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Considerations of the Impact of $PM_{2.5}$ Particulate Matter a Health: The Meaning and Impact of Levels and Air Quality Limits on the Aburrá Valle Region in Colombia

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Abstract

There is no doubt that health issues are extremely important when dealing with the impact of air pollution. Increasingly, society is becoming more aware of the enormous risks of pollution. However, information on the relationship between exposures of population to pollution, particularly $PM_{2.5}$ urban concentrations, is not completely clear for the public and even for environmental authorities. Although, WHO has published guidelines for this, their interpretation to actual urban situations in underdeveloped countries cities is somewhat confusing. The author has review, WHO guidelines and applied them to the particular situation in the city of Medellín and the Aburrá Valley region, in Colombia. This region, because of its topography and climate, experiments high $PM_{2.5}$ episodes in some months of the year, and when that occurs, there are all kind of speculation in the media about this and about the high numbers of death people that this causes. It is proposed to have a more equilibrated approach on this issue when taking mitigating measures and when communicating to the people on the health effects associated. At the same time, it is important to promote research on health issues and their relationship with the environment at the local level, and also to understand the local factors that relate climate, atmospheric visibility and pollution episodes. There must be efforts to establish sensible mitigation and protection of people and property in the face of pollution episodes and not just stimulate fear and a chain of accusations and finger pointing among the communities based on misguided interpretations of the health effects of pollution episodes.

Keywords: Air pollution; Air quality; Health effects; Urbanization

Introduction

The complexity of the issue of health-air pollution relationships

There is no doubt that health issues are extremely important when dealing with the impact of air pollution. Increasingly, society is becoming more aware of the enormous risks of pollution. From a risk standpoint, emphasis is placed on how dangerous progress is, especially that of cities, which spread dramatically across the land, rapidly swallowing natural resources, creating inequalities and injustices [1-6]. Some argue that in this way the planet is being driven to some kind of collective suicide due to the combined impact of global warming and pollution. From a more positive perspective, although progress has been the cause of much of the environmental deterioration, others suggest that it will help to get out of the problem. This can happen with new technological vectors such as nanotechnology, with new concepts such as circular economy, with new models of service and exchange of goods, wisely making use of an intensive and efficient use of resources and developing mechanisms for processes to be regenerative and non-polluting.

At the same time, cities do not cease in their constant change, which makes them increasingly attractive, leading humanity to a growing urbanization. Cities offer culture, education, recreation, social organization, health care, access and transportation facilities, goods distribution mechanisms, access to information and communications, among others, which are very attractive to almost all city inhabitants of the planet. These generally include almost all of those who feel anxious, responsible, and concerned about the dire predictable demographic, climatic, ecological and social situations. Considering that there will be 9 billion people in the world by 2050, a number of specialists consider that it is better to have people in cities than to have them dispersed since impacts can be better controlled and resources can be better utilized [2-5].

It is important to achieve points of equilibrium and proper functioning for these phenomena of opinion, growth, health status, physical realities, economy, and social structures. It is not through mechanisms of fear, sowing anxieties and fears, establishing accusations and social divisions and calls for an idealized past (which never existed and will not return) that these balances are achieved. What is required is to recover the force of reason, driven by noble and humanistic emotions and goals, and a more spiritual vision, so that through imagination, creativity, inventiveness and committed, loving and persistent teamwork, better operating points can be reached [2,4,5]. Persons have the responsibility of working from their own being and human sense, to understand that their lives do not end with death, but go beyond it. All must be aware that human beings are one of the youngest species on the planet, and still have a lot to evolve.

The need for high quality information on health issues

In this sense, it is important to have high quality information, so that decisions have increasingly good foundations. It is not easy to have objective information on health issues and their relation to pollution, given the complexity of the phenomena and the many variables that influence the behaviour of the human body, including some as complex to isolate and to study as is in itself the system of individual and community beliefs.

