduction

As early as the 18th century, the territory of Princeton University (USA) began to be called a campus, and today university campuses (UC) are classified as city-type campuses, UC located in the suburbs, and university villages. Moreover, worldwide, and in Ukraine in particular, city-type UC are the most widespread, and, therefore, the problems inherent in highly urbanized territories also spread to such student towns.

As a rule, in UC, in addition to the educational and administrational buildings, there are also student dormitories, libraries, sports fields, medical facilities, cafes and canteens with the rest areas – recreational territories (RT) – concentrated around them. On the one hand, the location of UC in the center of a big city is very prestigious, for example, as in the case of the University of Göttingen (Georg-August-Universität Göttingen), but on the other hand, the university recreational territories are located near tense roads and, therefore, are exposed to significant technogenic influences from motor vehicle engines (MVE) emissions.

It is well-known that MVE are able to emit a large number and variety of harmful substances – toxicants into the atmosphere. These are, in particular, nitrogen and carbon oxides, sulfur compounds, unburned hydrocarbons, aldehydes, etc. Emissions of small solid particles (or particulate matter, PM) are also dangerous – adsorbing other pollutants on their developed surface they are able to easily get in the bodies of humans and higher animals.

Entering the atmosphere, MVE exhaust gases, on the one hand, mix with each other and disperse in the atmospheric air; on the other hand, complicated physical and chemical transformations occur leading potentially to the formation of new, even more dangerous substances. In addition, numerous studies have proved that in large cities, especially on the territories near roads, the maximum permissible concentrations (MPC) of certain toxicants are significantly exceeded, sometimes over ten times (Povtoreiko and Kamskykh, 2017; Kofanov et al., 2020; KNAHU, 2021; Kofanov et al., 2022).

Therefore, the purpose of the research is the evaluation of the environmental safety level of the UC recreational territories on the example of campuses of Kyiv universities, located nearby highly loaded roads, using a complex of express methods of analysis, mathematical modeling and criterion-based approach, considering the main green economy principles.

Many studies by national and foreign scientists have been devoted to the problems of UC planning and the formation of a specific educational environment. In particular, the paper by Haar (2011) presents an analysis of the development of first academic villages, and then modern university city campuses on the territory of the USA, using the example of the University of Illinois at Chicago, Columbia College Chicago and Roosevelt University. The author paid special attention to those problems and tasks that arise in the formation of a unified educational environment on the campus. The paper also demonstrates feedback – it shows how the university environment affects the city development and the lives of its inhabitants. The problems of the UC planning, the architectural design of the university buildings, the development of urban space, etc., have also been discussed in detail, as well as the socio-economic problems and the numerous advantages associated with the strategic placement of the UC in the city.

S. Troost, one of the campus planners of Michigan State University believes that the term ‘UC planning’ covers the long-term direction of the natural and artificial environment for higher education purposes, which involves the best possible use of the territory to combine teaching, research and other goals and missions of the college or university, including those of safety, environmental sustainability, and recreation (HubStar, 2022a; HubStar, 2022b).

According to MSU (2017), the university pays considerable attention to the complex process of UC development, focusing on planning its activities on ecological, economic and cultural principles, ensuring a high-quality educational and research process. In particular, the principles of UC planning are grouped into such categories as general principles of development, principles of land use and development of UC objects, their environmental sustainability, mastery of open space, maintenance of parking lots, roads and other utility networks.

And in the context of our research, we focus on the principles of UC environmental sustainability, namely:

- minimization of the impact on the natural environment, rational use of land and water resources, protection of ecosystems and implementation of the concept of green (circular) economy, as well as the low impact on the environment principles;
- preservation of biodiversity on the territory of the UC, increasing the stability of natural ecosystems by creating, restoring and maintaining the so-called unspoiled 'green blocks';
- preventing traffic jams and reducing emissions by prioritizing pedestrian traffic, and minimizing vehicle routes, as well as renewables usage;
- climate change mitigation, preparation for emergency situations and minimization of their negative consequences.

Scientists also pay attention to developing and maintaining the image of the university. In particular, image issues have been considered by Manzoor et al. (2020), Fuchs et al. (2020), Schlesinger et al. (2021) and in the United Nations Environment Programme documents (2014). Papers emphasize that campus planning based on environmental and sustainability principles is one of the key factors for the university positive image formation, as well as an important criterion for the priority choice of the educational institution by applicants (*Fig. 1*).

At the same time, using the ideas of various authors (UNEP, 2014; Manzoor et al., 2020; Schlesinger et al., 2021), we propose to elaborate the model for forming a positive university image and taking into account the negative factors that impact it (*Fig. 2*). The model considers the special importance of environmental and sustainability components and defines features of satisfaction or dissatisfaction of students, staff and applicants.

The analysis of the world experience (Genta et al., 2019; Papadas et al., 2019; Sima et al., 2019; Bokolo, 2021; Fissi et al., 2021) shows that the most appropriate approach for the strategic planning of green and sustainable UC territories is the authors' schematic model presented in *Fig. 3*. In particular, the most important components of this approach are not only the implementation of renewable energy sources, minimization of the human impact on the natural environment and increasing the stability of natural ecosystems but also constant environmental monitoring and ecological state assessment, rational use of land and water resources, reducing emissions from vehicles, as well as environmentally conscious behavior and eco-initiatives of students, staff and visitors that in the most cases are among the necessary features of university positive image formation (*Figs. 1, 2*).

