MEASURING AIR POLLUTANTS IN AN INTERNATIONAL ROMANIA AIRPORT WITH POINT AND OPEN PATH INSTRUMENTS*

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The general purpose of the study is to evaluate the air quality and health risks associated with operations of an international airport, located in the west side of Romania. Two monitoring stations were established near apron and equipment was set up to monitor volatile organic compounds (VOC’s), fine particulate matter (PM2.5 and PM10), nitric oxides NO, NO2 and NOx, carbon monoxide CO, ozone Oz, sulfur dioxide SO2, and other gaseous compounds (continuously measured by open path monitors), as well as wind speed and direction, traffic and aircraft activity. The paper will present the results obtained during the three day continuous measurements and the correlation between air quality and the airport traffic.

Key words: air pollution, air quality monitoring, open path AQM, DOAS, point measurements.

1. INTRODUCTION

Interests in aircraft and airport air pollutant emissions have been rising ever since the substantial increase in commercial turbojet traffic in the 1970’s. For example, aircraft emissions produce air contaminants such as NOx, HC, and fine particulate matter (PM), which in turn can become involved in broader environmental issues related to ground level ozone (O3), acid rain, climate change, and present potential risks relating to public health and the environment. Airport-related sources of emissions have the ability to emit pollutants that can contribute to the degradation of air quality of their nearby communities. As such, national and international air quality programs and standards are continually requiring airport authorities and government bodies to address air quality issues in the vicinity of airports. Similarly, attention must also be paid to other possible airport-related environmental impacts associated with noise, water quality, waste management, energy consumption and local ecology in the vicinity of airports, to help ensure


both the short- and the long-term welfare of airport workers, users, and surrounding communities [10].

Notably, significant improvements have been made over the past two decades regarding aircraft fuel efficiency and other technical improvements to reduce emissions. However, these advancements may be offset in the future by the forecasted growth of airport operations and other aviation activities. Because aircraft are only one of several sources of emissions at an airport, it is also considered essential to effectively manage emissions from terminal, maintenance and heating facilities, airport ground service equipments (GSE), and various ground transport traveling around, to and from airports. Optimizing airport design, layout and infrastructure, modifying operating practices for greater efficiencies, retrofitting the GSE fleet to “no-“ or “low-“ emitting technologies, and promoting other environmentally-friendly modes of ground transport are some of the current opportunities airports and the rest of the aviation industry can adopt or apply to help meet these goals and encourage sustainable development in commercial air transportation.

Presently, the regulations and standards affecting aircraft and other airport sources of emissions typically fall into two distinct categories:

- Measures that set limits on particular sources of emissions. These include both aircraft engine emission standards (as adopted into national and multi-national regulations) and national measures establishing limits for non-aircraft sources such as stationary facilities (e.g. boilers, generators, incinerator) and road vehicles, and
- National regulations (in some States called “standards”) establishing ambient pollutant concentrations for local air quality conditions (e.g. local air quality limit values).

This distinction is important because, whilst all the individual emission sources operating at, or in the vicinity of, a particular airport may meet limits pertaining to that type of source (including standards for aircraft engines), the local pollutant concentrations thresholds still may not be met. This may be due to a variety of factors particular to each locality including road and air traffic volumes, topography, short term meteorological conditions, and proximity to other emission sources and/or high background pollution levels.

Airport studies confirm that aircraft continue to be a relatively small contributor to regional pollution although aircraft-related NOx contributions could increase as air traffic increases and other non-aircraft emission sources become progressively cleaner. Therefore, although reductions in aircraft emissions (through operational and air traffic measures and/or more stringent ICAO engine standards) can help to improve local air quality in the vicinity of airports, it is also important to consider the emissions from both regional and local road vehicles. Within this context, the emissions performance of new road vehicles as expected improved significantly in last years. Therefore, depending upon the circumstances in
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particular localities, the relative proportion of the total airport related emissions which are attributable to aircraft emissions could increase as a consequence [10].

