DELIVERABLE 5

Minutes of the Open-forum on air quality in subway systems

Action D3

Inception report June 2015

IMPROVE LIFE13 ENV/ES/000263

Coordinated by

idaea CSIC

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1. CONFERENCE REPORT - MINUTES

The meeting opened with a welcoming address by joint IMPROVE LIFE partners **Teresa Moreno (IDAEA, CSIC, Barcelona)** and **Eladio de Miguel (Head of Environmental Department, Transports Metropolitans de Barcelona)**. Teresa Moreno then gave a presentation outlining the primary objectives of the IMPROVE LIFE project and its defined Actions and Deliverables, and stressed the importance that is being given to open communication of all the results produced during the work programme (see website http://improve-life.eu/). She also emphasized the close working relationship between CSIC and TMB and thanked her colleagues working in the Barcelona Metro for their continued and enthusiastic collaboration, reminding the audience that such a positive attitude was not so easily forthcoming from many other subway operators around the world. In her view TMB are clearly making Barcelona a world leader in subway air quality investigation and management.

Session 1 was chaired by Teresa Moreno, and continued with a series of four presentations on different aspects of the Barcelona Metro system. **Vania Martins (IDAEA, CSIC, Barcelona)** overviewed what is currently known about personal exposure to inhalable subway particulate matter (PM), demonstrating how air quality in this system is (1) Better in the trains than on the platforms; (2) Improved by installing platform door screens in stations;

(3) Better during the summer months when ventilation systems are running at higher speeds; (4) Worse in confined stations such as those with a single tunnel and only one platform; (5) Worse in the city central, most congested part of the subway line. Applying a dosimetric study to subway air quality suggests that most fine PM inhaled during subway travel is deposited in the extrathoracic region of the human respiratory tract, and that the higher dose is received in the train because, in Barcelona at least, trains are frequent and platform waiting is short.

Maria Cruz Minguillón (IDAEA, CSIC, Barcelona) explained the techniques used to identify the various sources of PM in the subway environment, demonstrating how the particle chemistry is rich in carbon and especially iron due mainly due the contribution from rails, wheels and brake pads. The levels of Fe can be up to three times greater in the stations not fitted with platform screen doors. Furthermore, a careful examination of PM trace element chemistry using ratios between barium, strontium, copper and iron, reveals how the subway atmosphere differs depending on the type of brake pad used. A specific "Subway Source" can be clearly identified using source apportionment calculations, and contributes at least 50% of many metals such as Iron, Barium, Strontium, Copper, Manganese, Chromium, and Neodymium present in subway air.

Barend van Drooge (IDAEA, CSIC, Barcelona) reported on the kinds of organic chemicals present in subway air, identifying the obvious presence of various fragrances worn by passengers, as well as limited contributions from diesel fumes from night maintenance work, cigarette smoke (despite the underground ban on smoking), outdoor traffic emissions, outdoor biomass burning (especially in the outskirts of the city), lubricant oils, and, in the newer stations, plasticizers. Concentrations of toxic compounds such as benzo(a)prene are low and the same as those found in the Barcelona outdoor air. Once again, the newer stations fitted with platform screen doors show improved air quality.

Marc Veillette (Université Laval, Quebec, Canada) summarized the results of a joint Laval/CSIC study on bioaerosols found in the Barcelona Metro, describing the techniques used to sample bacterial and viral particles present in subway air and sourced from humans. Several types of bacteria are clearly present and are similar to those recently described from a study on the New York subway. An innovative aspect of the study was the identification of variations in influenza A and B viruses present in the air, depending on the time of year. Samples collected in the subway before Christmas, when flu was near its winter peak in the Barcelona

population for that year, predictably have higher concentrations than samples obtained after Christmas. Overall concentrations of bioaerosols in Barcelona Metro air are comparable to low levels in typical indoor air.