Fig. 1. *The main components that form the university image (based on Manzoor et al., 2020)*

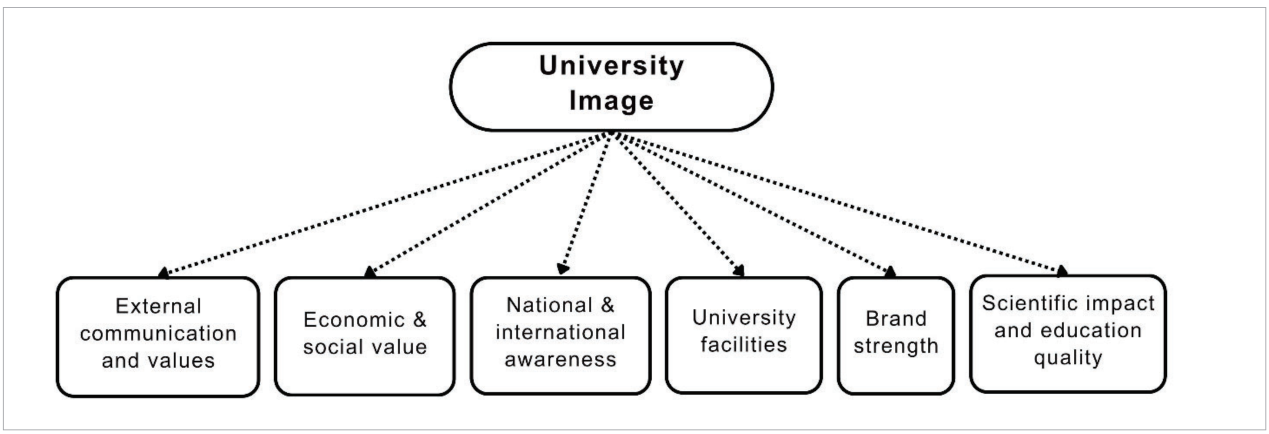


Fig. 2. *The model of forming the image of the university considering environmental and sustainability components, as well as features of satisfaction or dissatisfaction of students, staff and applicants*

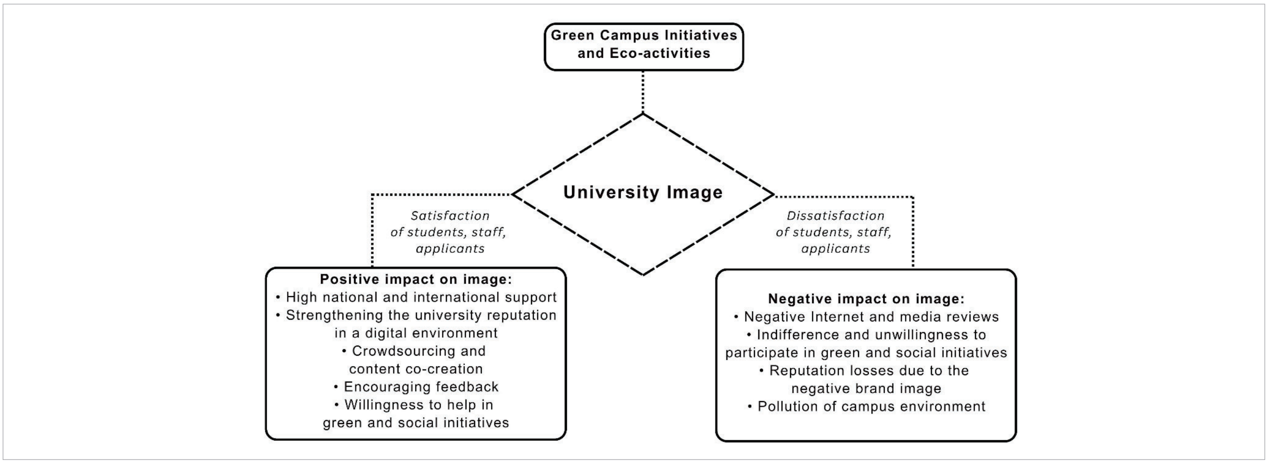
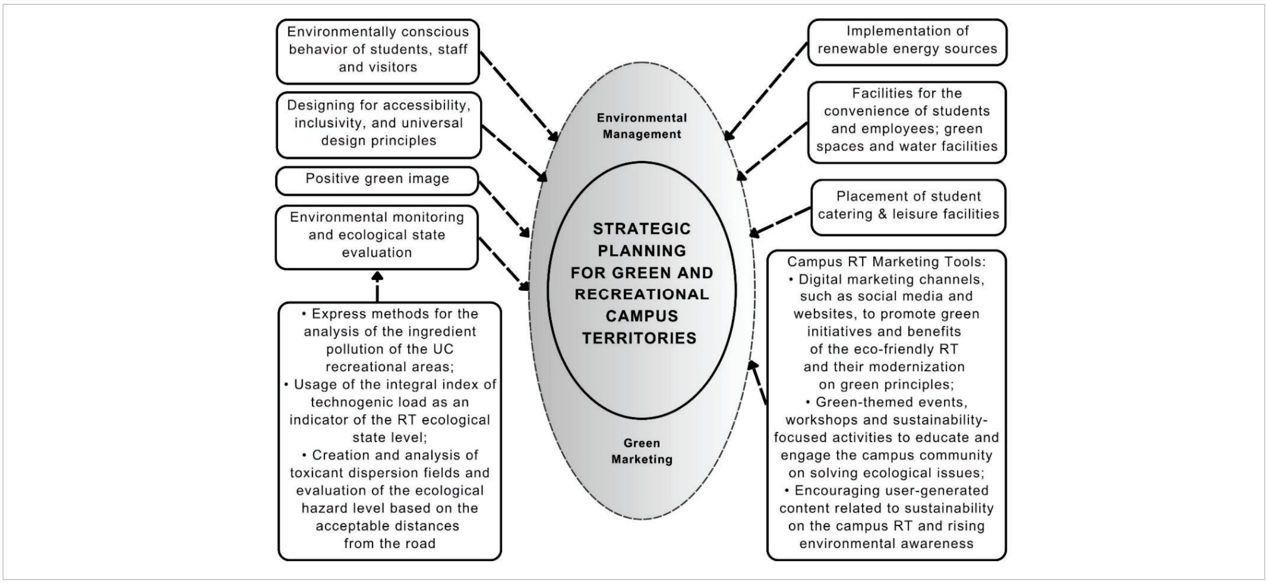


Fig. 3. *Synergistic combination of the principles of environmental management and green marketing for the purposes of strategic planning of university campus territories*



Thus, research on the planning and development of UC is an important issue, especially in ensuring the ecological safety of rest and recreational areas within their territories. We consider this is especially important due to the significant negative impact of motor transport pollution on city-type campuses. Strategic planning and improving the environmental conditions of university campus territories, especially recreational areas, are crucial tasks. To achieve this, it is also essential to use innovative marketing and managerial instruments (Nekmahmud and Fekete-Farkas, 2020; Shabbir et al., 2020; Kopnina, 2021) that will help to make campus territory eco-friendlier and more appealing and form the university positive image.

