UDC 502/504 **doi: 10.20998/2079-0821.2024.02.04**

O. H. LEVYTSKA, V. V. TSARENKO

ANALYSIS OF POLLUTANTS EMISSIONS IN THE CONDITIONS OF COMBUSTION OF ALTERNATIVE AND TRADITIONAL SOLID FUELS

The problem of pollutant emissions and the correlation of emission values with climate change is an extremely urgent task today. Climate change is causing glaciers to melt, which is causing water levels in reservoirs to rise. The issues of environmental pollution by the products of combustion of solid fuels are becoming more and more relevant. Among the pollutants that enter the air after the combustion of fuel in the furnaces of boiler units, there are also greenhouse gases that stimulate the greenhouse effect, causing climate change. The work determines emission indicators and emissions of pollutants into the atmospheric air. The task of the work is to identify and recommend the use of modern and effective methods for reducing emissions of pollutants into the atmosphere. The work uses analytical articles and sites that raise the problem of climate change. The work also shows the results of calculating pollutant emissions from combined heat and power boilers, carried out according to the recommendations of national guidelines. A high value of dust emission is typical for straw and flax fescue. In terms of nitrogen oxide emissions, wood waste has the highest values. Slightly lower values for the emission of carbon dioxide, methane, NMVOC are determined for wood waste. It is important to note that when gaseous fuels are burned, there will be no emissions of suspended particulate matter. It should also be noted that natural gas and wood waste do not contain sulfur-containing compounds, which ensures the absence of sulfur dioxide in flue gases when fuels are burned. However, when gases are burned, mercury compounds can be released in trace amounts. One of the options for solving the problem is the transition to alternative energy sources. The development of such sources is already underway, but their implementation in practice, unfortunately, is slow.
Keywords: emissions; atmosphere; fuels; climate change, gases.

О. Г. ЛЕВИЦЬКА, В. В. ЦАРЕНКО

АНАЛІТИКА ВИКИДІВ ЗАБРУДНЮЮЧИХ РЕЧОВИН В УМОВАХ СПАЛЮВАННЯ АЛЬТЕРНАТИВНИХ ТА ТРАДИЦІЙНИХ ТВЕРДИХ ПАЛИВ

Проблема викидів забруднюючих речовин та кореляція значень викидів зі зміною клімату є надзвичайно актуальним завданням сьогодення. Зміна клімату спричиняє танення льодовиків, що веде до підвищення рівня води у водоймах. Питання забруднення навколишнього середовища продуктами згоряння твердого палива стають все більш актуальними. Серед забруднюючих речовин, які потрапляють в повітря після згоряння палива в топках котельних агрегатів, є і парникові гази, що стимулюють парниковий ефект та можуть бути причиною зміни клімату. В роботі визначаються показники емісії та викиди забруднюючих речовин в атмосферне повітря. Завданням роботи є виявлення та рекомендація до використання сучасних та ефективних методів зменшення викидів забруднюючих речовин в атмосферу. У роботі використані аналітичні статті та сайти, які порушують проблему зміни клімату. У роботі також наведено результати розрахунку викидів забруднюючих речовин від комбінованих теплоенергетичних котлів, виконаних відповідно до рекомендацій національних методик. Високе значення викиду пилу характерно для костриці солом'яної і льняної. За рівнем викидів оксидів азоту деревні відходи мають найвищі значення. Дещо нижчі значення викиду вуглекислого газу, метану, НМЛОС визначаються саме для деревних відходів. Важливо відзначити, що при спалюванні газоподібного палива не буде викидів зважених твердих частинок. Також слід зазначити, що природний газ і деревні відходи не містять сірковмісних сполук, що забезпечує відсутність діоксиду сірки в димових газах при спалюванні палива. Однак при спалюванні газів сполуки ртуті можуть виділятися в незначних кількостях. Одним з варіантів вирішення проблеми є перехід на альтернативні джерела енергії. Розробка таких джерел вже ведеться, але їх реалізація на практиці, на жаль, відбувається повільно.
Ключові слова: викиди; атмосфера; палива; зміна клімату, гази.

Introduction. Environmental pollution is a problem that often affects the functioning and life of a critical number of regions and territories.

