Investigation of Failures and Vulnerabilities in Road Traffic Air Quality Management System during 2020 Pandemics

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Abstract. Air deterioration and high toxicity affects life quality and longevity. Most important is pollution and toxicity impact upon health and disease management. Air born sicknesses and health problems are a permanent challenge for air dependent life-forms. Lately have been recorded manifestations and a complex phenomenology of air partially transferred pathogenic agents. The air quality is subject to investigation in order to provide a better management of the pollution control system. Pollution is a major contributor to air quality deterioration and to health problem multiplication. Present day pandemic is thought to be partially transmitted through air and by direct contact. Low air quality may be a serious contributing factor to sickness promotion. Air pollution due to road traffic and livestock is one such factor. The main objective of the paper is to investigate some important failures and vulnerabilities recorded in the road traffic air quality monitoring system during 2020 pandemics in our country and in Cluj. Thus, the evolution of chemical composition has been put under the spot of scientific investigation. Failures and weak points have been acknowledged and considered for improvement. At least twelve significant system failures and multiple vulnerabilities have been recorded due to sensor faults and unit malfunction. Social lockdown reduced all pollutants, but some units failed to indicate it properly.

1. Introduction

Air Quality Management System is implemented and operational by some years now, but its failures and vulnerabilities must be investigated in order to support the proper adjustments for technical and economic optimisations. Directive 2004/107 / EC, 2008/50 / EC, Decision 2011/850 / EC and Directive (EU) 2015/1480 are defining the terms, rules, reference methods, data validation and location points in ambient air quality investigation. Air quality is very important for life development. Many air-born diseases are reported nowadays [1], [2], [3]. High toxicity of the ambient air and the chemical stress are causal factors for many of the current health problems [4]. Benzene compounds (generated by road traffic and by fuel distribution networks), nitric oxides and CO_2 are toxic for human health [5], [6], [7].

Some developments and applied protocols have been realized in order to improve the air quality control and pollutant emissions management in relation with the road traffic and transportation field [8]. These contributions outline the road traffic pollution upon pathologic developments [9]. Some pollutants like particulate matter may be contained by using exhaust after-treatment systems [7], [10]. Fuel and oil combustion, evaporation and spill represent the cause for the environmental pollution and toxicity [10], [11]. Electronics [13] and mathematical modelling of the operational process from internal combustion engines [14], [15] constitutes basic support for pollution management. Improving efficiency regarding fuel consumption and energy transformation depends mostly upon the management system [16]. The electronic engine control [13] or the operational management system [16] facilitate, for both

compression ignited and for spark ignition engines [15], in the same time improved performances and lower fuel consumption with reduced pollutant emissions in ambient air [16], [17].

Figure 1 highlights the measurements made by the European Space Agency during the first three months of 2020 regarding the pollution with nitrogen dioxide during the COVID pandemics [18], showing the fact that road traffic lockdown in multiple countries have positively impacted the air quality. Reduction of road traffic values generates a reduction in pollutant emissions, as a following reasonable consequence, but there comes a justified question: may be measured correctly the pollutant trend? The present paper investigates the failures and vulnerabilities in road traffic air quality management system.

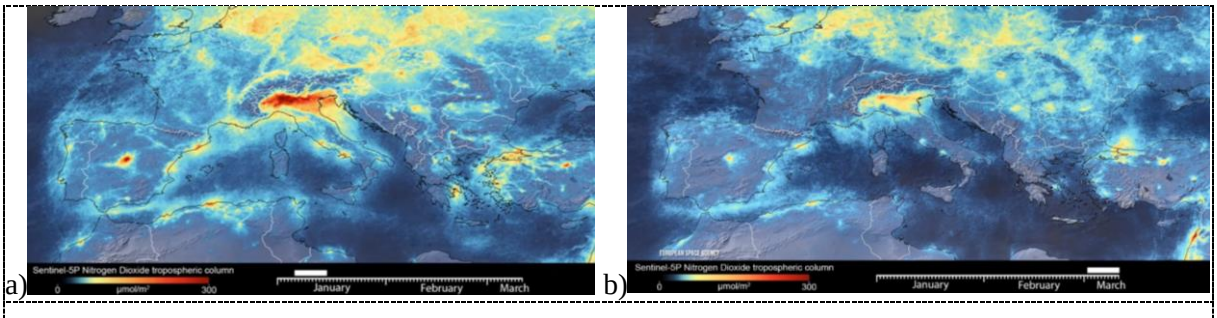

Figure 1. Pollution high level in Italy first part of January 2020 (a) and March (b) same year [18].

2. Applied investigation

Some of the most dangerous pollutants and air toxicity are generated by the road traffic, animal intensive factory farming, some industries and air transport [17], [18]. Main objective of the applied investigation consists in monitoring the actual values of pollutants recorded by four stations in Cluj-Napoca. These units (CJ1, CJ2, CJ3, CJ4) are positioned in central areas of the city, as they measure air quality.

Figure 2 presents the hardware infrastructure available for applied measurements and for pollutant data monitoring and investigation.

