Quantitative assessment of aviation emissions for international airport zones in Georgia

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Abstract

This article discusses the ICAO-recommended method for determining the amount of pollutants emitted from the engines of civil aircraft aircraft and calculates the levels of carbon monoxide (CO/CO_2), unburned hydrocarbon (C_nH_m) and nitrogen oxides (NO_x/NO_2) emissions for international airport zones in Georgia, which will be emitted during 2022 summer flight schedule. Our research addresses the necessity of investigating and assessing the ecological hazards in the airport zones caused by the pollutants emitted from the engines.

Keywords: Air emissions, air pollution, mass of pollutants, airport area, standard take-off cycle, aircraft engine operating mode, exhaust gases, emission index.

During the movement of aircraft both on the territory of the aerodrome, as well as during their take-off and landing - the so-called During the take-off (landing) cycle (ADC), as well as in the horizontal movement at the last altitude in the air, air pollutants are released from the engines, which according to the requirements of the International Civil Aviation Organization (ICAO) are grouped as follows: Carbon oxides - CO/CO2, Unburned hydrocarbons - CnHm, Nitrogen oxides - NOx/NO2 and airborne solid particles in the form of smoke- SN.

Each of the above substances, individually and collectively, has a negative impact on both the environment and climate. Carbon dioxide (CO_2) is the most viable (about 100 years), interferes with the lower layers of the atmosphere and accumulates there, which helps to increase the greenhouse effect. Carbon dioxide CO is produced due to incomplete combustion of fuel. It is poisonous to humans and warm-blooded animals when it enters their body through the respiratory tract. It plays a role in the formation of ozone in the troposphere. Nitrogen oxides (NO_x/NO_2) in the exhaust of the aircraft engine are also one of the most harmful substances. They negatively affect humans (respiratory organs) as well as vegetation and the ecosystem in general. Solid weighted particles SN, which are emitted directly from the engine or after secondary processes, form a complex mixture of particles containing various substances (heavy metals, sulfates, nitrates, ammonium, organic carbon, etc.) with dimensions of 2.5 micrometers or less. ისინი They have a negative impact on human health (damage to the respiratory system and blood vessels, increase the risk of death and the development of oncological diseases), as well as vegetation, polluting and contaminating soil and groundwater.

Data on which aircraft engine emits each of these substances per kilogram of fuel burned per second are provided in the relevant ICAO guidance document. [1].

The total impact of the listed components of the emissions on the environment and the planet's climate is not insignificant. The percentage of pollution from aviation engine emissions is about 3% of the total anthropogenic greenhouse effect (14% for road transport, 3.8% for rail, sea and other transport). In 2016, the ICAO Committee on Aviation Environmental Protection (CAEP) reached an agreement on the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) for international aviation [2] and according to that fact the aviation industries from all around the world from 2020 year should not increase hydrocarbon emissions, and by 2050 it should reduce it twice compared to 2005 levels. Currently, CORSIA unites 73 countries, which control 88% of the world's airlines.

Air pollution caused by air emissions is unevenly distributed in the airspace and covers both the lower part of the stratosphere - the surrounding area and areas of the airport, as well as its upper part and reaches the ozone sphere.

Exhaust from the engine generated during the take-off and landing cycle of the aircraft primarily pollutes the environment surrounding the airport, where usually there are settlements and agricultural land. In addition, as the engine operates in different modes at different altitudes, the exhaust emissions are different, both in terms of composition and quantity.

Figure 1 shows the conventional flight stages of the aircraft adopted by ICAO, and Table 1 shows the characteristics of the operations performed by the aircraft in the airport area and indicates the operating modes of its engine.