Under these circumstances, regular check, for purpose of the science but also to verify the levels according the environmental protection regulations have been carried out. For example in the East midlands airport a study focusing on the compounds known to be emitted by mobile sources (e.g., cars, trucks, and aircraft), with particular attention to compounds associated with aircraft operations (e.g., takeoff, landing, refueling, idling, and maintenance) was performed. The general goals of the Teterboro Air Quality study were to assess long-term ambient concentrations of selected air toxics in the immediate vicinity of the airport and to determine whether contributions from airport operations can be distinguished from the contributions of other background sources. A combination of real-time monitoring and discrete sampling equipment was used to quantify pollutants, meteorological data and vicinity traffic. Thus benzene is attested from continuous measurements not to be over the limits, also NO2 and PM10 [11] and insignificant contribution of other sources was confirmed. In [12] one demonstrates that Whilst the operation of aircraft is the most obvious source of emissions to air other key sources include the operation of cars, vans and buses to service the aircraft and those journeys, primarily by car, to and from the airport site made by passengers and staff. Still the levels of monitored concentrations for NOx, PM 10, PM 2.5, benzene were relatively modest. Ref. [13] reveals the fact that in several airports the air quality is determined by three sources: specific to the airport, vicinity road and other sources, forming a background, of important contributions, all.

The scope of the research undertaken and reported in the present article is to measure the concentrations of air pollutants in a regional Romanian airport in order to minimize the exposure of the passengers and the health risk involved. All airports in Romania are functioning according environmental allowances and balances, which include air quality assessments according mostly dispersion modeling. This method is subject of specific errors and continuous monitoring is to be preferred for final check. The first step of the research was to continuously measure the main pollutants generated by aircrafts landing, taxiing and takeoff in the vicinity of the airport apron. The results of the 3 days measuring campaign are thus presented in this paper. From a Romanian perspective it is the first time that on line research in this area has been accomplished. The impact of Romanian airports on the air quality is basically not best known, the Romanian National Air Quality Monitoring Network is still in a development phase and is not covering airports’ vicinity [2]. The only available data on environmental impact of Romanian airports are given by environmental impact studies based on estimation from emission factors and rarely on direct measurements [9].

The measurements have been accomplished in a large regional airport, located in the west side of Romania. Major air pollutants have been measured over a 3 days period. For the measurements two mobile laboratories were used,
equipped with reference instruments, meteorological instruments and open path instruments. Both laboratories have been placed near airport apron. The episode refers to summer 2008, when the airport had a supplementary air traffic caused by special seasonal charter lines.

2. EXPERIMENTAL

The experimental setup consists in two mobile air quality monitoring laboratories, one from University Politehnica of Timisoara (UPT) and one from National Institute of R&D for Optoelectronics (INOE). Each laboratory is equipped with reference point instruments for major pollutants (SO₂, O₃, NOₓ, CO, CH₄, NMHC, THC and PM10), HORIBA AP370 type instruments and two DOAS instruments. The path of the DOAS instruments was set up along with airport taxiing lane and one DOAS path length was 60 meters and the other ~ 300 meters, oriented in the same direction (figure 1). Meteorological sensors (wind speed and direction, air temperature, pressure and humidity) were mounted around the mobile laboratories. Following pollutants have been continuously measured, with 10 sec resolution, over the entire measuring episode with high precision equipment [3]:

- **SO₂** measured with two Horiba APSA370 instruments, measurement principle is UV fluorescence, reference method: EN 14212:2005. The combined measurement uncertainty is $U = 1.76\%$ for recorded values;
- **NO, NO₂ and NOₓ** measured with two Horiba APNA370 instruments, measurement principle is chemiluminescences, reference method: EN 14211:2005. The combined measurement uncertainty is $U = 2.06\%$ for recorded values;
- **O₃** measured with two Horiba APOA370 instruments, measurement principle is UV photometry, reference method: EN 14625:2005. The combined measurement uncertainty is $U = 6.98\%$ for recorded values;
- **CO** measured with two Horiba APMA370 instruments, measurement principle is NDIR (Non Dispersive Infrared), reference method EN 14626:2005. The combined measurement uncertainty is $U = 4\%$ for recorded values;
- **CH₄, NMHC and THC** measured with two Horiba APHA370 instruments, measurement principle is FID (flame ionization detection), reference method EN 12619:2002. The combined measurement uncertainty is $U = 0.9\%$ for recorded values;
- **Other gases** have been measured with DOAS Instruments [6].

