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ASSESSING THE IMPACT OF EMISSIONS FROM SEVERODONETSK COGENERATION PLANT ON THE URBAN POPULATION HEALTH

Purpose. To determine the contribution of emissions of the state enterprise 'Severodonetsk Cogeneration Plant' to the air basin pollution level in Severodonetsk and the risks to public health.

Methods. Modelling of the pollutants spread from a single point source and assessment of chronic carcinogenic and toxic risks by using EOL-2000 [h] automated system with the 'Risk Indicator' utility for calculating the dispersion of emissions in the atmosphere. Risk Calculator (EPA US) helped to assess the risk levels for workers of different occupations, namely, outdoor workers, indoor workers, and builders. The seasonal wind rose was determined based on the Copernicus Climate Change Service (European Commission).

Results. According to the adopted modelling scenario (stable operation of the plant, a seasonal wind rose), the contribution of emissions from SE 'Severodonetsk CP' to the level of air pollution in Severodonetsk is extremely small, since the contents of all components are less than normal. However, the plant emits toxic compounds of manganese, vanadium, mercury as well as xylene and hydrogen fluoride, which are combined with background substances in the summation group. According to the modelling results, the sanitary protection zone of Severodonetsk CP does not require modification or adjustment.

Among all the emissions, chromium (VI) and nickel demonstrate oncogenic properties with a unidirectional effect on the lungs and nasal cavity. The individual carcinogenic risk of 6.01×10^{-6} generated by gas emissions of the plant is acceptable. Manifestation of chronic toxic effects from emissions of Severodonetsk CP is unlikely as indicated by the minimum (target) levels of non-carcinogenic risks.

Conclusions. Emissions from the planned activities of the CP during the cold period do not exceed MPC, and the risks to the health of the population living nearby residential areas and employees of enterprises are minimal. At the same time, the air quality in Severodonetsk is not satisfactory and requires measures to reduce risks. To perform this task, it is necessary to identify all sources of air pollution with the maximum contribution to the risks to the urban population health.

KEY WORDS: Severodonetsk, cogeneration plant, emissions, dispersion, concentration, health threat

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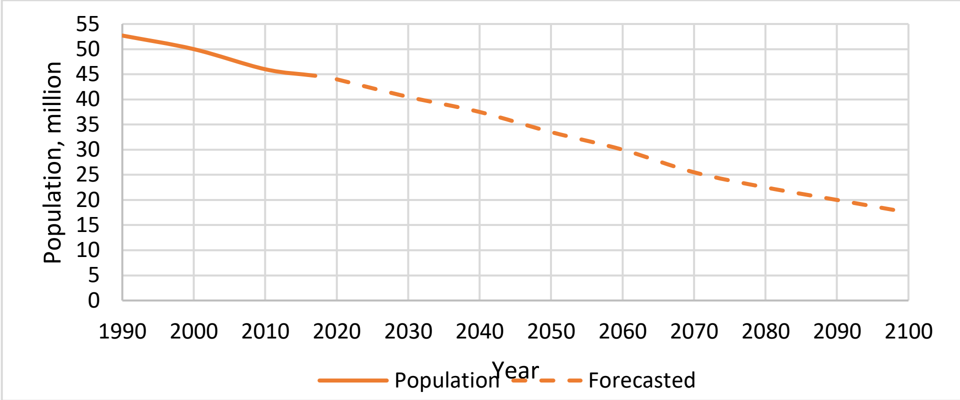
Introduction

According to the population change projections [1] based on reliable statistical models of fertility, mortality, and migration in Ukraine, the population is expected to regress threefold (Fig. 1) with severe population aging and the predominance of post-reproductive age groups of people incapable of work, which will require significant budget expenditure on health care within the framework of sustainable development (Goal 3 – Good health and well-being). Population size and



	1990	2017	2100
Population	52.7M	44.7M	17.5M

Fig.1 – Population Trends in Ukraine, 1990-2100 [2]

composition are not exogenous factors that countries need to consider when planning but rather results they can manage. The policy currently pursued by the state may affect the trajectories of births, deaths, and migration.

We are witnessing climate change, and we can say with a high degree of confidence that vulnerable populations are suffering, since extreme heat, drought, forest fires, and other exposures degrade the air quality and create a wide range of health problems and inequalities.

In the era of shifting global agendas and increasing attention to non-communicable diseases and injuries along with infectious diseases, reliable data on mortality reasons at the national level are required [3].

In 2019, lower respiratory tract infections took second place among 6 infectious diseases in children under 10, and the main reasons for the reduction of a full life of the over-50s were ischemic heart disease and stroke. Figure 2 presents the main causes of death in Ukraine and their change over 10 years, where cardiovascular diseases, liver diseases, and respiratory oncology are invariably in the lead (with an increase of 11.2%). It is worth noting that there is a signifi-

