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An Analysis the Environmental Pollution Emitted by Aircraft Engines at the Ercan International Airport

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Abstract

Airports are strategically important objects for each country, although the place of significant pollution, emitted by aircrafts, thus impacting air quality in nearby residential areas. The environmental challenges at Ercan airport are becoming more serious because of expansion of the airport, increasing scheduled flight and continued growth of passenger flow. Since 2019 passenger turnaround has reached 4 million, while the growth expected in the following years, by the opening of a new airport terminal. The present analysis estimates the level of emission from aircraft engines for chosen environmental parameters accounted for by utilization of three operation modes such as; taxi, landing and take-off cycles. In the period of aircraft parking, emitted pollutants are considered depending on operation hours of the APU. The data collection is based on last 6-month flight information with daily landing cycles. Application the ICAO Engine Exhaust Emission fixed data set methodology, allows for assessment of emission species such as CO_2, HC, NOx, CO, and SO_2 using estimation of fuel consumption level, burned out from different engine models adding applicable coefficients.

1. Introduction

Aviation industry is a fast-growing transportation sector mainly due to the rising worldwide economy affected by globalization, which contributes to climate change, particularly in relation to environment pollution producing emissions, thereby deteriorating air quality during flights and ground operations in airport areas. Current environmental challenges interest the science associations and policymakers, particularly violation of the maximum limit value of carbon dioxide pollution near the congested airports (Masiol and Harrison, 2014). The Paris Agreement following the Kyoto Protocol has been focused on carbon dioxide (CO_2) emission from aircraft engines while there has been an important omission ignoring nitrous oxides (NOx), H_2O and other short-lived greenhouse gasses (Lee et al., 2020). Different types of air pollutants are presented from aviation as an emission that potentially have an effect on humanity and the environment. Particularly the following exhaust gas emission species generated by the engines can be considered primary, which is necessary taking action to reduce in following years (International Civil Aviation Organization, 2020).

a) nitrogen oxides (NOx), including nitrogen dioxide (NO_2) and nitrogen oxide (NO);

b) volatile organic compounds (VOC), including non-methane hydrocarbons (NMHC);

c) carbon monoxide (CO);

d) particulate matter (PM), fraction size PM2.5, PM10; and

e) sulphur oxides (SOx)

Fossil fuel is the main source of carbon dioxide (65%-CO_2) which is a global issue in relation to utilization of the overall fuel combustion that consists of basic elements for computing of emission. Consequently methane (CH_4) covers 16% emission from agricultural activities, waste, energy, biomass burning and nitrous oxide (NO_2) is 6%, of the global emission, which is total 14% comes from transportation sector, by burning fossil fuels on the road, rail, air, as well as marine vehicles (EPA, 2021; Edenhofer, 2015; Change, 2014). During the last 20 years GHG emission from aviation within European Union countries has increased by 22% consisting of 15 Mt CO_2

e, and in the same period worldwide civil aviation figures has been doubled increasing by 141% which for international aviation totalled 129.2 Mt CO_2 e. The share of landing and take-off (LTO) air transport emissions of air pollutants in 2018, the largest was found for non-methane volatile organic compounds (NMVOC) by 39%, followed by PM (26 %), NOx and SOx (15 %) (European Environment Agency, 2020).

The data obtained from the United Nations Framework Convention on Climate Change (UNFCCC) shows a significant proportion of global emissions produced by aviation engines over 2% of yearly greenhouse gasses in 2017 shearing above 10 Mt of CO_2 e. Even the share of emitting exceeded 10% in five countries, including Cyprus at 10.1%, Switzerland 10.4%, Luxembourg 14.2%, Malta 16.7%, and Iceland 19.9% accordingly, confirming the fact that emission from aviation continue to grow faster than from the industrial in general comparing between 1990 to 2017. Thanks to taking effective action Cyprus has reached to decrease aviation emission from 1990 to nowadays, (Gössling and Humpe, 2020). Air transportation is an important major economic sector in the aviation industry. Huge investment in new generation aircrafts in synergy with modern airport construction dictates growth demand for air transportation services which is expected to reach their peak nearly in 2030, (Zaporozhets and Synylo, 2017; Ekici and Şöhret, 2020; Toksuslu, 2021).

