UDC 504.054 (045)

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MONITORING OF AIR POLLUTION PRODUCED BY AIRCRAFT IN THE VICINITY OF AIRPORT

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Abstract. *Air pollution resulting from airport emissions and aircraft noise is a growing concern because of the expansion of air traffic over the years. Monitoring (measurement) and modeling techniques enables the assessment of historical, existing or future air pollution in the vicinities of airport.*

Keywords: aircraft engine emission; aircraft noise; air pollution monitoring; environmental monitoring; environmental protection means.

1. Introduction

Air pollution resulting from airport emissions and aircraft noise is a growing concern because of the expansion of air traffic over the years. On the ground of ICAO data [4], future air traffic movements are forecast to grow at a mean annual rate of 5 to 7 %.

During last decade a lot of investigations focused on the evaluation of aircraft engine impact on local and regional air quality in the vicinity of the airport [1, 7, 8].

Currently the basic objects of attention are NOx and fine particle emissions from aircraft engine emissions as initiators of photochemical smog and regional haze, which further direct impact on human health. Significant concerns regarding regional air pollution around the airports are effective for city airports, which are quite closely located to habitation area, so the impact of aircraft emissions on urban air quality is high.

Aircraft noise is the most significant cause of adverse community reaction related to the operation and expansion of airports. Limiting or reducing the number of people affected by significant aircraft noise is therefore one of ICAO's main priorities and one of the key environmental goals [4].

Thus, the monitoring of air pollution produced by aircraft emissions and noise is an actual task, providing evidence on the actual pollution for improving of air quality regulation systems, thus aiding an increased understanding and control of airport-related air pollution to help ensure both the short- and the long-term welfare of airport workers, users, and surrounding communities.

2. Instrumental monitoring of air pollution

Aircraft (during approach, landing, taxi, take-off and initial climb of the aircraft, engine run-ups, etc.) is the dominant sources of air pollution at airports in most cases under consideration [2, 10].

According to emissions inventory results the aircraft contribution is more than 50 % from total pollution of the airport [2, 10]. Emission inventory of aircraft engines are usually calculated on the basis of certificated emission indexes, which is provided by the engine manufacturer and reported in the database of ICAO [3]. The certificated emission indices rely on well-defined measurement procedures and conditions during engine test. Under real circumstances, however, operation (power setting, time-in-mode and fuel flow rate) and meteorological (air temperature, humidity and pressure) conditions may vary from ICAO definition, consequently deviation from the certificated emission indices may occur.

Monitoring of aircraft noise is targeted on the aircraft noise control and for the reduction of noise levels within the habitation areas. However the noise monitor station should also be located within the airport area to provide the accurate noise assessment of the efficiency of developed noise abatement (and emission reduction) procedures [6] and of the noise, and emission interdependencies.

The monitoring of aircraft pollution at airports allows determining real emission indexes, source strengths, contribution of aircraft emissions to measured concentrations, noise characteristics and meteorological data (velocity and direction of wind, temperature and humidity of ambient air) that will serve as input data for validation and modernization of the models of the airport local air quality and environmental capacity. This idea has been realized within the International airport Boryspil (KBP). Nowadays traffic volumes of the airport are getting close to its operational capacity.

Basic objectives of experimental investigation within the KBP:

1. Determination of aircraft emission indices under real operation conditions and comparison to ICAO databank.

2. Assessment the contribution of aircraft emissions to the measured NOx concentration at the airport.

3. assessment of the interrelationships between noise levels and emission indices during real flight operation conditions.

4. modernization and validation of complex model PolEmiCa [9] for different operational and meteorological conditions.

5. on the ground of improved models to develop the practical recommendations for instrumental monitoring of aircraft engine emissions and the assessment of its contribution to airport air pollution.

6. development of the MaxEnt Model [5] for the assessment of the environmental capacity.

3. Scheme disposition of monitoring stations

Instrumental monitoring of air pollution produced by aircraft engine emissions at KBP was conducted by two stations (stationary station A and movable station B) under real operation conditions: idle (aircraft is taxing) and maximum (aircraft is accelerating on the runway or takes-off).

