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# Air Pollution Management in Two Colombian Cities: Case Study

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## Abstract

This document is a case study that focuses on the air pollution problems of Bogotá and Medellín. These are the largest; most populated and industrialized cities of Colombia. The document presents a brief description of the evolution of relevant institutional aspects. It describes the pollution problems of these cities, their sources, their effects on health and the measures to control and to prevent them. Following the framework of the WDR 2003[1], this document analyzes how society becomes aware of air pollution problems and the mechanisms that have generated the decision to undertake air pollution control strategies. It also discusses the mechanisms which have been in place to balance legitimate, competing social interests, and the means by which the adopted solutions are executed. Finally, the document presents a series of lessons and recommendations.

*Key words*: Air Pollution, Regulation, Institutions, Colombia.

*JEL classification:* N5, O13, Q20.

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1 World Development Report (2003) - Sustainable Development in a Dynamic World: Transforming Institutions, Growth, and Quality of Life. The World Bank. Washington.

## Resumen

Este documento es un estudio de caso sobre los problemas de contaminación del aire en Bogotá y Medellín, las dos ciudades más pobladas e industrializadas de Colombia. El documento presenta una breve descripción de los asuntos institucionales más relevantes; describe los problemas de contaminación en esas ciudades, sus fuentes, sus efectos sobre la salud, y las medidas que se han tomado para controlarlos. Siguiendo la metodología analítica del Informe sobre el Desarrollo Mundial del Banco Mundial[2] del año 2003, en este documento se analizan los mecanismos a través de los cuales la sociedad se hizo conciente de los problemas de contaminación del aire; los mecanismos por medio de los cuales se generó demanda social para darles solución; los mecanismos existentes para balancear intereses legítimos y en conflicto y los mecanismos mediante los cuales las soluciones adoptadas fueron implementadas. Finalmente, el documento incluye una serie de lecciones y recomendaciones.

*Palabras clave*: polución aérea, regulación, instituciones, Colombia.

*Clasificación JEL*: N5, O13, Q20.

## I. Description of the Case

### A. Introduction to the Cities

#### 1. Bogotá

Bogotá is located in an Andean plateau at an altitude of 2.560 m above sea level. Its average annual temperature is 14.8ºC, with daily variations that range between 1 and 26 ºC.[3] . Monthly average temperatures vary less than 1 ºC. The average annual precipitation in the city is about 672 mm and average annual wind speed is 1.5 m/s. Thermal inversions occur during the months of January, February and June, and between August and December[4]. Those are the drier and warmer months of the year.

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2 World Development Report (2003) - Sustainable Development in a Dynamic World: Transforming Institutions, Growth, and Quality of Life. The World Bank. Washington.

3 *Informe anual de la red de monitoreo de calidad del aire de Bogotá* (2002). DAMA. Bogotá.

4 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). "Contaminación atmosférica". E. Sánchez y E. Uribe. *La contaminación industrial en Colombia*. DNP. PNUD. Bogotá.

Bogotá is the capital city of Colombia and its largest economic center[5]. This city and the neighboring municipality of Soacha have 2.334 industrial establishments[6]. Between 1980 and 2000, this city contributed with 22% of the Gross National Product[7] on the average, and produced 24.6% of the national industrial output. The value of its industrial production was US $ 5.2 billion. Bogotá has a population of 6´789.122[8] inhabitants and an annual growth rate of 2.08%[9]. It houses close to 15% of Colombia's national population.

In 1999, Bogotá had 995.788 vehicles[10]. More recent information is not available. It is estimated that between 1998 and 2002 the number of cars in the city grew by 200.000[11]. About 88% of the vehicles are private, 5.6% are taxis, 3% are motorcycles and 2.3% are public buses[12]. Nineteen percent of the passengers are transported in 80% of the vehicles, mostly private.

Gasoline represents seventy five percent and Diesel 25%[13] of the energy consumed by the transportation sector in Colombia. While automobiles, campers, light trucks and small buses use gasoline, public buses use diesel[14]. Although the use of natural gas has increased, its participation is still not significant[15].

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5 *De Bogotá a la región: apuntes para un modelo de desarrollo regional* (2003). Contraloría de Bogotá, D. C.

6 *www.dane.gov.co.*

7 *Encuesta anual manufacturera* (2000). DANE. Bogotá.

8 *Proyecciones departamentales de población por sexo y edad, 1990-2015* (2003). DANE. Bogotá.

9 Departamento Administrativo Nacional de Estadísticas-DANE. *www.dane.gov.co.*

10 *Plan de gestión ambiental de Bogotá* (2002). Departamento Técnico-Administrativo del Medio Ambiente. Bogotá.

11 *Air Monitoring Network of Bogota. Annual Report* (2002). DAMA. Bogotá.

12 *Plan de gestión ambiental de Bogotá* (2002). Cit.

13 *Análisis de conveniencia del uso del gas natural comprimido vehicular en Colombia* (2002). Colombiana de Hidrocarburos S. A. Informe de consultoría. Bogotá.

14 ONURSAL, B. and GAUTAM (1997). *Contaminación atmosférica por vehículos automotores*. Experiencias en siete centros urbanos de América Latina. Banco Mundial. Washington.

15 *Análisis de conveniencia del uso del gas natural comprimido vehicular en Colombia* (2002). Cit.

According to a survey conducted in 1989 the number of fixed sources of pollution in Bogotá was 1.300[16]. The Environmental Department of Bogotá – *Departamento del Medio Ambiente de Bogotá* (DAMA) reported that number of fixed sources to be 2.372 in 1999[17]. More recent information is not available. According to that information, fixed sources of air pollution grew 182% between 1989 and 1999. The industrial areas of Bogotá are mainly located to the south and southwest of the city.

Yearly emissions by fixed sources of air pollution in Bogotá amount to about 2.198 tons of dust, 6.503 tons of $SO_x$ and 1.687 tons of $NO_x$[18]. Industrial kilns and furnaces represent seventy five percent of fixed sources of air pollution. The technological deficiencies of Small and Medium Industrial Enterprises[19] have been associated with high levels of industrial pollution in Bogotá[20]. The main sources of energy for the manufacturing industry of Bogotá are diesel (44.9%), crude oil (*Crudo de Castilla*) (24.7%), and coal (7.5%)[21].

**2. Medellín**

The city of Medellín is located in the Aburrá Valley at an altitude of 1460 meters above sea level. The Aburrá Valley is located in an inter-Andean depression surrounded by mountains that rise 3000 meters above sea level[22]. Its average annual temperature is 20 ºC. Thermal inversions occur during 25 to 35% of the days of the year[23].

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16 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). *Op. cit*.

17 *Informe de gestión gmbiental en el Distrito Capital. Enero 1998-diciembre 2000*. (2000-2001). Departamento Administrativo del Medio Ambiente, DAMA. Bogotá.

18 *Plan de gestión ambiental de Bogotá* (2002). Cit.

19 Firms which have between 11 and 200 employees and a total patrimony between 501 y 15.000 minimum monthly wages (Law 50 of 2000).

20 CRUZ, G. y URIBE, E. (2002). *El efecto del regulador y de la comunidad sobre el desempeño ambiental de la industria en Bogotá*. CEDE. Universidad de los Andes. Bogotá.

21 *Plan de gestión ambiental de Bogotá* (2002). Cit.

22 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Área Metropolitana del Valle de Aburrá. Medellín.

23 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). En: E. Sánchez y E. Uribe. *Op. cit*.

Located next to Medellín are nine other municipalities in the Aburrá Valley. These are: the municipalities of Barbosa, Bello, Caldas, Copacabana, Envigado, Girardota, Itagui, La Estrella, and Sabaneta[24]. Medellín and these nine municipalities integrate the Metropolitan Area of the Aburrá Valley.

The population of Medellín is 2'026.789[25]. This corresponds to 65% of the total population of the Aburrá Valley[26]. It is expected that by year 2020 Medellín will have one million additional inhabitants[27].

The total area of the Aburrá Valley is 812 $K^2$. Forty one percent of this territory is occupied by the urban areas of Medellín and the additional nine municipalities which integrate the Metropolitan Area.

There are 1412 industrial establishments relevant for air pollution control in Medellín and in the 10 municipalities of the Metropolitan Area of the Aburrá Valley[28]. The main sources of industrial pollution in the region are paper, cement, brisk and steel[29]. The sources of energy for the industrial sector of the Aburrá Valley are hydroelectric energy (16.6%), diesel (12.2%), coal (49.2%) and crude oil (22.1%)[30]. In 2000, the value of its industrial production amounted to US $ 3.6 billion which corresponds to nearly 16% of the country's total production[31].

In 2002 there were 387.000 mobile sources of air pollution in the region[32]. Their growth rate is 10% per year[33]. The average age of public transpiration

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24 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

25 *Ibid*.

26 2414860 million people.

27 *Proyecto metrópoli 2002-2020*. (2002). Plan Integral de Desarrollo Metropolitano del Valle de Aburrá. Área Metropolitana del Valle de Aburrá. Medellín.

28 *www.dane.gov.co.*

29 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). En: E. Sánchez y E. Uribe. *Op. cit*.

30 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

31 *www.dane.gov.co*.

32 HOYOS, O. (2002). *Informe de gestión*. Área Metropolitana del Valle de Aburrá. Medellín.

33 *Proyecto Metrópoli 2002-2020* (2002). Cit.

vehicles is 16.7 years. Total emissions by mobile sources amount to 73.876 tons of pollutants per year[34].

## B. Institutional Aspects

Before 1993, environmental institutions in Colombia were mainly concentrated in rural areas, national parks and forests[35]. Until 1993 there were several national and regional institutions with responsibilities for environmental control, regulation policy and management. The National Institute of Natural Resources (INDERENA), an agency of the Ministry of Agriculture, was primarily responsible for the administration and management of protected areas. The National Planning Department coordinated the activities of 18 Regional Autonomous Corporations. These Corporations acted as environmental authorities at the regional and local level. None of these institutions had responsibilities related to air pollution control.

The Code of Natural Resources (Decree 2811 of 1974) was elaborated under the coordination of Mr. Julio Carrizosa, who was then Director of INDERENA[36], with the "…help of a technical team and members of the academia"[37]. There is no reference to or evidence of public consultation in the processes. This Code did not include specific regulations for air pollution control. However, it indicated that the national government should approve regulations to prevent air pollution[38]. Consequently, Law 02 of 1979, also known as the Sanitary Code, defined the general criteria for future developments of regulations related to the management and control of wastes, effluents and emissions that could affect human health. This Code

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34 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

35 SÁNCHEZ, E. y URIBE, E. (1994). *La contaminación industrial en Colombia*. DNP. PNUD. Bogotá.

36 *Instituto Nacional de Recursos Naturales y del Medio Ambiente*. National Institute of Environmental and Natural Resources.

37 *Las voces del SINA* (2002). Ministerio del Medio Ambiente.

38 Article 75 of the Code of Natural Resources.

was prepared by the "Unit of Environmental Health"[39] of the Ministry of Health in coordination with INDERENA[40], ANDI[41] and ACODAL[42].

Following the guidelines of the Sanitary Code, the Ministry of Health approved Decree 2 of 1982 which defined national air ambient standards for five air pollutants. The process for the definition of those standards was also coordinated by the Ministry of Health with INDERENA, ANDI and ACODAL. As in the case of the Sanitary Code, no form of public consultation was undertaken. This could be attributed to the fact that air pollution was not considered a priority by the general public, information relative to its effects on human health were largely unknown to the general public, and mechanisms for public participation were very limited[43].

The enforcement of the standards of Decree 02 of 1982 was delegated to the health authorities and not to the environmental authorities. This could be attributed to the fact that the Sanitary Code included other regulations related to the protection of human health.

Table one presents the maximum ambient standards approved by the Ministry of Health. The analytical bases for the definition of these standards could not be traced.