During the campaign the INOE Horiba APHA370 instrument (measurement of CH₄, NMHC and THC) was not in function due to the lack of hydrogen fuel, thus data from that instrument were not available, and only the data from UPT
Horiba APHA370 instrument were reported. The detailed flights schedule was obtained and all international and national/regional flights were counted, in addition, due to the summer period, all charter flights were considered.

3. RESULTS AND DISCUSSIONS

The experimental results are presented in figures 2 to 9. In figure 1 is presented a view of the airport structure, lane, apron and taxiing area. The position of the two monitoring stations and the reflectors from DOAS are also given in figure 1. The monitoring stations are marked with 1 for UPT and 2 for INOE.

Figure 3 shows the carbon monoxide CO recorded values, measured with 3 different instruments: two reference NDIR point measurement instruments and one DOAS-IR Siemens-Hawk instrument. A very good correlation of the measured values can be observed, especially for the CO-UPT and CO-DOAS instruments. The different methods used for CO measurements have given same result; the high concentration recorded values and background concentration values are similar for point and open path instruments. The CO-INOE measurements are in the same trend but the measured values are with ~ 0.4 mg/m$^3$ lower than the other instruments (figure 2). This could be caused by an error in span gas calibration. On top of the figure 2 are drafted the departures and arrivals of national/regional, international and charters corroborated with the carbon monoxide measured values. The dependency between aircraft traffic on the apron and the CO measured values is visible in figure 2, the higher values for CO have only been recorded during the departure or landing of the aircrafts. This result is important because it demonstrates that the selected placement of the mobile air laboratories near the airport facilities and apron is ideal for depicting the air quality and the measured values can be considered representatives for the airport facilities surroundings.

The measured values for carbon monoxide are much lower than the 10 mg/m$^3$ limit value, regulated by 2000/69/EC Directive. The measured values were normal because the airport location is far-off from the city or any main road and the only CO source is represented by the aircrafts.
Figure 3 shows the mean measured values of sulphur dioxide SO$_2$ from two instruments. The SO$_2$ concentration in air is continuously measured and recorded (one value every second) and mediated every 3 minutes. Because the SO$_2$ - INOE instrument has given high variations (in short term intervals) two 4$^{th}$ degrees polynomial trend lines are added to the graph, one for the recorded values of each instrument. The correlation between the instruments is acceptable, just differences of about 5 µg/m$^3$N are recorded, differences that can be considered equivalent within the measurement uncertainty.

The recorded values for SO$_2$ are not higher then the 350 µg/m$^3$N limit value regulated by 1999/30/EC Directive but they are about 10 times higher then the background values (7 µg/m$^3$N). The 3 minutes mean value have been used for an easy observation of the influence of airplanes traffic on pollutants concentration, that is the main purpose of this study. The SO$_2$ concentrations below 150 µg/m$^3$ have only moderate (and reversible) irritant effect on human respiratory system,
but in synergy with NO\textsubscript{x} and high air humidity can cause permanent pulmonary impairment (according to CCOHS - Canadian Centre for Occupational Health and Safety). The only possible source responsible for the SO\textsubscript{2} high values is the airplane fuel because there are no other possible emission sources of SO\textsubscript{2} in the airport vicinity (no main road traffic or industrial areas). The ground support vehicles are limited in number (5 busses and 2 passenger cars) and their contribution to airport emissions is insignificant [1].