Scheme for disposition the monitoring stations in airport was developed with taking into account modeling results (complex model PolEmiCa) of transportation and dilution contaminants by jet (stationary station A) from aircraft engine and its transfer by wind and atmospheric turbulence (movable station B) for differential operational and meteorological conditions, fig. 1.

Stationary station A is displayed near runway (18L-36R) in east direction and on opposite side to taxiway A2. Mast is located at distance of 60m from runway axis and height of sample point installation is 3m. Container with equipment is distance of 80m from runway axis.

Station B (movable van) is oriented to dominant wind direction and displayed at distance 120m from runway axis in west direction and opposite guide path near 36R end of runway, fig. 1. Dominant wind direction is south-east (130-170°).

Noise monitoring was performed by moveable station equipped with sound level meter "Octave 110A".

The basic principles of the location choosing of moveable station within the airport and outside:

– nearby the defined nominate departure/arrival aircraft routes;

– standard noise certification points in accordance with the ICAO standards' demands;

– defined sensitive points within airport area to correct assess of the efficiency of the noise abatement procedures and noise pollution in whole.

In results, there were 4 points for aviation noise control and 2 points for combined noise and emission monitoring, fig. 1.

4. Emission index estimation under real operation conditions

Processing and analysis results of measurement data at station "B" has highlighted that a lot of peak concentrations at plumes clearly correlate with operation mode of aircraft engine. So, maximum operation mode of aircraft engine (accelerating stage on the runway) is characterized by the highest value of NOx, while the idle operation mode (taxing stage on the main taxiway) – higher value of CO_2.