Indeed, airlines are coming into a competitive period after COVID-19 pandemic. Taking into account uncertainty of the current situation in the world with transformational processes that brings their instability, there is expectation that global passenger flow will be back at the 2019 level nearly in 2024, thereby forecasted to increase at an average 3.3% every year until 2040, rising passenger numbers to 7.8 billion travelers. In spite of the current gradual recovery of passenger and cargo air traffic, it is predicted that the Asia/Pacific region will become fast growing incoming two decades (IATA, 2022) including Tukey with their global air transportation infrastructure, therefore impact to widened Northern Cyprus aviation activities. During the last two decades intensity of direct flights from different airports Turkey to Ercan increased up to 27000 landings per year, where passenger turn around reached more than 4 million from 2018 to 2019 accordingly, (see figure1) (Imanov et al., 2022).

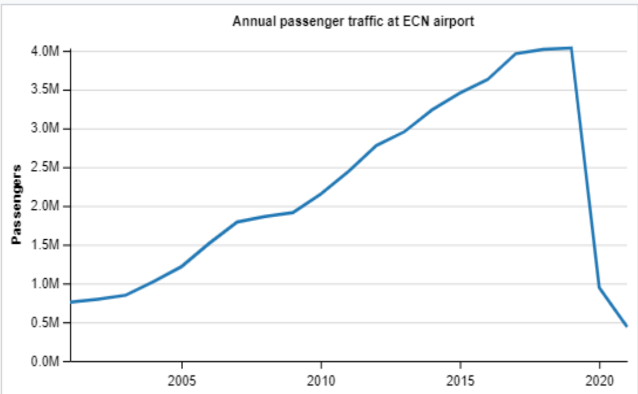

Figure 1. Annual air passenger flow at Ercan airport

As a result of the rise in passenger numbers, particularly to Ercan airport the growth of scheduled flights leads to amount of fuel consumption during approach phase, landing, taxing, ramp service, take-off which contribute rise of emission exhaust gasses produced by power sources (Engines, auxiliary power unit (APU)) more than previous years. By the reason of global warming the exhaust gas temperature (EGT) value is increase due to extra fuel burn in cruise altitude, therefore it causes more atmospheric pollution (Yildiz and Imanov, 2022), that is problem at global scale, while the landing and takeoff (LTO) operations are absolutely as a local issue, obviously having a negative effect of human health (Koo et al., 2013).

Gas emissions produced by aircraft engines are one of several sources at airports. Additionally, ground equipment, providing power to the aircraft and APU (small gas turbine engine fitted on each aircraft) operation, during ramp service are other sources of the air pollution which also have a high impact on air quality at the airport including nearby habitats. There is evidence that Earth's surface is undergoing radical climate change because of GHG emission past 40 years reaching its peak, therefore island biodiversity, its developments in living, needed special attention due to their isolation (Veron at al., 2019).

Northern Cyprus is one of the islands located in the Mediterranean Sea, discovering one of attractive destinations chosen by tourists from different countries of the world. Travelers can reach the country by the air to Ercan airport, also using marine transportation to Kyrenia or Famagusta only from Turkey, due to 48 years international sanction.

Figure 2. Ercan International Airport

Ercan airport, which is available for international flight only, indicates an unbroken increase in the number of air travelers during the last 2 decades (figure 1). By the entry to service the new projected airport there is expected increase of flights, accordingly the greenhouse gas emissions generated by the aircraft will be increased consequently. Therefore, the aim of the study is to estimate aircraft engine emission spices such as CO_2, NOx, CO, SO_2, HC along with other chemical compounds, under the landing and take-off cycles at Ercan International Airport during the last 6 months of the year 2022. It is notable that, there wasn't any previous research performed for the estimation of aircraft related emission level dedicated to Ercan airport.