Figure 2. Cluj-Napoca Air Quality Management units distributed in the most populated areas [17]

Definition of PM10 values by empirical polynomial model is presented as follows for CJ1 and CJ4:

$$PM10(CJ1|CJ4) = (1.3 \dots 2.4) * 10^3 * Mt^2 - (0.2 \dots 0.4) * Mt + 27, \quad (1)$$

where PM10(CJ1|CJ4) is the PM_{10} estimated average value supported by a polynomial model in the investigated time period of 100 hours for the CJ1 & CJ4 stations; Mt – monitoring time.

Material and method used in applied research of the present investigation is outlined in table 1. Most significant failures were recorded by station CJ2 in monitoring nitric oxide compounds and derivates.

Table 1. Specific technical data regarding Air Quality Management System used in applied study

Pollutant	Method	Station Unit	Chemical formula
Benzene	SR EN 14662, part 1-3	CJ1	C6H6
Ethylbenzene	SR EN 14662	CJ1	C8H10
Nitric oxides	SR EN 14211	CJ1, CJ2, CJ3, CJ4	NO / NO_2
Carbon monoxide	SR EN 14626	CJ1, CJ2, CJ3	CO
Ozone	SR EN 14625	CJ2, CJ3, CJ4	O_3
Sulphur dioxide	SR EN 14212	CJ1, CJ2, CJ3, CJ4	SO_2
Polycyclic aromatic HC	SR EN 15549	CJ1, CJ2	$C_{14}H_{10}$; ... $C_{32}H_{14}$;
Particulate matter	EN 12341	CJ1, CJ4	PM_{10} and $PM_{2,5}$

Most recorded failures during the investigation are based on individual specific posts or system failures. One of the investigated hypotheses is measuring sensors failures due to maintenance faults.

During the investigation presented in the present paper were recorded 12 significant failures of the Air Quality management system which support our conclusion on the importance of remote access and service implementation. An important vulnerability of the system is generated by the un-even type of the measurements. Some pollutants are not monitored on some stations due to the specific differences.

The individual failures shown in figure 3 and the multiple fault values in figure 4 were taken from air quality road traffic pollution management system. In the station unit CJ1 most failures were recorded with m, o, p-xilen emissions, but there were also considerable failures with benzene and some with NO_x.

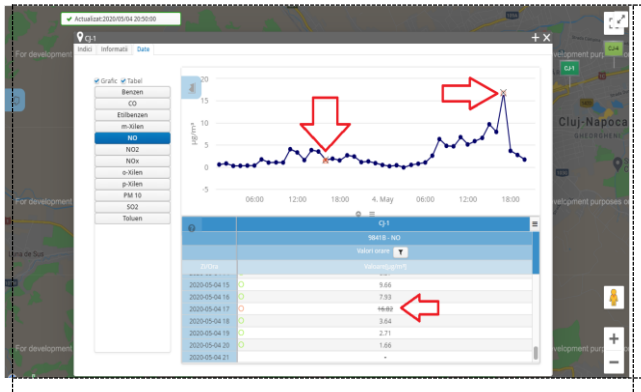

Figure 3. Seldom recorded failures for NO [17].

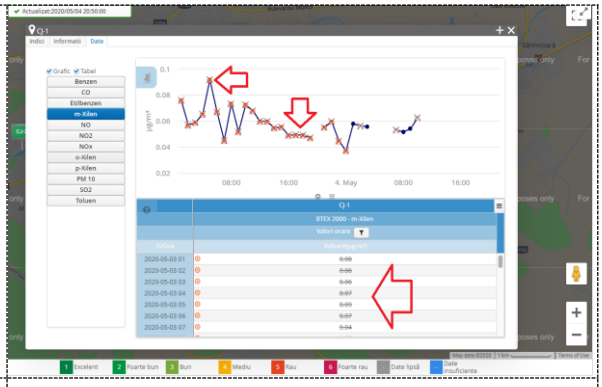

Figure 4. General measuring failure [17].

Definition of NO_x average estimated values by an empirical polynomial model is represented as eq. (2):

$$NO_x(CJ1|100h \dots 28April \dots 3May) = 6.1 * 10^3 * Mt - 1.53 * Mt + 105.1, \quad (2)$$

where NO_x (CJ1|10h…28April…3May) is the NO_x estimated average value calculated with a polynomial model on the 100 hours investigated time period; Mt – monitoring time.

In figures 5 to 14 are graphically represented the pollutants hourly recorded values on a 100 hours investigation period. Nitric oxides were specially studied on all the available stations in Cluj-Napoca city in order to properly investigate the failures and vulnerabilities of air quality monitoring units. The graphical representations allow a better study on the failures and vulnerabilities of the monitoring units.

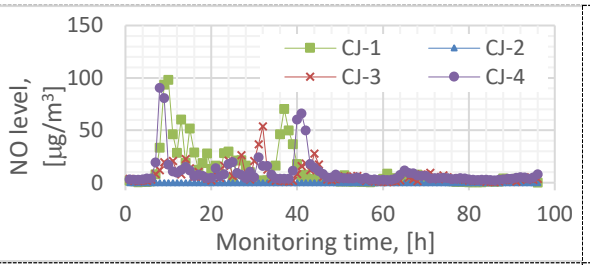

Figure 5. NO values recorded and studied.

