

## Report

# Towards establishing air quality guidelines for Pakistan

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## نحو وضع دلائل إرشادية لجودة الهواء في باكستان

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**الخلاصة:** بالرغم من وجود معايير قابلة للتنفيذ تتعلق بالجودة الوطنية البيئية لمكافحة الملوثات في باكستان، إلا أنه لم يتم أبداً وضع دلائل إرشادية لجودة الهواء المحيط في باكستان، إذ إنه لا يوجد نظام موثوق للرصد الوبائي والسمومي في باكستان يمكن أن يوفر قاعدة لوضع الدلائل الإرشادية لمختلف ملوثات الهواء. وتتناول هذه الورقة البحثية الدلائل الإرشادية لمنظمة الصحة العالمية المعنية بجودة الهواء، وكذلك المعايير المطبقة في بعض بلدان إقليم شرق المتوسط، وإقليم جنوب شرق آسيا. وبناءً على هذه الدلائل الإرشادية وكذا المعطيات المتاحة حول الوضع الحالي لتلوث الهواء في باكستان، فقد تم إعداد دلائل إرشادية وطنية مقترحة لجودة الهواء للتعامل مع ستة من الملوثات الرئيسية.

**ABSTRACT** While enforceable National Environmental Quality Standards for pollutants exist in Pakistan, ambient air quality guidelines have never been established. However, there is no reliable epidemiological/toxicological monitoring system in place in Pakistan to provide a basis for establishing guidelines for various air pollutants. This paper reviews the World Health Organization air quality guidelines as well as standards applied in countries of the Eastern Mediterranean and South-East Asia Regions. Based on these, and available data on the existing air pollution situation in Pakistan, national air quality guidelines are proposed for 6 major pollutants.

Vers l'établissement de lignes directrices pour la qualité de l'air au Pakistan

**RÉSUMÉ** Si des normes nationales de qualité environnementale applicables aux polluants existent au Pakistan, des lignes directrices afférentes à la qualité de l'air ambiant n'ont jamais été établies. Cependant, il n'y a pas de système de surveillance épidémiologique/toxicologique fiable en place au Pakistan pouvant servir de base à l'établissement de lignes directrices pour les différents polluants atmosphériques. Le présent article examine les directives de l'Organisation mondiale de la Santé relatives à la qualité de l'air ainsi que les normes appliquées dans les pays des Régions de la Méditerranée orientale et de l'Asie du Sud-Est. Sur cette base, et sur la base des données disponibles sur la situation actuelle concernant la pollution atmosphérique au Pakistan, des lignes directrices nationales pour la qualité de l'air sont proposées pour 6 principaux polluants.

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## Introduction

The protection of ambient air quality in Pakistan is provided through the enforcement of the National Environmental Quality Standards, introduced in July 1996. These standards impose limits on the concentration of specified gaseous emissions from industrial units and automobiles. The standards were imposed, however, without giving careful consideration to the desired ambient air quality. As such, the real objective of minimizing the risk to health of humans and animals and of damage to the environment in general may not be being achieved. There is therefore a need to establish national air quality guidelines in Pakistan.

Depending upon natural phenomena and human activities, the ambient air may contain a number of pollutants. The 6 pollutants that account for the large majority of air pollution worldwide and for which standards are usually specified include carbon monoxide (CO), ozone (O<sub>3</sub>), oxides of nitrogen (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), lead (Pb) and suspended particulate matter (SPM). For SPM, 2 classifications are generally employed, i.e. total suspended particulate matter (TSP) and particulate matter less than 10 µm in diameter (PM<sub>10</sub>). NO<sub>x</sub> are generally reported as nitrogen dioxide (NO<sub>2</sub>). The impacts of these pollutants, when present in excessive quantities, on human health, vegetation and property have been described by the United States Environmental Protection Agency [1] and in many textbooks.

No reliable epidemiological/toxicological studies have been undertaken in Pakistan to provide recommended pollutant concentration limits in order to protect human health. It is therefore necessary to consult worldwide guidelines and the standards enforced in countries where the geographical and socioeconomic conditions and the level of available pollution control technology are similar to Pakistan. This

paper reviews World Health Organization (WHO) air quality guidelines as well as standards applied in countries of the Eastern Mediterranean and South-East Asia Regions. Based on these, and available data on the existing air pollution situation in Pakistan, national air quality guidelines are proposed for 6 major pollutants.

## Setting the guidelines

Air quality guidelines are derived from epidemiological/toxicological data. The criteria used in establishing air quality guidelines have been discussed by Schwela [2] and are generally based on the concept of acceptable risk of occurrence of effects caused by air pollutants. Due to the incomplete knowledge about the effects of pollutants, uncertainty factors are applied to lower the risk of an effect induced by air pollutants.