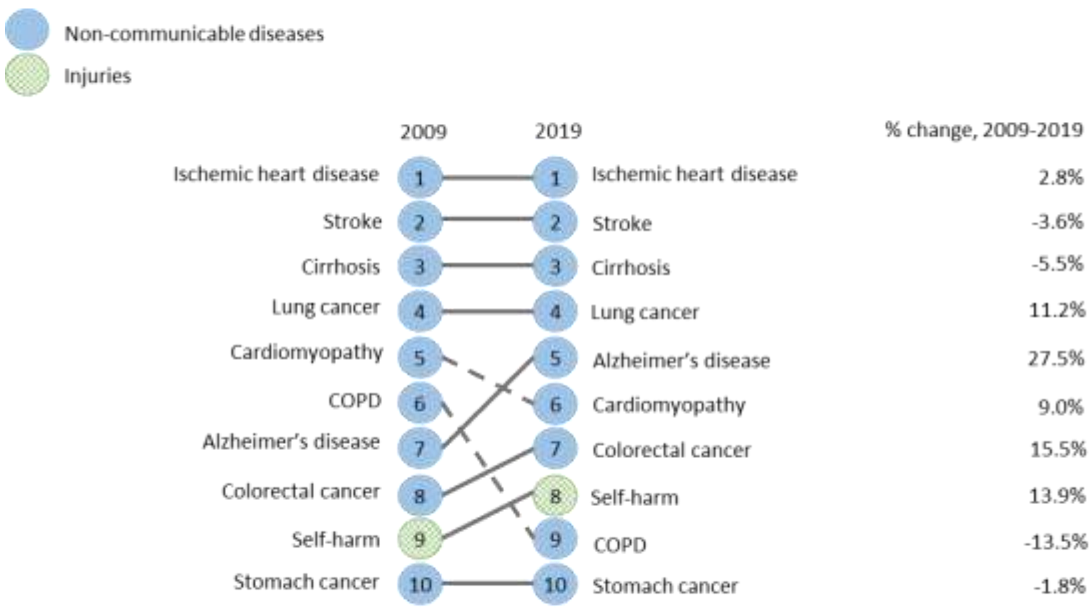


Fig.2 – Top 10 Causes of Death in Ukraine for All Age Groups (2009, 2019) [2]

cant increase of 27.5% in Alzheimer's disease (a type of dementia), one of the causes of which is air pollution by particulate matter, nitrogen oxides, carbon monoxide, and ozone as has recently been discovered [4].

Ukrainian researchers state a significant correlation between the level of morbidity of the population of our country (including children) and the volume of emissions of SO_2, CO_2, N_2O [5,6], radiation background [7] with a significant proportion of diseases of the respiratory, circulatory, and nervous systems. Work [6] also notes that industrially developed oblasts (Donetsk, Dnipropetrovsk, Luhansk, Zaporizhzhia, Kharkiv, Kyiv, and Lviv) are in the catastrophic risk zone, where the likelihood of developing respiratory diseases is high, and the relationship between emissions into the atmosphere (both from stationary sources and transport) and the incidences of tuberculosis is direct and very close ($R = 0.941$).

Combined heat and power generation (cogeneration) has high heat and resource efficiency. It is the CP that makes the decarbonization scenario of the European Union more cost-effective. Gas-fired CPs play an important role in reducing emissions, especially in densely populated urban areas. The transition of CPs from coal to natural gas can reduce CO_2 emissions by more than 70% improving the air quality on the way to carbon neutrality by 2050 [8]. However, possible adverse health and environmental consequences of such systems have not been adequately studied, and their contribution to air pollution must be considered on a case-by-case basis.

Paper [9] studied the potential role of cogeneration systems in the incidences of three environmental diseases, namely, asthma, allergic rhinitis, and atopic dermatitis. The author noted a tendency for an increase in incidences of these diseases in six South Korean cities with new CPs, but the relative risk was statistically significantly increased only for CO and NO_2.

Burning natural gas to generate energy resulted in increased concentrations of PM_{10} and NO_2 in the air near the plant [10]. Although the level of pollutants was below the limits established by the European legislation, the number of daily visits to emergency services and hospitalizations of the elderly and age-related susceptibility correlated with the concentrations of pollutants measured at a distance of 1 and 3 km from the facility.

In addition to gas and dust emissions, noise exposure is a serious problem during the operation of CP, which negatively affects human health and ecosystems. Work [11] studied the effect of noise generated by cogeneration systems, estimated the environmental characteristics of the noise cancellation system. It noted that modelling of changes in sound power level, noise reduction efficiency, steam release, and the silencer service life showed that the health benefits for a person were much higher than the negative effects of noise, while the health impact due to the background (traffic) noise increased.

Vulnerable groups of the population are most susceptible to the effects of air pollutants, which include people with diseases of the lungs, cardiovascular system, and diabetes; children, adolescents, and the elderly; people staying outdoors for a long time; people with low income; people living or working near busy highways.

Thus, with the urban growth, the problem of maintaining health becomes more and more urgent especially in cities with a high technogenic load. It is vital to take care of the health of the population immediately as a component of national security at the state level. To do this, first, it is necessary to identify the sources of danger in the given territories, determine their impact on people and the environment and in case of exceeding the permissible exposure limits develop plans for their reduction or elimination. Cogeneration plants will be present in the overwhelming majority of Ukrainian cities for many years to come as one of the permanent sources of air pollution. The transition to renewable energy sources within the framework of the European Green Deal [12] will probably not take place quickly enough. Therefore, assessing the contribution of the operation of such plants to air pollution and public health risks remains relevant and, thus, is of scientific interest.

The purpose of the research is to determine the contribution of emissions from Severodonetsk CP as one of the old operating enterprises of the city to the level of air pollution in Severodonetsk and to the public health risks. This is as an intermediate stage of a comprehensive study to identify the main hazardous sources in order to manage these risks (eliminate or minimize) according to the Law of Ukraine 'About the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period till 2030' and the Sustainable Development Goals.

Materials and methods

Modelling of the spread of emissions from a single point source and assessment of chronic carcinogenic and toxic risks was performed using EOL-2000 [h] automated system for calculating the dispersion of emissions into the atmosphere with the 'Risk Indicator' utility recommended by the Ministry of Ecology and Natural Resources of Ukraine. The initial data used in the modelling included information on the qualitative and quantitative composition of the CP emissions (Table 1); the parameters of the emission source (height 240 m, diameter 6.5 m, volumetric flow rate of waste gases 600,000 m^3/h, temperature 110°C); geographical, meteorological, and climate parameters of the area (the seasonal wind rose of Severodonetsk (Fig. 3) determined based on the global environmental and safety monitoring service called Copernicus Climate Change Service [13]). The size of the calculated field for mapping concentration isolines was 10,000×10,000 m, the step of the grid nodes was 500 m; background loads were taken into consideration as well.