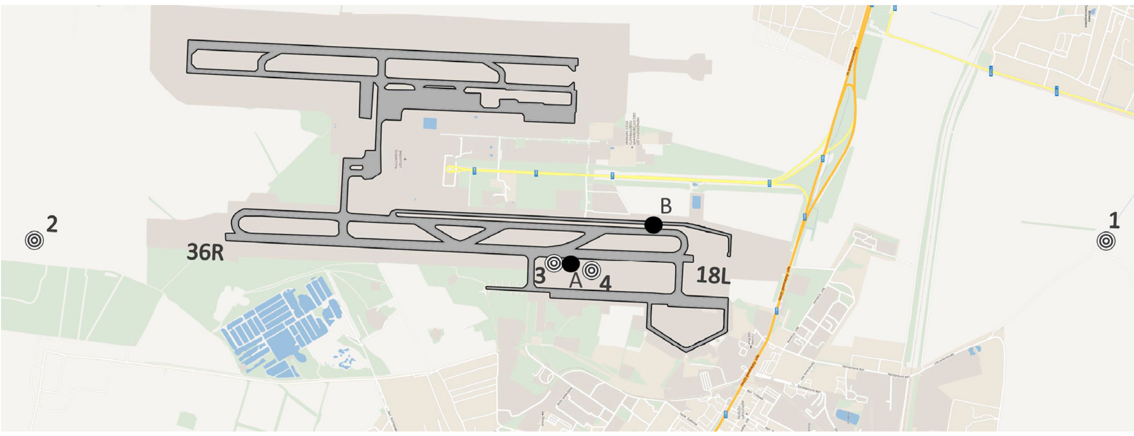
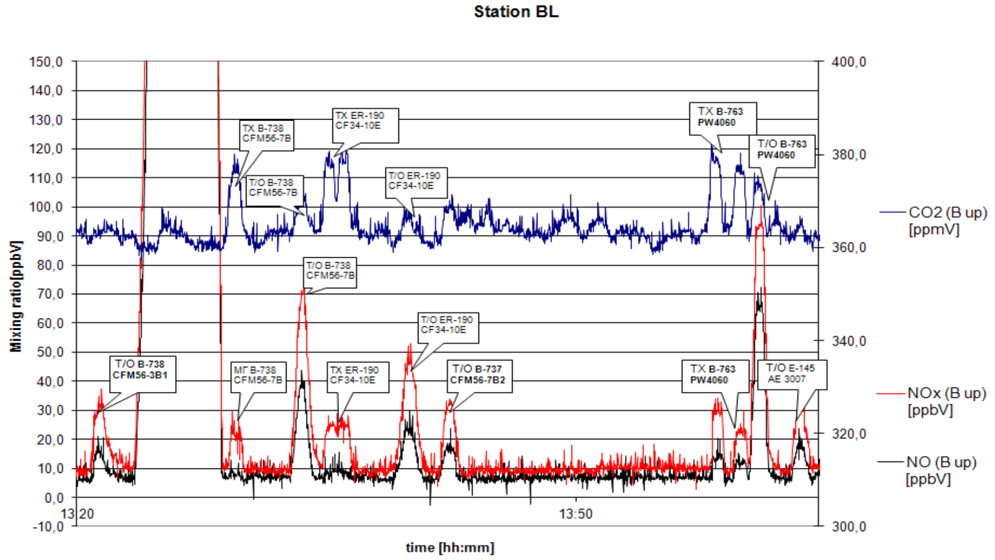
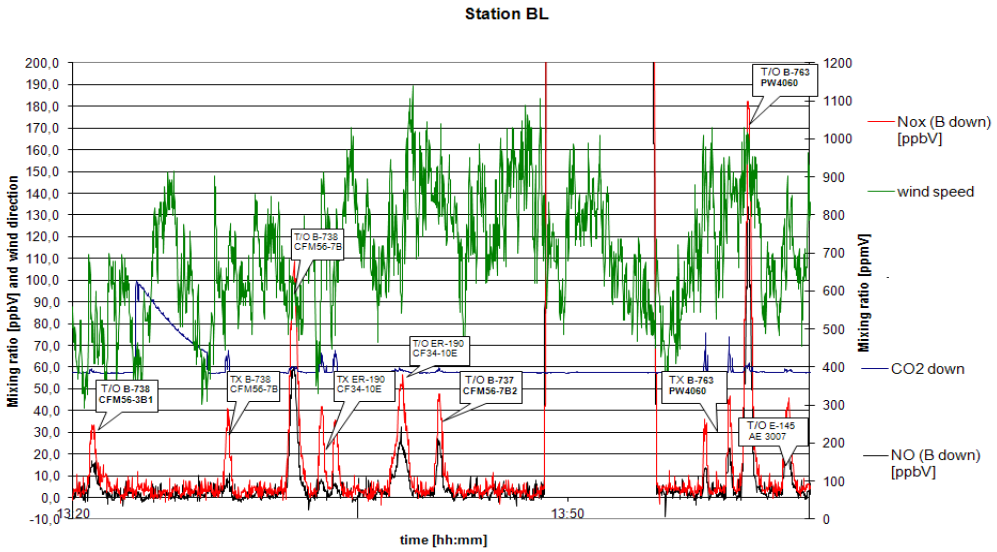


Fig. 1. Location of monitoring stations at Kyiv Boryspil airport:
A – air pollution monitoring stationary station A; B – air pollution monitoring movable station B;
1–4 noise monitoring measurements



a



б

Fig. 2. Background and plume concentration for NO, NOx, CO_2 at mobile station B for period 13:00÷14:00 with air sample point at height of 3m (a) and 6m (б)

These results of measured concentration (NO, NOx, CO_2) provide the possibility to calculate NOx emission indexes for real operation conditions on the ground of equation [7]:

$$EI(X) = EI(CO_2) \times \frac{M(X)}{M(CO_2)} \times \frac{Q(X)}{Q(CO_2)},$$

where M – the molecular weight;

Q – concentrations (mixing ratios, column densities, etc.) of the species. CO2 can be determined by FTIR emission and absorption spectrometry with very low detection limits.

Determined emission indices of aircraft engines under real operation conditions were compared with ICAO values, fig. 3.

The observed variations between determined and certificated emission indexes are most likely caused by operational (thrust) and meteorological (air temperature and humidity) conditions under real circumstances which are quite different from well defined conditions during certification procedure.

Nevertheless these differences are important since the ICAO data [3] is currently used to calculate emissions from airports.