Future the paper is organized as follows: Section 2, is expressing the Literature Review, Section 3, represents the Methodology, Section 4, describes Result of the study, Section 5, represents Discussion and finally Conclusion is introduced.

2. Literature Review

Most recent publications state the negative effect of air transportation on quality of the air at the airports (Ekici and Sohret, 2020), other investigations embrace the harmful effect of the aircraft emitted emission on human health (Tokuslu, 2021). A large number of articles are published during the last 2 decades revealing the significant contribution of the civil aviation emission on air pollution in urban residential areas located nearby of the airports (Bossioli et al., 2013; Zaporozhets and Synylo, 2017).

The study carried out by Zhang et al (2019), in 70 airports in China to calculate the CO_2 emissions from on-ground airport operations, defines 5 factors affecting pollution of airport areas with GHG, which indicates an increasing trend of urbanization in western part of the country. Enzler, (2017) found that the tendency to rise of air travel is mostly dependent on higher income of the population. Economic growth, contributing development in certain cities leads to urbanization, which has been a key driving factor of aviation carbon dioxide emission (Li et al., 2019). In this context, the rise of air passenger flow to Northern Cyprus corresponds with this hypothesis.

The study of Kurtenbach et al, (2015) compares the measured values nitrogen oxide (NOx) based on calculation of carbon dioxide (CO_2) from aircraft engine emissions during taxi and take-off, in Boryspil International Airport for accurate assessment and it is impact on local air pollution using complex model PolEmiCa. In 2010, Yilmaz (2017) has investigated the aircraft engine gas emission level upon landing and take-off at Kayseri airfield in Turkey, where the amount of emitted gasses continued nitrogen oxides (NOx), hydrocarbons (CH_4), and carbon monoxide (CO) was calculated. Using the combustor model named Brink, (2020) has investigated the effect of standard jet fuel composition on the CFM56-7B engine, to define available levels of NOx and CO, hence found that the result leads to negative impact on air quality.

Applying the System Aviation's Global Emission (SAGE) model, Kim et al. (2007) with Lee et al. (2007) states that the biggest fuel consumption related emissions occur at the flight level between 9 to 12 km at cruise altitude. Generally, most published materials reported that the amount of burned fuel on the ground during ramp service, taxi and take off within one kilometer above ground level consist 5-7 % of total jet fuel consumption, (Kim et al., 2007; Simone et al., 2013).

There is evidence that most study outcomes concluded up to 10% of fuel is burned below 1 km at airport area during taxi because engine power adjustment which may increase fuel consumption rate (Nikoleris et al., 2011) or because of unaccounted burns of fuel during APU operation on the ground (Ratliff et al., 2009). Ground support equipment is also a significant source of emission at an airport territory which supplies ground service for passengers and baggage using buses, food carrier machines, cargo loaders, refueling tanks as well as pushback and anti-icing vehicles. Indeed, there are few research publications available for airport related emissions produced by ground service equipment, ground power units (GPU) and APUs (Presto et al, 2011; Masiol and Harrison, 2014).

3. Data and Methodology

3.1. Data

To examine the aircraft related level of emissions has been employed precisely identified real aircraft and engine data (Scholz, 2015; ICAO), 2020) landed in Ercan airport in regular bases, gathered from open resources and available flight schedules, Table 1.