Our studies also confirm that the combination of the principles of environmental management and green marketing leads to the most environmentally friendly effect, which can be demonstrated by the example of strategic planning of green and recreational territories of leading world university campuses. This makes it possible to synergize ecologically oriented issues and maximize their benefits for both nature and humans. This idea is substantiated by the experience of environmentally friendly university campuses planning, particularly, of the Tokyo

Institute of Technology, Japan (TIT, 2022), DePaul University, USA (DPU, 2022), the Hong Kong University of Science and Technology, Hong Kong (HKUST, 2022), Vakif (foundation) universities of Turkey, Koc University (KU, 2022), the Vanderbilt University, USA (HubStar, 2022b; VU, 2022), the Loyola University, USA (Smithgroup, 2021) and others. One more important issue is the perspective of the greening of vehicles that move on the roads nearby UC. This case should necessarily include the modification of traditional fuels and the introduction of a variety of alternative types of fuels and energy (Vasylkevych, 2016; Vasylkevych, 2017; Butler, 2020; Kumar, 2020).

Methods

The national urban environmental monitoring system of Ukraine includes monitoring posts of the Borys Sreznevsky Central Geophysical Observatory (2022) and mobile pollution control stations for monitoring the urban atmospheric air state. However, monitoring posts usually do not cover the territory of university campuses; therefore, it is important to create an algorithm for forecasting the ecological state of the UC recreational areas, as well as assessment of their ecological safety level. In this context, the introduction of express methods for analysis of the ecological state of the territories, as well as mathematical modeling and criterion-based approach on the basis of the green economy principles, becomes especially important.

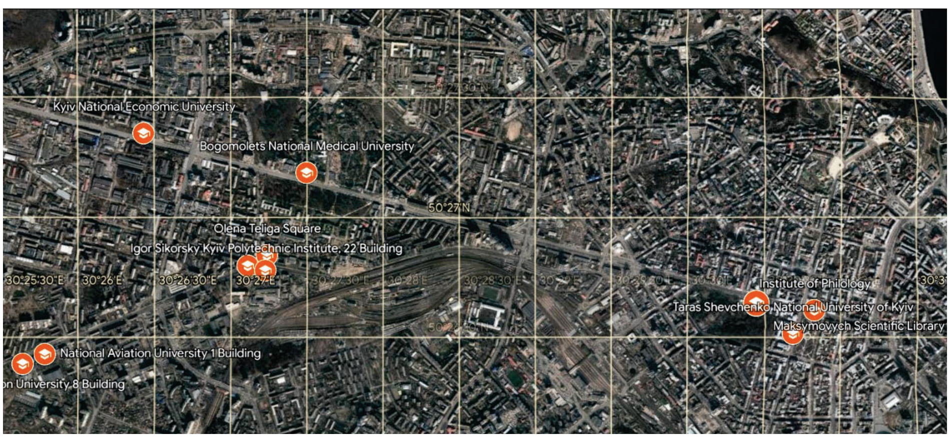
In research, densimetry, viscometry, stalagmometry, conductometry, potentiometry and some optical methods, in particular, refractometric investigation, have been used as express methods of analysis. The objects of physical and chemical analysis are soil samples taken at a depth of up to 10 cm in the investigated UC recreational territories, located in the central part of Kyiv (*Fig. 4*), as well as samples of atmospheric precipitation – rain and snow.

Samples of soil and atmospheric precipitations on the investigated UC territories were taken in accordance with the requirements of DSTU ISO 10381-5:2009 (2009) (State Standard of Ukraine) at 5 observation points at approximately the same distance from the road. Water ground extracts were prepared from the soil samples according to the method described in DSTU 8346:2015 (2015) and taking into account DSTU 4287:2004 (2004).

Conductometry. It has been established that the electrical conductivity of natural waters, as well as soil extracts, is determined mainly by the content of sodium Na^+, potassium K^+, calcium Ca^{2+}, magnesium Mg^{2+}, hydrocarbonate HCO_3^- ions, etc. (Dickson, 1984). At the same time, the presence, for example, of ferrum (II) Fe^{2+}, ferrum (III) Fe^{3+}, aluminum Al^{3+}, manganese (II) Mn^{2+} ions, complex ions, as well as ammonium ions NH_4^+, nitrite ions NO_2^-, nitrate ions NO_3^-, hydrophosphate ions HPO_4^{2-}, etc., will have almost no effect on the electrical conductivity of water solutions. The concentration of H^+ and OH^- ions in such natural solutions is usually insignificant and does not exceed 0.1–0.2%.

The electrical conductivity of the solutions was measured according to the standard method at the

Fig. 4. *Places of sampling on the territories of investigated UC (Google Earth satellite image, Kyiv, Ukraine)*



temperature of 298.15 K (ASTM D1125-23, 2023); the specific electrical conductivity of solutions x was calculated according to formula (1). The electrical resistance of the experimental electrochemical cell was measured by an alternating current conductometer with a temperature sensor and its compensator. The number of measurements for each sample was at least 5 times.

$$\chi = K / R \tag{1}$$

Where: *K* is the constant of the experimental glass electrochemical cell with platinum electrodes (the cell has been calibrated with standard solutions of potassium chloride KCl); *R* is the electrical resistance of the cell with the test solution, Ohm.