Table 1

Emission Characteristics of Severodonetsk CP

Substance code	Substance	Average daily MPC, mg/m^3	Hazard class	Actual emission, g/s	Actual gross emission, t/year
110	Vanadium Pentoxide	0.002	1	0.0010	0.0080
123	Iron Oxide	0.04	3	0.0226	0.1796
143	Manganese	0.001	2	2.0016	15.9100
164	Nickel Oxide	0.001	2	0.0002	0.0016
183	Metallic Mercury	0.0003	1	0.00011	0.0009
203	Chromium (VI)	0.0015	1	0.0002	0.00143
301	Nitrogen Dioxide	0.04	3	16.6980	132.7300
322	Sulphuric Acid	0.1	2	2.0059	15.9440
328	Soot	0.05	3	0.0139	0.1105
330	Sulphurous Anhydride	0.05	3	157.8232	1254.500
342	Hydrogen Fluoride	0.005	2	0.0019	0.0151
410	Methane	0.15	3	1.0144	8.0633
616	Xylene	0.2	3	0.0365	0.2901
13000	Carbon Dioxide	3	4	9.5082	75.5790

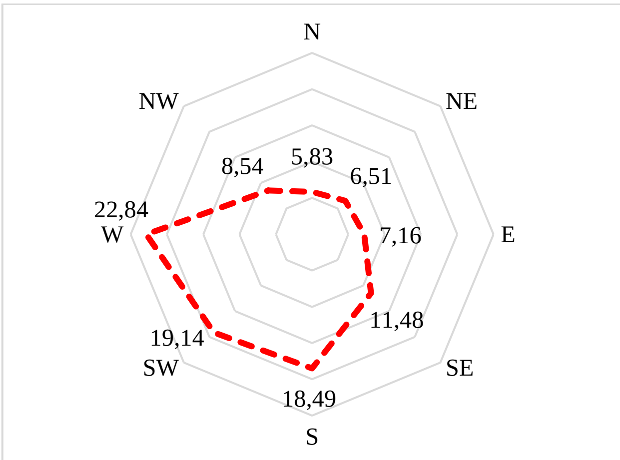


Fig.3 – Seasonal Wind Rose in Severodonetsk (Winter) [14]

Table 2 presents the background concentrations of pollutants in the atmospheric air of Severodonetsk [15]. The dispersion calculation was not carried out if the sum of the maximum surface concentrations from the emission sources for the ingredient divided by the MPC was less than the calculation expediency constant.

Table 2

Background Content of Pollutants in the Atmospheric Air of Severodonetsk

Substance code	Substance	Concentration, mg/m^3		Ratio of C_i to one-time MPC
		Annual average	Maximum	
203	Chromium (VI)	0.00007	0.00084	0.047
301	Nitrogen Dioxide	0.03	0.05	0.15
303	Ammonia	0.02	0.04	0.1
316	Hydrogen Chloride	0.04	0.12	0.2
322	Sulphuric Acid	0.0068	0.024	0.023
328	Dust	0.1	0.2	0.2
330	Sulphurous Anhydride	0.019	0.041	0.038
337	Carbon Oxide	1	2	0.2
1325	Formaldehyde	0.008	0.016	0.229

Results

SE ‘Severodonetsk CP’ is a power enterprise of Severodonetsk, one of the largest cogeneration plants in Ukraine designed for heat and power supply of the city and the giant of the chemical industry of Ukraine PrJSC ‘Severodonetsk Azot Association’. The electric power of the CP is 260 MW, the heat capacity is 906 Gcal/hour; commissioned in 1952. It runs on natural gas, belongs to the objects of the third hazard class with the size of the standard sanitary protection zone (SPZ) of 300 m.

As a result of modelling of the dispersion of emissions, we mapped the fields of isolines of concentrations of individual chemical substances and groups of summation of combined action formed by the emission and background compounds with a total number of 7 groups (Table 3).

Table 3

Summation Groups Formed by Hazardous Impurities and Background Pollutants

Substances included in the summation group	Summation group number
Ammonia - Formaldehyde	5
Vanadium and Compounds - Manganese and Compounds	10
Vanadium and Compounds - Sulphurous Anhydride	11
Vanadium and Compounds - Hexavalent Chromium	12
Sulphuric Acid - Sulphurous Anhydride	28
Nitrogen Dioxide - Sulphurous Anhydride	31
Sulphurous Anhydride - Gaseous Fluoride Compounds	35

Modelling of the dispersion of emissions showed that concentrations of all individual substances and summation groups did not exceed the MPC. This means that the SPZ of Severodonetsk CP does not require correction even taking into account the wind rose. In addition, the stack is located on the industrial site of the chemical plant (on the western side relative to the residential part of the city) within which there are many stationary sources of emissions of substances of a higher hazard class with the SPZ of significantly larger dimensions overlapping the SPZ of the CP. The distance from the stack to residential buildings in Severodonetsk (in the east) and the village of Pavlograd (in the south-west) is about 2 km.

The Risk Indicator utility makes it possible to calculate the average annual concentration of a pollutant from the given source and to quantify the chronic inhalation health risks posed by these pollutants taking into account the background. The individual carcinogenic risk is calculated through the unit risk (IUR_i, [mg/m^3]$^{-1}$) according to formulas (1, 2):

$$IUR_i = SF_i \times 1/m \times V, \quad (1)$$

$$ICR_i = IUR_i \times C_i, \quad (2)$$

where SF_i – Slope Factor, [mg/(kg×day)]$^{-1}$;

m – average body weight, kg;

V – pulmonary ventilation volume, m^3/day;

ICR_i – individual carcinogenic risk;

C_i – concentration of a carcinogen in the air, mg/m^3.

