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# LEGAL METROLOGY AND THE AUTOMOTIVE AIR POLLUTION CONTROL IN BRAZIL

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**Abstract** − This paper will present metrology's role on air pollution control in Brazil, the benefits for society and how Inmetro's Legal Metrology Directorate (Dimel, in its Portuguese acronym) is developing this work.

Automotive vehicles are very significant air pollution source in Brazil [1]. To change this situation, two years later the Federal Government established the Automotive Vehicles Air Pollution Control Program (Proconve, in its Portuguese acronym), providing to the car manufacturers a gradual schedule to the implementation of cleaner automotive technologies on new vehicles. Today the exhaust emissions reduction for these vehicles is up to 97% [2].

For in-use vehicles, Proconve demanded to all Brazilian states the implementation of an Inspection and Maintenance (I/M) Program. At least once a year these vehicles should be submitted to an I/M authority to check its general conditions and to measure its exhaust emissions.

The emissions measurement is performed with two different instruments: gas analyzers (for spark ignition engines) and opacimeters (for Diesel engines). Both instruments are under legal metrological control and are submitted to type evaluation and verification, performed by National Institute of Metrology, Standardization and Industrial Quality (Inmetro).

**Keywords**: vehicle emissions, legal metrology.

## 1. INTRODUCTION

Legal metrology is defined [3] as the "part of metrology relating to activities which result from statutory requirements and concern measurement, units of measurement, measuring instruments and methods of measurement and which are perform by competent bodies". Its main goal is "to specify and to ensure, in a regulatory or contractual manner, the appropriate quality and credibility of measurements related to official controls, trade, health, safety and the environment" [4].

Legal metrology activities in Brazil are Brazilian National Institute of Metrology, Standardization and Industrial Quality (Inmetro) responsibility, which also collaborates for its application uniformity throughout the world with an active participation on international forums such as the Common Market of the Southern Cone (Mercosur) and the International Organization of Legal Metrology (OIML).

Pollution and the growth of urban areas walk side-by-side since the Industrial Revolution. Urbanization creates a constant need of people and goods transportation, with longer and longer distances. Even with several options (trains, bikes, subway) automobiles are preferred for personal transportation in major cities all around the world, mostly where public transportation is deficient.

Brazil is the most populated country in South America with more than 180 million inhabitants, with 30% living in the metropolitan regions of Rio de Janeiro (RJMR) and São Paulo cities (SPMR), in the southeast part of the country [5]. The RJMR has the biggest demographical density (1.700 inhab/km$^2$) with an urbanization level of 96,8% [6]. In this area the mobile emission sources (mainly automobiles) are responsible for 77% of the total amount of atmospheric pollutants [6].

According to the Brazilian National Association of Automotive Vehicles Manufacturers (Anfavea, in its Portuguese acronym), vehicles production presented a significant growth in the last five decades [7], as shown in Table 1.

Table 1. Brazilian vehicle production.

| Year | Total production (units) |
|---|---|
| 1957 | 30.542 |
| 1960 | 133.041 |
| 1970 | 416.089 |
| 1980 | 1.165.174 |
| 1990 | 914.466 |
| 2000 | 1.691.240 |
| 2005 | 2.530.840 |
| 2008 | 3.111.965 |

Brazilian vehicles fleet is also concentrated in the southeast part of the country, followed by the south part, as shown on Fig. 1.

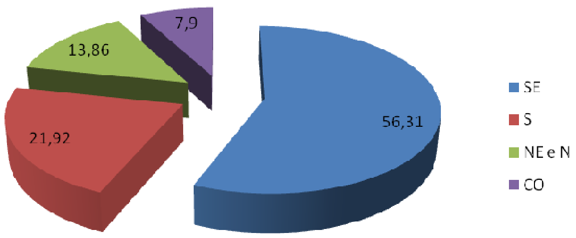


Fig. 1. Vehicle fleet distribution on the 5 Brazilian regions.

Life quality is directly affect by this growing fleet not only when population faces constant traffic jams but also when these vehicles emissions are not controlled, leading to a degradation in air quality. Automotive vehicles emissions contain several compounds like carbon monoxide (CO), nitrogen and sulfur oxides ($NO_x$ and $SO_x$), hydrocarbons (HC) and particulate matter (PM) that may cause health problems.