Table 1. National air Ambient Standards Approved by Decree 2 of 1982.

| Pollutant[44] | Unit | Standard | | | |
|---|---|---|---|---|---|
| | | Daily* | Annual ** | 8 hours | 1 hour |
| TSP | µg /$m^3$ | 400 | 100 | - | - |
| $SO_2$ | µg /$m^3$ | 400 | 100 | - | - |
| CO | µg /$m^3$ | - | - | 15 | 50 |
| $NO_x$ | µg /$m^3$ | 100 | - | - | - |
| $O_3$ | µg /$m^3$ | - | - | - | 170 |

*sample collected during one day; **geometric average of all daily samples continuously collected during 12 months.

39 Under the direction of Mr. Germán Gómez. He was also DAMA's Director during 1994.

40 *Instituto Nacional de Recursos Naturales y del Medio Ambiente.* Cit.

41 National Association of Industries.

42 National Association of Sanitary Engineers.

43 Interview with Mr. Julio Carrisoza. INDERENA's Director from 1973 to 1978. July 2004. Bogotá.

44 Total Suspended Particles (TSP); Sulfur Dioxides ($SO_2$); Carbon Monoxide (CO); Nitrogen Oxides ($NO_x$); Ozone ($O_3$).

Consequently, in accordance to the Sanitary Code and to Decree 02 of 1982 national and local health authorities became responsible for air pollution control. In Bogotá, the Department of Transportation was also responsible for controlling air pollution emissions generated by vehicles[45]. The Ministry of Health and the City's Department of Health also had the mandate to control pollution emissions. However, there is no reference to a coordinated air pollution control program with strategies aimed at improving air quality. During this time, the roles and jurisdictions of different agencies with environmental responsibilities in urban settings were not clearly defined or limited[46]. Between 1982 and 1993 the human and financial resources dedicated to air pollution control were scarce[47].

Before 1991, news related to the environment in the mass media was scarce and referred mainly to global environmental issues, such as ozone depletion and climate change[48]. Technical information relative to the environmental quality of rural and urban areas of the country only circulated in limited circles within the national government and academia. By the late eighties, most environmental NGO's concentrated in rural issues. However, during those years FUNDEPÚBLICO[49] (*Fundación para la Defensa del Interés Publico*; Foundation for the Defense of the Public Interest) begun to use legal actions to solve air pollution problems[50].

Between 1991 and 1993, the Department of National Planning developed the environmental component of the Industrial Restructuring Project financed by the World Bank. As a part of that effort, the information gathered by the air monitoring stations since 1967 was analyzed. Although the information was

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45 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). En: E. Sánchez y E. Uribe. *Op. cit*.

46 MONCAYO, V. M. y SÁNCHEZ, E. (1994). "Aspectos jurídicos de la contaminación industrial". En: E. Sánchez y E. Uribe. *Op. cit.*

47 SÁNCHEZ, E. y VARGAS, C. (1994). "Estructura institucional y financiera del control de la contaminación y oferta analítica". En: E. Sánchez y E. Uribe. *Op. cit.*

48 *Comunicación y medio ambiente. Elementos para la definición de estrategias informativas en temas ambientales* (1993). INDERENA, PNUD.

49 Created by Mr. Germán Sarmiento; a lawyer and environmental activists.

50 SÁNCHEZ, E. y MEDINA, G. (1994). En: E. Sánchez y E. Uribe. *Op. cit*.

fragmented and incomplete, it was useful to detect the presence of air pollution problems in the main Colombian cities, including Bogotá and Medellín; especially with relation to particulate matter. The results were published in 1994[51].

After a widely democratic process, Colombia's environmental regulations and institutions were restructured by Law 99 of 1993[52]. This Law assigned the Ministry of the Environment responsibilities related to the approval of national environmental regulations and air pollution control policies. It also created new urban environmental authorities in cities with populations greater than one million inhabitants[53]. The responsibility for air pollution monitoring and definition of local air pollution policies and regulations was transferred from several sectoral institutions (such as Health and Transport) to these new urban environmental authorities, and in the case of smaller municipalities to the CARs. They are also responsible and for the enforcement of air pollution regulations to fixed sources. Local transportation authorities enforce air emission standards to mobile sources.

In 1995, the Environment Department of Bogotá (*Departamento Administrativo del Medio Ambiente de Bogotá*, DAMA) was assigned responsibilities in the areas of air pollution control, regulation and policy in Bogotá[54]. In 2001 the city of Bogotá adopted local air ambient standards[55] which are stricter than those approved by the national government in Decree 02 of 1982. These stricter standards were approved based on a combination of reasons. "The information provided by the air monitoring network indicated that in some areas of the city the levels of $PM_{10}$ and TSP were higher than the national standards, and there was new international information related to the effects of smaller particles on human health. In addition, the National ambient standards approved in 1982 were incomplete and lower than those recommended by the World Health Organization"[56].

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51 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). En: E. Sánchez y E. Uribe. *Op. cit.*

52 RODRÍGUEZ, M. (1998). *La reforma ambiental en Colombia: anotaciones para la historia de la gestión pública ambiental*. Fundación FES. Bogotá.

53 Article 66, law 99 of 1993.

54 *Ibid.*

55 *Resolución* 391 of 2001 by DAMA.

56 Interview with Mr. Manuel Felipe Olivera. Director of DAMA form 1998 to 2001. July 2004. Bogotá.

The standards recommend by this organization were the main reference for the new regulations approved by DAMA. Table two presents the new air ambient standards approved by DAMA in 2001 for Bogotá.

Table 2. Local Air Ambient Standards for Bogotá Approved by *Resolución* 391 of 2001.

| Pollutant[57] | Unit | Standard | | | |
|---|---|---|---|---|---|
| | | Daily* | Annual ** | 8 hours | 1 hour |
| TSP | µg /$m^3$ | 340 | 95 | - | - |
| $PM_{10}$ | µg /$m^3$ | 170 | 65 | - | - |
| $SO_2$ | ppb | 141 | 34 | - | - |
| CO | ppm | - | - | 11 | 39 |
| $NO_2$ | ppb | 121 | 52 | - | 168 |
| $O_3$ | ppb | 141 | - | 65 | 83 |

*sample collected during one day; **geometric average of all daily samples continuously collected during 12 months.

On the other hand, the Metropolitan Area of the Aburrá Valley was created in 1980, as a public institution responsible for planning and coordinating the development of the municipalities of the Aburrá Valley; including the city of Medellín. In addition to its functions related to regional planning and to the coordination of regional policies, the Metropolitan Area also acts as an environmental control agency since 1994[58]. That year, the Environmental Unit of the Metropolitan Area of the Aburrá Valley was created[59].

## C. The Monitoring Stations and their Data

This section presents, for each city, a brief history of their air monitoring programs. It also presents the trends of air pollution with time. The differences in the level of information and analysis between the two cities relate to the unequal development of their monitoring efforts, and to the availability of information.

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[57] Total Suspended Particles (TSP); Particles Smaller that 10 microns ($PM_{10}$); Sulfur Dioxides ($SO_2$); Carbon Monoxide (CO); Nitrogen Oxides ($NO_x$); Ozone ($O_3$).

[58] *www.metropol.gov.co*.

[59] Metropolitan Decree no. 011 of 1994.

**1. Bogotá**

Air monitoring in Bogotá began in 1967[60], 15 years before air regulations were approved and air pollution control responsibilities were assigned by Decree 02 of 1982. That year, six monitoring stations were installed by the Ministry of Health and the Pan-American Health Organization. This network operated between 1967 and 1974. The installation and operation of this network was promoted by the Pan- American Health Organization. It did not result from a local interest in air pollution control[61]. At the time, there was no evidence of the health effects of air pollution in Colombia.

In 1983 after the approval of the air standards of Decree 02 of 1982, the city's Department of Health installed and operated network of 12 air monitoring stations. They operated until 1989. Between 1990 and 1991 the Japanese Cooperation agency, JICA, financed the installation and operation of 5 more monitoring stations. As in the case of the air monitoring stations installed in 1967 by the Pan American Health Organization, the stations installed by the Japanese Cooperation Agency where largely the result of the donor's interest. The duration and usefulness of the three networks installed before 1991 was limited by the institutional, technical and financial deficiencies of the local and national agencies responsible for their operation[62]. None of those network stations operated after 1991. Despite the existence of those stations, there is no reference of an air pollution control program that could use the data from those stations, as an input for the design and adjustment of air pollution control strategies before 1991.

Between 1967 and 1974, the network of stations installed by the Pan-American Health Organization and administered by Ministry of Health presented readings which detected high levels of Total Suspended Particles (TSP) and of Sulfur Dioxides ($SO_2$)[63]. At that time, the country had not adopted ambient standards.

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60 SÁNCHEZ, E. y HERRERA, C. (1994). "El estado del ambiente en Colombia". En: E. Sánchez y E. Uribe. *Op. cit.*

61 Interview with Mr. Julio Carrisoza INDERENA's Director from 1973 to 1978. July 2004. Bogotá.

62 *Sistema de información ambiental de Colombia: conceptos, definiciones e instrumentos de la información imbiental de Colombia* (2002). IDEAM. Bogotá.

63 SÁNCHEZ, E. y HERRERA, C. (1994). En: E. Sánchez y E. Uribe. *Op. cit.*

The two networks of stations operated by the Department of Health between 1983 and 1989 and by JICA between 1990 and 1991 detected average annual concentration of Total Suspended Particles (TSP) with concentrations levels higher than the national ambient standards[64] defined by Decree 02 of 1982[65]. JICA reported that the ambient concentration of $PM_{10}$ was associated with the use of Diesel by the transport sector[66]. The analytical bases for this conclusion are not known. In some places and during sporadic events, the levels of Ozone ($O_3$), Nitrogen Dioxide ($NO_2$) and Carbon Monoxide (CO) were also above ambient standards. The annual average concentrations of $SO_2$ were lower than the national standards[67].

Between 1991 and 1997 there was no air monitoring in Bogotá. In 1997, DAMA installed a new network with 12 air monitoring stations. This new network and its stations were designed and selected by an international consortium contracted by DAMA, following an open international bidding process. Most of the parameters selected were those of Decree 02 of 1982 (TSP, $SO_2$, CO, $NO_x$, and $O_3$). Additionally, $PM_{10}$, and $PM_{2.5}$ were also included. This was based on international evidence that related these pollutants with ARI, as well as the high levels of TSP detected from the previously existing stations. The network monitored $PM_{2.5}$ until 1999, when the equipment necessary to measure this parameter was damaged. Map one shows the location of the stations.

Table three presents the pollutants measured at the air monitoring stations of Bogotá[68].

Consistent with previous information, the monitoring network installed by DAMA in 1997 shows that particulate matter is an important pollutant in Bogotá. Figure one presents the arithmetic average annual concentrations of $PM_{10}$ *in Bogotá form 1998 to 2002*.

However, air pollution levels vary widely across the city. Figure two presents the arithmetic average annual concentration of $PM_{10}$ in several monitoring stations during 2002. The highest values correspond to industrial areas.

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64 100 $\mu g/m^3$.

65 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). En: E. Sánchez y E. Uribe. *Op. cit.*

66 ONURSAL, B. and GAUTAM (1997). *Op. cit.*

67 100 $\mu g/m^3$.

68 *Air Monitoring Network of Bogotá* (2000). Annual Report. DAMA. Bogotá.

Map. 1. The Location of the Air Monitoring Station in Bogotá.