Non-carcinogenic risks are determined by the coefficient and hazard index (HI) according to formulas (3, 4)

$$HQ_i = C_i / RfC_i, \quad (3)$$

$$HI = \Sigma HQ_i, \quad (4)$$

where HQ_i – toxicant hazard ratio i;

RfC_i – reference concentration of a toxicant i, mg/m^3.

The resulting risk values are interpreted as follows (Table 4).

Table 4

Classification of Risk Levels (EPA USA)

Risk level	Hazard coefficient of *non-carcinogenic* effect for an individual substance	Hazard index of *non-carcinogenic* effect for groups of substances of unidirectional effect	Individual *carcinogenic* risk throughout life
High	> 3	> 6	> 10^{-3}
Alarming	1.1 – 3	3.1 – 6	$1.1 \cdot 10^{-4} – 1.0 \cdot 10^{-3}$
Acceptable	0.11 – 1.0	1.1 – 3	$1.1 \cdot 10^{-6} – 1.0 \cdot 10^{-4}$
Minimum (target)	0.1 and less	1.0 and less	10^{-6} and less

Chromium (VI) and nickel manifest carcinogenic properties in the emissions from Severodonetsk CP, and they have a unidirectional effect on *the lungs* and *nasal cavity* (Table 5). The lifetime carcinogenic risk from exposure to chromium in the amount taken with consideration of the background content was $8.46 \cdot 10^{-4}$ (alarming). The same risk from exposure to nickel was $5.257 \cdot 10^{-9}$ (minimal), i.e. chromium was the main contributor to risk. However, when assessing the contribution of the CP emissions to the individual carcinogenic risk (column 7 determines the concentration of a carcinogen introduced by Severodonetsk CP into the atmospheric air, and column 8 assesses the individual carcinogenic risk based on the concentration from column 7), the result decreased by two orders of magnitude and became acceptable. Thus, we can conclude that the main contribution to risks is compounds coming from sources other than those contained in emissions from the CP as evidenced by the data in Table 5.

Table 5

Carcinogenic Risks of the CP's Planned Activities (Based on the Atmospheric Air Criterion)

CAS code (*group code)	Substance name (combined action group)	Average annual concentration C_i, mg/m^3	SF_i, mg/(kg*day)	IUR_i, m^3/mg	ICR_i (*ICR of combined action)	Contribution of CP emissions to C_i, mg/m^3	Contribution of CP emissions to ICR
18540-29-9	Chromium (VI)	0.0000705	42	12	0.00084601	$5 \cdot 10^{-7}$	$6 \cdot 10^{-6}$
*122	Lung impact group (Cr(VI), Ni)	-	-	-	*0.00084602	-	*$6.01 \cdot 10^{-6}$
*135	Nasal cavity impact group Cr(VI), Ni	-	-	-	*0.00084602	-	*$6.01 \cdot 10^{-6}$
7440-02-0	Nickel	0.00000002	0.91	0.26	$5.26 \cdot 10^{-9}$	$2.00 \cdot 10^{-8}$	$5.20 \cdot 10^{-9}$

Table 6 presents the calculated average annual concentrations of compounds based on the background values as well as the value of the hazard index from the impact of these toxicants. Thus, we can see that the contribution of the CP emissions to the state of the city's air basin is extremely small but it introduces such compounds as manganese, vanadium, mercury, xylene, and hydrogen fluoride.

The hazard ratios for all individual substances were in the range from minimal to acceptable (column 5).

For the group of unidirectional effect on *the respiratory organs*, the hazard index was 3.72 (alarming).

In this group of combined action, PM (HQ = 2.01), NO_2 (HQ = 0.75) and Cr(VI) (HQ = 0.705) made the greatest contribution to the risk; for summation group No. 31, the hazard index was 1.002 (acceptable). Columns 6, 7 show the values of the contribution of emissions from Severodonetsk CP to the formation of the total average annual concentrations of pollutants as well as non-carcinogenic risks, which indicate the minimum (target) level of toxic effect.

Table 6

Non-Carcinogenic Risks from the CP's Planned Activities (Based on the Atmospheric Air Criterion)

CAS code (*group code)	Substance name (combined action group)	Average annual concentration C_i, mg/m³	Reference concentration, mg/m³	HQ_i (*HI)	CP contribution to the average annual concentration, mg/m³	CP contribution to HQ (*HI)
*100	Respiratory impact group (PM_{10}, NO_2, Cr(VI), V, SO_2, HF)	-	-	*3.717		*0.030
PM_{10}	PM_{10}	0.1005	0.05	2.010	0.0005	0.01
*31	Summation group No. 31	-	-	*1.002	-	*0.014
10102-44-0	Nitrogen Dioxide	0.03010131	0.04	0.753	$1.01 \cdot 10^{-4}$	0.003
18540-29-9	Chromium (VI)	0.0000705	0.0001	0.705	$5 \cdot 10^{-7}$	0.005
*10	Summation group No. 10	-	-	*0.405	-	*0.405
*101	CNS impact group (xylene, Mn, Hg)	-	-	*0.405	-	*0.405
7439-96-5	Manganese and Compounds	0.00002024	0.00005	0.405	$2.02 \cdot 10^{-5}$	0.405
*11	Summation group No. 11	-	-	*0.250	-	*0.012
7446-09-5	Sulphur Dioxide	0.01995734	0.08	0.250	$9.57 \cdot 10^{-4}$	0.012
7440-62-2	Vanadium and Compounds	0.00000001	0.00007	$1.429 \cdot 10^{-4}$	$1.00 \cdot 10^{-8}$	$1.429 \cdot 10^{-4}$
1330-20-7	Xylene	0.00000037	0.3	$1.233 \cdot 10^{-6}$	$3.70 \cdot 10^{-7}$	$1.233 \cdot 10^{-6}$
7664-39-3	Hydrogen Fluoride	0.00000002	0.03	$6.667 \cdot 10^{-7}$	$2.00 \cdot 10^{-8}$	$6.667 \cdot 10^{-7}$
7439-97-6	Mercury and Compounds	$1.11 \cdot 10^{-9}$	0.003	$3.707 \cdot 10^{-7}$	$1.11 \cdot 10^{-9}$	$3.707 \cdot 10^{-7}$