According to Hem (1970), it is possible to estimate quite accurately the salinity (mineralization) of the investigated systems with the help of measurements of the electrical conductivity of solutions (in particular, water soil extracts, water samples, etc.). So, with a proportionality coefficient equal to 0.65, the salt content in the samples was determined according to the formula:

$$Salt\ content_{solution} = \chi_{solution} \cdot 0.65 \tag{2}$$

Where: *x* is electrical conductivity, μS/cm; 0.65 is the proportionality coefficient (Hem, 1970).

Potentiometry. It is generally known that the value of the pH indicator of surface waters is quite stable, as a rule, which is due to the 'functioning' of the natural buffer system 'water solution of carbon dioxide – hydrocarbons'. Thus, after establishing the fact of a significant change in the pH values of water or soil extracts, it is possible to conclude that great amounts of electrolyte contaminants penetrated the natural environment.

So, the potentiometric method of analysis (potentiometry) makes it possible to investigate the dynamics of the pH indicator values and determine the limits of its natural fluctuations. The pH meter EV-74 with temperature compensation and a glass electrode as an indicator electrode was used to measure the electromotive force (EMF).

The silver chloride electrode was used as a reference electrode; its standard electrode potential varies insignificantly in the investigated temperature range.

To measure the EMF of the soil extracts, the soil samples were dried for several days (to stop microbiological processes). A layer approximately 1–2 cm thick was flattened, obtaining the shape of a square or circle, and then quartering was carried out. Water soil extracts were prepared according to DSTU 8346:2015 (2015); measurements were carried out immediately after filtering the solution. The pH meter was pre-calibrated using 5 standard buffer solutions with well-known pH values.

It is known that the penetration of surface-active substances (determined using the *stalagmometri method*), emulsions and suspensions of various origins, electrolyte substances, heavy metal compounds, etc. into the natural waters significantly worsens water quality and ecological situation.

Refractometry is one of the optical methods of analyzing natural and artificial systems, based on the phenomenon of polarization of molecules under the action of visible light radiation. Therefore, it was chosen as a method by which it is possible to obtain information about the sudden pollution of waters not only by electrolyte substances (that can be quite easily determined by the methods of conductometry and potentiometry) but also by organic substances, suspensions, etc.

The refractive coefficient of solutions directly depends on the concentration of dissolved substances, which is caused by increasing the density of the solution (which has been determined by the *pycnometric densitometric method*) and the interaction of light with the substance (Tereshchenko, 2019). The refractive index *n* of the solution depends linearly on the concentration of dissolved substances, namely:

$$n = n_0 + k \cdot C(X) \tag{3}$$

Where: n_0 – the refractive index of the pure solvent; *C(X)* – the concentration of a substance in a solution; *k* – the empirical coefficient.

The RPL-3 Abbe-type refractometer was used in our study. To eliminate iridescence and obtain a distinct image of the border, a dispersion compensator was embedded into the refractometer; the scale of the device was graded for a temperature of 20°C. The refractometer was justified to reference liquids and the zero point of the device was checked with distilled water before starting work (Tereshchenko, 2019).

In our study, refractometry was used qualitatively – firstly, for identifying pollutants, and, secondly, for expressing control of the quality of the studied environments. Quantitative determination of the concentration of toxicants was not carried out. The presence of emulsions in solutions was determined using the Tyndall effect (Xiao et. al, 2019). The refractive coefficient of the samples was measured at a temperature of 20 ± 0.1°C and at a wavelength λ of the D-spectrum line of the gaseous sodium. The measurements were repeated 5 times until the results coincided.

Organoleptic observations and the method of *viscometry* were also used for the express analysis of the quality of the studied environments. After determining the ingredient contamination of a certain UC recreational territory, it was recommended to use more precise methods of analysis, such as quantitative reagent analysis.

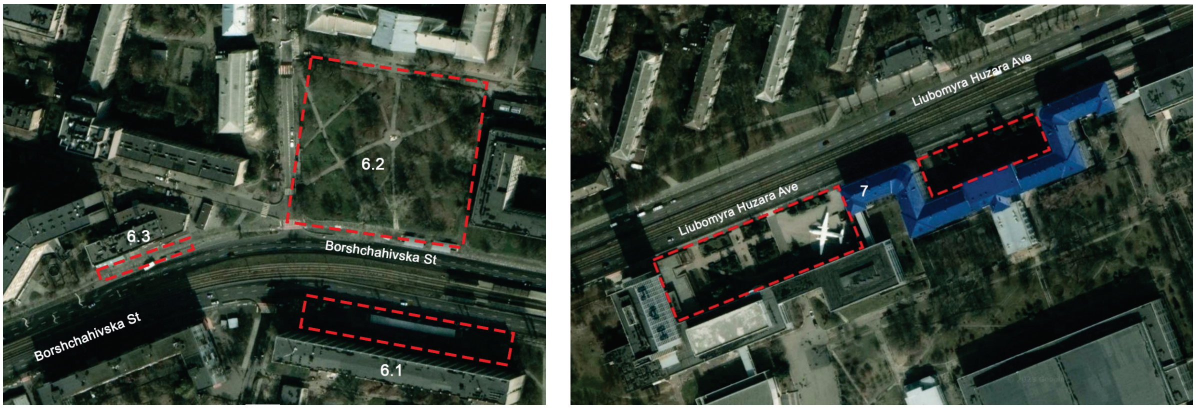
To assess the state of the air environment surface layer in the university campuses RT, spatial mathematical models of the dispersion fields of pollutant substances, which are the ingredients of MVE emissions, were created. Development of toxicant dispersion fields was carried out in the MathCad using the flame approximation model implemented in it by solving the semi-empirical equation of turbulent diffusion of certain pollutants (Kofanov, 2020).