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Underdeveloped countries tend to lag in this field, which requires knowledge, statistics, discipline, and funds to be dully established. There is a tendency to just follow international air quality standards and replicate their health-oriented conclusions to the local situation. Considering this, a first effort that is worthwhile is to develop studies and establish meaningful data to help determining the extent to which air pollution affects the health of populations in developing countries cities and rural areas. Although the issue of environmental pollution have been addressed, in some way, in these countries for nearly 50 years, the main body of knowledge on pollution-health relations that is in the public domain or that has penetrated the collective consciousness, and even the scientific conscience, is still insufficient. For example, in 2005, the OPS (Pan-American Organization of Health) found that from 1994 to 2004 there were only 85 referenced studios on air pollution and its health effects in the Latin America and the Caribbean region and none of them was produced in Colombia [8]. As per the local authorities as a source of information on health and air pollution for the city of Medellín, but in reality [9], it does not go deeply into that. The official report of the quality of life of the city [10] only mentions health impacts on the context of air pollution concentrations and their comparisons to WHO limits.

At the collective level, there are the World Health Organization (WHO and the Pan American Health Organization (PAHO), entities that are attentive to the collection of scientific and research published information on health and pollution. They interpret and convert it into indicators and quality limits that can be used by local authorities and by the various social organizations, as ways to manage situations that arise with air pollution. In this way, those organizations are seeking a better quality of life and it is wise to rely on their advice in regions that lack information that is more specific.

The interpretation of information on health-air pollution relations

In this sense, it is worth analyzing the information presented and interpreting it, in such a way that there is good judgment and wisdom when informing the public, the media and when making decisions. It is not advisable just to simply make quick readings of the indicators, of the limits, and of the alert levels.

For example, at first, simple interpretations could indicate that a limit that is established, protects in such a way that, when values exceed the limit, the situation is dangerous. On the other hand, if they are under the limit, the situation is safe. However, it is clear that there are variations in the air quality data, especially when there is equipment that measures instantaneously and is able to register and measure excursions of short or long duration to very high values, well above some limit. In this case, how is the limit and its level of protection interpreted?

Another example and a second level of interpretation, shows that there are several impacts associated with pollution, which will depend on many variables including individual behavior and the defense mechanisms that individuals can assume in relationship to what they perceive to be dangerous. These include variables such as the duration of the polluting episode and its levels. In the case of particulate matter, the characteristics of the material, its sizes and forms.

A deeper level of interpretation has to do with all the complex issues related to the pollution situation and its effects. All these issues are integral, part of a system, and the actions that cities, authorities and persons take when reacting to what is perceived as crisis or a danger, will give rise to feedback cycles and loops of a nature that is not always linear and predictable [11-13]. Horst Rittel [14] coined the term "wicked problem", perceiving the limitations of the linear approach to design and planning. According to this view, traditional planning methods are inadequate for the solving of ill-structured problems, because of lack of information and transparency, as complexity creates barriers to information sharing. Now the case of large cities in underdeveloped countries is extreme, considering that poverty, lack of resources and lack of education and social inequalities are part of this complexity.

Apart from the complexities, it is worth at least to try to attain some consistency in the basic figures that are presented to the public, at least those that have official origin. In principle, it is desirable to know the impact of pollution on health, reflected in an indicator that everyone can understand, and if possible, correlated with air quality data. Unfortunately, sometimes the official information is not clear. For example, when consulting material for preparing this paper, it was seen that a presentation by the Pan American Health Organization, OPS, (2014), [15] mentions that 9.4 excess deaths occur per 100,000 inhabitants due to air pollution. Considering that the world has about 7,000 million population, this means 658,000 annual deaths will occur in the world. However, in the same report, and in the WHO guide [16], there are 2 million deaths per year in the world due to air pollution. This means 28.5 deaths per 100,000 inhabitants, which is 3 times higher.

Extrapolating both figures to the Aburrá Valley region, with 3.84 million population, the death indicator attributable to air pollution would give either 359 deaths per year (0.98 deaths per day) or 1,091 annual deaths (2.99 deaths per day) Obviously these two figures give very different information.

At the same time, the local main newspaper [17] stated 5 deaths per day due to air pollution in the city of Medellín, with 2.64 million people, which would mean 74 deaths per 100,000 inhabitants. Other media, international media mentioned 8 deaths per day [18]. All these wildly different indicators create disconcert and fear among the communities and show the lack of real data and research behind the figures.