Table 1. Aircraft types, Engine and APU models

Aircraft	Engine	APU
A320	CFM56-5B4/3 (50%), V2527-A5 (50%)	APS 3200, Honeywell 131-9B
A321	CFM56-5B3/3 (30%), V2533-A5 (70%)	APS 3200, Honeywell 131-9B
B737-800/900	CFM56-7B26	Honeywell 131-9B

Different aircraft types may contain considerable versions in engine and APU manufacturing technology, though Airbus A320 family and Boeing 737-800 are similar on their engines. In spite of the similarity in engine and APU installation, the emission characteristics have different factor values. Consequently, it is important to define aircraft type rates operated to Ercan airport for proper evaluation emission values from each dedicated aircraft. Only Turkish Airlines and Pegasus Airlines are operated to Northern Cyprus using 3 types of aircrafts, including Airbus A320 and A321 where covers 52% and 20% scheduled flight cycles, and Boeing 737-800 where 28% of operations.

Another major data is the number of aircraft movements that are chosen for daily, 1 month, 3 month, and 6 months periods between February and August in 2022 and each aircraft type with carried passenger which is indicated according to obtained information. The statistical data is defined by the amount of landing cycles for calculation during 6 month scheduled daily flights arriving at Ercan airport (see figure 3).

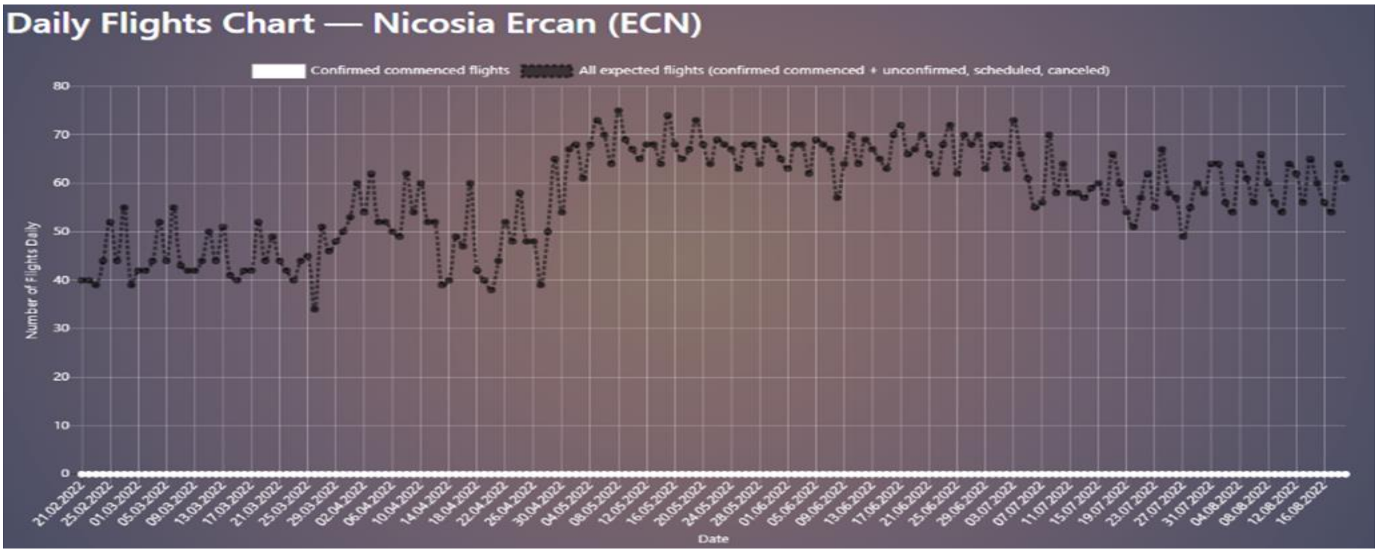

Figure 3. Daily flight Chart to Ercan Airport. Source: (Spotter Lead, 2022)

Table 2 represents aircraft movements to Ercan airport from February up to August 2022 where demonstrated the distribution by day and month, 3 month, and 6 months with average landing cycles. For the last 6 months the peak is above 70 flights in May and July and bottom line is in March and April where monthly flights are below 40 landing cycles, respectively.