For example, the article (Laela et al., 2023) determined the concentrations of arsenic in soil and rice, while samples were taken in several cities and regions of East Java, and high levels of this pollutant were found in several places. Clogging of water is also dangerous. Thus, the transfer of microplastics through the food chain has an adverse effect on organisms (Rahmayanti et al., 2022) living in water.

Authors of the article (Piracha et al., 2022) are reported about significant temperature differences between urban areas and adjacent rural regions as a characteristic feature of urbanization. Frequent emissions of pollutants in cities include carbon, sulfur, nitrogen, and dust compounds.

The article (Houngbégnon et al., 2019) states that intersections are the areas with the highest levels of exposure to PM 2.5, which negatively affects drivers and passengers in traffic.

And, of course, high risks exist in industrial zones. According to studies presented in (Lin et al., 2021), it was found that areas located in the zone of influence of industrial facilities that are sources of volatile combustible gases in many cities are not monitored, but the probability of an increase in the level of such substances remains high.

The issues of environmental pollution by the products of combustion of solid fuels are becoming more and more relevant. Among the pollutants that enter the air after the combustion of fuel in the furnaces of boil-er units, there are also greenhouse gases that stimulate the greenhouse effect, causing climate change.

In particular, the authors (Bauer et al., 2015) considered scenarios for assessing the impact of policies stabilization of climate change in fossil fuel markets, where oil and gas are shown to generate higher revenues than coal, while the latter is the largest among those considered by the source of CO_2 emissions.

Global warming is steadily leading to the melting of glaciers and, as a result, an increase in the level of the World Ocean.

Traditional natural gas is becoming a scarce resource. New alternative gaseous and solid fuels are emerging. Experts are inclined to interpret "alternative

energy" as non-traditional energy sources. These include solar energy, wind energy, geothermal energy, and biomass. At the same time, the importance of developing energy solutions that not only minimize environmental impact, but also use inexhaustible or renewable resources to meet energy needs is emphasized (Ківвa, 2022).

The problems of comparing the quantitative and qualitative composition of combustion products when using natural gas and alternative fuels remain relevant.

The work presents estimated comparative assessment of emissions re-lease in combustion products during work of high-power steam boilers with the use of traditional fuel – natural gas and alternative fuels – blast-furnace and coke-oven gases generated in the process of technological cycle at iron and steel and coke-chemical enterprises. Biomass has also been investigated as an alternative resource.

Calculation algorithm is shown and formulas for assessment of car-bon content in exhaust gases and biomass are defined, conclusions on ecological efficiency of gaseous fuels and biomass are given.

The main factor disrupting the climate balance is the use of coal fuels and inefficient use of energy. Greenhouse gases such as CO_2, CH_4 and N_2O, that are generated due to human activity can cause an increase in the greenhouse effect.

According to the data of United States Environmental Protection Agency the fossil fuel combustion produces about 65% of global emishsions of greenhouse gases (United States Environmental Protection Agency Website, Covert et al., 2016).

Excessive amounts of these gases trap the sun's heat in the lower atmosphere, preventing it from escaping back into space. This causes the planet to heat up, which in turn leads to an increase in the average annual temperature on Earth (Ukrainian Climate Network).

Rising temperatures on Earth contribute to the melting of glaciers in Greenland, the Arctic and Antarctica, leading to the release of water into the oceans. This leads to a rise in sea level, and as a result, coastal areas become victims of flooding. During the twentieth century alone, global sea level increased by 20 cm and continues to rise annually. The reservoir has already deepened entire islands and poses a threat to cities such as Melbourne, New York, Dakar, not to mention Venice or Amsterdam (Марченко et al., 2020).

Methodology. When determining the gross emission of hazardous substances for combustion units, there is used the method of continuous measurements with the application of in-process control devices or as per calculation of the index of hazardous emission – the specific value of emissions that is determined for a particular unit and takes into consideration the fuel characteristics, in particular its chemical composition, combustion processes and methods of emission reduction, assessment of the purification systems performance (Збірник показників емісії, 2004).

Index of hazardous emission and lower wet heating value of this fuel were calculated according to procedure (Збірник показників емісії, 2004). To determine the indexes of emissions of NOx and sulphurous anhydride, it was used the parameters of the effectiveness of primary measures to reduce emissions, efficiency of flue gases purification from pollutant, purification plant performance coefficient, low load (Збірник показників емісії, 2004). In the calculations, we set the fuel consumption equal to 1 t.