Interpreting the WHO information on $PM_{2.5}$

An attempt is now presented to interpret WHO's guide to health and to visualize on this basis the situation in the Aburrá Valley. The guide says that the burden of diseases due to air pollution is more than two million premature deaths per year. Those can be attributed to the effects of air pollution in open and enclosed urban spaces. More than half of this burden of disease falls on the populations in developing countries. The real figure is not mention in the guide. A value of 2 million will be taken, brought to 2015 with an annual rate of 1.25%, as the basic mortality data used in this analysis, which amounts to 2.25 million premature deaths per year for the world in 2015.

The document states that the existing evidence on airborne particulate matter (PM) and its effects on public health show that there are adverse health effects with the exposures currently experienced by urban populations in both developed and developing countries. The range of effects on health is wide, and occurs particularly in the respiratory and cardiovascular systems, affecting the whole population. It is indicated that the risks increases with exposure, and that there appears to be no threshold value below which there are no adverse effects on health. It implies that the lowest level of concentrations showing adverse effects is not much higher than the background concentration, which is estimated at 3-5 $\mu g/m^3$ for particles of less than 2.5 μm ($MP_{2.5}$) in the United States and in Western Europe. The background concentrations for the Aburrá Valley, range from 3 to 10 $\mu g/m^3$ [19]. Epidemiological evidence reveals adverse effects of PM upon both short and long exposures.

As even for low background concentrations there are health impacts, it is considered that no standard or guide value will provide complete protection to all people against all possible events or adverse effects of particulate matter on health. It is therefore pointed out that the process of establishing air quality guidelines for fine PM should be geared towards achieving the lowest possible concentrations taking into account local public health constraints, capacity and priorities.

Following this, $PM_{2.5}$ has adverse effects at all levels, even at those in the background, and therefore, in establishing standards, the lowest possible concentrations are sought, taking into account local capacities to assume the cleanliness of the environment. Only a zero level could perhaps ensure that there are no impacts. One might wonder, then, how is the behavior of the curve that correlates the levels of $PM_{2.5}$ pollution to the health effects. In this sense, although the WHO documents do not give a clear direct guide, an indirect one can be deducted, as will be shown. The guide mentions two situations and two different levels of impact. The first has to do with the long-term impacts, which can be deduced from the average annual $PM_{2.5}$ concentrations, which are those resulting from the statistical analysis of the concentrations measured at sampling stations in a given region, averaged as a daily mean, on the 365 days of the year. For these annual mean concentrations, WHO has proposed four guideline levels, which are defined in Table 1.

According to this table, it is desirable to achieve an AQG value of at least 10 μg/m^3. In addition, WHO establishes three additional levels, referred to as "interim targets", of 15, 25 and 35 μg/m^3 for which mortality risks increase at specified percentages relative to that existing for the AQG level. The risk of mortality for AQG is not directly stated, but it is clear, as will be seen below, that this is not a zero risk.

The second WHO guide has to do with the acute impacts resulting from pollution episodes leading to some higher daily concentrations of $PM_{2.5}$. These correlate with the average of the top 1% of the annual daily data, which is, essentially the average of the three highest daily data of daily concentration occurring in a region in a given year. For these cases WHO also has four levels, which are defined in Table 2.

According to this table, it is desirable to achieve an AQG value of 25 μg/m^3. In addition, WHO establishes three additional levels, also denominated "interim targets", of 37.5, 50 and 75 μg/m^3 for which short-term mortality risks increase at specified percentages compared to the AQG level. The short-term mortality risk for GCA is not directly stated, but it is also clear, as will be seen below, that it is not a zero risk.

Application of WHO health $PM_{2.5}$ guideline information to the case of the Aburrá Valley

In order to reach a reasonable approximation to determine short-term and long-term risks of premature mortality associated with WHO levels in terms of $PM_{2.5}$ levels in the world and in the Aburrá Valley region, an analysis of some existing information on $PM_{2.5}$ and its relationship to what is meant by Tables 1 and 2, will be described.