Results and Discussion

Since the key objects of our study are the university campuses RT, in *Fig. 5* and *Fig. 6*, human rest areas that were selected for the research are shown. They are, for example, city-type university campuses RT: 1) Kyiv National Economic University named after Vadym Hetman (*Fig. 5a*); 2) Bogomolets National Medical University (*Fig. 5b*); 3) Taras Shevchenko National University of Kyiv; 4) Maksymovych Scientific Library of the Taras Shevchenko National University of Kyiv; 5) Educational and Scientific Institute of Philology of the Taras Shevchenko National University of Kyiv (park areas) (*Fig. 5c*); 6) National Technical University of Ukraine 'Igor Sikorsky Kyiv Polytechnic Institute' (Igor Sikorsky Kyiv Polytechnic Institute), 6.1 – Educational building № 22; 6.2 – Olena Teliga Square near the Educational building № 18; 6.3 – student catering establishments (*Fig. 6a*); 7) National Aviation University (Educational buildings № 1, № 8 and № 8A) (*Fig. 6b*). *Figs. 5* and *6* were created with the help of Google Maps satellite images.

Fig. 5. *Rest areas nearby: a) Kyiv National Economic University named after Vadym Hetman; b) Bogomolets National Medical University; c) Taras Shevchenko National University of Kyiv; Maksymovych Scientific Library of the Taras Shevchenko National University of Kyiv; Educational and Scientific Institute of Philology of the Taras Shevchenko National University of Kyiv (park areas)*

Fig. 6. *Rest areas nearby: a) Educational building № 22 of the Igor Sikorsky Kyiv Polytechnic Institute; Olena Teliga Square near the Educational building № 18 of the Igor Sikorsky Kyiv Polytechnic Institute; student catering establishments, etc.; b) Educational buildings № 1, № 8 i № 8A of the National Aviation University*



a *b*

The results of the calculation of the toxicant concentrations of the air surface layer on the studied RT under various, most dangerous meteorological conditions (direction and speed of the average wind) are presented in *Figs. 7–9* in the multiplicity of exceeding their maximum single permissible concentrations (MPCm.s.).

It is well known that the dispersion of harmful substances in the air is due to atmospheric turbulence, which occurs due to molecular diffusion and turbulent diffusion (major role) of gaseous substances. Turbulent diffusion, in turn, consists of two main components – thermal and dynamic. Thermal diffusion provides convective turbulence and is associated with a vertical temperature gradient of the air, while dynamic diffusion provides mechanical turbulence and occurs during the movement of air masses under the action of wind.

So, as can be seen in *Figs. 7* and *8*, under the chosen most dangerous meteorological conditions (direction and speed of the average wind), there is a significant exceeding of the maximum single permissible concentrations of carbon monoxide and nitrogen oxides (in terms of nitrogen dioxide NO2) not only in the center of the road but also at the distance more than 15 m from the center of the road. So, ecologically acceptable (safe) concentrations of these toxicants will be achieved at a distance nearby 12–17 m from the road center. It is especially noticeable for nitrogen oxides because of their exceeding the maximum single permissible concentrations nearby 30–37 times in the road center.

The situation with PM_{10} is not so dramatic because of its exceeding the maximum single permissible concentrations by 1.4–1.6 times in the road center and ecologically acceptable concentrations distance in average nearby 1.5–2 m from the center of the road (*Fig. 9*). But it is necessary to note that in addition to the primary pollution from traffic flows, secondary pollution also occurs due to the mechanical transfer of pollutants and their interactions, including under the influence of the sunlight, precipitation, etc. This is especially related to PM, which can actively adsorb harmful, including carcinogenic, substances throughout their localized state. All this causes a serious danger to the environment and human health.

To determine the level of environmental safety of RT on university campuses and their ranking according to the level of environmental hazard, a criterion-based approach was proposed. Such an approach makes it possible to take into account the ingredient pollution of certain environmental components, as well as the type and place of human rest.

An integral index of technogenic load I_T was proposed as an indicator of the ecological safety level of the investigated territories. On the basis of this indicator, the changes in the ecological state of the university campuses RT were evaluated, and recommendations on the reduction of the harm to human health were developed (Borysov and Kofanova, 2019).

Fig. 7. *Dispersion fields of carbon monoxide in the zone of influence of the road (Borshchagivska St., Kyiv, Ukraine) on a) the territory of the Olena Teliga Square with a southwesterly average wind speed of 5 m/s, and b) RT near Educational building № 22 of the Igor Sikorsky Kyiv Polytechnic Institute with a westerly average wind speed of 5 m/s*

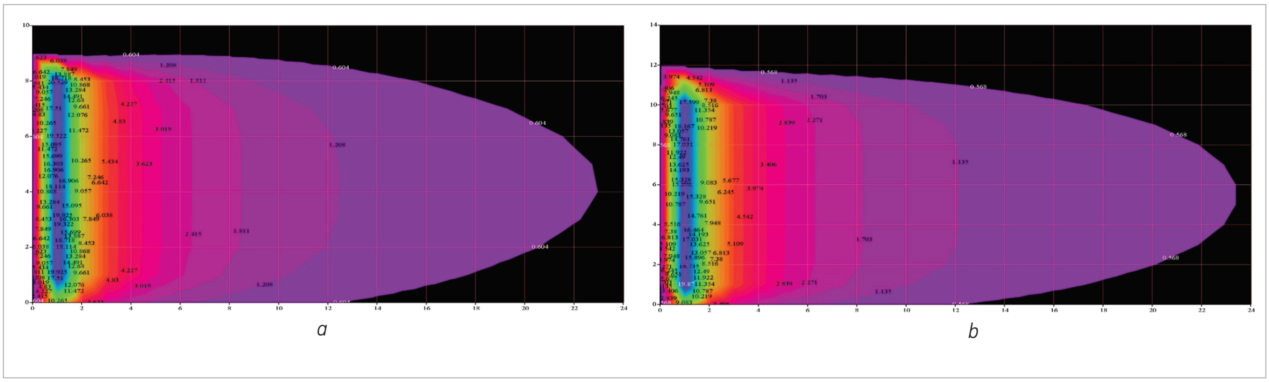


Fig. 8 *Dispersion fields of nitrogen oxides in terms of nitrogen dioxide NO2 in the zone of influence of the road (Borshchagivska St., Kyiv, Ukraine) on a) the territory of the Olena Teliga Square with a southwesterly average wind speed of 5 m/s, and b) RT near Educational building № 22 of the Igor Sikorsky Kyiv Polytechnic Institute with a westerly average wind speed of 5 m/s*