Results and discussion Pollutant emissions from solid fuel combustion include non-methane volatile organic compounds (NVOC), dust, soot, methane, compounds of sulphur, carbon, nitrogen and are partially captured in gas cleaning equipment. The problem of capturing of pollutants during fuel combustion in small household installations is actual because additional equipment is expensive to install, and the capacity of heating systems, as a rule, is not so large as to be checked by inspection authorities.

Therefore, a significant part of pollutant emissions that are generated during the combustion of solid fuels is simply not taken into account in the summary reports about emissions.

Below the emissions from the combustion of coal or coal briquettes based on the data (Методики розрахунку викидів забруднюючих речовин, 2011) are examined and are shown on Fig. 1.

In addition, when burning coal or coal briquettes, 3169 kg of carbon dioxide is released per ton of fuel.

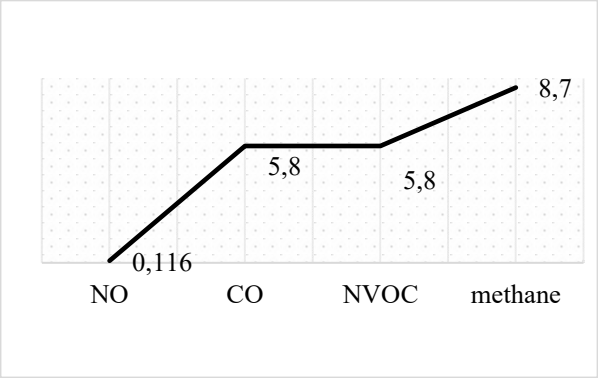


Figure 1 – Emissions of harmful substances during the combustion of coal or coal briquettes, kg per ton of fuel (using data of Методика розрахунку викидів забруднюючих речовин, 2011)

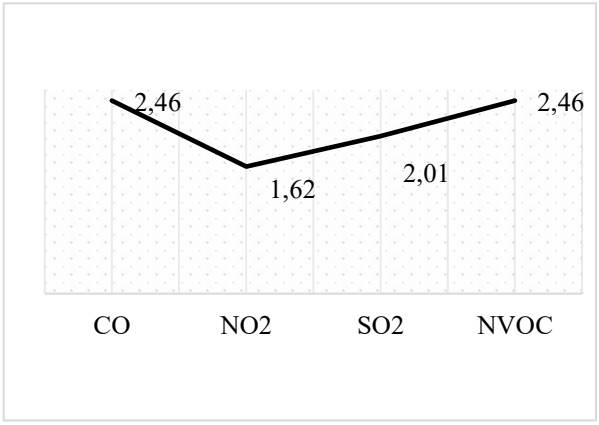
From the graph of Fig. 1 it can be seen that the expected high levels of methane, carbon monoxide and NVOC emissions have been obtained.

Emissions from the burning of peat or peat briquettes based on data (Методики розрахунку викидів забруднюючих речовин, 2011) are shown on Fig. 2.

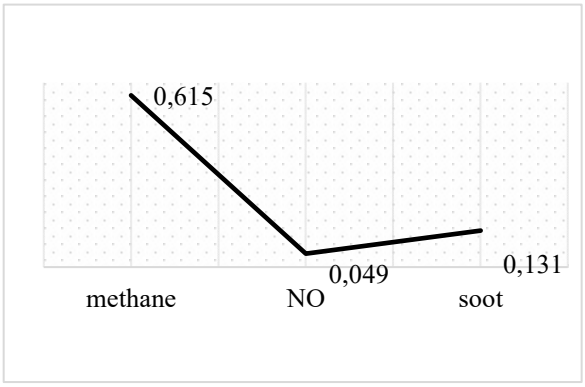
In addition, when burning peat or peat briquettes, 1070 kg of carbon dioxide is emitted per ton of fuel. Taking into account this fact and the data of Fig. 2, emissions from the combustion of peat or peat briquettes are the highest in terms of carbon dioxide, significantly lower in terms of other pollutants. Among the latter, there are higher emissions for carbon oxides and NVOC and the lowest emissions for nitrogen oxide.

Emissions from combustion of wood waste, straw, flax firewood, sunflower husk are shown on Fig. 3. These alternative fuels are often used today in small industries or households.