The first consideration is the level of annual premature deaths attributable to $PM_{2.5}$, in both its short and long term manifestations. The following has been considered by the author:

- Departing form the excess annual current worldwide deaths attributable to air pollution (by 2015), estimated at 2.25 million (the 2 million given by WHO in 2005 projected to 2015) , the impact of $PM_{2.5}$ on this total deaths was taken as very important, so 75% factor applicable to the 2.25 million total was chosen. Out of this, the impact of the $PM_{2.5}$ on long-term deaths, associated to mean yearly averages, was taken as 33%, while the impact of the $PM_{2.5}$ on short-term deaths (due to episodes) was taken as the more important one, and given 67%.
- Based on this, it was estimated that the excess annual current worldwide deaths from $PM_{2.5}$ long-term effect is 0.56 million, while the excess annual current worldwide deaths due to $PM_{2.5}$ short-term (episode) effects is 1.13 million.
- At present (2012-2015) and based on a study done by the author [20], using available data for 25 cities of the world, there are mean annual concentration for $PM_{2.5}$ in such 25 cities ranging between 9.3 and 55.6 μg/m^3, with an average of 22.6 μg/m^3. The mean value for Medellín (to be taken as the Aburrá Valley), is 26.9 μg/m^3 (Figure 1). Accordingly, it is considered that the current situation of the world is reflected in the average situation of the sample of 25 cities for the case of average annual values.
- In order to approximate the situation of 24 h concentrations, with its averages of three maximum values per year, information was taken from the air pollution monitoring network of the

	PM_{10} (μg/m^3)	PM_{25} (μg/m^3)	Basis for the selected level
Interim target-1 (IT-1)	70	35	These levels are associated with about a 15% higher long-term mortality risk relative to the AQG level.
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% (2-11%) relative to the IT-1 level.
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% (2-11%) relative to the IT-2 level.
Air Quality Guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to PM_{25}.

[a]The use of PM_{25} guideline value is preferred

Table 1: WHO air quality guidelines and interim targets for particulate matter: annual mean concentations[a].

	PM_{10} (μg/m^3)	PM_{25} (μg/m^3)	Basis for the selected level
Interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over the AQG value).
Interim target-2 (IT-2)	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over the AQG value).
Interim target-3 (IT-3)*	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over the AQG value).
Air Quality Guideline (AQG)	50	25	Based on relationship between 24 h and annual PM levels.

[a]99th percentile (3days/year). *For management purposes. Based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means. The frequency distribution of daily PM_{25} or PM_{10} values usually approximates to a log-normal distribution.

Table 2: WHO air quality guidelines and interim targets for particulate matter: 24 h concentations[a].