The following restrictions and simplifications presented uncertainty in the modelling performed:

- background values of pollutants were taken in the residential area and not in the working area of PrJSC 'Severodonetsk Association Azot' where the stack is located (in this way, one can additionally assess the health risks to workers of these enterprises);
- all emissions of chromium compounds were accounted for as Cr(VI);
- solid particles of various aerodynamic radius were accounted for as PM_{10};
- the calculation of risks was not differentiated depending on the exposure.

Discussion

The city of Severodonetsk is currently the regional centre of Luhansk oblast, part of Severodonetsk-Lysychansk agglomeration, located in the eastern part of Ukraine in the west of Luhansk region on the left bank of the Siversky Donets river, in the steppe zone. The terrain within and around the city is flat with small uplifts (50-80 m above sea level); the city centre rises above the outskirts by an average of 5 m. The territory of the city occupies 4210 hectares including 2030 hectares under residential buildings and 2060 hectares under industrial facilities (operating and not). The population size has increased significantly because of migration processes (mainly due to the armed conflict) and ranges from 110 to 125 thousand people according to various estimates. The air quality in Severodonetsk has changed significantly over the past decade. The air pollution index has gradually fallen from 10.1 in 2011 to 6.4 in 2014 and 5.6 in 2019 due to deindustrialization. The ecological situation in different districts of the city is heterogeneous and depends mainly on two factors, namely, emissions from stationary sources and vehicles, the amount of which has increased manifold. The main problem associated with air pollution by industrial enterprises is their proximity to the residential area of the city and suburban villages. It should also be noted that the number of solid fuel boilers used by enterprises of various forms of ownership has increased in the city, which are distributed throughout the residential area. They can be considered as a diffuse source of emissions. The main harmful components of emissions from such boilers are nitrogen and sulphur oxides, carbon oxides, dust, and carcinogens (formaldehyde, benzo(a)pyrene, etc.). On the eastern side of the city, close to residential buildings (300 m), there is Severodonetskteplokomunenergo utility company, which supplies heat to some parts of the residential area and runs on natural gas. According to the seasonal wind rose, a significant part of emissions from this enterprise come in the direction opposite to the city, but the situation requires additional study with control (monitoring) of exposure and risks. The analysis of the reasons for the unsatisfactory quality of the atmospheric air in Severodonetsk as well as assessment of the inhalation carcinogenic and non-carcinogenic risks to the health of the local population are given in works [16-18].

Table 7 shows the results of the clarification of the risk levels for workers of enterprises located within the SPZ using the Risk Calculator [19] recommended by the EPA US for Outdoor Worker, Indoor Worker (exposure time is 8 h/day, 225 days a year, 25 years), and Construction Worker (exposure time is 8 h/day, 250 days a year, 1 year) scenarios. Pollutant concentrations are taken from Tables 5, 6 (columns 3).

Table 7 shows that the non-carcinogenic risk is *acceptable* for all workers, and the carcinogenic risk for outdoor and indoor workers is interpreted as *alarming* and completely depends on the background content mainly of chromium (VI).

Table 7

Chronic Inhalation Carcinogenic and Non-Carcinogenic Risks for Workers

Chemical	*IUR*, $(\mu g/m^3)^{-1}$	*RfC*, mg/m^3	Concentration, $\mu g/m^3$	Outdoor Worker		Indoor Worker		Construction Worker	
				HQ	*Risk*	*HQ*	*Risk*	*HQ*	*Risk*
Chromium(VI)	$8.4\cdot10^{-2}$	$1.0\cdot10^{-4}$	$7.05\cdot10^{-2}$	$1.45\cdot10^{-1}$	$4.35\cdot10^{-4}$	$1.61\cdot10^{-1}$	$4.83\cdot10^{-4}$	$1.68\cdot10^{-1}$	$2.01\cdot10^{-5}$
Hydrogen Fluoride	-	$1.4\cdot10^{-2}$	$2.00\cdot10^{-5}$	$2.94\cdot10^{-7}$	-	$3.26\cdot10^{-7}$	-	$3.40\cdot10^{-7}$	-
Manganese and Compounds	-	$5.0\cdot10^{-5}$	$2.02\cdot10^{-2}$	$8.32\cdot10^{-2}$	-	$9.24\cdot10^{-2}$	-	$9.64\cdot10^{-2}$	-
Mercury and Compounds	-	-	$1.12\cdot10^{-6}$	-	-	-	-	-	-
Nickel	$2.6\cdot10^{-4}$	$2.0\cdot10^{-5}$	$2.00\cdot10^{-5}$	$2.05\cdot10^{-4}$	$3.82\cdot10^{-10}$	$2.28\cdot10^{-4}$	$4.24\cdot10^{-10}$	$2.38\cdot10^{-4}$	$1.77\cdot10^{-11}$
Nitrogen Dioxide	-	-	30.1	-	-	-	-	-	-
Sulphur Dioxide	-	-	20.0	-	-	-	-	-	-
Vanadium and Compounds	-	$1.0\cdot10^{-4}$	$1.00\cdot10^{-5}$	$2.05\cdot10^{-5}$	-	$2.28\cdot10^{-5}$	-	$2.38\cdot10^{-5}$	-
Xylenes	-	$1.0\cdot10^{-1}$	$3.70\cdot10^{-4}$	$7.60\cdot10^{-7}$	-	$8.45\cdot10^{-7}$	-	$8.81\cdot10^{-7}$	-
Total Risk/HI				*$2.28\cdot10^{-1}$*	*$4.35\cdot10^{-4}$*	*$2.54\cdot10^{-1}$*	*$4,83\cdot10^{-4}$*	*$2.65\cdot10^{-1}$*	*$2.01\cdot10^{-5}$*