In addition, due to rising temperatures, the deep layer of the Earth, which previously remained frozen for thousands of years, begins to melt – this is the so-called permafrost or permafrost. This leads to a series of serious problems: as the permafrost melts, the ground above it shifts, causing buildings and infrastructure to collapse.



a

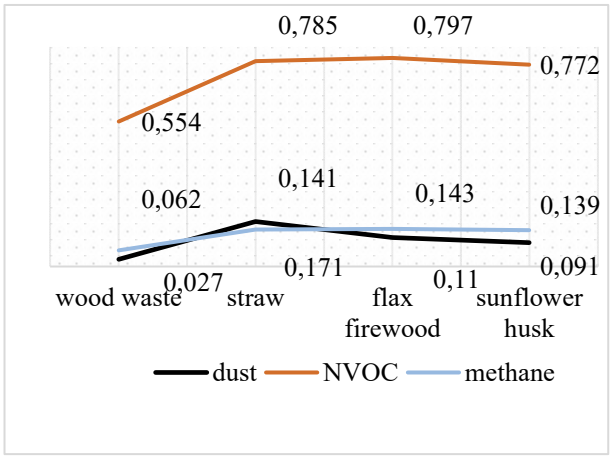


b

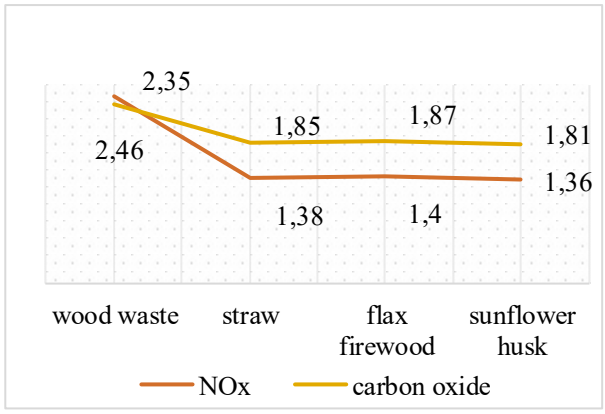
Figure 2 – Emissions of harmful substances: a – CO, NO_2, SO_2, NVOC, b – methane, NO, soot, during the combustion of peat or peat briquettes, kg per ton of fuel (using data of Методика розрахунку викидів забруднюючих речовин, 2011)

Emissions of harmful substances during the combustion of various types of fuels in boilers are shown in Fig. 3. Sulfur dioxide emissions when burning straw will be 2 kg per ton of fuel, when burning sunflower husks – 3.2 kg per ton of fuel.

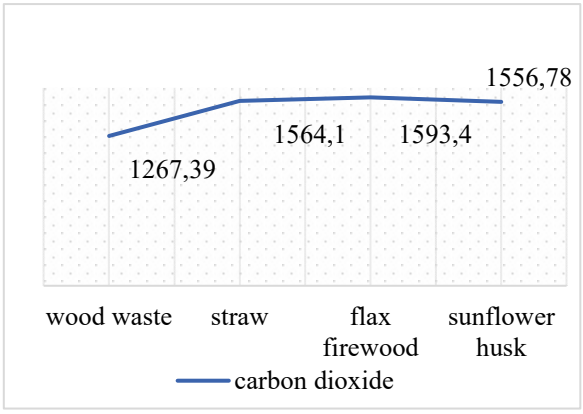
A high value of dust emission is typical for straw and flax fescue. In terms of nitrogen oxide emissions, wood waste has the highest values.



a



b



c

Figure 3 – Emissions of harmful substances: a – dust, NVOC, methane, b – NOx, carbon oxide, c – carbon dioxide, during the combustion of different types of fuels, kg per ton of fuel

Slightly lower values for the emission of carbon dioxide, methane, NVOC are determined for wood waste.

Conclusions. Comparing the considered alternative and traditional sources of emissions, it should be said that carbon dioxide emissions are very high for all types of fuels, but the highest emission values are shown for traditional coal and coal briquettes. Logically, carbon monoxide emissions are also highest for coal and coal briquettes.

Estimates of methane and NVOC emissions also indicate to the advantage of alternative fuels. Emissions of these pollutants for traditional coal are the highest among all the fuels considered.

Emissions of alternative fuels contain dust or soot in small quantities.