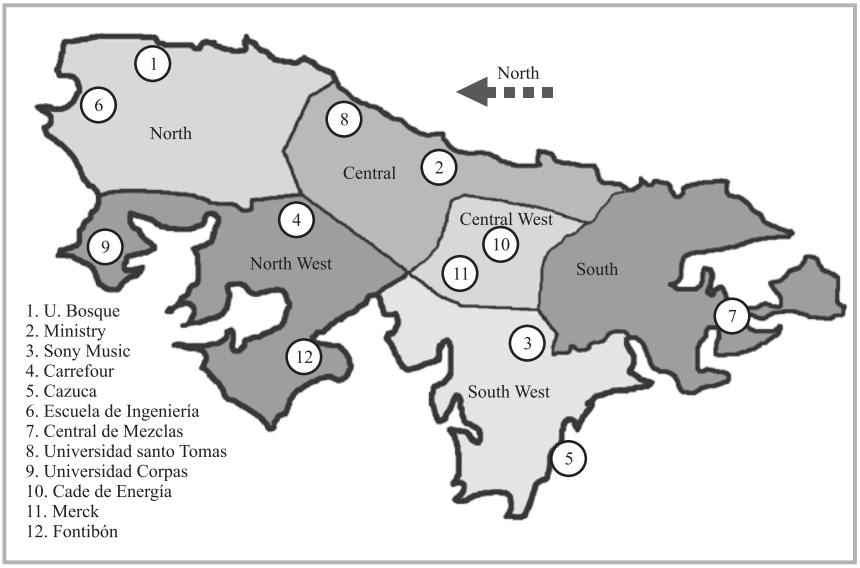



Table 3. Pollutants Measured at the Air Monitoring Stations of Bogotá.

| Station | Pollutant | | | | | | |
|---|---|---|---|---|---|---|---|
| | $SO_2$ | $NO_x$ | CO | $O_3$ | $CH_4$ | $PM_{10}$ | TSP |
| Universidad del Bosque | *X* | *X* | | | | *X* | *X* |
| Ministry of the Environment | X | X | X | X | | X | X |
| Sony Music | X | X | X | | | X | X |
| Carrefour | *X* | *X* | | | *X* | *X* | *X* |
| Cazuca | *X* | *X* | *X* | *X* | | *X* | *X* |
| Escuela de Ingeniería | | *X* | | | *X* | *X* | *X* |
| Central de Mescalas | | *X* | | | | *X* | *X* |
| Universidad Santo Tomás | *X* | *X* | | | | *X* | *X* |
| Universidad Corpas | *X* | *X* | *X* | *X* | | *X* | *X* |
| Cade de Energía | *X* | *X* | | | | *X* | *X* |
| Merck | *X* | *X* | *X* | *X* | | *X* | *X* |
| Fontibón | *X* | *X* | *X* | *X* | | *X* | *X* |

Figure 1. Average Annual Concentration of $PM_{10}$ in Bogotá from 1998 to 2002.

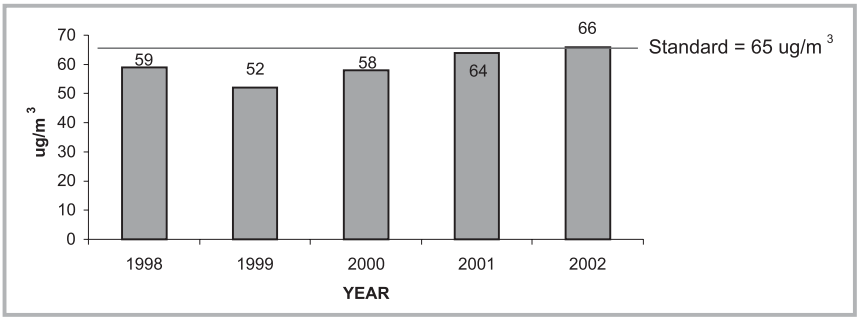
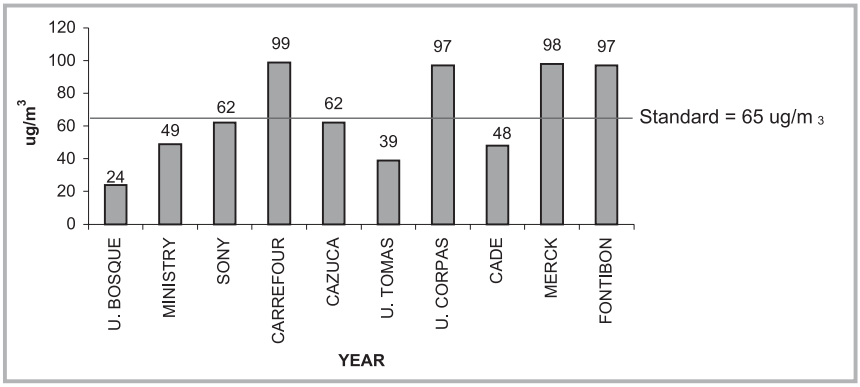



Figure 2. Average Annual Concentration of $PM_{10}$ at several air stations in Bogotá; 2002.




During 2002, the average daily concentrations of TSP were above the local standard on 23 occasions in one of the 14 monitoring stations**:** in the *Cazuca* station (figure 3). In this station, average daily concentrations of TSP were above 50% of the local standard in 27% of the cases. The *Cazuca* Station is located in the economically poorer areas of the city; mining and manufacturing industries are frequent. Figure two presents the average annual concentrations of TSP at the *Cazuca* monitoring station. As the figure shows, at this site the average annual concentrations of TSP more than triple the local standard. It is interesting to notice that seasonal variations in the air concentrations of suspended particles have not been detected[69].

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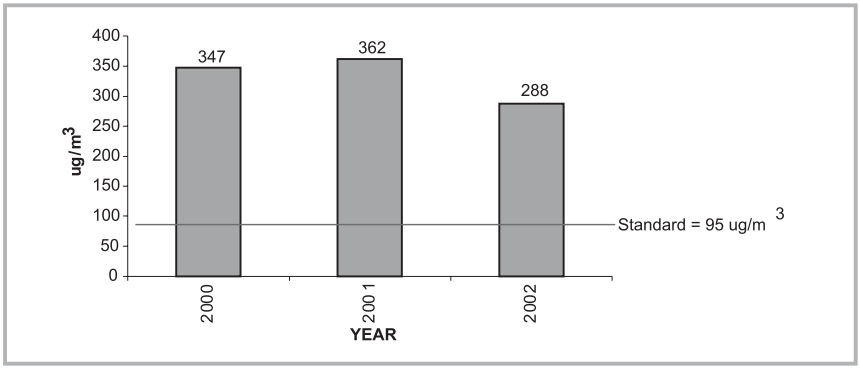
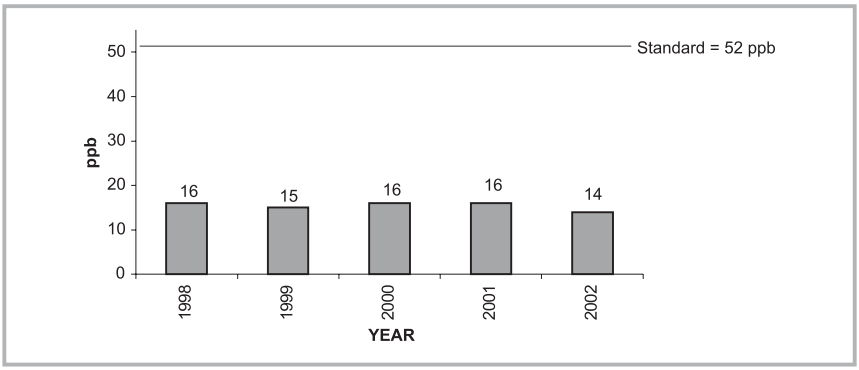
69 MÉNDEZ, M. (2003). "Análisis de intervención: efectividad de las políticas para reducción de la contaminación por fuentes móviles en Bogotá". Master's Thesis. Facultad de Economía. Universidad de los Andes. Bogotá.

Figure 3. Average Annual Concentration of TSP at the Cazuca Monitoring Station from 2000 to 2002.




Figures four and five present the arithmetic annual average concentrations of $NO_2$ and $SO_2$ from 1998 to 2002 in Bogotá[70], across all the monitoring stations. Since 1998, the annual average concentrations of $NO_2$ in Bogotá have remained between 14 and 16 ppb; that is less than 30% of the local standard. Since 1998, average annual concentrations of $SO_2$ have remained between 11 and 15 ppb, with an increasing trend. However these concentrations are less than 50% of the local standard.

Figure 4. Average Annual Concentration of $NO_2$ in Bogotá from 1998 to 2002.

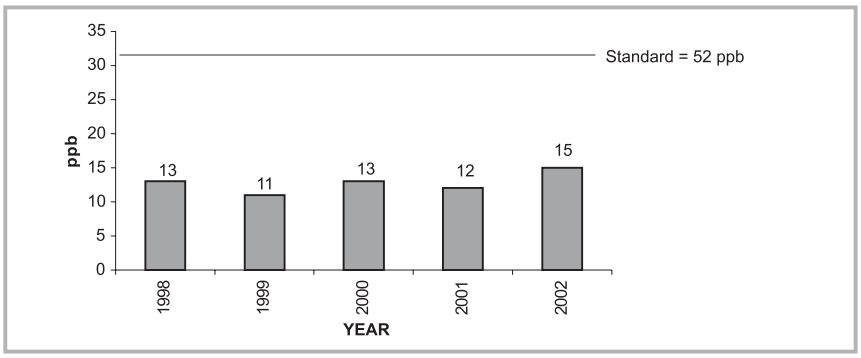



Since 1998, maximum hourly concentrations of CO are generally under 50% of the local standard. In 2002 the concentrations of $O_3$ were higher than the standard in 0.72% of the one hour readings. Based on these

70 *Air Monitoring Network of Bogotá* (2002). Cit.

observations DAMA has determined that the control of TSP and of $PM_{10}$ should be a priority for the city, that the increases in $O_3$ should be reversed, and that present levels of CO, $NO_2$ $SO_2$ should be maintained low[71].

Figure 5. Average Annual Concentration of $SO_2$ in Bogotá from 1998 to 2002.




## 2. Medellín

Air monitoring in Medellín began in 1967[72]. That year, four monitoring stations were installed by the Ministry of Health and the Pan-American Health Organization. They operated until 1974. As in the case of Bogotá, the installation and operation of this network was promoted by the Pan- American Health Organization. It did not result from a local interest in air pollution control[73]. As in the case of Bogotá, those stations detected high levels of TSP[74].

In 1983 after the approval of Decree 02 of 1982 which, as indicated in section 2.1 included air emission standards, the Department of Health operated seven stations. In 1983, these stations detected average annual concentrations of $SO_2$ in Medellín of 22.7 $\mu g/m^3$. Between 1985 and 1989 average annual $SO_2$ concentrations were 35 $\mu g/m^3$ [75]. These concentrations were below the

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71 Interview with Mr. Carlos Mario Tamayo. Director of Environmental Quality at DAMA. December 2003. Bogotá.

72 SÁNCHEZ, E. y HERRERA, C. (1994). En: E. Sánchez y E. Uribe. *Op. cit.*

73 Interview with Mr. Julio Carrisoza Inderena's Director from 1973 to 1978. July 2004. Bogotá.

74 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). En: E. Sánchez y E. Uribe. *Op. cit.*

75 *Ibid*.

standards of decree 2 of 1982 (table 1). By 1992 there were four stations in operation; their operating conditions were deficient[76]. As in the case of Bogotá, the stations installed in 1967 by the Pan-American Health Organization and by the city's Department of Health in 1982 were not part of air pollution control programs that could use the data form those stations as inputs for the design and adjustment of air pollution control strategies.

Presently there is a network of 18 stations if the Aburrá Valley[77.] Ten of them are located in the city of Medellín[78], and 8 in the other municipalities of the Aburrá Valley[79]. This network has the capacity to read TSP, $PM_{10}$, $SO_2$, $NO_x$, CO, and $O_3$. The functioning of the monitoring station has been interrupted in several occasions due to "legal problems" and difficulties related to the calibration of the equipment[80]. Consequently, there are frequent information voids.

Readings during the years 2001, 2002 and 2003 indicate that the average annual concentrations of heavy metals, $NO_x$, $SO_2$ and CO, do not pose health risks in Medellín or the municipalities of the Metropolitan Area of the Aburrá Valley[81 ,82 ,83]

The ambient concentration of suspended particles appears to be the main air pollution problem in the Aburrá Valley[84]. In June of 2002, the average

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76 *Ibid.*

77 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

78 They are located at: the *Politécnico*, the *Universidad de Antioquía*, the *Universidad de Medellín*, the *Universidad Nacional*, the Universidad Pontificia Bolivariana, down town Medellín and in *EEPPMM*.