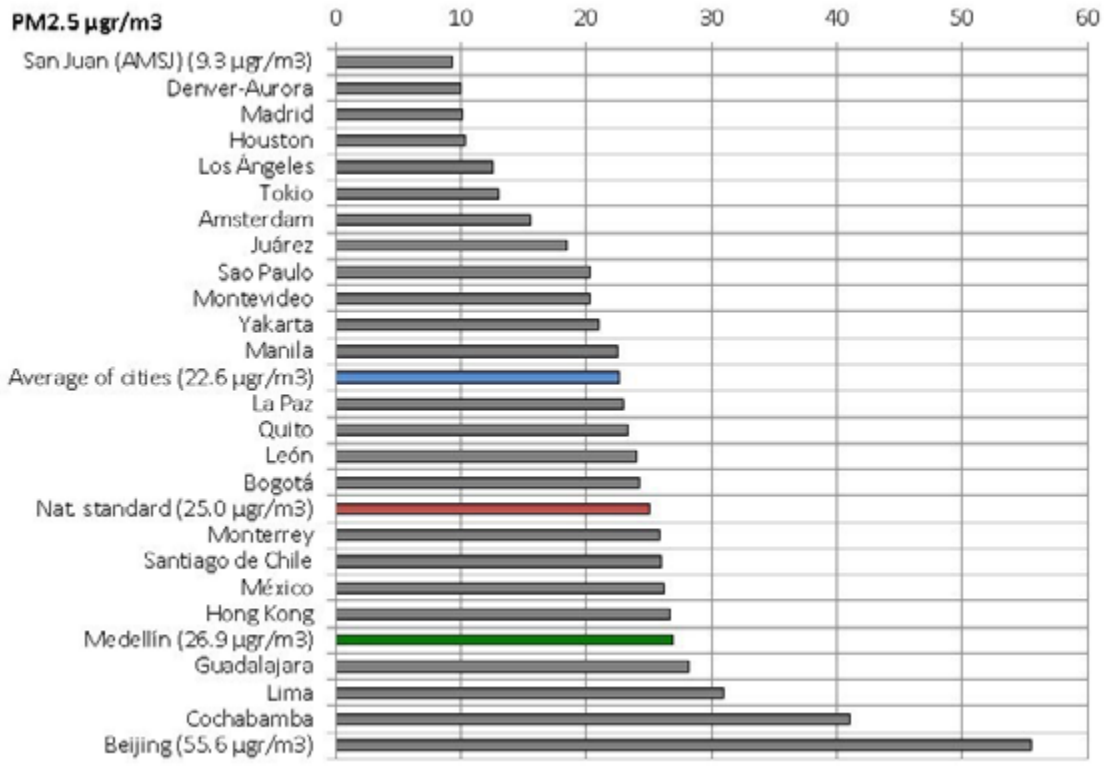

Figure 1: $PM_{2.5}$ annual mean concentrations for a sample of 25 cities in the world [19].

city, based on data [20] delivered by the Calaire laboratory of the National University of Colombia, Sede Medellín. This laboratory administered at the time the system of automatic air quality stations for the region. According to the information received and registered in 9 stations, it was found that in the years 2014-2016, the percentile of data with values greater than 99.2% of the days, was 66.4 µg/m^3. Relating this value to the daily average, a factor of 2.47 is obtained. The author has applied this factor to the mean of the cities of the world, to get a 24 h percentile value of 99% for the mean of cities of 56.5 µg/m^3. These values will be taken to interpret the health data in Table 2 of WHO.

- With those figures, mortality impacts can be estimated, as shown in Tables 3 and 4. Figure 2 and 3 show the relationships found between associated expected premature deaths and $PM_{2.5}$ concentrations, both for annual mean values and for 24 h concentrations at 1% maximum value in a year.

- Accordingly, it is found that the total associated premature deaths coming from short-term (episodes) and from long-term (annual averages) would be 2.41 deaths per day if quality levels are achieved similar to the WHO GCA and 2.81 deaths per day for critical cases, such as those that would occur if the quality deteriorates to levels such as those in Beijing. Both extremes are not predictable in the short term for the region, which currently appears to have 2.56 deaths per day.

Conclusions

It follows from the foregoing considerations that there is no basis for the extreme high air pollution mortality figures that tend to be reported by the media, during high level pollution episodes attributable to atmospheric phenomena in Medellín and the Aburrá Valley, that tends to occur in the months between March and May April. Total associated deaths would be in the neighborhood of 2.6 deaths per day and not as high as the 8 deaths per day that some media mention.

It seems clear that it is not possible to achieve the total elimination of premature deaths, even when air quality it significantly improved. Ate the same time, no catastrophic increases in mortality are to be expected, when pollution episodes occur. Therefore, it does not seem wise for the society to entertain whole paraphernalia of accusations and finger pointing when there are higher pollution levels, mainly caused by climatic and atmospheric effects.

A region like the Aburrá Valley seems to have the capacity to react with wisdom, with a sense of planning and with the use of strategic tools, since no disastrous situations are occurring with the episodes. Of course, unless an entire new belief system is created that makes people feel that they are going to die or that they are going to experience serious consequences. In such a case, it can be considered that the health situation of people whose mental states are quite susceptible or influentiable will be seriously affected.

Because of the lack of awareness, this could happen at present. This shows that it seems advisable to establish personal protection systems that allow susceptible people to have the means to go through episode crisis without serious negative consequences. The most obvious is the use of low-cost personal protection filters, recommended by the authorities. This can be done when $PM_{2.5}$ average 24 h $PM_{2.5}$ concentrations reach red alerts or even orange alerts. Naturally, there must be other measures associated with the establishment of alert states, so that population that