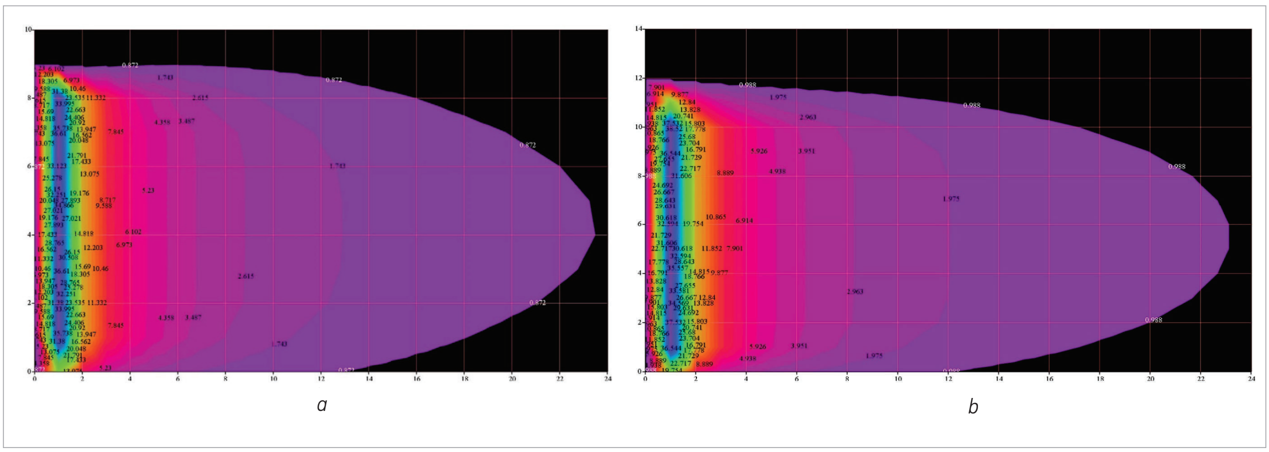
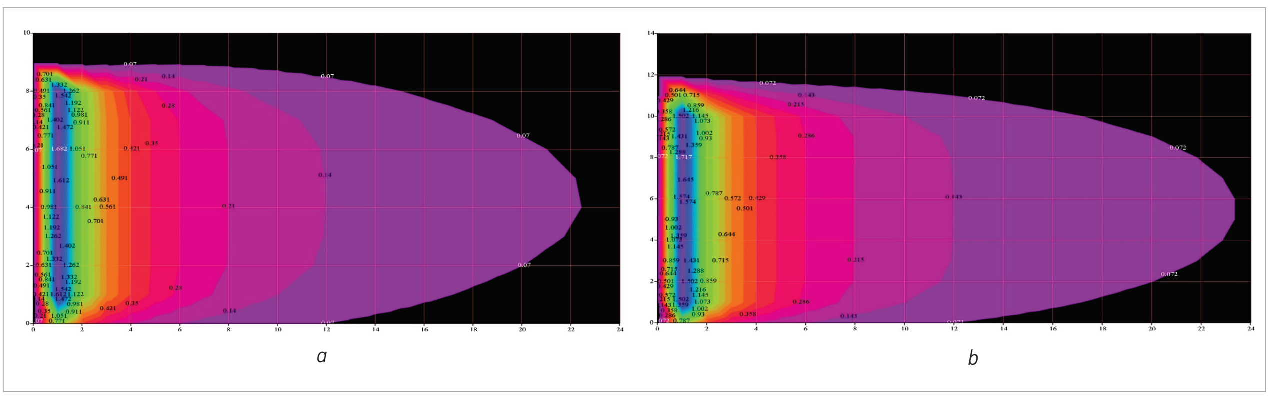


Fig. 9 *Dispersion fields of PM10 in the zone of influence of the road (Borshchagivska St., Kyiv, Ukraine) on a) the territory of the Olena Teliga Square with a southwesterly average wind speed of 5 m/s and b) RT near Educational building № 22 of the Igor Sikorsky Kyiv Polytechnic Institute with a westerly average wind speed of 5 m/s*



On the basis of the determined indicators of pollution of certain environmental components (atmospheric air, soil, precipitation, etc.), I_T was calculated according to the formulae:

$$I_T = \sum_{i=1}^{n} k_i \cdot x_i , \qquad (4a)$$

or

$$I_T = k_A \cdot x_A + k_S \cdot x_S + k_W \cdot x_W , \qquad (4b)$$

Where: n is the number of indicators; k_i – k_A, k_S, k_W are weighting factors for individual indicators; x_i – x_A, x_S, x_W are values of pollution indicators forming I_T (in points) (Borysov and Kofanova, 2019).

Indicators of soil and precipitation pollution were determined using the express analysis methods described above – conductometry, potentiometry, optical methods, etc., with organoleptic observations, densimetry, viscometry, and stalagmometry.

Atmospheric air pollution levels were determined according to spatial mathematical models using a computational experiment. Calculations were carried out under the most unfavorable meteorological conditions (VRU, 2007) using field observations of traffic flows on the roads located nearby the studied UC recreational areas. Observations were recorded by video filming, using also online web cameras where they were available.