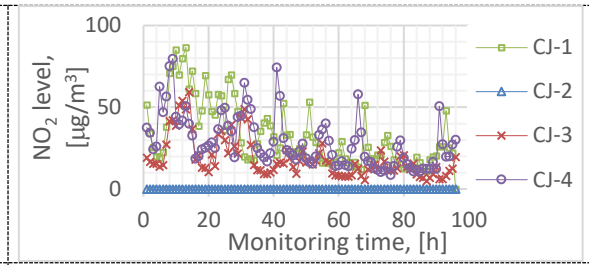

Figure 6. NO_2 actual values for investigation.

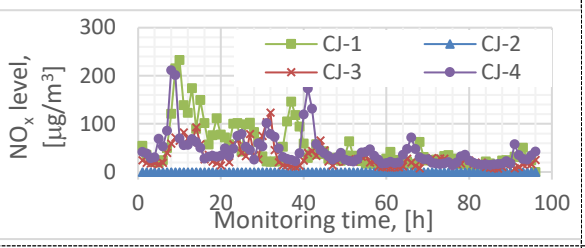

Figure 7. NO_x actual values variation recorded.

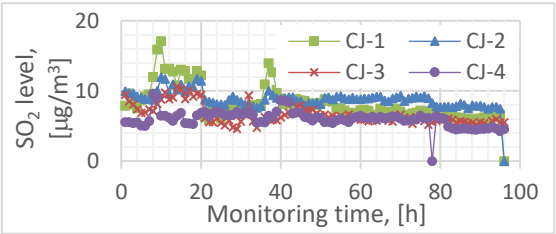

Figure 8. SO_2 actual values for investigation.

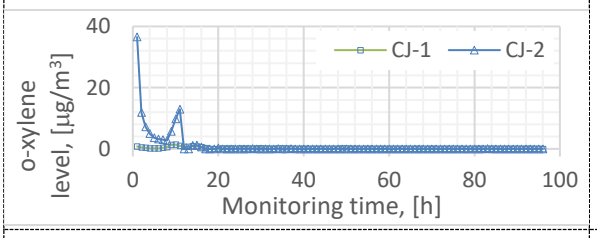

Figure 9. Actual values for o-xilen at CJ1 / CJ2.

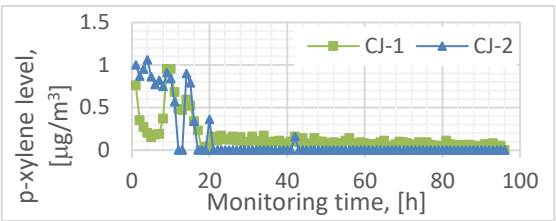

Figure 10. Actual values for p-xilen recorded.

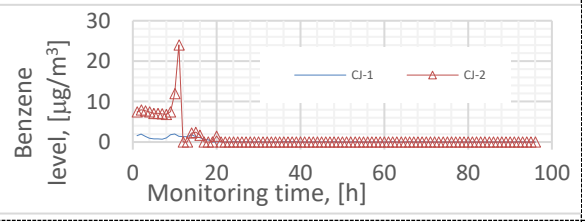

Figure 11. Benzene values at two stations.

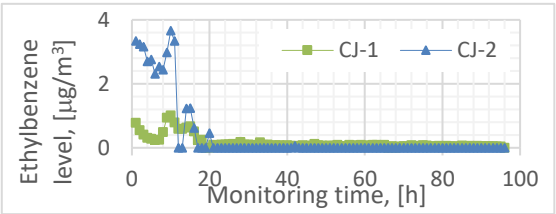

Figure 12. Actual values for ethylbenzene test.

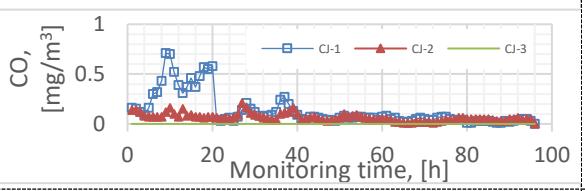

Figure 13. CO values recorded by CJ1, CJ2.

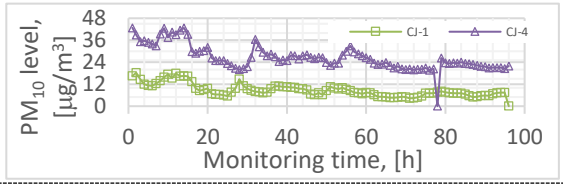

Figure 14. PM_{10} actual values at two stations.

3. Observations and conclusions

Both theoretical and the applied parts of the investigation have been realized successfully as planned. It was possible to show the real values which were recorded and monitored to outline the failures and vulnerabilities of the air quality system.

In the recorded set of values has been highlighted a decrease with an average of 45% of NO level starting from 28 April 2020 till 3rd of May 2020. Also, there was a reduction with 30% of NO_2. The approaching weekend (1-3 May) and the low temperatures (6÷13˚C), coupled with the imposed social lockdown measures contributed to overall reduction in pollution. The system failures must be further studied, and faults eliminated.

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