Except the above, we can add that Severodonetsk CP needs modernization of equipment, the introduction of modern cleaning systems as well as reconstruction for using various types of fuel including biomass and municipal solid waste. This would solve the problem of utilization of household waste because currently there are no waste sorting or waste processing plants in the region. Therefore, all waste, without exception, is buried in overcrowded solid waste landfills, and a large number of unauthorized landfills have appeared in suburban areas.

Conclusions

In the adopted modelling scenario (stable operation of the considered plant, a seasonal wind rose, etc.), emissions from the CP during the heating season do not exceed the allowable concentration limits according to OND-86. It is the method implemented by EOL-2000 calculation modules. However, concerning the 2020/2021 heating season some deviations from the results are quite likely due to the frequent failure of worn-out equipment of the plant (power boiler and heating mains) with possible emergency emissions.

Thus, gas emissions from Severodonetsk CP during the period under study create additional to the existing *minimal* risks of threat to the health of the population of nearby residential areas or workers of operating enterprises located within the SPZ of the CP. The situation requires real measures to reduce risks but not because of the planned activities of the CP. First of all, it is necessary to identify all sources of air pollution with the greatest contribution to the risks to the health of the urban population.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

References

1. Vollset, S.E., Goren, E., Yuan, C.-W., Cao, J., Smith, A.E.…Murray Ch. J.L. (2020). Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study. *The Lancet*, *396*(10258), 1285–1306. http://doi.org/10.1016/s0140-6736(20)30677-2
2. Institute for Health Metrics and Evaluation (IHME). *[Ukraine] profile***.** Seattle, WA: IHME, University of Washington, 2018. Retrieved from http://www.healthdata.org/ukraine?language=134
3. Vos, T., Lim, S.S., Abbafati, C., Abbas, K.M., Abbasi, M. & al. (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10258), 1204–1222. http://doi.org/10.1016/s0140-6736(20)30925-9
4. Peters, R., Ee, N., Peters, J., Booth, A., Mudway, I. & Anstey, KJ. (2019). Air Pollution and Dementia: A Systematic Review. *J Alzheimers Dis, 70(s1), 145-163. http://doi.org/10.3233/JAD-180631*
5. *Nekos, A. N.*, Muromtseva, Yu. I. (2021). Estimation of the Air Emissions of Pollutants Influence on Primary Morbidity Indicator of the Population : Case in Kharkiv Region – Ukraine. *Visnyk of V. N. Karazin Kharkiv National University Series "Ecology"*, (24), 57-65. http://doi.org/10.26565/1992-4259-2021-24-05
6. Tarasova V. V. (2013). The impact of air pollution on public health. *Agrosvit, 16*, 24-28. Retrieved from http://www.agrosvit.info/pdf/16_2013/6.pdf (In Ukrainian)
7. Volosovets, O.P., Kryvopustov, S.P., Kriuchko, T.O., Honchar, M.O., Abaturov, O.Ie….Lukovnikova E. A. (2018). Influence of ecologically unfavorable environment on the incidence and prevalence of diseases of the circulatory system in children of Ukraine. *Health of Society*, *7*(5), 229-236. http://doi.org/10.22141/2306-2436.7.5.2018.158608 (In Ukrainian)
8. COGEN Europe. *Cogeneration 2050: the Role of Cogeneration in a European Decarbonised Energy System.* Brussels: COGEN Europe (2011). Retrieved from http://www.buildup.eu/en/node/35071
9. Moon, J. (2020). Cogeneration plant and environmental allergic diseases: is it really an eco-friendly energy source? *Ann Occup Environ Med*., 32(1):e38. http://doi.org/10.35371/aoem.2020.32.e38
10. Agostino Di Ciaula. (2012). Emergency visits and hospital admissions in aged people living close to a gas-fired power plant. *European Journal of Internal Medicine*, *23*(2), e53-e58. http://doi.org/10.1016/j.ejim.2011.09.013.
11. Marcinkowski, A. & Kopania, J. (2021). Environmental Performance of Noise Reduction System in Cogeneration Plants—A Life Cycle Assessment Study. *Energies*, *14*, 1324. http://doi.org/10.3390/en14051324
12. The European Green Deal**.** Retrieved from http://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
13. Climate Data Store. Retrieved from http://cds.climate.copernicus.eu/toolbox-editor/64739/52_wind_rose
14. Borshchun, Yu. & Kravchenko, I. (2020). Retrospective study of wind roses in Severodonetsk. *Proceedings of the All-Ukrainian Scientific-Practical. Conf. with International Participation: Future scientist-2020,* Severodonetsk, 2020, Dec. 4, Volodymyr Dahl East-Ukrainian national university (pp.50-52). Retrieved from http://dspace.snu.edu.ua:8080/jspui/handle/123456789/3734 (In Ukrainian)
15. Ecological passport of the region. Luhansk region. (2020). *Department of Communal Property, Land, Property Relations, Ecology and Natural Resources*. Retrieved from http://www.eco-lugansk.gov.ua/images/docs/ekopasport/Ekopasport_2019.pdf
16. Kravchenko, I.V. (2021). Analysis of the current state of the air and assessment of inhalation non-carcinogenic risk to the health of the population of the Severodonetsk-Lysychansk agglomeration. *Environmental sciences*, *2*(35), 7-14. http://doi.org/10.32846/2306-9716/2021.eco.2-35.1 (In Ukrainian)
17. Kravchenko, I. (2021). Assessment health carcinogenic risk of the population of the Severodonetsk-Lysychansk agglomeration. *Proceedings of the International Scientific Conference: The current stage of development of scientific and technological progress*, Karlsruhe, Germany, 2021, Feb. 9, No 15 (pp.41-44). http://doi.org/10.30890/2709-1783.2021-15
18. Kravchenko, I. (2021). Assessment of the risk of immediate toxic effects in the population of the Severodonetsk-Lysychansk agglomeration. *Proceedings of the XII International Scientific and Practical Conference: Current issues, achievements and prospects of Science and education*, Athens, Greece, 2021, May 3-5 (pp. 13-14). Retrieved from http://eu-conf.com/wp-content/uploads/2021/05/XII-Conference-Current-issues-achievements-and-prospects-of-Science-and-education.pdf (In Ukrainian)
19. RAIS Chemical Risk Calculator. *The Risk Assessment Information System*. Retrieved from http://rais.ornl.gov/cgi-bin/prg/RISK_search