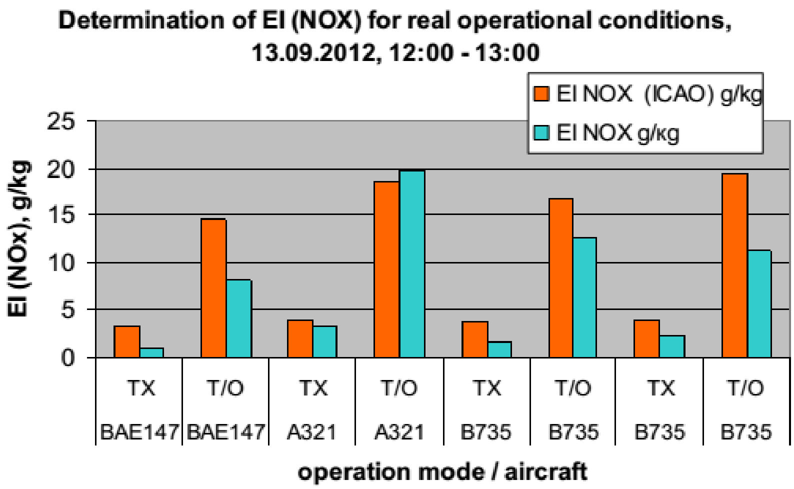


Fig. 3. Emission indices of NOx estimated by AC32M and comparison to ICAO database

5. Validation of complex model PolEmiCa by measurement campaign at KBA

The results of measurement campaign in KBA used as input and validation data set for modeling task due to complex model "PolEmiCa". For this task the period 12:30÷13.00 was chosen, which is characterized by 5 peaks of NOx concentrations and corresponding to 5 aircrafts (BAE 147, A321, B735) accelerating (maximum mode of engine) on the runway, table 1.

Complex model "PolEmiCa" [9] calculates instantaneous concentration (3 seconds) and assesses puffs for each engine of the aircraft separately, because of their separate influence on averaged concentration at point of monitor installation.

As shown from Table 1, the modeling results for each engine are in good agreement with the results of measurements as the system AC32M.

Better correlation between measurement and modeling results has observed with using CFD codes (Fluent 6.3), which allow give a realistic checked material and taking into account lateral wind, ground impact on jet structure and its behavior.

Table 1. Comparison measured and modeled concentrations from aircraft engine emissions

Time	Aircraft	Operation mode	AC32M	PolEmiCa CFD	PolEmiCa			
			peak	peak	1engine	all engines	1 engine	all engines
			NOx	NOx	NOx	NOx	NOx	NOx
12:36	BAE 147	T/O	22,066	33,9	35,1	70,46	48,9	202,3
12:39	A321	T/O	44	54,2	90,85	182,9	184,2	371,2
12:42	B735	T/O	94,095	76,57	60,03	120,9	35,3	71,1
12:58	B735	T/O	29,2	23,4	42,34	85,30	33,7	67,76

5. Results of aircraft noise and emission monitoring at KBP

The assessment of noise and emission pollution is possible by means of modeling systems as well as instrumental measurements.

The results of the measurements allow us to validate constructed noise and pollution models in the vicinity of the KBP created with help of Integrated Noise Model (INM, FAA, USA) and Emission Dispersion Modelling System (EMDS, FAA, USA).

The comparison of measured and modeled noise levels and concentrations of pollutants has shown that correlation coefficients are rather high (*KK*=0.9…0.99) (fig. 4).