Considering the alternative fuels, it is difficult to single out one type of fuel that can be called the most environmentally friendly. Of course, emissions occur when all fuels are burned, and for each fuel there are pollutants for which the emission is relatively higher, as well as there are substances for which the emission is relatively lower.

In any case, all the types of considered alternative fuels are competitive in comparison with traditional coal, for some substances they have lower emission values. At the same time, one and all the wood waste, straw, flax firewood, sunflower husk are the waste that is recyclable and the environmental problems are solved with their use.

One of the options for solving the problem is the transition to alternative energy sources. The development of such sources is already under-way, but their implementation in practice, unfortunately, is quite slow.

Список літератури

1. Laela, N., Pasma S. A., Santoso M. Arsenic Levels in Soil and Rice and Health Risk Assessment via Rice Consumption in Industrial Areas of East Java, Indonesia. *Environment and Natural Resources Journal*. 2023, No 21(4), pp. 370-380.

2. Rahmayanti, R., Adji, B. K., Nugroho, A. P. Microplastic Pollution in the Inlet and Outlet Networks of Rawa Jombor Reservoir: Accumulation in Aquatic Fauna, Interactions with Heavy Metals, and Health Risk Assessment. *Environment and Natural Resources Journal*. 2022, No 20(2), pp. 192-208.

3. Piracha A., Tariq Chaudhary M. Urban Air Pollution, Urban Heat Island and Human Health : a review of the Literature. *Sustainability.* 2022, No 14(15). URL: https://doi.org/10.3390/su14159234

4. Houngbégnon P., Ayivi-Vinz G., Lawin H., Houessionon K., Tanimomon F., Kêdoté M., Fayomi B., Dossougbété S., Agueh V. Exposure to PM2.5 Related to Road Traffic : Comparison between Crossroads and Outside of Crossroads at Cotonou, Benin. *Open Journal of Air Pollution.* 2019, No 8, pp. 108–117.

5. Lin S., Liu Z., Qian J., Li X., Zhang Q. Flammability and Explosion Risk of Post-explosion CH4/air and CH4/coal dust/air Mixtures. *Combustion Science and Technology.* 2021, no 193 (8), pp. 1279–1292.

6. Bauer N., Bosetti V., Hamdi-Cherif M., Kitous A., McCollum D., Méjean A., Rao S., Turton H., Paroussos L., Ashina Sh., Calvin K., Wada K., Vuuren D. CO_2 emission mitigation and fossil fuel markets: Dynamic and international aspects of climate policies. *Technological Forecasting and Social Change. Elsevier B.V.* 2015, No 90 (A), pp. 243–256.

7. Ківвa. І. Вугілля, нафта та газ, прощавай-те! Електроенергію добуватимуть у космосі. URL: https://zaborona.com/vugillya-nafta-ta-gaz-proshhavajte-elektroenergiyu-dobuvatymut-u-kosmosi/ (дата звернення: 09.08.2024).

8. Global Greenhouse Gas Emissions Data. United States Environmental Protection Agency Website. URL: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data (дата звернення: 09.08.2024).

9. Covert T.R., Greenstone M., Knittel C.R. Will We Ever Stop Using Fossil Fuels? URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2720633> (дата звернення: 10.08.2024).

10. Ukrainian Climate Network. URL: https://ucn.org.ua/?page_id=66 (дата звернення: 10.08.2024).

11. Марченко Ю., Капустинська Т., Тищук О., Фронощук М. Планетарний масштаб: все, що треба знати про кліматичну кризу – простою мовою і з подарунками.URL:https://vygravaino.platfor.ma/articles/eko (дата звернення: 10.08.2024).

12. Збірник показників емісії (питомих викидів) забруднюючих речовин в атмосферне повітря різними виробництвами. 2004. Український науковий центр технічної екології, No. 1, pp. 184

13. Методика розрахунку викидів забруднюючих речовин та парникових газів у повітря від використання палива на побутові потреби в домогосподарствах: наказ № 98 від 22.04.11. 2011, Держкомстат України, pp. 19.

References

1. Laela, N., Pasma S. A., Santoso M. Arsenic Levels in Soil and Rice and Health Risk Assessment via Rice Consumption in Industrial Areas of East Java, Indonesia. *Environment and Natural Resources Journal*. 2023, No 21(4), pp. 370-380.