These pollutants negative effect on human health may be increased when combined with some personal habits (like smoking), previous respiratory diseases (like asthma) or even some specific weather conditions (like very dry weather).

Considering all these factors many countries and world regions developed programs to control vehicle emissions and manage the situation. Some are very know like the Euro Standards (European Union) and Tier Standards (United States of America) and are adopted by other countries, completely or as a reference for their own program/standard.

Brazilian Federal Government established in 1988 the Program for Automotive Vehicles Air Pollution Control (Proconve, in its Portuguese acronym), providing to the automobiles manufacturers a gradual schedule to implement cleaner automotive technologies on new light and heavy vehicles. The program was planned based on developed countries experiences and had good acceptance within all participants (manufacturers, importers, research centers and governmental institutions). It is considered one of the best programs to mobile sources emissions control [2].

Proconve's primary goal is to reduce air contamination fixing emissions limits, inducing manufacturers' technological development and determining that vehicles and engines shall comply with these limits on standardized tests under reference conditions.

Emissions from vehicles with spark ignition (Otto cycle) engines are measured with an instrument named gas analyzer. In a brief description [8], this instrument has a sampling probe that should be introduced into the exhaust tail pipe to take gas samples. This sample is then conducted through the internal gas handling system until the optical bench equipped with non-dispersive infrared technology (NDIR) where carbon monoxide (CO), carbon dioxide ($CO_2$) and hydrocarbons (HC) can be measured. Once these components have different optical responses (CO @ 4,7 μm, $CO_2$ @ 4,2 μm and HC @ 3,3 μm) the measurement can be simultaneous.

Emissions from Diesel cycle engines are measured with a partial flow opacimeter [9]. This instrument has an internal measuring chamber with a light source and a receiver (photocell or a photo diode) with known distance between them ($L_A$) and known response value with clean air inside the chamber. When the opacimeter's sampling probe is introduced into the exhaust tail pipe smoke fills the measuring chamber and changes the receiver reading. This variation is used to calculate smoke opacity (N) which can be converted into light absorption coefficient (*k*) using the Beer-Lambert Law (1).

$$k = \frac{-1}{L_A} \times \ln\left(1 - \frac{N}{100}\right) \qquad (1)$$

## 2. METHODOLOGY

Since 1996 is Inmetro's responsibility to provide reliability to measurements performed with gas analyzers and opacimeters. The method to achieve this goal is to submit these instruments to legal metrological control, which was divided into two different parts: Type Evaluation and Verifications (initial and subsequent).

### *2.1. Type Evaluation*

All new models shall be submitted to type evaluation before they are put on the market. This process consists of systematic evaluation and performance testing of two units of each instrument model (or type) against documented requirements. All results are contained in an evaluation report and if these units fulfil all requirements the model may be approved [3].

In Brazil the requirements are documented on a Technical Metrological Regulation (TMR), specific for each kind of instrument. The TMR is usually written based on a recommendation of the International Organization of Legal Metrology (OIML). If there's no recommendation available the TMR requirements should be based on another international document with wide acceptance, such as International Organization for Standardization (ISO) or International Electrotechnical Commission (IEC) documents.

The type evaluation process comprises a documental evaluation (instruction manuals, drawings, etc), a visual inspection (markings, correct use of measuring units, indications legibility, etc) and the performance tests.

#### *2.1.1. Gas analyzers*

Between 1996 and 2000 there was no Brazilian TMR available and type evaluation was performed based directly on the OIML International Recommendation R 99 available at that time (1991 edition). Inmetro selected the main aspects and 11 performance tests stated on that document which should be immediately required and wrote an internal testing procedure to guide its activities [10].

In this period 10 gas analyzers models were submitted to type evaluation and successfully tested under this internal simplified procedure. There was no new model between 2001 and 2005.

In 2000 the OIML R 99 was revised and became an ISO and OIML joint publication named *ISO 3930/OIML R 99 Instruments for measuring vehicle exhaust emissions* [8].