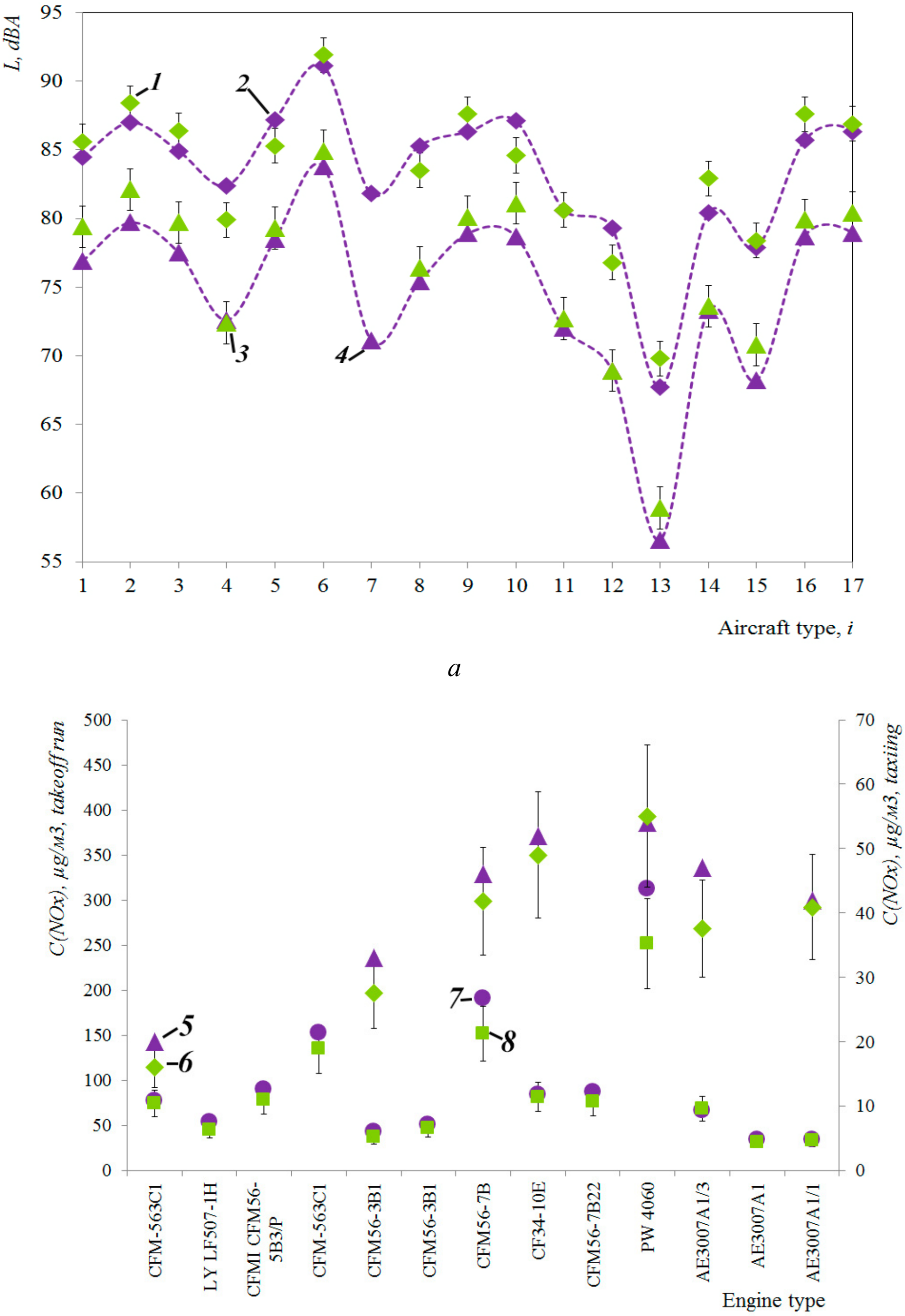
Measured data allow us to assess noise and emission interdependencies during taxing and takeoff run stages and confirm the linear dependence between noise levels, operational modes and emission indexes and possibility of the applying of Linear Interpolation to the ICAO Engine Emission Data (Fig. 5).

The obtained functions are the following:

$$SEL = 1{,}1482 \cdot EI(NOx) + 67{,}196 \,, \quad R^2 = 0{,}8034$$

$$L_{A\max} = 1{,}4772 \cdot EI(NOx) + 60{,}236 \,, \quad R^2 = 0.8479$$

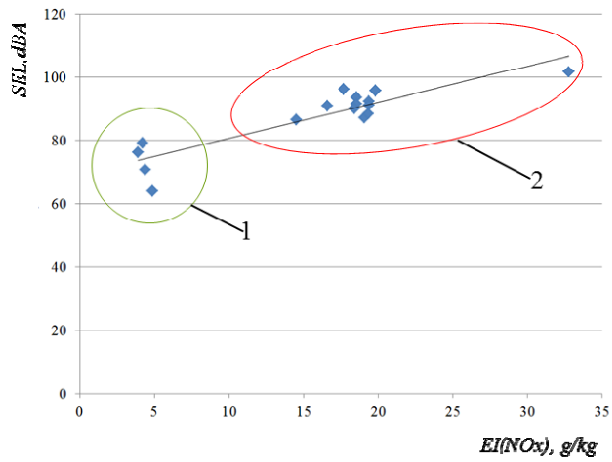
The additional instrumental issues are required for assessment of noise and emission interdependencies during taking off and climbing and different types of profiles.