79 They are located at Barbosa, Bello, Corantioquia, Envigado, La Estrella, Girardota (Liceo and COMFAMA), Guayabal, Itagüí and Sabaneta.

80 HOYOS, O. (2002). *Op. cit.*

81 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

82 *www.metropol.gov.co.*

83 HOYOS, O. (2002). *Op. cit.*

84 *Ibid.*

concentrations of TSP were above standards of Decree 02 of 1982[85] in 3 of the 14 monitoring stations of the Metropolitan area[86]; and in all cases they were above the 50% value of the standard. Additionally, the average concentration of $PM_{10}$ was close to or above the ambient standard[87] in the two stations which monitored this variable[88]. A similar situation was observed during 2003. Data gathered during the first semester of 2003 also detected $O_3$ concentrations higher than the ambient standards[89].

With the data collected by the monitoring stations, the Metropolitan Area is developing a program to model suspended particles and their sources. This program has the objective of providing additional elements for the design and implementation of air pollution control strategies[90].

## D. Health Effects

The effects of air pollution on health have been studied in Bogotá. However, those results have not been published. This section summarizes the results of those studies, which are mainly Masters' theses from local Universities. Increases in air concentrations of particulate matter (TSP) and nitrogen dioxide ($NO_2$) have positive effects on the number of daily counts of respiratory hospital admissions (RHA)[91]. While a 50% increase in the concentration of TSP augmented the daily RHA by 120%, an 100% increase in the concentration of $NO_2$ augmented the daily RHA by 12%. The effects of Ozone on RHA were not detected.

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85 100 μg / $m^3$.

86 Itagüí, Universidad de Medellín, Universidad Nacional.

87 65 μg /$m^3$.

88 Guayabal and Corantioquia.

89 87 ppb.

90 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

91 LOZANO, N. (2003). "Air Pollution in Bogotá Colombia: A Concentration Response Approach". Masters Thesis. Department of Agricultural and Resource Economic. University of Maryland ant College Park.

The economic effects of air pollution on the health status of children were also studied[92]. A pollution index that includes air concentrations of NO, $NO_2$, and $PM_{10}$ was associated with morbidity rates of children under five years of age. It was found that this index has a positive effect on children's´ morbidity, and that the effect is larger in children under one year of age. Statistically significant associations have also been detected between the concentration of $PM_{10}$ and mortalities associated with Acute Respiratory Illnesses (ARI)[93]. Contingent valuation studies were conducted during 2000 to estimate the economic costs of morbidity from ARI in Bogotá[94]. It was found that the willingness to pay to avoid one day of a bad episode caused by air pollution is US $ 4.3.

According to the Metropolitan Area of the Aburrá Valley, the frequency of respiratory diseases has increased in all of the municipalities of the Metropolitan Area and the frequency of ARI is "very relevant"[95]. However, the author could not find any empirical study that relates ARI and air pollution in the city and which could be used to support this assertion.

## E. Institutional Interventions

### 1. Bogotá

In some areas of Bogotá and during specific periods of the year, the city experiences relatively high concentrations of some air pollutants, particularly of particle matter. The city's air pollution strategy aims at maintaining lower levels of some pollutants ($NO_2$ $SO_2$, CO), at preventing the increase of $O_3$

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92 CALIXTO, D.C. y DÍAZ, A.V. (1996). "Valoración económica del impacto ambiental del aire sobre la salud de los habitantes menores de 5 años en Bogotá". Masters Theses. Facultad de Ciencias Económicas y Administrativas. Universidad Javeriana, Bogotá, Colombia.

93 URDANETA, S. (1999). "Mortalidad por infecciones respiratorias agudas y contaminación de aire: una estimación de funciones dosis-respuesta para Bogotá". Masters Thesis. Facultad de Economía. Universidad de los Andes. Bogotá, Colombia.

94 MATURANA, J.G. (2000). "Disponibilidad a pagar por daños a la salud de la contaminación atmosférica". Master's Thesis. Facultad de Economía. Universidad de los Andes. Bogotá.

95 *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

and at decreasing $PM_{10}$ and TSP[96]. Its long term target is to maintain air pollution bellow the maximum levels recommended by the World Health Organization.

DAMA is responsible for coordinating "The Air Pollution Prevention and Control Program of Bogotá"[97]. The air pollution control strategy is based on a diverse group of complementing actions. This program includes: i) air monitoring and air quality data collection; ii) the generation of public awareness through the dissemination of environmental information; iii) training of key actors within the industrial and transportation sectors; iv) the promotion of clean fuels; v) the improvement of fuel quality; vi) the improvement in urban mobility; vii) monitoring and control of fixed and mobile sources of emission; vii) technology transfer, and ix) institutional coordination. In most cases, the benefits of each of these actions have not been systematically evaluated. Between years 2000 and 2002 DAMA invested US $ 1'921.500 in activities related to air pollution control[98].

The Air Pollution Prevention and Control Program of Bogotá requires the active participation of different public and private agents. A Committee was established to facilitate coordination at al local level. It operates under the direction of DAMA, and is integrated by representatives from the Ministry of the Environment, the city's departments of health and transportation, the *Universidad de los Andes*, TRANSMILENIO, and the National Industry Association - ANDI. This Committee seeks to coordinate the implementation of the different components the Program for Air Pollution Prevention and Control Program[99]. Since June of 2002, the city of Bogotá also participates in the Clean Air Strategy of the World Bank[100]. Through technical and economic cooperation, this Strategy strengthens the city's Program for Air Pollution Prevention and Control.

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96 Interview with Mr. Carlos Mario Tamayo. Director of Environmental Quality at DAMA. December 2003. Bogotá.

97 *Plan de gestión ambiental de Bogotá* (2002). Cit.

98 *Informe de gestión 2001-2003* (2003). DAMA. Bogotá.

99 Interview with Mr. Carlos Mario Tamayo. Director of Environmental Quality at DAMA. December 2003. Bogotá.

100 *Informe de gestión 2001-2003* (2003). Cit.

**a. Data Collection**

As indicated, DAMA installed a new air monitoring network with 14 stations in 1997. These stations monitor the ambient concentrations of TSP, $PM_{10}$, $SO_2$, CO, Nitrogen Oxides ($NO_x$), $O_3$, and Hydrocarbons (HC). The network also monitors the following relevant meteorological relevant variables**:** wind speed and direction, solar radiation, temperature, and relative humidity. The data provided by the network is presently used to monitor air quality with respect to local ambient standards and to observe tendencies. In the future, the information provided by the network is expected to be used to activate control measures and to prevent pollutions episodes. It will also be used to provide data and information for research in areas relevant for urban planning, transportation systems and impact evaluation, as well as to validate dispersion models[101].

Presently, the Engineering Department of the *Universidad de los Andes* and the *École Polytechnique Fédérale de Laussane* are using the data collected by the network to develop an air model (Cell dispersion model)[102]. The data of the air monitoring network of Bogotá has also been used conduct research projects. Among these, various studies have evaluated the economic impact of air pollution on human health and on the prices of urban property[103, 104, 105, 106, 107, 108]. During 2002, after five years of continuous operations, administrative and technical problems lead to the suspension of the operations of the network[109]. The network reassumed operations in

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101 Auditoria a la Operación y Manejo de la Información de la Red de Monitoreo de la Calidad de Aire (2002). DAMA-IDEAM. Bogotá.

102 Doctorate thesis of Erika Zárate.

103 URDANETA, S. (2000). *Mortalidad por infecciones respiratorias agudas (ira) y contaminación del aire: una estimación de funciones: dosis respuesta para Santa Fe de Bogota*. Facultad de Economía. Universidad de los Andes. Bogotá.

104 CARRIAZO, F. (2000). "La contaminación del aire y el precio de la vivienda en Bogotá". Master's Thesis. Facultad de Economía. Universidad de los Andes. Bogotá.

105 IBÁÑEZ, A.M. and MCCONNELL, K.E. (2001). *Valuing Morbidity: Acute Respiratory Illness in Bogotá, Colombia*. Paper prepared for AERE workshop. Bar Harbor, Maine.

106 LOZANO, N. (2003). *Op. cit.*

107 MATURANA, J.G. (2000). *Op. cit.*

108 MÉNDEZ, M. (2003). *Op. cit.*

109 *Air Monitoring Network of Bogotá* (2002). Cit.

August of 2003. After an evaluation of the network, its operation was transferred by DAMA to *Instituto de Estudios Ambientales*, IDEAM, in 2002[110]. The annual cost of the monitoring network of Bogotá is of approximately US$ 200.000[111].

**b. Education Training and Awareness**

DAMA's environmental education programs are aimed at the general public and at key actors within the transportation and manufacturing sectors. Those programs seek to increase awareness regarding air pollution problems and to promote the adoption of clean production processes and fuels. It also seeks to encourage the appropriate maintenance of public and private transportation vehicles.

"The day with no-car" is the main strategy used to raise awareness about air pollution and the importance of public and alternative means of transportation. Twice a year, private cars are not allowed to circulate in the city; only public buses and taxis may be used, and public transportation and bicycles are encouraged. The impacts of the "day with no- car" on the levels of air pollution are not conclusive[112, 113].

Since 1996, DAMA has conducted public campaigns to promote vehicle maintenance. The campaign "Be Synchronized with Bogotá" promotes vehicle maintenance through massive media. As a part of this program, 750 mechanics have been trained in the maintenance of diesel and gasoline vehicles[114].

Additionally, in 1997, the Department of the Environment of Bogotá, DAMA initiated the ACERCAR program for the transfer of environmentally sound technology to small and medium industrial enterprises. Between April

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[110] *Auditoría a la operación y manejo de la información de la red de monitoreo de la calidad de aire* (2002). Cit.

[111] *Ibid.*

[112] *www.dama.gov.co*.

[113] *Bogotá, cómo vamos: cambios en la calidad de vida de la ciudad 2000-2002* (2003). Casa Editorial El Tiempo, Fundación Corona, Cámara de Comercio de Bogotá. Bogotá.

[114] *www.dama.gov.co*.

2002 and April 2004, this program conducted 6000 technical consultations and 600 detailed environmental evaluations of small and medium industrial establishments, and organized four international seminars[115]. As a part of this program subsidies are granted to private firms for the environmental re-conversion of their industrial plants. The impact of this program on air pollution reduction has not been evaluated. In 2003, this program was extended to the transportation sector with the objective of providing information and technology related to the maintenance of vehicles and cleaner fuels. Between April and December of 2003 this program assisted 55% of the total transportation firms with training and technology transfer. The impact of this program on pollution control has not been evaluated.

Since November of 1998, DAMA publishes air quality data in its web page[116]. This information includes a complete description of the air monitoring network, the daily, weekly, and monthly reports, and all the reports published between 1998 and 2002. Information related to the day with no car is also published. This web page also includes a form in which complaints can be presented by the public to DAMA.

The level of awareness about air pollution in Bogotá can be assessed by the number of complaints to DAMA. Twenty three hundred (2300) complaints were sent to DAMA between January and October of 2003, of which 35 % were related to air pollution[117]. Between 2002 and 2003, the number of air related complaints grew by 4%. Information from earlier years is not available.

Additionally, the awareness of the general population with respect to air pollution problems has been evidenced in hedonic studies. These studies have concluded that air pollution problems negatively affect the prices of homes in Bogotá. This tendency reflects social awareness with relation to pollution problems. A study conducted using a hedonic equation determined that a one percent increase in the air concentration of TSP lowered the prices of houses by 0.126%[118]. In this

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[115] *Ibid*.

[116] *www.dama.gov.co*; the number of visitors to this page has been 765.000 during the last six years of existence.

[117] *Informe de gestión 2001-2003* (2003). Cit.

[118] CARRIAZO, F. (2000). *Op. cit.*

study the average price of the houses was US $ 26.300 of 1998. That is to say that a one percent increase in the concentration of TSP would lower the price of a the average house by US $79,38.