With the help of the developed spatial mathematical models of the main pollutants' dispersion, which are the ingredients of MVE emissions, a significant hazard for the rest of the young people in the studied RT of the university campuses was set. In particular, the concentrations of such dangerous pollutants as carbon monoxide and nitrogen oxides (in terms of nitrogen dioxide) exceeded their $MPC_{m.s.}$ by tens of times. *Fig. 10* shows the diagrams of ecologically acceptable distances from the road, determined with the help of developed mathematical models and a computational experiment for the studied university campuses RT.

In order to rank the studied UC recreational areas and evaluate their ecological safety, an integral indicator– the index of technogenic load I_T (formula (4b)) – was calculated. Its calculation involves the assessment of each component of the natural environment (atmospheric air, soil, precipitation, etc.) by gradation from 1 to 4 points, where 1 point is an ecologically acceptable level of territory pollution, while 4 points is an ecologically unacceptable level.

The level of air pollution of the UC rest areas was assessed by the multiplicity of investigated pollutants $MPC_{m.s.}$ exceeding; the degree of pollution of soils and precipitation was assessed by the content of certain toxicants, in particular, radioactive elements, heavy metals, acid-salt pollution, etc.

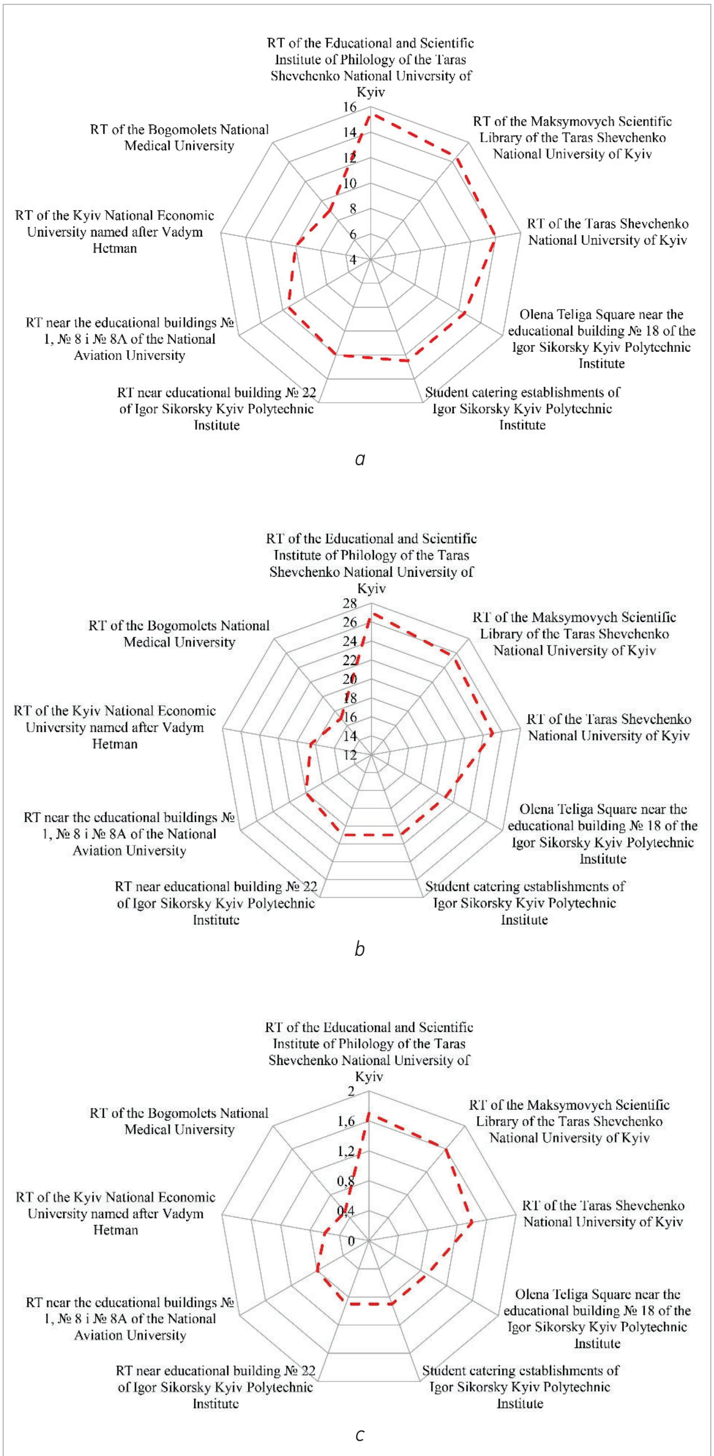
Therefore, on the basis of the analysis of the dispersion fields of the MVE emissions pollutants (*Fig. 7–9*) and literature data (Borysov and Kofanov, 2018; Baklanov and Zhang, 2020; Giunta, 2020; Sicard et al., 2023), the following gradation of the hazard levels of the air surface layer was proposed (without taking into account the synergistic effects of air pollution with several harmful pollutants, as well as the geometry of roads):

- ecologically hazardous environment (very high level of pollution) – 4 points, if the multiplicity of the certain pollutant $MPC_{m.s.}$ exceeding is greater than 8.0;
- high level of pollution – 3 points, if this ratio is 4.4–8.0 $MPC_{m.s.}$;
- the average level of pollution – 2 points, if the multiplicity of exceeding of the certain pollutant $MPC_{m.s.}$ is 2–4.4 points;
- low level of pollution – 1 point, if the multiplicity of exceeding the $MPC_{m.s.}$ is 1.1–1.9 points;
- ecologically safe level – 0 points, under the conditions when there is no exceedance of $MPC_{m.s.}$ of the pollutant.