a

b

Fig. 4. Comparison of measured and modeled noise levels (a) and concentrations (b) of pollutants (points 1 and 3):
1 – *SEL*, modeling results, dBA;
2 – measured *SEL*, dBA;
3 – L_{Amax}, modeling results, dBA;
4 – measured L_{Amax}, dBA;
5 – modeled NOx concentration during taxiing C(NOx), modeling results, μg/m^3;
6 – measured NOx concentration during taxiing, μg/m^3;
7 – modeled NOx concentration during takeoff run C(NOx), μg/m^3;
8 – measured NOx concentration during takeoff run C(NOx), μg/m^3



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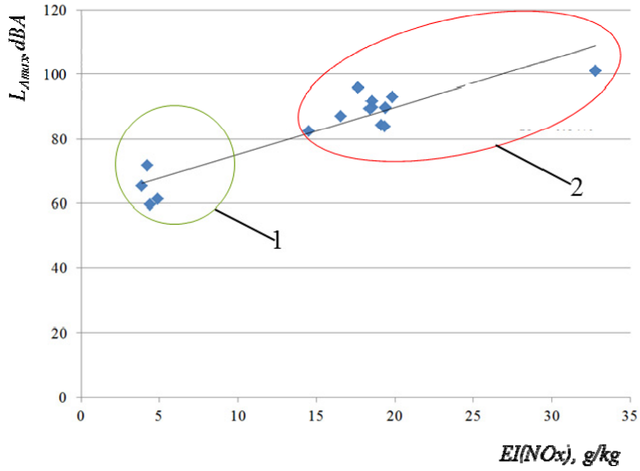


b

Fig. 5. Assessment of noise and emission interdependencies: *SEL* (*a*), L_{Amax} (*b*) and emission index NOx for ground stages of LTO cycle: 1 – taxiing; 2 – takeoff run

6. Case study of the implementation of noise and emission monitoring results

On the basis of the MaxEnt Model [5] for the environmental airport capacity's assessment the algorithm (fig.6) and application programs were designed using the data for local conditions. It should be noted that during the third stage of the algorithm – Impact Assessment – the results of noise and emission measurements and modeling are used to provide accuracy of the model. Due to the lack of the systematical noise and emission assessment data at real flight operations in the vicinity of airports in Ukraine, the first validation of the proposed algorithm was performed on the basis of modeling results such systems as INM and EDMS. Realizing weaknesses of existing modeling systems, for the validation of the proposed algorithm in real operational conditions, noise and emission measurements were held at the busiest airport of Ukraine (KBP).

The results of the measurements allowed us to gain the next targets: clarification of the emission factors of engines and aircraft noise levels in operational conditions, especially for CIS-build aircraft; description of the noise and emission interdependencies during real flight operation, particularly for taking-off and landing modes.

The proposed model allows decision-making persons to execute a few types of forecasting: short and long-term. To demonstrate the opportunities of the MaxEnt Model let's consider test operational case at KBP for the runway 36R-18L (Fig. 7). Operational runway capacity is getting close to the maximum. 3 control zones ($l = 1…3$) with noise levels upper than normative level ($L_{den} = 60$ dBA) were determined during aircraft operation and should be decreased. It is also necessary to reduce total amount of NOx (as the dominant type of air pollution during take-off stages) to meet the environmental protection standards in control zones at least on 4 %.