Figure 1. Aircraft standard take-off and landing cycle according to ICAO

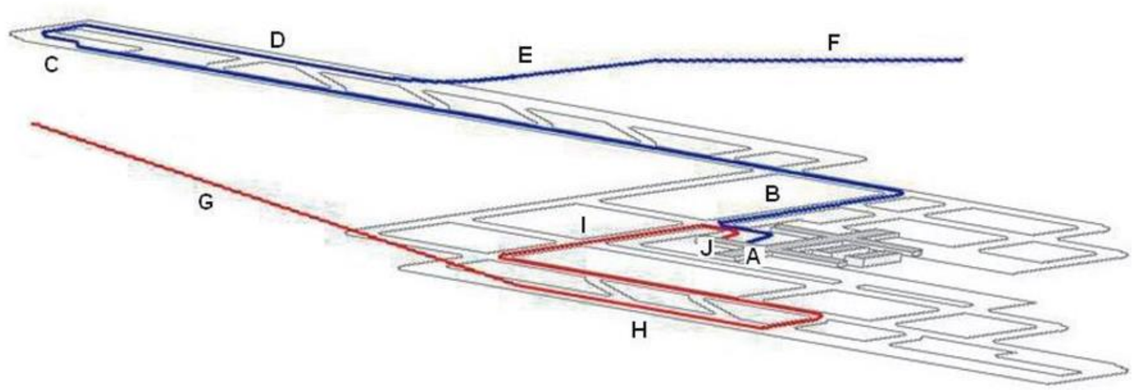

Table 1. Landing Take-Off (LTO) cycle definition according to ICAO databank

Operating mode	Duration (min)	Engine power (%)	Remark
Take-off	0,7	100	
Climb	2,2	85	
Approach	4,0	30	
Taxi	26	7	Before take-off - 19 minutes, after take-off - 7 minutes

As stated in the ICAO Guidelines [3], in the airport area and the surrounding environment air pollution from aviation emissions occurs during the standard take-off and landing cycle, ie up to 900 m above the aerodrome surface. As the aircraft moves at higher altitudes, emissions from its engine are no longer present in the airport area.

It should be noted that the concentration of harmful components of aircraft emissions in the air and the characteristics of their spatial distribution in the atmosphere and in the airport area largely depend on both local and global meteorological conditions at the time. The wind direction and speed play an extremely important role in concentrating harmful components of aircraft emissions in the air. The influence of other factors (air temperature and humidity, solar radiation) have less influence and has a more complex dependence on these factors. The methodology for assessing aircraft engine emissions is set out in the International Civil Aviation Organization Guidance Paper [4], which states that the mass of each pollutant emitted into the atmosphere during the run-off of the standard take-off cycle operations is due to the mass of each pollutant in M_i (kg):

$$M_i = \Sigma EI_{ij} * G_j * T_j.$$

Where i - is the number of the contaminant;

j - is the number of engine operating mode during the Landing Take-Off (LTO) cycle;

EI_{ij} – is "i" pollutant emission index during "j" engine operation mode;

G_j - is the amount of fuel consumed by the engine (kg / s) during "j" engine operation mode;

T_j - is the duration of operation of the engine during "j" engine operation mode.

Based on the ICAO database of air emissions of different types of aircraft engines, using the above formula and Excel spreadsheets, it is possible to calculate the individual and total mass of exhaust pollutants from air engines for any airport at any time during its operation. If the flight schedule and number of flights performed (or to be performed), types of aircraft and their engines are known. There are seven operating civil airports in Georgia. Three of them are international - Tbilisi, Kutaisi and Batumi, whose operating loads are much higher than the others. Consequently, the air pollution rates caused by the operation of international airports will be much higher than those of the locals, so the article discusses only the international airports mentioned above. Using the methodology described above, the share of emissions from aircraft engines involved in changing global climatic conditions (creating a greenhouse effect, promoting the emergence of ozone holes, etc.) was calculated. In particular, the amounts of carbon monoxide (CO/CO_2), unburned hydrocarbons (C_nH_m) and nitrogen oxides (NO_x/NO_2) for the zones of international airports in Georgia. For instance, we used the flight schedule of summer 2020 . The results are given in the table below.