Table 2. Ercan airport aircraft movements statistic data

Aircraft movements	1 Day (12 AUG)	30 Days (per day)	3 Month (per day)	6 Month (per day)
Take-off	31	898 (30)	2891 (32)	5409 (30)
Landings	31	897 (30)	2894 (32	5425 (30)
SUM	62	1795	5786	10834
Average LTO	62	60	64	60
Average delay	25	23	23	20

3.2. Methodology

The main approach for estimation of the intended parameters is applied in three operation modes; taxi, landing and take-off cycles however, APU operation hours in parking mode considered as an additional emitted pollutant. For the opening assessment of the aircraft engine and APU produced emission at Ercan international airport used simplified methodology to identify approximate value of the pollutant species, as CO_2, NOx, CO, CH and SO_2 which are main elements of pollution. As a Methodological measurement implemented the value of fixed emission factor "Engine Exhaust Emission Data Bank" issued by International Civil Aviation Organization (2020) which, used for assessment of the emission volume Table 3. Standard LTO cycle times for approach and landing takes 4 minutes, taxi-way (in-out) is approximately 4-6 min, and take-off with preliminary preparations consist of 2 min, hence APU ground operation is 1 hour. Taking into account stabile weather performance at Ercan airport, variation of ambient temperature and wind speed have not impacted the result of study.

Table 3. Emission Factors Defined by International Civil Aviation Organization, (2020)

Aircraft	CO_2	HC	NOx	CO	SO_2	Fuel Consumption
A320	2665	0.34	9.90	8.14	0.42	843
A321	3195	0.17	16.23	5.81	0.51	1011
B737-800/900	2784	0.72	12.30	7.07	0.44	881

ICAO defined LTO emission factor/aircraft (kg/LTO/aircraft)

As the APU fuel consumption and GHG data are not indicated in the ICAO database, the figures refer to manufacturer standards. ICAO Engine Exhaust Emission Data Bank provides an available data set for emission species assessment such as CO_2, HC, NOx, CO, and SO_2 using defined factors, estimated fuel consumption rate and engine model. Correspondence of the engines fitted to appropriate aircraft checked referring to engine manufacturer databank. Notable, that this study contains LTO emission evaluation only, and other airport related sources of pollution is not covered in current estimation. Emission calculation methodology based on simple and advanced approaches for NOx, HC, CO, SO_2 and CO_2 conducted by multiply the number of single LTO cycles by the emission factor for each species according to ICAO definition, afterwards sum up each obtained value for all participated aircraft for 6 months LTOs in order to gain quantity of total emission (in kg) for every pollutant species using below simple formula: (International Civil Aviation Organization, 2020).

Emission of Species X = Σ (number of LTO cycles) × (emission factor)

(in kg) all aircraft of aircraft Y for species X

Notable, that given formula does not apply for specific engine types, operation model and aircraft time-in-mode function.

4. Result of Study

This research considers the environmental aspect at the Ercan International Airport for the period of last 6 months in 2022 for evaluation of aircraft engine emission affected on air quality. For these purposes were used the data collected from the aircrafts landed in Northern Cyprus, which illustrated in

Table 1 and Figure 4. Table 2 shows that, the current period 10834 landing and take-off were conducted using Boeing 737-800, Airbus A320 and A321 types equipped CFM56-5B/7B engines. The emission index determined by the ICAO, one of the important values for calculation of emission species identified in the Table 3 which indicates emission coefficient for each type of aircraft. Although similarities of the engine types on each type of the aircraft, taking into account take-off mass the emission indexes are varied in different ranges. Due to highest fuel consumption (1011 kg/LTO) the A321 is the source of a huge amount of produced emission of the CO_2, NOx and SO_2. A320 and B737-800 roughly in the same level of many species except CH which B737-800 produces twice higher than A320. Of all 3 aircrafts nitrogen oxide (NOx) has the worst negative impact on the atmosphere. Ercan airport serves on average 30 landings per day, but during summer it has reached over 70 LTO scheduled flights. For the period investigation of the data during 6 month estimated emission rates were was carbon dioxide (CO_2) - 30737 kg (170 kg per/day), hydrocarbon (HC) - 3990 kg (22 kg per/day), nitrogen oxide (NOx) - 131655 kg (731 kg per/day), carbon monoxide (CO) - 78801 kg (437 kg per/day) and sulphur dioxide (SO_2) - 4854 kg (27 kg per/day) respectively as per Table 4.