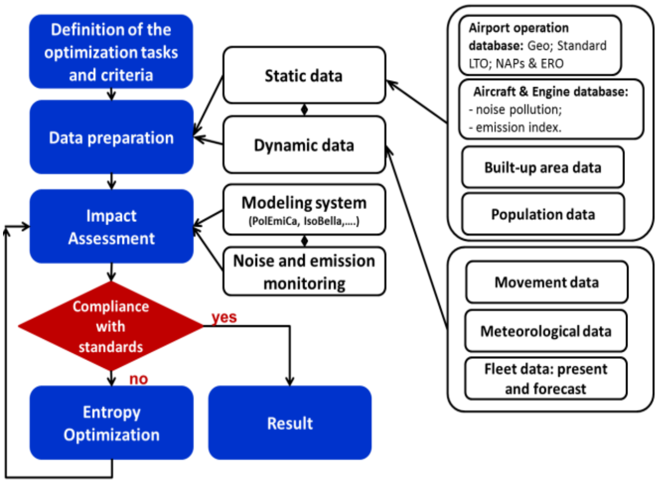


Fig. 6. Algorithm of the MaxEnt Model

The implementation of either aircraft distribution among routes (j = 1…3), either noise and emission reduction operational procedures (N&EROPs, k = 1…5), was proposed to reduce the impact on environment in control zones (Fig. 7), taking into account different efficiency of the procedures and noise and emission interdependencies during their implementation (Fig. 8).

The proposed MaxEnt Model [5] chooses the best modes, routes for every aircraft type (Fig. 9) so the environmental and operational constraints are fulfilled, and the area of the environmental protection zone is decreased (Fig. 7). The implementation of the listed routes and N&EROPs in the ration defined by the entropy optimizing allowed to reduce noise and emission to prescribed levels, and decrease the area of the environmental protection zone by 10.6 % (noise restrictions); sanitary and hygienic zones on 4.3 % (decreasing of NOx) (Fig. 7).

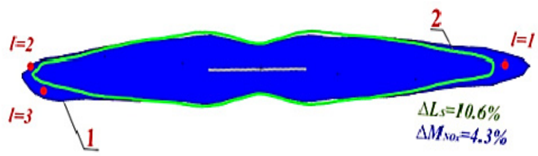


Fig. 7. Comparison of the noise equivalent levels L_{den} = 60 dBA before (1) and after (2) optimized aircraft distribution; l = 1…3 – control zones

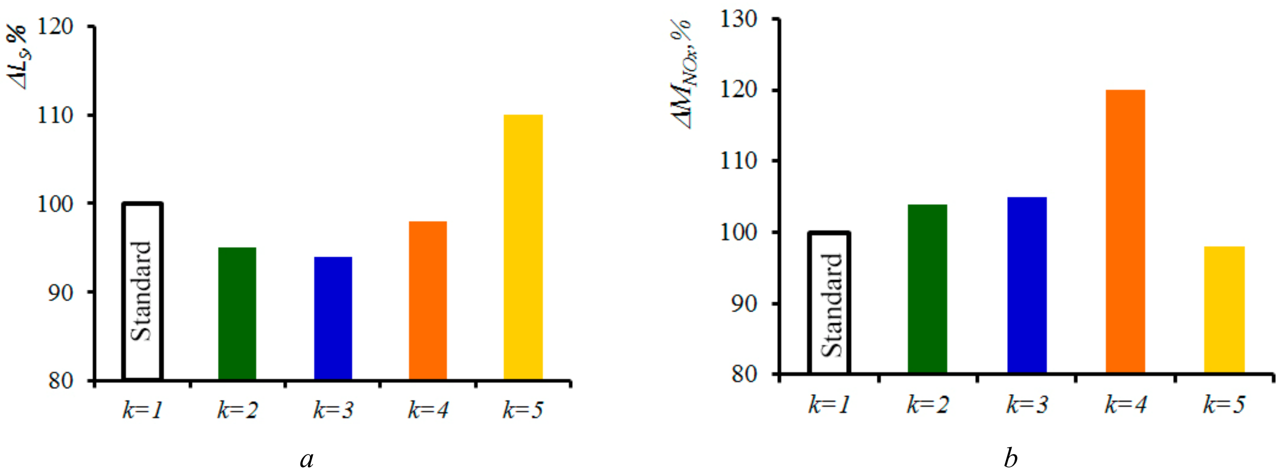
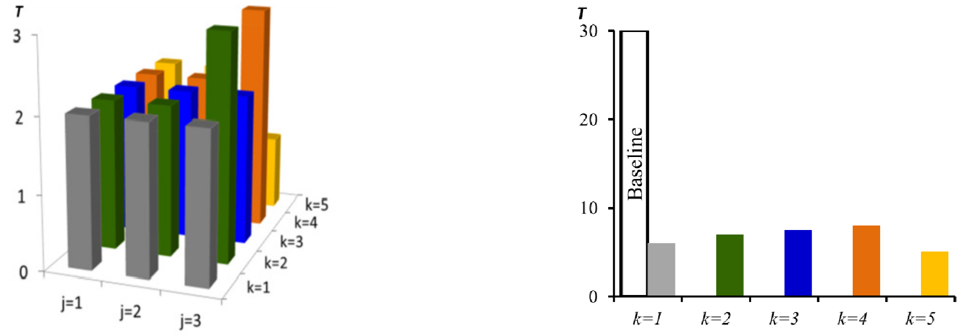