**c. Public Transportation**

By the early nineties congestion problems in Bogotá were critical[119]. Between 1992 and 1998 the average speed in the city went from 20 k/h to 10 K/h[120]; the average age for public transportation vehicles was 20 years and the average trip in public transportation lasted 1 hour and 10 minutes[121].

Transmilenio, a massive system for public transportation, was inaugurated in December 2000[122]. Today, about 15% of the seven million daily trips in public transportation vehicles in Bogotá are made in Transmilenio. Between 2000 and 2001, the average travel time lowered by 15% and more that 50% of that change can be attributable to the Transmilenio System[123].

Transmilenio uses high capacity buses[124] which run at an average speed of 27 K/h along 56 Kilometers of exclusive corridors. For each new bus that is added to the Transmilenio system, seven old buses are destroyed. Half of a 20% local surtax on gasoline, mostly paid by private vehicles, is used for the construction and expansion of the Transmilenio system; the other half is directed towards the maintenance and improvement of the geometry and design of public roads. DAMA, as an environmental authority, did not play a role in the decision making process that led to the implementation of the Transmilenio System.

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[119] ARDILA, A. (1998). "El problema del transporte en Bogotá**:** diagnóstico y perspectivas para el metro". *Debates de coyuntura económica. El metro en Bogotá, ¿cómo financiarlo?* Fedesarrollo, Fonade, no. 47. Bogotá.

[120] *Plan de gestión ambiental de Bogotá* (2002). Cit.

[121] CHAPARRO, I. (2002). *Evaluación del impacto socioeconómico del transporte urbano en la ciudad de Bogotá: el caso del sistema de transporte masivo, Transmilenio*. CEPAL. Santiago de Chile.

[122] *www.transmilenio.gov.co*.

[123] *Bogotá, cómo vamos: cambios en la calidad de vida de la ciudad 2000-2002* (2003). *Op. cit.*

[124] 160 passengers per bus.

A recent research study concluded that although the average monthly ambient concentrations of $PM_{10}$ have increased since 1996, the Transmilenio massive transportation system has contributed to lowering emissions of those particles[125]. The same study found that this massive transportation system has also contributed to significantly lowering the ambient concentrations of ozone[126]. Between 2.000 and 2001, average concentrations of $SO_2$, $NO_2$ and $PM_{10}$ declined by 44%, 7% and 25% respectively, as reported by the air monitoring stations located near one of Transmilenio's lines[127].

As an integral part of the Transmilenio System, 259 K of bicycle paths have been constructed in Bogotá. The administration of the city estimates that 4% of the total number of trips is made by bicycle[128]. The administration of Bogotá included a series of educational projects that seek to promote the bicycle as an alternative means of transportation in its Environmental Plan for the 2001-2009 period [129].

**d. Traffic Restrictions**

In Bogotá 20% of the private vehicles are immobilized form 7:00 to 9:00 a.m. and from 5:00 to 7:00 pm., according to their plate numbers on a daily basis. This has increased the average speed of public and private transportation by 20% and 24% respectively, and has increased the use of public means of transportation[130]. Additionally, vehicle for public transportation, including taxis, is also immobilized once a week, with the exception of the buses of the Transmilenio system. An evaluation of the impact of this measure shows a 21% reduction on Ozone concentrations during peak traffic hours[131].

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[125] MÉNDEZ, M. (2003). *Op. cit.*

[126] The concentrations of $PM_{10}$ and Ozone have been lowered by 18% and 56% respectively near the Transmilenio lines.

[127] Carrera 13 and calle 39.

[128] *Bogotá, cómo vamos: cambios en la calidad de vida de la ciudad 2000-2002* (2003). *Op. cit.*

[129] *Plan de gestión ambiental de Bogotá* (2002). Cit.

[130] *www.transitobogota.gov.co.*

[131] MÉNDEZ, M. (2003). *Op. cit.*

### e. Regulations

Control actions in Bogotá are based on the enforcement of regulations presented in table three.

Table 3. Regulations for Air Pollution Control Approved by DAMA.

| Regulation | Objective | Comments |
|---|---|---|
| *Resolution* 556 of 2003 by DAMA | Establishes local standards for mobile sources of emissions and establishes fines and sanctions for the violation of those standards. | These standards include CO (%) and HC (ppm) for gasoline vehicles; they are stricter for newer vehicles. For diesel vehicles the only standard is opacity (%) which also tends to be stricter for newer vehicles. These standards can not be compared with others such as the Euro standards which are presented in units of weigh of emitted pollutant per distance traveled (Ex. gm/km).<br><br>Random controls are made on the streets with the coordination of the police and the transportation departments. |
| *Resolution* 391 of 2001 by DAMA | Establishes local ambient standards (see table 2). | These standards are stricter than the national standards (Decree 2 of 1982). |
| *Resolution* 1208 of 2003 by DAMA | Establishes local standards for fixed sources of emission. | Monitoring and control programs of industrial plants conducted by DAMA are based on the standards of this regulation. |

*Resolutions (Resoluciones)* 556 of 2003 and 1208 of 2003 define local emission standards for mobile and fixed sources of pollution, respectively. Both regulations set standards that are stricter than those of the national regulations approved since 1982[132]. The approval of

[132] Decree 02 of 1982.

those standards was based largely on the review of international literature and regulations[133].

*Resolution* 556 presented in Table 3 defines the procedures for the enforcement of air emission standards by mobile sources. As previously mentioned, the annual total cost of the yearly emission's revision is US $ 5´536.800 and environmental benefits could not be found; although they were evaluated.

Finally, it should also be mentioned that between 2002 and March of 2004, 23 legal actions were pressed in relation to air pollution problems in Bogotá[134]. Eighteen of them were related to fixed sources of air pollution. In half of those cases, the judges ordered the polluters to stop emissions. In 28% of the cases, and in accordance with the article 116 of the Political Constitution of 1991, the judges ordered the use of alternative dispute resolution mechanisms[135]. Through those voluntary processes and with the mediation of a conciliator, agreements are sought between peoples in conflict[136].

**f. Control Actions**

The Air Pollution Prevention and Control Program of Bogotá includes actions to control emissions generated by mobile sources. The city government requires all private and public vehicles to submit to a yearly emissions' evaluation. These evaluations are conducted by authorized service stations[137], which issue a certificate indicating compliance to standards defined by DAMA. The cost of the evaluation is US $ 9. Between October of 2002 and October of 2003, 615.200 vehicles obtained their emission's

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[133] Interviews with Mr. Carlos Mario Tamayo Director of Environmental Quality at DAMA; and Mr. Carlos Herrera Environmental Director of ANDI. March 2004. Bogotá.

[134] Interview with Mr. Orlando Sepúlveda from the Legal Unit of DAMA.

[135] The Alternative Dispute Resolution mechanisms were recently regulated by Law 640 of 2001.

[136] RODAS, J. C. (2001). "La conciliación y los conflictos ambientales". *Justicia ambiental*. Universidad Externado de Colombia; Instituto de Estudios del Ministerio Público; CAR. Bogotá.

[137] Presently there are 312 authorized service stations in Bogotá.

certificate (about 40% of the vehicles were not tested)[138]. Therefore the total annual cost of the yearly evaluation was US $ 5'536. 800. The traffic police routinely require those certificates and conduct random emission inspections on the streets of Bogotá. A US $67 fine[139] is applied to those vehicles which do not possess the certificates or do not meet the standards. During the first semester of 2003, 45.320 inspections were conducted. There was a 60% compliance of vehicles, and a 5% increase with respect to the previous year. The remaining 40% did not comply and the degree of non-compliance was not registered. The effects of these controls on air quality were evaluated but could not be proven[140].

In addition, on a yearly basis, each industrial plant makes a self-evaluation and a declaration of its emissions. Every year, DAMA randomly selects a group 70 of the 2.372 fixed sources of emissions to verify the content of those declarations. In 2003, these industries presented a 63% compliance rate with air emission standards defined in national regulations (Decree 02 of 1982) and of 41% for the stricter local standards (*Resolución* 391 of 2001).

According to a survey conducted in year 2001[141], 64% of the air pollution control measures taken by fixed sources in Bogotá, included preventive changes in the production processes; and 36% adopted end of the pipe solutions. Processes modifications included changes in energy sources. Fifty two percent of the industries that adopted preventive measures for air pollution control also increased their profits. However, the relation between abatement and increase in profits was not investigated.

## 2. Medellín

The Metropolitan Area of the Aburrá Valley acts simultaneously as a planning and development agency, as well as an environmental authority. The

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[138] *Informe de gestión ambiental en el Distrito Capital. Enero 1998–diciembre 2000*. (2000-2001). Cit.

[139] This fine is doubled is it is not paid within three days.

[140] MÉNDEZ, M. (2003). *Op. cit.*

[141] CRUZ, G.; URIBE, E.; CORONADO, H. y GARCÍA, J. *La gestión ambiental y la competitividad de la industria* (2002). Informe final de consultoría. CEDE. Universidad de los Andes. Bogotá.

Environmental Unit of this institution is responsible for implementing the air pollution control program of the Aburrá River watershed. As in the case of Bogotá, the air pollution strategy of this region includes a series of complementary actions[142]. They include air monitoring, research, land use planning, and promotion of clean production technologies, environmental education, massive transportation systems, and traffic management. In most cases, the benefits of each of these actions have not been systematically evaluated. As in the case of Bogotá, the implementation of the air pollution control program of the Aburrá River watershed requires the participation of different public and private institutions. Among them are the Metro of Medellín, the departments of planning and transportation of Medellín and of the municipalities of the Aburrá Valley, and the private associations of industries and of the transportation sectors[143]. Unlike the case of Bogotá where the effects of some of the government's air pollution control actions have been evaluated, this has not been the case in the Aburrá Valley. Information related to the air pollution control investments of the Metropolitan Area of the Aburrá Valley is not included in the public reports that this organization presents to the general public.

**a. Education Training and Awareness**

The environmental education programs of the Metropolitan Area are aimed at the general public and at key actors within the transportation and manufacturing sectors. A massive environmental education program known as "if air was lacking" ("*si le falta el aire*") seeks to prevent pollution caused by mobile sources[144]. The content and the impact of this environmental education program have not been evaluated. Since 1996, the Metropolitan Area has developed a program to promote cleaner production systems by the industrial sector[145]. This program is similar to the ACERCAR program of Bogotá. As a part of this program, different

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[142] *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

[143] HOYOS, O. (2002). *Op. cit.*

[144] *Ibid.*

[145] *www.metropol.gov.co.*

institutions and associations of the private sector[146] and of the government[147] created the "Clean Production Committee"[148]. This Committee has the objective of facilitating the industrial sector of the region access to cleaner production technologies. Information relative to the results and impact of the activities to promote the adoption clean production systems by the manufacturing sector is not available.

The Metropolitan Area has published "environmental guidelines" for the management of air pollution in the industrial sector[149]. In addition, three "Clean Production Agreements" have been signed between the Metropolitan Area, acting as the environmental authority of the region, and the private sector[150]. In those agreements the government and the private sector coordinate the design of environmental regulations, administrative processes, economic incentives, environmental evaluation and monitoring methods[151].

Although the Environmental Unit of the Metropolitan Area includes information in its web page relative to air pollution control and to air quality, the information provided is less detailed and updated than that provided by DAMA.

Evidently, the Metropolitan Area has undertaken a series of environmental education programs and programs to facilitate the access to cleaner technologies. However, their results, impact and benefits have not been evaluated.

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[146] The local chapter of the National Association of Industries (ANDI), the local chapter of the Chamber of Commerce, and *Fedemetal*.

[147] The Metropolitan Area, the *Universidad de Medellín*, the *Universidad de Antioquía*, the *Gerencia Ambiental de la Gobernación de Antioquia*, the Autonomous Regional Corporation of Antioquia and and *Cornare*.

[148] HOYOS, O. (2002). *Op. cit.*

[149] *Ibid.*

[150] *www.metropol.gov.co.*

[151] ESTERLING, A. (2003). *Evaluación y perspectivas de los convenios de concertación para una producción más limpia en Colombia*. Informe de Consultoría. Ministerio del Medio Ambiente.