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ОЦІНКА ВПЛИВУ ВИКИДІВ СЄВЄРОДОНЕЦЬКОЇ ТЕЦ НА ЗДОРОВ’Я МІСЬКОГО НАСЕЛЕННЯ

Мета. Визначити внесок викидів державного підприємства «Сєвєродонецька ТЕЦ» у рівень забруднення повітряного басейну міста Сєвєродонецьк та в ризики загрози здоров'ю населення.

Методи. Моделювання поширення забруднюючих домішок з одиночного точкового джерела і оцінка хронічних канцерогенних та токсичних ризиків проводилась за допомогою автоматизованої системи розрахунку розсіювання викидів в атмосфері ЕОЛ-2000 [h] з утилітою «Показник ризику». Для оцінки рівнів ризиків професійних контингентів «працівник на вулиці», «працівник в приміщенні» і «будівельник» використовували Risk Calculator (EPA US). Сезонна роза вітрів визначена на базі сервісу глобального моніторингу навколишнього середовища і безпеки Copernicus Climate Change Service (European Commission).

Результати. За прийнятим сценарієм моделювання (стабільна робота установки, сезонна роза вітрів) внесок викидів ДП «Сєвєродонецька ТЕЦ» у рівень забруднення атмосферного повітря міста Сєвєродонецьк вкрай малий, оскільки вміст всіх компонентів менший за нормовані значення, але діяльність установки привносить у міське повітря токсичні сполуки марганцю, ванадію, ртуті, а також ксилол і фторид водню, які поєднуються з фоновими речовинами у групи сумації. За результатами моделювання санітарно-захисна зона Сєвєродонецької ТЕЦ не вимагає уточнення або корегування.

Онкогенні властивості в складі викидів проявляють хром (VI) та нікель з односпрямованим впливом на легені і носову порожнину. Індивідуальний канцерогенний ризик 6.01×10^{-6}, створюваний газовими викидами установки, є прийнятним. Прояв хронічних токсичних ефектів від викидів Сєвєродонецької ТЕЦ малоймовірний, на що вказують мінімальні (цільові) рівні неканцерогенних ризиків.

Висновки. Викиди від планової діяльності ТЕЦ в холодний період року не перевищують допустимі концентраційні межі ($ГДК_{мр}$), а ризики загрози здоров'ю населення прилеглих житлових районів і працівників підприємств є мінімальними. У той же час, якість атмосферного повітря в м. Сєвєродонецьк не є задовільною і потребує заходів по зниженню ризиків. Для цього необхідно виявити всі джерела забруднення атмосферного повітря з максимальним внеском у ризики загрози здоров'ю міського населення.

КЛЮЧОВІ СЛОВА: Сєвєродонецьк, ТЕЦ, викиди, розсіювання, концентрація, загроза здоров'ю

Список використаної літератури

1. Vollset S.E., Goren E., Yuan C.-W., Cao J., Smith A.E. et al. Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study. *The Lancet.* 2020. Vol. 396. No 10258. P.1285–1306. DOI: http://doi.org/10.1016/s0140-6736(20)30677-2
2. Institute for Health Metrics and Evaluation (IHME). *[Ukraine] profile***.** Seattle, WA: IHME, University of Washington, 2018. Available from Ukraine]. URL: http://www.healthdata.org/ukraine?language=134
3. Vos T., Lim S.S., Abbafati C., Abbas K.M., Abbasi M. et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet.* 2020. Vol. 396. No 10258. P.1204–1222. DOI: http://doi.org/10.1016/s0140-6736(20)30925-9
4. Peters R., Ee N., Peters J., Booth A., Mudway I., Anstey KJ. (2019). Air Pollution and Dementia: A Systematic Review. *J Alzheimers Dis*. No 70(s1). P.145-163. DOI: http://doi.org/10.3233/JAD-180631
5. Nekos A. N., Muromtseva Yu. I. Estimation of the Air Emissions of Pollutants Influence on Primary Morbidity Indicator of the Population : Case in Kharkiv Region – Ukraine. *Вісник Харківського національного університету імені В.Н. Каразіна, серія «Екологія».* 2021. No 24. P.57-65. DOI: http://doi.org/10.26565/1992-4259-2021-24-05
6. Тарасова В.В. Вплив забруднення атмосферного повітря на стан здоров'я населення. *Агросвіт.* 2013. №16. С.24-28. URL: http://www.agrosvit.info/pdf/16_2013/6.pdf
7. Волосовець О.П., Кривопустов С.П., Крючко Т.О., Гончарь М.О., Абатуров О.Є. та ін. *Вплив екологічно несприятливого довкілля на захворюваність та поширеність хвороб системи кровообігу у дітей України. Health of Society*. 2018. Т.7. №5. С.229-236. DOI: http://doi.org/10.22141/2306-2436.7.5.2018.158608
8. COGEN Europe. *Cogeneration 2050: the Role of Cogeneration in a European Decarbonised Energy System.* Brussels: COGEN Europe; 2011. URL: http://www.buildup.eu/en/node/35071
9. Moon J. Cogeneration plant and environmental allergic diseases: is it really an eco-friendly energy source? *Ann Occup Environ Med*. 2020. Vol. 32. No 1. P.e38. DOI: http://doi.org/10.35371/aoem.2020.32.e38