As discussed earlier, indicators of geochemical pollution of soils and atmospheric precipitation with dangerous toxicants content were determined by methods of express analysis (conductometry, potentiometry, densimetry, viscometry, stalagmometry, refractometry, etc.), as well as by means of analytical reagent analysis. Since radioactive pollution was not detected at any of the studied objects, the maximum number of points corresponding to dangerous soil or precipitation pollution is 3 points in case of pollution of the territory with heavy metals, 2 points in the presence of acid-salt pollution, and 1 point in case of ecologically acceptable test results.

Therefore, taking into account all types of investigated RT pollution, the integral index of technogenic load I_T for all UC components is $2 \le I_T \le 20$, since the weighting factors in formula (4b) for all pollution components were assumed equal to 1. If necessary, these coefficients can

Fig. 10 *Ranking by the level of ecological safety based on ecologically acceptable distances from the road (in meters) in relation to the studied university campuses RT by pollutants that are the main ingredients of MVE emissions, namely: a) by carbon monoxide, b) by nitrogen oxides in terms of nitrogen dioxide NO_2; c) by PM_{10}, calculated under the most unfavorable meteorological conditions*

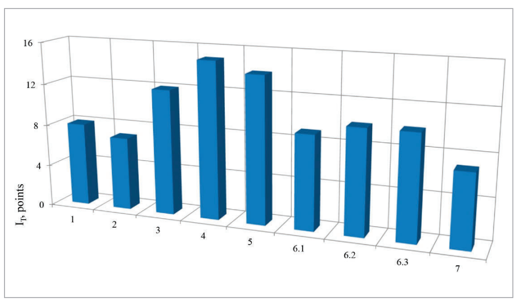


be adjusted taking into account the geometric characteristics of the road and the type of human rest.

Fig. 11 presents an assessment of the level of environmental safety of the studied RT of city-type university campuses according to the integral index of technogenic load I_T. As can be seen, I_T and the level of environmental safety are maximally unacceptable for the rest areas of the Taras Shevchenko National University of Kyiv (column № 3), the Educational and Scientific Institute of Philology of the Taras Shevchenko National University of Kyiv (park areas) (column № 5) and especially for the area near the Maksymovych Scientific Library of the Taras Shevchenko National University of Kyiv (column № 4).

The territories and recreational areas of the Bogomolets National Medical University (column № 2), the National Aviation University (column № 7) and the Kyiv National Economic University named after Vadym Hetman (column № 1) are more acceptable from an ecological point of view. Other studied RT of university campuses have an average level of environmental safety (*Fig. 10*). Thus, the pollution caused by the emissions of MVE on most RT of the university campuses leads to a significant health hazard to people who are not even aware of it. The situation is especially dangerous for those resting people (students, teachers, applicants, members of their families, etc.) who have diseases of the cardiovascular system and chronic respiratory diseases, including asthma.

Fig. 11. *Assessment of the level of environmental safety of the studied RT of the university campuses according to the integral index of technogenic load I_T*



Conclusions

Therefore, the main purpose of university campuses strategic planning is to achieve the harmonious unity of nature, humans, and architectural complexes, making it possible to appropriately organize special green zones for students and employees, which in turn significantly contributes to the positive university image formation.

It has been found out that UC located in large cities and especially in their central areas suffer a lot from the excessive technogenic load typical for highly urbanized areas and especially from the emissions of MVE. This, in turn, creates additional health hazards for students, lecturers, staff, applicants, etc., especially if educational buildings, dormitories and rest areas are located next to highly loaded roads.

In the study, the level of environmental safety of recreational territories of Kyiv city university campuses was assessed taking into account the impact of vehicle emissions dangerous ingredients. The level of pollution of the UC atmospheric air surface layer, soil, precipitation, etc. was analyzed using a complex of express methods of analysis, mathematical modeling and criterion-based approach and considering the main principles of environmental management and green marketing. With the help of computational experiments, environmentally acceptable distances from the road were determined allowing us to apply a criterion-based approach to the assessment of the RT environmental safety level on the basis of the proposed integral index of technogenic load I_T.

To reach the aim set in the study, a complex of express methods for analysis (conductometry, potentiometry, densimetry, viscometry, stalagmometry, refractometry, etc.) of the ingredient pollution of recreational areas of the UC from the emissions of MVE was applied. The level of ecological safety of the studied RT, the level of environmental safety of the studied UC recreational territories were assessed by means of the criterion-based approach, data on the integral index of technogenic load, taking into account the type of RT. Propositions for human health hazards minimization and improvement of the environmental monitoring system were developed, in particular by the usage of the methods of chemical analysis, including methods of quantitative analysis in combination with computational experiment and mathematical modeling methods, while determining facts of contamination of a certain component of the environment.

The study also suggests that suburban-type UC, which as a rule are located at a considerable distance from highly loaded roads, are more ecologically acceptable than those UC, which as a rule are located in megacities. The formation of a unified, convenient and functional, ecologically safe educational environment is the crucial element of the university success and its positive image.

It is considered that the rational and well-thought-out planning of the UC territory, the original architectural design and landscape design of the campus space, emphasizing the planning of green recreational areas, are essential for the appropriate rest of students and employees. In particular, our research confirms that a combination of environmental management and green marketing principles generates beneficial effects on both the environment and human well-being. Leading universities around the world pay significant attention to strategic planning of green and recreational areas to maximize benefits for university, humans and nature preservation synergizing ecologically oriented issues.

Obtained results can be used for the design and reconstruction of university campuses, recreational areas, etc., as well as for the planning of roads located nearby the UC, improving traffic on them. We also consider it reasonable to foresee the enhancement of the student environmental activities in their research work, as well as to promote the creation of student communities for monitoring the environmental state of campuses and the development of startup projects aimed towards purifying the UC territory components from toxic substances. This, in turn, will contribute greatly to attracting investor capital for green and recreational campus areas improvement and positive university image formation.

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