**b. Alternative Transportation Systems**

The Metro system of Medellín was inaugurated in December of 1995. This massive transportation system has become the pivotal center for the development of public transportation in this city[152]. The Metro of Medellín transports about 300 thousand passengers per day at an average speed of 35 kilometers per hour[153]. This corresponds to about 9% of the total transportation demands of the city[154]. Presently there is an ambitious program for the extension of bicycle paths[155].

**c. Control Actions**

The air pollution control program of the Aburrá River watershed includes actions to legally control emissions generated by mobile sources. The Metropolitan Area requires all private and public vehicles to submit to a yearly emissions' evaluation[156]. These evaluations are conducted by 20 authorized service stations which issue a certificate indicating compliance to standards. During 2002, 150.000 vehicles (this corresponds to about 38.78% of the total number of vehicles) obtained their emission's certificate. During the first semester of 2003 there was a 6.23% increase in the number of certificates granted with respect to the same period of the previous year. The cost of the evaluation is US $ 9 per vehicle. The total cost paid in 2002 was US 1'350.000. Twenty two percent of the collected amounts are transferred to the Environmental Unit of the Metropolitan Area. Ninety percent of the inspected vehicles had gasoline engines; the rest were powered by diesel[157]. There is no information

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[152] *Perfil del estado de los recursos naturales y del medio ambiente en Colombia* (2001). Instituto de Hidrología Meteorología y Estudios Ambientales, IDEAM. Bogotá.

[153] *Política para mejorar el servicio de transporte público urbano de pasajeros* (2002). Cit.

[154] *Área metropolitana del Valle de Aburrá - Corantioquia*. (2003). Actualización del Plan Estratégico Ambiental Metropolitano, PEAM 2003-2012. Medellín.

[155] *Proyecto metrópoli 2002-2020* (2002). Plan Integral de Desarrollo Metropolitano del Valle de Aburrá. Área Metropolitana del Valle de Aburrá. Medellín.

[156] HOYOS, O. (2002). *Op. cit.*

[157] *Informe de gestión ambiental en el Distrito Capital. Enero 1998-diciembre 2000* (2000-2001). Cit.

available as to failure rate of these control actions. The traffic police routinely requires those certificates and conducts random emission inspections. Fines equivalent to 10 minimum legal daily wages are applied to those who do not possess the certificate and of 30 minimum legal daily wages to those whose vehicles do not meet the standards[158].

Additionally, the environmental Unit of the Metropolitan Area conducts random inspection visits to industries[159]. One hundred sixty inspections were conducted during 2003; this corresponds to about 30% of the total number of industrial establishments.? In addition, 53 inspection visits were conducted in response to public demands and complaints. Information relative to the degree of non compliance for these random inspection visits is not available.

Unlike the case of Bogotá, the Metropolitan Area of the Aburrá Valley has not approved specific regulations for air pollution control. Consequently, national regulation and standards are applied.

**d. Cleaner Fuels**

The quality and the availability of fuels have not been the same in Bogotá and in Medellín. The national government[160] promoted the use of natural gas in Bogotá earlier than in Medellín[161]. Likewise, the diesel fuel produced by the national oil agency[162] for Bogotá has lower sulfur contents. Local governments do not participate in the design of national energy policies or in the decisions related to the availability and quality of fuels. The National Government determines which fuels and of what quality are available in each city. As a result, one of the main elements of local air pollution control strategies (fuel types and quality) lies beyond the control of local authorities.

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[158] HOYOS, O. (2002). *Op. cit.*

[159] *Ibid*.

[160] The Ministry of Mines and the Department of National Planning (DNP).

[161] *La cadena del gas natural en Colombia: 2001-2002* (2003). Unidad de Planeación Minero Energética; Ministerio de Minas y Energía. Bogotá.

[162] Ecopetrol.

Since the early nineties, the national government has adopted policies aimed at promoting the massive use of natural gas for the industry, the transportation and the domestic sectors. In 1991, the national government adopted the National Program for the Promotion of Natural Gas Consumption[163]. Since then, the promotion of this fuel has been a priority for succeeding national administrations[164,165]. The national policies for the promotion of gas consumption include: i) acceleration of gas reserve exploitation; ii) the construction of transportation and distribution infrastructure; iii) strengthening of institutional and regulatory framework, and iv) the generation of positive incentives for the participation of the private sector in the production and commercialization of gas. The production of Natural Gas grew by a factor of 6.5 between 1990 and 2000,[166] and consumption grew by 10% between 2002 and 2003. This growth was mainly attributed to the increased demand by the transport sector[167].

Between 1997 and 2001 there was an increase of 161% in the number of cars running on Natural Gas in Colombia[168]. Nearly 7400 cars were converted to Natural Gas during that period. Between 2002 and 2003, the consumption of vehicular natural gas grew from 1'060.102 to 1216.561 BTU and from 135.609 to 327.914 BTU in Bogotá and in Medellín respectively[169]. It is interesting to note that while the demand in Medellín is about one third of that of Bogotá, the number of cars in this city triples that of Medellín. Additionally, it is evident that the growth rate in the consumption of vehicular natural gas is much higher in Medellín. It is estimated that by

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163 *Programa para la masificación del consumo de gas* (1991). Documento CONPES DNP-2571-UINF-DIREN. Departamento Nacional de Planeación. Bogotá.

164 *El sector del gas en Colombia* (2000). Documento sectorial. Departamento Nacional de Planeación.

165 *Balance y estrategias a seguir para impulsar el Plan de Masificación de Gas* (2000). Documento CONPES 3190. Departamento Nacional de Planeación. Bogotá.

166 *La cadena del gas natural en Colombia 2000-2001* (2003). UPME. Ministerio de Minas y Energía. Bogotá.

167 *El Tiempo*, Newspaper, April 1 2004.

168 *Análisis de conveniencia del uso del gas natural comprimido vehicular en Colombia* (2002). Cit.

169 *www.mme.gov.co*.

2010 a total of 80.000 vehicles for public transportation, mainly taxis (85%), will use natural gas in Colombia[170].

Between 1999 y 2002, as a part of the "Program for Air Pollution Prevention and Control", DAMA and ECOPETROL[171] promoted the re-conversion of 4890 public vehicles from gasoline to natural gas[172]. Through its ACER-CAR program, DAMA advertised the environmental and economic benefits of re-conversion to Natural Gas among taxi owners and provided them with technical and financial information[173]. The average monthly savings for a taxi that converts form gasoline to natural gas in Colombia are about US $100[174]. There are no subsidies involved. These savings are mainly associated with differences in fuel prices. The reconverted cars are allowed to carry advertisements regarding their use of Natural Gas. To investigate the economic and technical viability of using natural gas in the Transmilenio massive transportation system, a prototype bus is under evaluation[175].

Additionally, DAMA developed a guide for the environmental management of the service stations that sell Natural Gas. The contents and the technical standards of this guide were developed and negotiated with the regulated sector and became enforceable regulation[176]. Evidently, environmental and energy authorities have been interested in the conversion of vehicles from gasoline and diesel to natural gas. However, the potential environmental effects of their policies and programs have not been evaluated.

The use of cleaner fuels by the industrial sector has also grown in Bogotá. While the participation of coal dropped from 41% to 7.5% between 1992 and 1998, the participation of Natural Gas grew from 2% to 7 %[177].

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[170] *La cadena del gas natural en Colombia 2000-2001* (2003). Cit.

[171] Colombian Oil Company (*Empresa Colombina de Petróleos*).

[172] *Análisis de conveniencia del uso del gas natural comprimido vehicular en Colombia* (2002). Cit.

[173] Informe de gestión ambiental en el Distrito Capital. Enero 1998-diciembre 2000 (2000-2001). Cit.

[174] *Análisis de conveniencia del uso del gas natural comprimido vehicular en Colombia* (2002). Cit.

[175] Interview with Mr. Ricardo Moncada Advisor of Transmilenio S.A. April 2004. Bogotá.

[176] Resolución 19/02.

[177] *Plan de gestión ambiental de Bogotá* (2002). Cit.

The environmental benefits of the program for the promotion of natural gas have not been evaluated.

Since 1991, leaded gasoline is not produced in Colombia[178]. With the exception of Sulfur, the quality of diesel and gasoline in Colombia is similar to that of industrialized countries[179]. The content of Sulfur in the Diesel fuel produced for Bogotá by ECOPETROL[180] is 1/3 of that for the rest of the Country[181]. The decision to lower the Sulfur content of the diesel produced for Bogotá resulted from a comparison with international standards[182]. This decision was taken by ECOPETROL in coordination with DAMA in year 2000[183]. Five hundred industrial plants and commercial establishments and most of the vehicles for public transportation, including Transmilenio, are operating with this cleaner fuel in Bogotá.

## II. Application of the WDR 2003

In this section, the case of air pollution management in Bogotá and Medellín is discussed and analyzed following the framework of the WDR 2003. The following aspects are addressed:

1. How, and to what extent, society became aware of the air pollution problems of these two cities.
2. The mechanisms that generated the decision to undertake air pollution control strategies.
3. The mechanisms that were in place to balance legitimate, competing social interest.

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178 ONURSAL, B. and GAUTAM (1997). *Op. cit.*

179 *Ibid.*

180 Colombian Oil Company (*Empresa Colombina de Petróleos*).

181 1000 ppm for Bogotá versus 3.000 ppm for the rest of the country. By 2005 the content of Sulfur in Diesel will be 500 ppm and in gasoline 300 ppm.

182 Interview with Mr. Manuel Felipe Olivera, Director of DAMA from 1998 to 2001. March 2004. Bogotá.

183 Interviews with Mr. Alberto Carderón President of Ecopetrol from 1998 to 2002 and with Mr. Manuel Felipe Olivera, Director of DAMA from 1998 to 2001; March and July of 2004. Bogotá.

4. The means by which the adopted solutions were executed, and the sustainable (long term) nature of the commitment.

## A. How Society Became Aware of the Air Pollution Problems

Although ambient air standards were only approved in 1982, air quality monitoring in Bogotá and Medellín has existed since 1967[184] when the Pan-American Health Organization installed a network of stations in those cities, which operated until 1974. The interest of this international agency in air pollution control played a more important role than the local interest[185]. At the time information relative to the health effects of air pollution in Bogotá and in Medellín were not known. In both cases those networks detected the presence of high levels of TSP.

During the next nine years, air quality information was not gathered. After a long period in which air quality data was unavailable, the national government approved its first air emission standards in 1982[186]. Those standards were approved in order to develop a regulatory agenda defined by the Code of Natural Resources in 1974 and by the Sanitary Code in 1979[187]. Those two codes indicated that the national government should approve specific regulations and standards to prevent air pollution. More than a response to social demands, the standards set by Decree 02 of 1982 were the result of the development of a regulatory agenda that had been determined by previous regulations designed and approved by the government without any form of public participation.

Between 1990 and 1991 the Japanese Cooperation agency, JICA, financed and operated five air monitoring stations in Bogotá. These stations also detected high environmental levels of particulate matter. However, the information provided by the monitoring stations that operated until 1991

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[184] SÁNCHEZ, E. y HERRERA, C. (1994). En: E. Sánchez y E. Uribe. *Op. cit.*

[185] Interview with Mr. Julio Carrisoza, Inderena's Director from 1973 to 1978. July 2004. Bogotá.

[186] Decree 02 of 1982.

[187] Interview with Mr. Julio Carrisoza. Cit.

was not systematically analyzed or widely published[188]. Therefore the level of public information regarding air quality in Bogotá was limited.

The Environmental Department of Bogotá, DAMA, initiated environmental control actions in 1995 and installed a new air monitoring network in 1997. The data gathered by the network is published by DAMA in internet[189]. This web page also publishes information related to the development of the "The Air Pollution Prevention and Control Program of Bogotá"[190]. This includes information related to: i) the operation of air monitoring stations; ii) technical information related to air pollution control; iii) the evaluation of control strategies such as "the day with no car", the Transmilenio transportation system and the technology transfer programs to the industrial and transportation sectors. Seminars and workshops on air pollution issues are also announced on this web page and the presentations of those seminars are made available. This web page has had more than 755.000 visitors since 1998. In the case of the Aburrá Valley this type of detailed public information is not as readily available. The web page[191] publishes general information related to control actions of fixed and mobile sources of air pollution; air quality data is presented in very general terms.