Fig. 8. Average decreasing of (a) noise contour area, L_{den} = 60 dBA, ΔL_S, % and of (b) of mass NOx, A320, ΔM_{NOx}, %: k = 1…5 – type of N&EROPs



a *b*

Fig. 9. Results of the MaxEnt optimization: (*a*) aircraft distribution (T) among the routes and N&EROPs, example for A320; (*b*) comparison of optimized and baseline scenarios: $j = 1\ldots3$ – routes, $k = 1\ldots5$ – type of N&EROPs

7. Conclusions

Aircraft activities impact evaluation by measurement campaign and modeling techniques is providing a more accurate representation of its contribution to total air pollution in airport area and the improvement for:

- estimation of aircraft emission indices for actual operation conditions and calculation precisely emission inventory of aircrafts;
- initial information (emission index, concentration) for control of sanitary-hygienic air quality of the airport;
- scientific grounding for sanitary-hygienic zone sizes around the airport;
- practical recommendations for instrumental monitoring of aircraft engine emissions;
- improving of local air quality modeling system;
- estimation of aircraft engine contribution to total air pollution inside the airport and grounding for airport charges.

The emission inventory, concentration modeling and measurement elements of an air quality assessment can be used individually, and or combination, to aid the process of understanding, reporting, compliance and mitigation planning by providing information concerning aircraft contribution.

Assessment of the noise and emission pollution and their interdependencies is one of the basic stages of the MaxEnt Model and it was performed on the basis of results of noise and emission measurements at KBP. The results will be directed on achieving the following objectives:

– further studying of the aircraft noise and emission interdependencies during real flight operations;

– definition of the role of all operating procedures in formation of total pollution in the airport's vicinity;

– development of decision making tool for aviation noise and emission reduction and effective monitoring system.

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Received 10 June 2014.

К. В. Синило[1], К. І. Кажан[2]. Моніторинг забруднення атмосферного повітря повітряними суднами в зоні аеропорту

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Досліджено проблему забруднення атмосферного повітря внаслідок експлуатації повітряних суден, що загострюється через зростання обсягів авіаційних перевезень в останні роки. Проведено моніторинг якості атмосферного повітря за такими параметрами як авіаційна емісія та шум. Показано, що в комплексі з методами моделювання моніторин дозволяє виковувати оцінку існуючого та перспективного стану забрудненості повітря в зоні аеропорту.

Ключові слова: авіаційний шум; екологічний моніторинг; емісія авіаційних двигунів; засоби захисту довкілля; моніторинг забруднення повітря.

К. В. Синило[1], К. І. Кажан[2]. Мониторинг загрязнения атмосферного воздуха воздушными судами в зоне аэропорта

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Исследована проблема атмосферного воздуха в результате эксплуатации воздушных судов, которая становится особенно актуальной в связи с увеличением авиационных перевозок в последние годы. Проведен мониторинг качества атмосферного воздуха по таким показателям как авиационный шум и эмиссия. Показано, что в комплексе с методами моделирования мониторинг позволяет оценивать существующий и перспективный уровни загрязненности воздуха в районе аэропорта.

Ключевые слова: авиационный шум; мониторинг загрязнения воздуха; средства защиты окружающей среды экологический мониторинг; эмиссия авиационных двигателей.

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