10. Agostino Di Ciaula. Emergency visits and hospital admissions in aged people living close to a gas-fired power plant. *European Journal of Internal Medicine*. 2012. Vol. 23. No 2. e53-e58. DOI: http://doi.org/10.1016/j.ejim.2011.09.013.
11. Marcinkowski A.; Kopania J. Environmental Performance of Noise Reduction System in Cogeneration Plants—A Life Cycle Assessment Study. *Energies*. 2021. No 14. P.1324. DOI: http://doi.org/10.3390/en14051324
12. The European Green Deal. URL: http://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
13. Climate Data Store. URL: http://cds.climate.copernicus.eu/toolbox-editor/64739/52_wind_rose
14. Бощун Ю., Кравченко І. Ретроспективне дослідження рози вітрів м.Сєвєродонецьк. *Майбутній науковець-2020*: *матеріали всеукраїнської наук.-практ. конф. з міжнародною участю.* Сєвєродонецьк: Східноукраїнський національний університет імені Володимира Даля, 4 грудня 2020 г. С.50-52. URL: http://dspace.snu.edu.ua:8080/jspui/handle/123456789/3734
15. Екологічний паспорт регіону. Луганська область, 2020. *Департамент комунальної власності, земельних, майнових відносин, екології та природних ресурсів.* URL: http://www.eco-lugansk.gov.ua/images/docs/ekopasport/Ekopasport_2019.pdf
16. Кравченко І.В. Аналіз сучасного стану повітря та оцінка інгаляційного неканцерогенного ризику здоров'ю населення Сєвєродонецько-Лисичанської агломерації. *Екологічні науки*. 2021. No 2(35). С.7-14. DOI: http://doi.org/10.32846/2306-9716/2021.eco.2-35.1
17. Kravchenko I. Assessment health carcinogenic risk of the population of the Severodonetsk-Lysychansk agglomeration. *The current stage of development of scientific and technological progress: International scientific conference*, Karlsruhe, Germany, 9 Feb. 2021. No 15. P.41-44. DOI: http://doi.org/10.30890/2709-1783.2021-15
18. Кравченко І.В. Оцінка ризику прояву негайних токсичних ефектів у населення Сєвєродонецько-Лисичанської агломерації. *Current issues, achievements and prospects of Science and education. Abstracts of XII International Scientific and Practical Conference*. Athens, Greece, 2021, May 3-5. С.13-14. URL:http://eu-conf.com/wp-content/uploads/2021/05/XII-Conference-Current-issues-achievements-and-prospects-of-Science-and-education.pdf
19. RAIS Chemical Risk Calculator. *The Risk Assessment Information System*. URL: http://rais.ornl.gov/cgi-bin/prg/RISK_search

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ОЦЕНКА ВОЗДЕЙСТВИЯ ВЫБРОСОВ СЕВЕРОДОНЕЦКОЙ ТЭЦ НА ЗДОРОВЬЕ ГОРОДСКОГО НАСЕЛЕНИЯ

Цель. Определить вклад выбросов ГП «Северодонецкая ТЭЦ» в уровень загрязнения воздушного бассейна города Северодонецк и в риски угрозы здоровью населения.

Методы. Моделирование рассеивания выбросов из одиночного точечного источника и оценка хронических канцерогенных и токсических рисков проводилась с помощью автоматизированной системы расчета ЭОЛ-2000[h] с утилитой «Показатель риска». Для оценки уровней рисков профессиональных контингентов «работник на улице», «работник в помещении» и «строитель» использовали Risk Calculator (EPA US). Сезонная роза ветров определена на базе сервиса глобального мониторинга окружающей среды и безопасности Copernicus Climate Change Service (European Commission).

Результаты. По принятому сценарию моделирования (стабильная работа установки, сезонная роза ветров) негативный вклад выбросов ТЭЦ в состояние воздушного бассейна города крайне мал (содержание всех компонентов меньше нормированных значений), но привносит соединения марганца, ванадия, ртути, ксилол и фтористый водород. Санитарно-защитная зона Северодонецкой ТЕЦ не требует корректировки. Онкогенные свойства проявляют хром (VI) и никель с однонаправленным воздействием на легкие и носовую полость. Индивидуальный канцерогенный риск 6.01×10^{-6}, создаваемый газовыми выбросами установки, является приемлемым. Проявление хронических токсических эффектов от выбросов Северодонецкой ТЭЦ маловероятно, на что указывают минимальные (целевые) уровни неканцерогенных рисков.

Выводы. Выбросы от плановой деятельности ТЭЦ в холодный период года не превышают допустимые концентрационные пределы ($ПДК_{мр}$), а риски угрозы здоровью населения близлежащих жилых районов и работников предприятий минимальны.

КЛЮЧЕВЫЕ СЛОВА: Северодонецк, ТЭЦ, выбросы, рассеивание, концентрация, угроза здоровью

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