Airport	The aircraft and engine to be used	Number of Landing Take-Off (LTO) cycles	Aviation emissions, kg			
			HC	C O	NOx	Sum
Tbilisi International Airport	**A320**, CFM56-3C2	2493	5234	32640	35287	73161
	A321, CFM56-3C3	1237	2498	15886	19218	37601
	A223, PW1519G	124	7	617	664	1287
	B737, CFM56-3C1	2637	1513	29488	25370	56370
	E190, CF-10E	434	924	7854	4172	12950
Total in Tbilisi Airport Zone, kg			**10175**	**86484**	**84710**	**181370**
Kutaisi International Airport	**A320**, CFM56-3C2	1172	2460.55	15344.65	16589.16	34394.36
	A321, CFM56-3C3	62	125.1	796.21	963.21	1884.63
	B737, CFM56-3C1	88	50.48	984.04	846.63	1881.15
	E290, PW1919G	310	16.52	1601.24	1720.26	3338.02
Total in Kutaisi Airport Zone, kg			**2650**	**18730**	**20120**	**41500**
Batumi International Airport	**A320**, CFM56-3C2	667	1400.33	8732.83	9441.10	19574.26
	A321, CFM56-3C3	336	678.55	4314.96	5219.97	10213.48
	B737, CFM56-3C1	381	218.56	4260.44	3665.54	8144.54
	A223, PW1519G	51	2.69	253.71	272.90	529.30
Total in Batumi Airport Zone, kg			**2300**	**17560**	**18600**	**38460**
In all three international airport zones, t			**16**	**122**	**123**	**261**

As it can be seen from the table, during the summer period of this year (approximately 8 months) the air of Tbilisi International Airport will be polluted with 181 tons of air emissions, Kutaisi - 41 tons, Batumi - 38 tons. Also, the emissions from vehicles used in aircraft maintenance services at the airport will be added to that, however the report of that vehicles is a separate issue and is not discussed in this article. To clarify the results, it is indicating to mention again that this article also does not discuss aviation emissions that are emitted into the atmosphere during the flight of an aircraft at altitudes above 900 m (so-called cruising speed flight conditions), as the emissions emitted at such times do not reach the airport area.

According to the Georgian Civil Aviation Agency, monitoring of carbon dioxide emissions released into the atmosphere annually after January 1, 2020 has started by airlines registered in Georgia. The results presented in the aviation emission calculations will be relevant to the implementation of the measures required to comply with CORSIA requirements.

Moreover, additional studies are to be conducted to determine how the above-mentioned emitted harmful substances are distributed in each airport and the surrounding environment - considering the meteorological and climatic conditions in the air, soil and groundwater.

Conclusions

1. It is necessary to determine the amount of aviation emissions in the international airport zones of Georgia according to the data for 2019/2020 and to determine the relevant level of environmental threat in the vicinity of the airports for comparison with the data of the following years;
2. In order to meet the requirements of CORSIA, it is necessary to develop a computer program to determine the amount of annual aviation emissions and the consequences of the emissions to the environment;

References:

[1] Emissions databank ICAO, Doc. 9646-AN/943].

[2] Airport Air Quality Manual. Doc9889. ICAO.

[3] ICAO, Doc 9889;
[4] ICAO Document 08_CORSIA Eligible Emisions Units_March 2022
[5] Website of the Georgian Civil Aviation Agency - https://gcaa.ge

საავიაციო ემისიების რაოდენობრივი შეფასება საქართველოს საერთაშორისო აეროპორტების ზონებისათვის

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ანოტაცია

სტატიაში განხილულია სამოქალაქო ავიაციის თვითმფრინავების ძრავებიდან გამონაბოლქვი მავნე ნივიერებების რაოდენობის განსაზღვრის ICAO-ს მიერ რეკომენდებული მეთოდიკა და გამოთვლილია თვითმფრინაბების ძრავებიდან გამოფრქვეული ნახშირბადის ოქსიდების (CO/CO_2), დაუწვავი ნახშირწყალბადების - (C_nH_m) და აზოტის ოქსიდების (NO_x/NO_2) რაოდენობები საქართველოს საერთაშორისო აეროპორტების ზონებისათვის, რასაც ადგილი ექნება 2022 წლის ზაფხულის ფრენის განრიგის განხორციელების დროს. დასმულია საკითხი ჰაერისა და აეროპორტების მიმდებარე გარემოს შესაბამისი დაბინძურებით გამოწვეული ეკოლოგიური საფრთხის შესწავლისა და შეფასების აუცილებლობის შესახებ.

საკვანძო სიტყვები: საჰაერო ემისიები, ჰაერის დაბინძურება, აფრენა-დაფრენის სტანდარტული ციკლი, თვითმფრინავის ძრავას მუშაობის რეჟიმი, გამონაბოლქვი აირები, ემისიის ინდექსი.