This version is more detailed and prescribes 23 performance tests for gas analyzers type evaluation.

The Brazilian TMR [11] for gas analyzers was published on August '05, covering all the ISO 3930/OIML R 99 requirements and 22 performance tests. In the following year two new models were sent to type evaluation and Inmetro also began to recall the manufacturers and importers to submit their models again, now based on the updated document. From the 10 previous models only 5 were still on the market.

Due to Inmetro's internal problems this new tests round couldn't be completed at that time and these activities were suspended until July '08.

To restart the job Inmetro decided to divide the type evaluations into a two stages process [12]. The first stage comprises documental evaluation, visual inspection and seven performance tests. If the model is successful in this stage it's considered approved for a 2 years period, in which the complementary 15 performance tests shall be performed. Definitive approval is obtained only when the whole process is concluded.

If the model has been submitted to type evaluation before on other country, Inmetro also decided to allow manufacturers and importers to present these evaluation reports issued by metrological authorities. These reports may be considered and exempt the model from some tests only if they have been performed as defined on ISO 3930/OIML R 99 [12].

The reference for gas analyzers' adjustment and performance tests are gaseous mixtures with known concentration of CO, $CO_2$ and HC (propane), simulating the automotive smoke exhaustion into the device's measuring chamber. These mixtures' composition shall be certified to comply with uncertainty requirements (1% or less) by a competent authority and shall be traceable to national, regional or international standards.

#### *2.1.2. Opacimeters*

Like gas analyzers, opacimeters type evaluation was performed without a Brazilian TMR. There was also an internal procedure based on international documents from ISO, IEC and the Physikalisch-Technische Bundesanstalt (PTB, german metrologyl institute). There is no OIML recomendation for opacimeters.

Between 1996 and 2000 nine opacimeter models were submitted to type evaluation and successfully tested under this internal procedure. There was no new model between 2001 and 2007.

Around October '07 two new opacimeter models asked for type approval and Inmetro started to develop its TMR. It was decided that the document should be based only on the ISO 11614 [9] because it may be more accepted (once it's an International Standard) and some of the previous reference documents were outdated.

The opacimeter TMR [13] was published on February '08 and the type evaluation process has only one stage, providing a definitive approval for models that comply with the TMR. Since then other two new models asked for approval and from the 9 previous models only 5 were still on the market.

The adjustment and performance tests of the opacimeter proceed as follows:

First the electric circuit of the light source and receiver shall be adjustable so that the readout can be reset to zero when the light flux passes through the measuring chamber filled with clean air. The opacimeter shall provide means of setting and checking full scale (e.g. by the use of a neutral optical density filter perpendicular to the light beam or, in the case of apparatus which read to 100% opacity, by turning off or blocking the light source completely).

In order to ensure that the apparatus is correctly adjusted for zero before the measurement begins, the opacimeter shall have an automatic or semi-automatic sequence.

The next step is to carry out an intermediate check with a neutral optical density filter applied perpendicular to the light beam which shall represent gas opacity between 15% and 80% of full scale and known to an accuracy of ± 1% opacity. It is important to be noted that these method, using neutral optical density filter, simulates the automotive smoke exhaustion into the measurement chamber.

### *2.2. Initial verification*

Measuring instrument verification is the procedure (other than type evaluation) which includes the examination and marking and/or issuing of a verification certificate, that ascertains and confirms that the measuring instrument complies with the statutory requirements [3]. In Brazil the requirements are stated on the same TMR used for type evaluation.

Every new instruments shall be submitted to initial verification before they are sold to the final user, when are performed some basic tests to confirm that the device keeps the approved model characteristics. Gas analyzers and opacimeters are submitted to 100% initial verification (all units).

If the device passes the tests it is sealed (to prevent unauthorized opening) and receives a verification mark. After this it can be sold on the market and be put in use.

### *2.3. Subsequent verifications*

The TMR may also demand subsequent verifications for the in-use measuring instruments. These verifications may be performed on periodic intervals or by request.

Gas analyzers periodic verifications shall be performed every 6 months. Opacimeters shall be verified once a year.