Additionally, mass media has also contributed to the dissemination of information related to air pollution. Between April of 2003 and April of 2004, DAMA of Bogotá made 10 press releases directed towards the mass media on issues directly related to air pollution[192].

DAMA and the Metropolitan Area of the Aburrá Valley develop various projects of environmental education and training in areas relevant to air

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[188] *Sistema de información ambiental de Colombia: conceptos, definiciones e instrumentos de la información ambiental de Colombia* (2002). Cit.

[189] *www.dama.gov.co*.

[190] *Plan de gestión ambiental de Bogotá* (2002). Cit.

[191] *www.metropol.gov.co*. This web page had more than 27.000 visitors from February 5 to May 25 2004. However, other non environmental issues related to the planning and to the development of the Aburrá Valley are also consulted (for example transportation, public services, security, etc.).

[192] *www.dama.gov.co.*

pollution control[193,194] The ACERCAR project in Bogotá mentioned in section I.E.1, and the clean production program of the Abuurá Valley mentioned in section I.E.2 target key actors of the industrial sectors and seek to increase their awareness with respect to pollution problems and economically efficient alternatives to address them. The ACERCAR program in Bogotá also targets the transportation sector.

Additionally, DAMA and the Metropolitan Area develop a series of environmental education and technology transfer projects aimed at controlling air pollution. The availability of information facilitates public participation and interventions related to air pollution control. In fact, 35 % of the twenty three hundred (2300) complaints sent to DAMA between January and October of 2003 were related to air pollution[195], and the number of air related complaints grew by 4% between 2002 and 2003. Although the health effects of pollutants are not yet broadly shared or understood in the city of Bogotá, 65% of the people relate respiratory illnesses with air pollution and the willingness to pay to avoid one day of a bad episode caused by air pollution is US $ 4.3[196]. Information related to public awareness in relation to air pollution in the Aburrá Valley is not as available. However, it is known that 4.5% of the 2.948 complaints received by the Environmental Unit of the Metropolitan Area during the first trimester of 2003 were related to air pollution[197]. Evidently the participation of air pollution related complains is much larger in Bogotá than in the Aburrá Valley (35% versus 4.5%).

## B. The Mechanisms that Generated the Decision to Undertake Air Pollution Control Strategies

To monitor and control the standards approved by Decree 02 of 1982, the Health Department of Bogotá installed a network of 12 air monitoring stations in 1983. The same year the Department of Health of Medellín installed seven stations. Bogotá's network gathered data until 1989. In the

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[193] *Plan de gestión ambiental de Bogotá* (2002). Cit.

[194] HOYOS, O. (2002). *Op. cit.*

[195] *Informe de gestión 2001-2003* (2003). Cit.

[196] MATURANA, J.G. (2000). *Op. cit.*

[197] *www.metropol.gov.co.*

case of Medellín, there were four stations which operated until 1992, albeit in deficient operating conditions[198]. In both cases high levels of TSP were detected in some of the monitoring stations.

The results form the monitoring stations installed in 1983 contributed to support the national government's decision to create institutions specialized in environmental problems of large urban settlements. The creation of new institutions specifically responsible for urban environmental management in cities over one million was considered a positive step for the implementation of long term air pollution control strategies. Under the previous institutional setting, the health authorities were responsible not only for air pollution control, but also for the administration of the public health system. The crucial importance and the urgencies associated with the administration of that system demanded most of the attention and resources of those institutions. Under those circumstances, the financial and institutional resources dedicated to air pollution were limited[199].

Although information on air quality has been gathered, and information related to the impact of air pollution on human health has increased, the national standards of Decree 2 of 1982 are still in place. The Ministry of the Environment has not examined the efficiency, efficacy and effectiveness of that regulation in light of new conditions and available information. The largely decentralized nature of the air pollution strategies in the cities of Colombia could explain the low priority assigned by the national government to air emission standards[200]. Additionally, the fact that urban environmental authorities have the capacity of making those standards stricter, based on their particular circumstances, could also contribute to explain this situation.

The city of Bogotá is the only case in Colombia where stricter local air ambient standards have been approved and where standards for additional pollutants such as $PM_{10}$ have been issued. As indicated in section I.E.1, in 2001, Bogotá moved to stricter local standards and included $PM_{10}$. This

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198 GÓMEZ, G.; MONTEJO, S. y SAAVEDRA, E. (1994). *Op. cit*.

199 SÁNCHEZ, E. y VARGAS, C. (1994). "Estructura institucional y financiera del control de la contaminación y oferta analítica". En: E. Sánchez y E. Uribe. *Op. cit.*

200 This is the opinion of the author.

could be explained by the relative political independence of the government of Bogotá at that time[201]. A recent study among representatives of the industrial sector[202] found that DAMA is among the environmental authorities that exercises the strictest control activities in Colombia[203].

In the case of Bogotá, as indicated in section 2.4.1, in addition to social demands, the data originating form the air monitoring station network helped the administration to determine that its air pollution control strategy should aim principally at maintaining low levels of some pollutants ($NO_2$ $SO_2$, CO), at preventing the increase $O_3$ and at decreasing $PM_{10}$ and TSP[204].

Using the data form the monitoring network, the administration and the Engineering Department of the *Universidad de los Andes* are presently working on the development of an air dispersion model for the city of Bogotá. This model has the objective of increasing the value of the network as a source of information for the design, evaluation and adjustment of environmental policies[205]. On the other hand, using data from the monitoring stations, the Environmental Unit of the Aburrá Valley is developing a program for modeling suspended particles and its sources. As in the case of Bogotá, this program has the objective of providing additional elements for the design, evaluation and adjustment of air pollution control strategies[206].

Not all of the actions that are presently considered to be integral components of the air pollution control programs of Bogotá and Medellín were designed and implemented with the objective of lowering air pollution. Some of them had the objective of controlling the traffic congestion problems. These are the cases of Transmilenio and of the daily restrictions in the use of private

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[201] *Ibid.*

[202] CRUZ, G.; URIBE, E.; CORONADO, H. y GARCÍA, J. *La gestión ambiental y la competitividad de la industria* (2002). Cotado.

[203] The Regional Corporation of Cundinamarca CAR is the only environmental authority that develops less control activities than the Environmental Unit of the Metropolitan Area.

[204] Interview with Mr. Carlos Mario Tamayo. Director of Environmental Quality at DAMA. Bogotá. December 2003.

[205] *Ibid*.

[206] *Elementos para el diagnóstico ambiental de los espacios natural y transformado en el Valle de Aburrá* (2002). Cit.

and public vehicles in Bogotá. This is also the case of the Metro system of Medellín. Those strategies created to improve mobility have contributed to lower air pollution in Bogotá[207]. Their effect in Medellín has not been evaluated. Similarly, the construction of bicycle paths and the promotion of bicycle use, with the objective of improving the quality and public enjoyment of public areas, are now considered to be part of the air pollution control programs of Bogotá and Medellín.

Originally, the promotion of fuels such as natural gas in transportation and industry had the objective augmenting the social benefits that could be derived from the efficient utilization of that resource[208]. Environmental considerations were not taken into account. As the potential contribution of cleaner fuels to the improvement of air quality became better known, environmental reasons became part of the promotion strategies of natural gas[209].

## C. The Mechanisms to Balance Legitimate, Competing Social Interests

Various of the components of the Air Pollution Prevention and Control Program of Bogotá and in the Aburrá Valley are not within the realm of environmental authorities and are not seen by the general public as environmental initiatives. They are in fact sector policies which could have positive externalities on air quality. That is the case of the components of the air pollution control programs that are related to the transportation and to the energy sectors. This is also the case of the surtax on gasoline which is a fiscal instrument to finance the improvement of public roads and of public transportation and the construction of bicycle paths. Although the development of those components has not been exempt of conflicts of interests[210], environmental issues are not part of them.

The writing and enforcement of environmental regulation has been a source of tension between DAMA and the representatives of manufacturing

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[207] MÉNDEZ, M. (2003). *Op. cit.*

[208] *Programa para la masificación del consumo de gas* (1991). Cit.

[209] *Balance y estrategias a seguir para impulsar el Plan de Masificación de Gas* (2000). Cit.

[210] *Bogotá, cómo vamos: cambios en la calidad de vida de la ciudad 2000-2002* (2003). Cit.

industry[211]. As indicated in section I.E.1, local emissions standards were developed in 2003[212] for the control of fix and mobile sources of air pollution. Both regulations set standards that are stricter than those of the national regulations approved since 1982. The approval of those standards was based primarily on the review of international literature and regulations. The regulated sector represented by ANDI[213] was consulted during the elaboration of the regulation that defined emission standards for fixed sources[214]. However, after the regulation was approved it has manifested that *Resolution* 1208 of 2003 "…is partially a copy of European standards which are not economically feasible for the conditions of Bogotá"[215] and that "…the need and levels of those standards have not been technically supported, therefore their economic efficiency is questionable.". Other stakeholders such as communities or NGOs have not been called to participate in the discussions related to the design and approval of air pollution regulations in Bogotá. Their absence indicates that there is room to increase the transparency of the process of regulation design and approval. The air regulations enforced by the Environmental Unit of the Aburrá Valley are those approved by the national government for the entire country. Specific ambient and emission standards have not been approved. Therefore, there have not been major debates between the local governments and the regulated sector in relation to air pollution standards. The fact that despite the monitoring and health information gathered, the national ambient standards approved in 1982 remain unchanged could also indicate the uneven participation of the different stakeholders in the regulatory process.

As in the case of Bogotá, every car in the Aburrá Valley has to obtain an emissions certificate. Although, as indicated before, the total costs paid for

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[211] Interviews with Mr. Carlos Mario Tamayo Director of Environmental Quality at DAMA; and Mr. Carlos Herrera Environmental Director of ANDI. March 2004. Bogotá. The author of this study was DAMA's Director when *Resolución* 160 of 1997 was approved.

[212] Resolución 1208 of 2003 for fixed sources; and Resolution 556 of 2003 for mobile sources.

[213] The National Association of Industries.

[214] Interviews with Mr. Arturo Sanchez Director of Environmental Quality of DAMA between 1994 and 1997 and with Mr. Manuel Felipe Olivera Director of DAMA from 1998 to 2002. Bogotá. December 2003.

[215] Interview with Mr. Carlos Herrera. Environmental Director of ANDI. March 2004. Bogotá.

the certificate of emissions are relatively high[216] and its environmental benefits have not been proven[217], there has not been a social reaction against these control programs. This could be related to the fact that these control programs are popular as they make people feel that they are making their contribution to improve environmental quality. Additionally, there is a relatively high level of awareness in relation to air pollution problems which, as indicated previously, is reflected in the willingness to pay for environmental quality[218,219].

The judiciary system has played a role in environmental control since the late eighties and early nineties. In fact, many of the early legal actions were used to solve air pollution problems. A Citizens' Rights Action (*Acción de Tutela*) was first used to demand the protection of the environmental rights of communities affected by air pollution problems in 1991[220]; the same year that this type of legal action was created by the Constitution. The frequency in the use of Citizens' Rights Action related to the protection of the rights to health and to life grew from 6.100 in 1995 to 20.500 in 1999[221]. Although not all of those cases are specifically related to air pollution[222], the growth in the use of this action is significant. Another type of legal action that has been used to control air pollution problems is the Popular Action. This type of action can be used to protect collective environmental rights[223], and can be presented by an individual on behalf of an undetermined group of people. Statistics as to the use of this type of action are not available.

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[216] US$ 5.536.800 in Bogotá and in 1.350.000 in the Aburrá Valley, during 2002.