Figure 4 shows the measured values for nitrogen dioxide NO\textsubscript{2}, with two identical instruments. The correlation between the instruments is good, polynomial trend lines have been added for better resolution. The recorded values are similar for both instruments and higher than the 200 µg/m\textsuperscript{3} limit value regulated by 1999/30/EC Directive. Because the highest measured values is overlapping airplane traffic on apron it is clear that the only possibility to reduce NO\textsubscript{2} concentration is to manage more efficient airplane taxiing procedures.
Figure 5 shows the measured values for methane CH$_4$, non-methane hydrocarbon NMHC (VOC) and total hydrocarbon THC, with one FID (flame ionization detection) instrument. The recorded values for methane are higher than the global background (1.7 ppm) with only 0.4 [ppm]. The values recorded for volatile organic compounds are up to 3 mg/m$^3$ in periods with high airplane traffic. These values are representing a serious concern for the passenger health, knowing that some of these volatile compounds (like benzene) are causing cancer [8]. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Key signs or symptoms associated with exposure to VOCs include conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. The measured values for VOCs are up to 3 mg/m$^3$ (3000 µg/m$^3$). These values emerge not only during airplanes departures or arrivals, but mostly when the airplanes are fueled.
Fig. 5 – CH₄, NMHC (VOC) and THC measurements.

The most relevant values recorded with INOE DOAS instrument are presented in figures 6 to 9. Very high values have been recorded for acrolein and tert-butyl. Also significant values were recorded for benzen, toluen, benzaldehyde, O-cresol, O-xylen, (2, 5) – dimethyl, and also for P-tolylddehyde.

Fig. 6 – DOAS measurements. Several species for the episode 25.06.2008.
Fig. 7 – DOAS measurements of several species for the episode 25.06.2008.

Fig. 8 – DOAS measurements of several species for the episode 26.06.2008.
It is well known that acrolein may be released to the environment in emissions and effluents from its manufacturing and use facilities, in emissions from combustion processes (including cigarette smoking and combustion of petrochemical fuels), from direct application to water and waste water as a slimicide and aquatic herbicide, as a photooxidation product of various hydrocarbon pollutants found in air (including propylene and 1,3-butadiene), and from land disposal of some organic waste materials. Acrolein is a reactive compound and is unstable in the environment [4]. In ambient air, the primary removal mechanism for acrolein is predicted to be reaction with photochemically generated hydroxyl radicals (half-life, 15–20 hours). Products of this reaction include carbon monoxide, formaldehyde, and glycolaldehyde. In the presence of nitrogen oxides, oxynitrate and nitric acid are also formed. Small amounts of acrolein may also be removed from the atmosphere in precipitation. Insufficient data are available to predict the fate of acrolein in indoor air [5]. But experimental data indicate that reaction of acrolein with ozone in specific conditions (k = 2.8 x 10^{-19} \text{cm}^3/\text{molecules-sec} at 25 °C; half-life, 59 days) or nitrate radicals (k = 5.9 ± 2.8 x 10^{-16} \text{cm}^3/\text{molecules-sec} at 25°C; half-life, 16 days) in the troposphere would be too slow to be environmentally significant [6, 7].

**Fig. 9 – DOAS measurements of several species during 26.06.2008.**
4. CONCLUSIONS

An episode of on line continuously measurements of the concentrations of relevant pollutants in a large international Romanian airport, for 3 consecutive days, in June 2008 was reported and analyzed. The summer period was chosen for the measurements because between May and September the air traffic is increased due to seasonal charters to summer holiday destinations. The high values have been recorded mostly when the airplanes are fueling. A matter of concern is the fact that the airplane parking/fueling area is near (~ 80 meters) the airport facilities, and that between “check in” location and departure by the special cars the passengers might be thus exposed to high concentrations of VOC. A very simple solution for this potential risk is to move the airplanes taxiing area in the opposite side of the airport or more far away as presently. This solution is an advantage also regarding the NO2 and SO2 exposure. The aircrafts should be stationed and maintained as far as possible from the passengers’ platforms and the airplanes should taxi near the airport passenger facilities only before departures. The period of measurements conducted is relevant but still not sufficient large to be considered as representative for air quality in the area, thus extended measurements should continue. The novelty of the accomplished research still consists in the fact that it reveals primarily in-situ measurement campaigns in a Romanian airport. The values recorded are a starting point in evaluating the airplane traffic impact on airport air quality. Also the fact that, main pollutants have been measured in parallel by different instruments, with good correlation, is to be outlined.

REFERENCES