The instrument owner may request verification before the expiry date of the periodic verification. In this situation it is named voluntary verification and may also be performed at any time when the previous verification is declared to be no longer valid (for instance, after a repair, when the seals and verification marks are removed).

## 3. RESULTS

### *3.1. Type approval and verifications*

Seven gas analyzers models have partial approval valid for two years (two models are new on the market). All these models are performing the complementary tests, that probably will end up around July '10.

Nine opacimeter models have complete approval (four models are new on the market).

Verifications have been performed for both instruments and they've been used on vehicles inspection, contributing to a better air quality.

### *3.2. Air quality in the Rio de Janeiro Metropolitan Region (RJMR)*

Until the beginning of 2009 Rio de Janeiro was the only Brazilian state that implemented the Inspection and Maintenance (I/M) Program for in-use vehicles.

As shown on Fig. 2 and Fig. 3, the levels of total particulate matter and inhalable particulate matter are decreasing in most regions of the RJMR (Fig. 4) since 1997, when the I/M Program started.

These results confirm the importance of an emissions control program and should encourage other states to comply with the regulations and establish their I/M Programs.

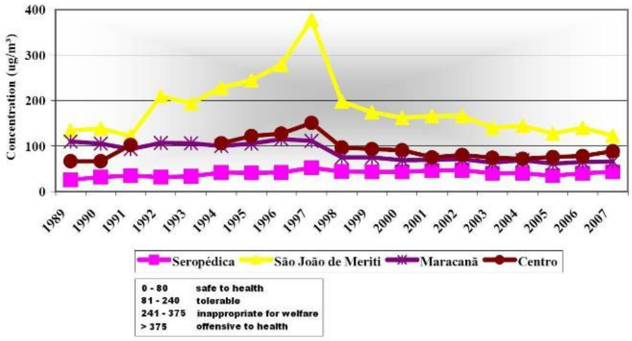


Fig. 2. Annual levels of total particulate matter in the RJMR.

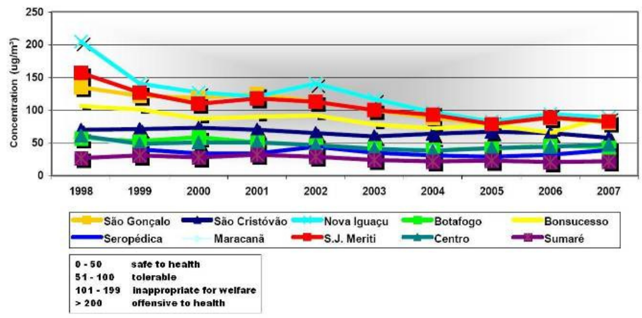


Fig. 3. Annual levels of inhalable particulate matter in the RJMR.

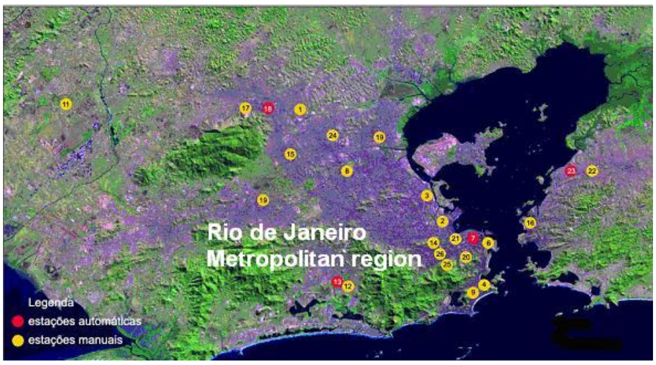


Fig. 4. Geographical distribution of measurement air stations at the RJMR.

São Paulo is finishing the preparation of its I/M Program, to be implemented until June '09.

## 4. CONCLUSIONS

Legal Metrology has an important role in the control of the air pollution produced by automotive vehicles because the legal metrological control provides reliability and uniformity to measurements performed with gas analyzers and opacimeters.

This work was developed in order to reach a result that, despite of being indirect, is of notable importance: the effective decrease of the air pollution levels.

Performing gas analyzers and opacimeters type evaluation and verifications is how Inmetro intends to contribute for the conservation and improvement of the environment, assuring means for effective control of air pollution.

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