[217] MÉNDEZ, M. (2003). *Op. cit.*

[218] CARRIAZO, F. (2000). *Op. cit.*

[219] IBÁÑEZ, A.M. and McCONNELL, K.E. (2001). *Op. cit.*

[220] SÁNCHEZ, E. y MEDINA, G. (1994). En: E. Sánchez y E. Uribe. *Contaminación industrial en Colombia* (1994). DNP. PNUD. Bogotá.

[221] *Estadísticas sobre la acción de tutela* (1999). Corte Constitucional. Consejo Superior de la Judicatura. Bogotá.

[222] There is no information as to the total number of legal actions specifically related to air pollution.

[223] Collective Environmental Rights include the right to a clean environment and the right to participate in the decisions that may affect it (Article 79 of the Constitution of 1991).

The Citizens' Rights Action is the most frequently used legal action to demand the solution of air pollution problems[224]. In Bogotá the Citizens' Rights Action has been used, almost exclusively, against fixed sources of pollution. They are mostly used by low income local communities that live in the vicinity of industries such as brick factories and tanneries and by small commercial establishments such as dry cleaners, carpenter's shops and restaurants.

Legal actions have been used to a lesser extent to demand the solution of the air pollution problems caused by mobile sources. In those cases Popular Actions have been used. In fact, a series of five popular actions were presented between 2001 and 2003 by independent citizens against the Transmilenio system in Bogotá[225]. Those citizens argued that this massive transportation system was causing air pollution problems. However, to this date, the decisions of the judicial system have been favorable to the Trasmilenio system.

In Bogotá, in all the cases where judges have ordered pollution control actions, those actions have been implemented[226]. In 28% of the cases the judges have ordered the use of alternative dispute resolution mechanisms in which DAMA has played a role in overseeing the compliance of those voluntary agreements.

Although specific information for the case of the Aburrá Valley is not available, the role of the judicial system should not be different.

On the other hand, the office of the General Attorney (*Procuraduría General de la Nación*) has a Delegate Office for Environmental Matters (*Procuraduría Delegada para Asuntos Ambientales*). The National media frequently publishes the findings or opinions of this office. Recently[227],

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[224] Interview with Mr. Orlando Sepúlveda from the Lagal Unit of DAMA. Bogotá. December. 2003.

[225] *Ibid.*

[226] *Ibid.*

[227] In Febmrury 14, 2004.

the national newspaper, EL TIEMPO, published a report by the Attorney General[228] which indicated that the air quality data provided by the environmental authority of Bogotá, DAMA was not entirely reliable. According to the Attorney General's Office, the monitoring stations were not located in adequate sites and the stations were deficiently maintained and operated. A similar evaluation is presently conducted in Medellín by the General Attorney's office.

### D. The Means by Which the Adopted Solutions are Executed

DAMA and the Environmental Unit of the Metropolitan Area are responsible for coordinating the implementation of the various components that contribute to air pollution control. In both cases a committee was established to facilitate coordination. In the case of Bogotá, DAMA heads the committee which is integrated by representatives from the Ministry of the Environment, the city's departments of health and transportation, the *Universidad de los Andes*, Transmilenio, and the National Industry Association - ANDI. In the case of Medellín, the committee is integrated by the Metro of Medellín, the departments of planning and transportation of Medellín and of the other nine municipalities of the Aburrá Valley, and by the private associations of industries and of the transportation sector[229].

The air monitoring stations of Bogotá and of the Aburrá Valley are presently used to compare air quality with respect to local ambient standards and to observe tendencies. However, in neither of those cases the local environmental authorities have adopted a systematic process for the evaluation of the environmental benefits of the different air pollution control and prevention actions. Most of the quantitative evaluations of pollution prevention and control actions in Bogotá have resulted from graduate

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[228] *Informe de control de gestión con fines preventivos sobre la operación y diseño de la red de monitoreo de calidad del aire de Bogotá* (2004). Procuraduría General de la Nación. Bogotá.

[229] HOYOS, O. (2002). *Op. cit.*

research projects in different Universities[230 ,231 ,232 ,233 ,234 ,235]. The results of these studies have not influenced decisions related to the design of air pollution policies in the Bogotá[236]. Similarly, the Metropolitan Area of the Aburrá Valley has not undertaken evaluations of the benefits and costs of its air pollution prevention and control actions. It is expected that, in the future, the information provided by the networks in Bogotá and in the Aburrá Valley will be used to generate control measures to prevent pollutions episodes, to adjust environmental policy and regulation and to design urban and transportation strategies.

Besides coordinating the implementation of the various components that contribute to the Air Pollution Prevention and Control Program of Bogotá, DAMA and the Metropolitan Area are also responsible for the enforcement of air regulations. As indicated in section I.E.1, a recent study[237] found that DAMA is among the environmental authorities which develops more control activities[238] in Colombia, while the Environmental Unit of the Metropolitan area is one of the agencies which has developed the fewest control activities. This difference in environmental control could be related to the fact that while DAMA acts exclusively as an environmental authority, the Metropolitan Area of the Aburrá Valley is mainly responsible for planning and coordinating the development of the municipalities of the Aburrá Valley. Its functions as environmental control agency were defined only until 1994[239]; that is 14 years after its creation. The environmental control actions of this institution are delegated to an Environmental Unit. Clearly, environmental control is not the

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230 MÉNDEZ, M. (2003). *Op. cit.*

231 CALIXTO, D.C. y DÍAZ, A.V. (1996). *Op. cit.*

232 URDANETA, S. (1999). *Op. cit.*

233 CARRIAZO, F. (2000). *Op. cit.*

234 IBÁÑEZ, A.M. and McCONNELL, K.E. (2001). *Op. cit.*

235 LOZANO, N. (2003). *Op. cit.*

236 Interview with Mr. Carlos Mario Tamayo. Director of Environmental Quality at DAMA. December 2003. Bogotá.

237 URIBE, E.; CRUZ, G.; CORONADO, H. y GARCÍA, J. (2001). *Op. cit.*

238 Number of fines and letters by DAMA to the industrial plant.

239 *www.metropol.gov.co.*

main mandate of the Metropolitan Area of the Aburrá Valley. In fact, environmental control could eventually be in contradiction with the main mandates of this institution, which include the planning and promotion of activities such as transportation systems, public infrastructure and housing projects[240]. Thus, it is not surprising that stricter environmental control is not undertaken and that stricter air regulations have not been approved.

On the other hand, the representatives of the industrial sector in jurisdiction of the Metropolitan Area of the Aburrá Valley consider that their environmental authority is institutionally unstable and inflexible. The level of control exerted by an environmental authority is important as it affects the environmental investments by the industry. As a matter of fact, in Bogotá the investments of industrial plants in pollution control are positively affected by the control activities of DAMA. That is, those investments grow as the control activities of DAMA increase.

Several components of the Air Pollution Prevention and Control Program of Bogotá and the cities and municipalities of the Aburrá Valley are not related to the enforcement of environmental standards. That is the case of central components such as the extended use of natural gas or the expansion of the massive transportation systems. In these cases, where the private sector is largely involved and where there are not public subsidies, long term sustainability would be largely dependent on financial viability.

## III. Lessons and Recommendations

The following are the main lessons and recommendations from this case study:

- National air quality standards were approved in 1982. The benefits, efficiency and effectiveness of those standards have not been rigorously evaluated. Since 1982, much information has been collected and research has provided a better understanding of the health effects of air pollutants. There is a need to evaluate, update and complement the standards approved in 1982, in light of this new information.

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[240] HOYOS, O. (2002). *Op. cit.*

- Local emission standards were developed in 2003 for the control of fixed and mobile sources of air pollution in Bogotá. The regulated sector, represented by ANDI[241].was consulted during the elaboration of the regulations that defined emission standards for fixed sources[242]. Other stakeholders such as communities or NGOs were not called to participate. Their absence indicates that there is room to increase the transparency of the process of regulatory design. Measures should be taken to control the capture of the environmental agencies by the regulated sectors, and to ensure a balanced participation of all interested stakeholders during the regulatory processes.

- A series of air pollution prevention and control actions have been implemented In Bogotá and Medellín. These include environmental education, technology transfer, traffic restrictions, control activities, the promotion of alternative fuels and massive transportation systems, amongst others. However, governmental efforts to evaluate the impact of those actions on air quality have been very limited. Under those circumstances, the environmental agencies of Bogotá and Medellín lack objective basis to determine the priority level of different actions and to promote them among the different social actors and stakeholders. The continuation, the scope and the level of priority assigned to those prevention and control actions should be based on the results of their quantitative evaluation.

- Not all of the actions that integrate the strategies for air pollution prevention and control in Bogotá and Medellín are implemented by the environmental agencies of those cities. In fact, projects and actions implemented by sectors such as transportation and energy could have important benefits in terms of urban air quality. This is the case of the massive transportation systems of Bogotá and Medellín, the restrictions in the use of private vehicles, the surtaxes on gasoline, and the promotion of bicycle use and of fuels such as natural gas. In this respect,

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[241] The National Association of Industries.

[242] Interviews with Mr. Arturo Sanchez Director of Environmental Quality of DAMA between 1994 and 1997 and with Mr. Manuel Felipe Olivera Director of DAMA from 1998 to 2002. Bogotá. December 2003.

environmental authorities should be aware of the opportunities of those actions, should evaluate their environmental benefits and, if appropriate, should contribute to their promotion.

- Since its creation in 1980, the Metropolitan Area of the Aburrá Valley has acted as a regional planner and promoter of development projects. This includes transportation, sanitation, infrastructure and housing projects. Fifteen years later this institution was restructured to undertake additional functions as environmental authority. There are potential conflicts of interest between its traditional responsibilities and the new environmental functions that this institution has been assigned. Under these circumstances, the transparency in the decision making processes related to the design an implementation of environmental control actions might be jeopardized. In the case of DAMA of Bogotá, such conflicts might also be present as this institution depends on the local administration which also promotes and develop such projects. In this last case, however, the fact that DAMA does not directly promote infrastructure projects with potential effects for air pollution lowers the risk of this type of conflict. Legal reforms to minimize the risk of conflicts of interests within environmental institutions should be proposed. Those reforms should also assign responsibilities to other agencies which can contribute to the prevention and control of air pollution (ECOPETROL, Ministry of Energy, etc.).

- The effects of air pollution on health have been studied in Bogotá. Negative effects of particulate mater (TSP) and $NO_2$ on respiratory illnesses have been reported in this city. However, most of those studies correspond to students' Masters thesis. Empirical evidence of the effects of air pollution on human health is not available for the city of Medellín. There is a need for additional studies that investigate the effects of air pollution on human health in Bogotá and in Medellín. Those studies should be part of a wide and long term governmental program on air pollution prevention and control. Their results should be taken into consideration for the design of air quality objectives in these two cities. Drawing from international studies would be a useful start in providing information on health impacts, and hence prioritizing which pollutants should be tackled first.

- The environmental authorities of Bogotá and Medellín have made important efforts to increase social awareness about air pollution

problems as described earlier. In Bogotá, for example, most people can relate respiratory illnesses with air pollution[243] . The mass media has also contributed to the dissemination of information related to air pollution. Actions to increase awareness about air pollution should be maintained; especially if citizens are expected to participate actively in the development of air pollution control and prevention actions, such as vehicle emissions' evaluation and traffic control measures.

- In addition to environmental authorities, other instruments have contributed to air pollution control and to increase public awareness. Those are the cases of the judiciary system, the mass media and the General Attorney's Office. The use of legal actions by NGO's, citizens and communities has increased significantly during the last decade. Environmental agencies should actively promote the use of these legal actions. Additionally, the Office of the General Attorney and the mass media have contributed to increase awareness about air pollution and to supervise the performance of environmental agencies.

- Although Colombia initiated air monitoring since 1967 and there is a relatively long tradition of air pollution control (since 1982), information related to air pollution management in Colombia is scarce, disperse and, in many cases, of poor quality. The continuity of institutional efforts has been interrupted and valuable information has been lost. Additional efforts should be made to build an institutional memory regarding pollution control programs.

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[243] MATURANA, J.G. (2000). *Op. cit.*