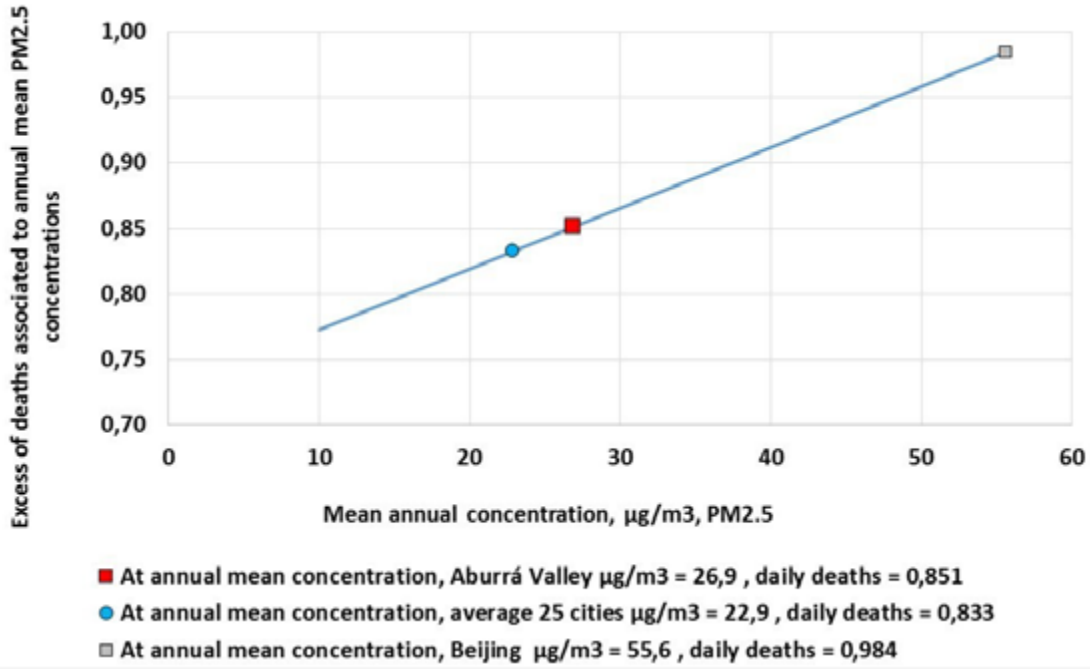

Figure 2: Associated expected premature deaths for mean annual $PM_{2.5}$ concentrations.

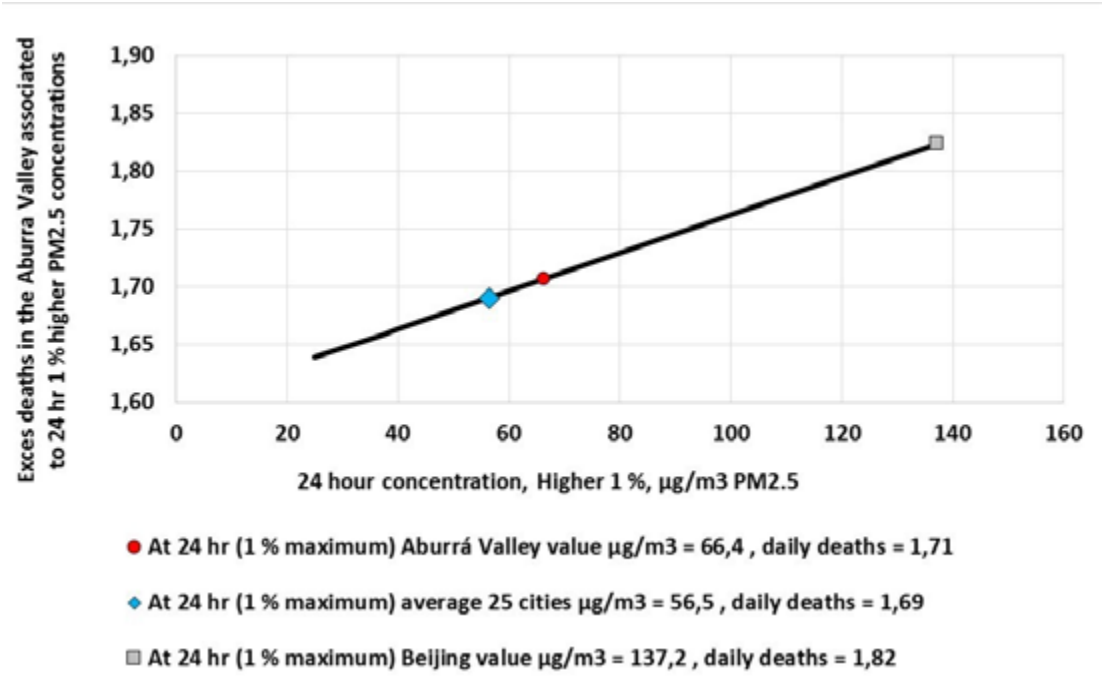

Figure 3: Associated expected premature deaths for 24 h $PM_{2.5}$ concentrations.

is more susceptible are not unnecessarily exposed to highly polluted environments when such events occur.