Session 2 of the Open Day was chaired by **Lidia Morawska (Queensland University, Australia)** and involved contributions from studies on other subway systems. **Violeta Múgica (Univ. Autón. Metropolitana-Azapotzalco, Mexico)** reported on a study from an unusual station in Mexico City where three subway lines converge and are stacked one above the other at different depths (10m, 25m, and 40m) with increasing humidity problems in the deeper stations. Concentrations of PM and Fe clearly increase with depth, almost doubling from the shallowest to deepest station, indicating the need for improved ventilation systems at deeper levels. **Luis García (Ingenieros Asesores SA, Spain)** introduced the audience to the problem of hydrogen sulphide (H_2S) build-up in some parts of the Paris Metro system due the interaction of bacteria with gypsum (calcium sulphate) present in the geological strata under the city, with concnetrations increasing with relative humidity. As well as producing an offensive smell and being a potential health problem, enhanced levels of this gas can damage copper wiring, and the likely solution will involve introducing new sensor technology to alert the need for remedial action. Finally, **Patrice Blondeau (Université de La Rochelle, France)** presented

modelling studies on how best to control PM levels inside trains in the new lines of the "Grand Paris" major expansion currently underway in the Paris Metro. He explained the predicted effects on train carriage air quality produced by using different types of filters and ventilation systems, emphasizing that high impacts on PM levels will result from different solutions adopted. Variables considered include ventilation, types of air conditioning filters, air recirculation and passenger numbers. The study clearly demonstrated need for engineers designing new underground lines and trains to take such parameters into account in order to maximize air quality in future subway systems.

Session 3 was chaired by **Xavier Querol (IDAEA, CSIC)** and involved a far-ranging discussion on the key issues relevant to the IMPROVE LIFE project. To fire the discussion, each of the Discussion Panel Members firstly presented a brief summary of their own studies related to subway air. Lidia Morawska, an expert in indoor air, outlined her work on infection spread in public transport, highlighting the importance of the proximity of passengers and the duration of each trip. Prof. Morawska sees a gulf of thinking between clinicians, engineers and scientists on this subject, and explained that ventilation is not the only mechanism to control infection spread in any transport systems, including our cars. **Caroline Duchaine (Université Laval, Quebec, Canada)** emphasized the need the develop surveillance methods of disease transmission in public vehicles, summarizing the results of a joint Laval/CSIC study on bioaerosols found in the Barcelona Metro. Bioaerosols in this unique environment are relatively unknown, and have humans as main sources unlike most situations outdoors. **Giorgio Buonanno (University of Cassino, Italy)** commented on the importance of measuring particle numbers in the city, and outlined a new study led by Teresa Moreno that has compared subway, tram, bus and walking commuting exposure to air pollution in Barcelona, and proposed particle surface area as an interesting parameter to be included in subways measurements. **Frank Kelly (King's College, London)** briefly overviewed progress on a currently ongoing study of air quality in the London Underground system, the oldest in the world, In this systems it is clear that air quality largely depends on the number of kilometers underground of each line (45% of the London tube is underground), with PM levels being higher at deeper stations and dropping to ambient outdoor levels within 5 minutes when travelling above ground. Finally **Alberto Giretti (Polyt. Univ. Marche, Ancona, Italy)** used his engineering expertise to demonstrate the need for intelligent control of subway ventilation systems using sensor networks. Prof. Giretti showed how simulation results can be used to

estimate pollutants exposure levels for passengers, and how the dynamic of pollutants in a given station is dependent on both external (meteorological conditions) and internal (piston effect, passenger flow) factors.

Xavier Querol then opened the discussion by emphasizing two key issues relevant to the subject of subway air quality. Firstly, all relevant stakeholders, both passengers and workers, need to be informed and their awareness raised of the question of air quality in underground transport systems. However, instead of generating exaggerated alarmist statements and headlines, which are likely to be counterproductive, an intelligent, positive approach to inform the public must be adopted. Greater awareness is likely to encourage subway companies to take the issue more seriously. Secondly, any suggested improvements must be cost effective and technically feasible. For example, can brake manufacturers be encouraged to change the metal content of their pads to produce more "ecologically sensitive" compositions and PM emissions?

The subsequent general discussion, led by the Chairman and involving both panel members and the audience, then ranged across a number of subjects, with three of the key subjects raised summarised as follows:

1. The question of air quality and health effects due to PM exposure during city commuting is **not** the same as targeting official Air Quality Standards designed for average PM mass levels in outdoor air, or Occupational Exposure Levels in the workplace. There is a need to compare the transient doses received when using different types of transport, and balance any negative health effects against positive effects such as the well documented cardiovascular benefits of exercise when walking or cycling.
2. "There are always technical solutions" (Patrice Blondeau) and, in the case of underground air quality these are likely to involve the adoption of new or improved systems of maintenance and energy use, such as regenerative braking and the use of intelligent sensors to allow "monitoring and control in real time" (Alberto Giretti)
3. The IMPROVE LIFE project needs to identify good practice to improve air quality underground and share this information with other subway operators around the world.