Table 4. Result of the study

Aircraft	LTO cycle	CO_2	HC	NOx	CO	SO_2
A320	5634	15014	1915	55776	45860	2366
A321	3033	9690	515	49225	17621	1546
B737-800	2167	6033	1560	26654	15320	953
Total	10834	30737	3990	131655	78801	4854
Daily	60	170	22	731	437	27

LTO Emission Summary/ (kg)

Aviation emissions contain their compounds exited from aircraft engine exhaust lines as a vapor, in converted gaseous atmospheric wastes such as CO_2, CO, NOx, SO_2, CH and other type organic pollutant species (Presto et al., 2011). The fuel products burned in combustor and emitted via aircraft exhausts are mainly contains of carbon dioxide (CO_2) approximately 72% at cruise altitude (Masiol and Harrison, 2014), while hydrocarbons (CH) and carbon dioxide (CO_2) are about 70 % emitted during LTO cycles (FAA, 2005). The fuel products burned in combustor and emitted via aircraft exhausts are mainly contains of carbon dioxide (CO_2) approximately 72% at cruise altitude (Masiol and Harrison, 2014), while hydrocarbons (CH) and carbon monoxide (CO) are about 70 % emitted during LTO cycles (FAA, 2005). Carbon monoxide is usually formed generally as a result of unburned jet fuels in combustion and thanks to development of the aircraft engine technology has reached significant reduction CO emission factor below 10 kg per LTO cycles with compliant ICAO requirements.

5. Discussion

Comparing our findings with other studies on the same topic it is obvious that it seems to be consistent and values are closely previously obtained numbers. Result of the measured NOx and CO2 appears higher than other emission variables emitted from CFM56-5B/7B engines. While operating, CFM56 family engines need to take into consideration its age and life cycles, monitor variation of fuel flow, and apply predictive analysis of remaining cycles of high- and low-pressure turbine components. Figure 4 represents dispersal of aircraft emissions for analysis applied CO2, SO2, HC, CO, and NOx in LTO modes.