This has little to do with the constant and imperative need to work in a sustained and persistent way to clean the air of the region and to generate the lowest pollution levels possible. There are several objectives, other than those of health that should be pursued, such as the following:

- It is desirable that the sky of the region be clear and clean. The city is not attractive with a layer of mists and smog that people easily relate to pollution. On the other hand, it has to be taken

Situation considered	Mean annual PM2.5, µg/m3	Increase in premature deaths as compared to the ones a AQG, %	Annual premature deaths in the world, million	Annual premature deaths in the world, deaths per thousand	Annual premature deaths in Aburrá Valley, persons
At GCA OMS	10.0	0.00	0.517	0.074	282
At very controlled situation	12.0	1.20	0.523	0.075	285
At OI 3 OMS	15.0	3.00	0.532	0.076	291
At highly controlled situation	16.1	3.68	0.536	0.077	292
At reachable controlled situation	21.5	6.91	0.553	0.079	302
At average, of a 25 cities sample in the world	22.9	7.74	0.557	0.080	304
At OI 2 OMS	25.0	9.00	0.563	0.080	307
At average concentration Aburrá Valley, 2014	26.9	10.14	0.569	0.081	311
At OI 3 OMS	35.0	15.00	0.594	0.085	324
At mean yearly concentrations of Beijing	55.6	27.36	0.658	0.094	359

Table 3: Mortality associated to mean annual $PM_{2.5}$ concentrations in the world and the Aburrá Valley under several considerations.

Situation considered	24- hour PM2.5, 1% high percentile, µg/m3	increase in premature deaths as compared to the ones a AQG, %	Annual premature deaths in the world, million	Annual premature deaths in the world, deaths per thousand	Annual premature deaths in Aburrá Valley, persons
GCA OMS	25.0	0.00	1.10	0.157	598
At very controlled situation	30.0	0.48	1.10	0.157	601
At OI 3 OMS	37.5	1.20	1.11	0.158	605
At highly controlled situation	39.8	1.47	1.11	0.159	607
At reachable controlled situation	53.1	2.80	1.13	0.161	615
At 24 hr 1% high percentile, average 25 cities in the world	56.5	3.14	1.13	0.162	617
At OI 2 OMS	50.0	2.50	1.12	0.161	613
At 24 hr 1% high percentile, Aburrá Valley, 2014	66.4	4.13	1.14	0.163	623
At OI 3 OMS	75.0	5.00	1.15	0.164	628
At 24 hr 1% high percentile, similar to Beijing	137.2	11.24	1.22	0.174	665

Table 4: Mortality associated to 24 h $PM_{2.5}$, 1% high percentile concentrations in the world and the Aburrá Valley under several considerations.

into account that this region often presents fog and cloudiness that have very little to do with pollution.

- Pollution is often the result of disorder, lack of culture, lack of cleanliness and social and cultural indiscipline. All these aspects are negative traits and cause social costs and inefficiencies. Controlling pollution is generally cost-effective.
- Each of the social actors, individually and collectively, should consider strategies to eliminate emissions to the lowest possible limits. Many simple things can be done: avoiding throwing garbage in causeways and streets; keeping vehicles and manufacturing processes in good condition; checking exhaust pipes and chimneys so that they do not show visible emissions, fumes and black deposits; avoiding the presence of dust, oil and other materials on the streets; keeping the sidewalks, streets, gardens, parks and green areas clean. An obvious measure is to avoid "walking chimneys in the streets", as they occur when people smoke in them; People who smoke tobacco or marijuana should understand their personal risks and their collective impacts and this habit should be severely restricted in the streets and parks.
- Improve the level of knowledge and technologies associated with pollution and the environment. For the Aburrá Valley, vehicles and transportation system are the main sources of air quality problems, with industries as a second important source. Continuous and decisive action must be made that will definitively resolve this situation, taking advantage of the advantages of the region, its attractive geography, its valley nature with a river that crosses it, its wealth in electricity and its human, technical and scientific capacity.
- It is important to promote research on health issues and their relationship with the environment.
- It is also important to understand the local factors that relate climate, atmospheric visibility and pollution episodes.
- There must be efforts to establish sensible mitigation and protection of people and property in the face of pollution episodes.

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