The Chairman Xavier Querol concluded with the prescient observation that, taking the long view, outdoor air quality in cities is showing a general trend towards improvement. As outdoor urban air gets cleaner so more attention will inevitably focus on the question of indoor air, including that in the subway environment.

Teresa Moreno then thanked the panel and audience for their attendance and participation in the meeting and especially the discussion. The Open Day continued with a field visit to the currently operating IMPROVE LIFE sampling site in Palau Reial station, and the nearby air pollution monitoring urban background site in IDAEA operated jointly by CSIC and Generalitat de Catalunya.

2. BRIEF BIOGRAPHIES OF OPEN DAY CHAIRPERSONS AND DISCUSSION PANEL MEMBERS

Giorgio Buonanno is an Associate Professor at the Department of Engineering in the University of Cassino, Italy, and has held invited academic positions at universities in the USA, Australia, Kazakhstan and Zambia. He has wide expertise in the measurement of airborne particles emitted from industrial plants (especially waste incinerators), urban areas, and indoor environments. Many of his most recent publications are focused on the emission of, and personal exposure to, ultrafine particles and their respiratory effects on children.

Caroline Duchaine is a Professor and Health Funds Senior Scholar at Université Laval and the Quebec Heart and Lung Institute. Her main expertise is in the characterization of bioaerosols and respiratory viruses and the effects of their exposure to humans, and she has over 350 publications. She has acted as expert witness for the Quebec Government in several bioaerosol court trials after tragedies related to mould problems in homes, was invited by the NASA to the Workshop on life detection in extraterrestrial samples, and has received several awards for her work.

Alberto Giretti works at the Department of Engineering and Architecture of Università Politecnica delle Marche, Italy. He has been the scientific co-ordinator and leader of several projects in various recent European Framework programmes, and has co-founded spin-off companies based on the applications of his research. His research interests include advanced modelling for energy efficient buildings, Health and Safety in Automated Construction site, and

Knowledge Based Systems for Design and Education support in Architecture and Building Construction.

Frank Kelly holds the chair in Environmental Health at King's College London, is Director of the Environmental Research Group operating the London Air Quality Network, and is Chairman of the UK Department of Health's Expert Committee on the Medical Effects of Air Pollution. His substantial research activity spans all aspects of air pollution research from toxicology to science policy, including the impact of London's Congestion Charging and Low Emission Zone, and the effect of urban air pollution and traffic management schemes on the respiratory health of schoolchildren.

Lidia Morawska is the Director of the International Laboratory for Air Quality and Health in Queensland University of Technology in Brisbane, and co-director of the Australia-China Centre for Air Quality Science and Management. She is a physicist by training who received her doctorate in Poland and continued her research in Canada as a Fellow of the International Atomic Agency before moving to Australia. With over 450 publications she is an expert on airborne particulate matter, a past President of the International Society of Indoor Air Quality and Climate, and is advisor to the WHO.

Teresa Moreno is a Senior Researcher at the Spanish Research Council (CSIC) in Barcelona. She is a geologist by training, educated to MSc level in Spain then receiving her doctorate in the UK followed by a Fulbright Award to visit the USA, before moving into the study of airborne particles as a British Medical Council Researcher in the lung toxicology group at Cardiff University. With her expertise on the chemistry and sources of atmospheric pollutants now back in Spain she is leading the Spanish-funded METRO and European-funded IMPROVE LIFE research projects on subway air quality.

Xavier Querol leads the highly prolific CSIC (IDAEA) Air Quality Research Group in Barcelona, has published several hundred scientific articles, and is active in a range of Advisory Committees for the EU and WHO. He has worked with the Spanish national and regional governments in major environmental issues such as the Aznacollar mining accident and the clean-up of the ceramics industry in Castelló, and he is currently a key national figure involved in efforts to improve air quality in Spanish cities. His most recent award has been the prestigious 2013 Jaume I Prize in Environmental Science.