2. Rahmayanti, R., Adji, B. K., Nugroho, A. P. Microplastic Pollution in the Inlet and Outlet Networks of Rawa Jombor Reservoir: Accumulation in Aquatic Fauna, Interactions with Heavy Metals, and Health Risk Assessment. *Environment and Natural Resources Journal*. 2022, No 20(2), pp. 192-208.

3. Piracha A., Tariq Chaudhary M. Urban Air Pollution, Urban Heat Island and Human Health : a review of the Literature. *Sustainability.* 2022, No 14(15). URL: https://doi.org/10.3390/su14159234

4. Houngbégnon P., Ayivi-Vinz G., Lawin H., Houessionon K., Tanimomon F., Kêdoté M., Fayomi B., Dossougbété S., Agueh V. Exposure to PM2.5 Related to Road Traffic : Comparison between Crossroads and Outside of Crossroads at Cotonou, Benin. *Open Journal of Air Pollution.* 2019, No 8, pp. 108–117.

5. Lin S., Liu Z., Qian J., Li X., Zhang Q. Flammability and Explosion Risk of Post-explosion CH4/air and CH4/coal dust/air Mixtures. *Combustion Science and Technology.* 2021, No 193 (8), pp. 1279–1292.

6. Bauer N., Bosetti V., Hamdi-Cherif M., Kitous A., McCollum D., Méjean A., Rao S., Turton H., Paroussos

L., Ashina Sh., Calvin K., Wada K., Vuuren D. CO_2 emission mitigation and fossil fuel markets: Dynamic and international aspects of climate policies. *Technological Forecasting and Social Change. Elsevier B.V.* 2015, No 90 (A), pp. 243–256.
7. Kivva. I. Vugillya, nafta ta gaz, proshchavaj-te! Elektroenergiyu dobuvatimut' u kosmosi. URL: https://zaborona.com/vugillya-nafta-ta-gaz-proshhavajte-elektroenergiyu-dobuvatymut-u-kosmosi/ (accessed 2024 August 9).
8. Global Greenhouse Gas Emissions Data. United States Environmental Protection Agency Website. URL: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data (accessed 2024 August 9).
9. Covert T.R., Greenstone M., Knittel C.R. Will We Ever Stop Using Fossil Fuels? URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2720633> (accessed 2024 August 10).
10. Ukrainian Climate Network. URL: https://ucn.org.ua/?page_id=66 (accessed 2024 August 10).
11.Marchenko Yu., Kapustins'ka T., Tishchuk O., Fronoshchuk M. Planetarnij masshtab: vse, shcho treba znati pro klimatichnu krizu – prostoyu movoyu i z podarunkami.URL:https://vygravaino.platfor.ma/articles/eko (accessed 2024 August 10).
12. Zbirnyk pokaznykiv emisii (pytomykh vykydiv) zabrudniuiuchykh rechovyn v atmosferne povitria riznymy vyrobnytstvamy. [Collection of emission indicators (specific emissions) of pollutants into the air by different productions]. 2004, Ukrainian Scientific Center of Technical Ecology [Ukrayinskij naukovij centr tehnichnoyi ekologiyi]. No. 1, pp. 184 (in Ukrainian)
13. Metodika rozrahunku vikidiv zabrudnyuyuchih rechovin ta parnikovih gaziv u povitrya vid vikoristannya paliva na pobutovi potrebi v domogospodarstvah: nakaz № 98 vid 22.04.11 [Methodology for calculating emissions of pollutants and greenhouse gases into the air from the use of fuel for household needs in households: decree no. 98 of 22.04.11], 2011, Derzhkomstat Ukrayini [State Statistics Committee of Ukraine], p. 19.

Відомості про авторів / About the Authors

Левицька Олена Григоріївна (Levytska Olena) – кандидат технічних наук, доцент, доцент кафедри Безпеки життєдіяльності Дніпровського національного університету ім. Олеся Гончара, м. Дніпро, Україна, ORCID: https://orcid.org/0000-0002-2598-3651, e–mail: LLevi@ukr.net

Царенко Валерія Вікторівна (Tsarenko Valeria) – студентка кафедри Безпеки життєдіяльності Дніпровського національного університету ім. Олеся Гончара, м. Дніпро, Україна, ORCID: https://orcid.org/0009-0004-3862-4860, e–mail: V.Tsarenko@ftf.dnu.edu.ua