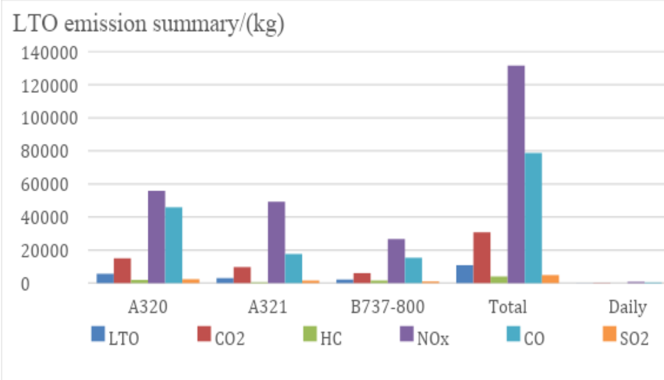

Figure 4. LTO emission distribution at Ercan Airport

Sulphur dioxide (SO_2) is emitted from different sources including fossil fuel combustion used by aircraft engines. Their impact from aviation activity is less than from natural or anthropogenic sources, which mainly affect human health.
The taxi mode contributes a higher emission than other selected configurations which is the leading source of pollution at airport areas (Toksulu, 2021). Implementation of the next generation air traffic management system using a Controller Pilot Data Link Communications (CPDLC) will significantly reduce delays during taxi-out, and at the gates by improving schedule reliability as well as decrease the fuel burn and carbon dioxide emissions (Cizrelioğullari and Imanov, 2023). Moreover, improvements in taxi operation have a direct relationship with take-off, climb-out, and approach, consequently impact in reducing carbon related emission categories.
The findings of the current study supported by the results of studies (Elbir 2008; Yilmaz, 2017; Zaporozhets and Synylo, 2017; Tokuslu, 2020; Tokuslu, 2021) conducted for the airports of Izmir, Kayseri, Kiyev, Tbilisi and Batumi. Nevertheless, those studies excluded analysis of Carbon and sulphur dioxides, Table 5.

Table 5. Level of aircraft related GHG emissions at airports (ton/year)

Airport	LTO Cycle	NOx	CO	HC
İzmir	91.980	197	138	21
Kayseri	7.887	102.64	66.9	8.4
Borispol	-	16.87	185.06	59.56
Batumi	3.056	39.78	25.92	3.26
Tbilisi	19005	247.33	161.21	20.24
Ercan	0834	3.990	131.655	78.801

Note: *The data for Ercan Airport covers a 6-month period.*

In addition, findings of the previous studies are consistent with the current results which concerns B73-8 and A320 families, validating the sources of main polluters in all airports. Monoxide and Hydrocarbons are main challenges in Ercan airport excessively higher than other airports. While the large number of LTO cycles in equivalent of outcomes, Izmir airport demonstrates improved performance for mitigation of GHG level. However, Tbilisi, Kayseri and Kiev airports are leaders in high levels of nitrogen oxide. The differentiation of variable outcomes, depends on geographical location, airport elevation, load factors and connectivity of flight schedules, as well as landing and approach patterns. Northern Cyprus is an attractive touristic area in the Mediterranean region whose travel flows are increasing every year. Commencing the Russian-Ukrainian war last year, contributed to multiple the rise of air traffic in parallel caused more air pollution. According to the projection passenger traffic and flight movements predicted would increase in next years. The prognostic assumption indicates that people living nearby the airports will susceptible harmful effect in the future, by drawing breath from emissions around degraded environment.

6. Conclusion

Emission components like CO_2, NOx, CO, SO_2, HC along with other chemical compounds generated from aircrafts and its power plants have a negative effect on the region particularly residential areas nearby the airports impacting on human health. This study considered to estimate aircraft engine emission spices under the landing and take-off cycles (LTO) at Ercan International Airport covering the period of 6 months, from February to July of the year 2022. Focused on analyzing the environment situation at Ercan International airport and summarizing the main reasons for air pollution and aircraft related emissions, it can be concluded that, large number of scheduled flights significantly impact environmental degradation. Engine emissions and existing compounds forming gaseous except CO2, SO2, NOx the Monoxides (CO) and Hydrocarbons (HC) are the main challenge in Ercan airport which are excessively higher than other airports.

Researchers involved in prevention of global warming arising from the aviation industry are making a huge investment to use alternative fuels, currently applied by Boeing and Airbus to mitigate the emission level and its components. Nearly there is consideration to use synthetic and biofuels as an alternative for conventional reactive fuel to reduce gas emissions produced by aircrafts.

Apart from engine emissions, APU is another source of pollutants. It is capable of providing electrical power to the whole aircraft system, on the ground, provides air conditioning during summer and winter time, and activates the hydraulic system. Currently Ercan airport is now supplied by an outsource electrical system, all arriving aircrafts are use the remote electrical units reducing APU operation during parking. Against older 11 aircraft parking areas, nowadays an airport is designed with 8 jet bridge gates and 12 apron parking zones, which makes APU operation less necessary. Due to entry to service new airports while affecting increased aircraft landings and passenger flows, policy makers in association with aviation authorities achieved objectives to reduce distribution of GHG and continue to apply future developments.

Ethical approval

Not applicable.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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