Depending on the pollutant, different averaging times are considered in establishing the guideline values of human exposure to air pollutants. In general, short and medium periods of time (10 minutes, 24 hours) are applied for pollutants that have acute effects on the respiratory tract (SO<sub>2</sub>, NO<sub>x</sub>, O<sub>3</sub>) or on the oxygen-carrying capacity of the blood (CO). Longer periods of time (1 month, 1 year) are applied for pollutants that have chronic effects on human health (Pb, particulate matter and SO<sub>2</sub>).

Perhaps the most widely publicized ambient air quality guidelines are those recommended by WHO [3,4]. Many countries use these guidelines for establishing air quality standards, especially those that lack basic data about exposure to pollutants in their country. The WHO 2000 guidelines for air pollutants [4] are reproduced in Table 1 (courtesy of WHO Regional Centre for Environmental Health Activities (CEHA) [5]), along with WHO 2000 guidelines for

Table 1 World Health Organization air quality guidelines [Source: 4]

Pollutant/Averaging time	Concentration ( $\mu\text{g}/\text{m}^3$ )
Carbon monoxide	
15 min	100 000
30 min	60 000
1 h	30 000
8 h	10 000
Ozone	
8 h	120
Nitrogen dioxide	
1 h	200
Annual	40
Sulfur dioxide	
10 min	500
24 h	125
Annual	50
Lead	
Annual	0.5
Total suspended particulate matter	
24 h	120
Annual	-
Particulate matter < 10 $\mu\text{m}$ diameter	
24 h	70
Annual	-

Europe [3]. Ambient air quality standards that have been set in some countries of the Eastern Mediterranean Region and South-East Asia Region are shown in Tables 2 and 3.

A detailed review of these guidelines reveals that 24-hour and 1-year averaging times have usually been used for particulate matter. WHO guidelines do not include values for suspended particulate matter [4]. It was argued that a threshold for this compound including the size-dependent fraction,  $\text{PM}_{10}$ , could not be established. It was therefore left to individual countries to establish standards with respect to the

exposure level. For an annual average, a minimum of 104 measurements are taken in a year, twice a week and 24 hourly at uniform intervals. For  $\text{SO}_2$ ,  $\text{NO}_2$  and  $\text{O}_3$ , 1-hour, 8-hour and 24-hour averaging times have been employed in different countries.

## Air pollution in Pakistan

Regular monitoring of ambient air quality is still not systematic in Pakistan. All the available information is based on random and short-term sampling conducted to assess the concentrations of various pollutants. Many such studies have reported the ambient concentration of air pollutants in various urban and rural centres of Pakistan, including Karachi, Hyderabad, Jamshoro, Lakhra, Multan, Dera Ghazi Khan, Faisalabad, Lahore, Gujranwala, Pind Dadan Khan, Sargodha, Fateh Jang, Khewra, Sialkot, Rawalpindi and Peshawar [6–21]. The range of various pollutants in the ambient air of these cities is summarized in Table 4.

In 2000, a survey of ambient air quality in Lahore, Rawalpindi and Islamabad was conducted under a joint project of the Japan International Cooperation Agency and Pakistan Environmental Protection Agency. The ranges of air pollutant concentrations in ambient air based on hourly averages are presented in Table 5 [22].

The concentration ranges of various pollutants in the ambient air of urban centres of Pakistan are presented in Tables 4 and 5. The upper ranges of  $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{PM}_{10}$  and Pb concentrations are higher than WHO limits [3].

The reported concentrations of pollutants in these surveys only give a general idea about the prevailing situation. A true picture of ambient air quality can only be obtained through well-defined long-term monitoring programmes. The situation calls for the establishment of a comprehensive

Table 2 Ambient air quality standards in some countries of the Eastern Mediterranean Region

Pollutant/ Averaging time	Egypt 1979 ( $\mu\text{g}/\text{m}^3$ )	Islamic Republic of Iran ( $\mu\text{g}/\text{m}^3$ )	Iraq ( $\mu\text{g}/\text{m}^3$ )	Kuwait ( $\mu\text{g}/\text{m}^3$ )	Saudi Arabia ( $\mu\text{g}/\text{m}^3$ )	Syrian Arab Republic ( $\mu\text{g}/\text{m}^3$ )	Tunisia ( $\mu\text{g}/\text{m}^3$ )
<b>Carbon monoxide</b>							
1 h	–	–	40 000	40 000	40 000	30 000	40 000
8 h	–	50 000	10 000	9 000	10 000	10 000	10 000
24 h	2 900	10 000	–	–	–	–	–
<b>Ozone</b>							
1 h	–	280	240	160	300	240	235
8 h	–	–	–	–	–	160	–
24 h	6	160	–	–	–	–	–
<b>Nitrogen dioxide</b>							
1 h	–	–	450	–	650	400	660
24 h	200	100	–	100	–	150	–
Annual	–	–	100	–	100	100	200
<b>Sulfur dioxide</b>							
1 h	–	210	400	800	700	350	–
24 h	200	–	260	500	350	125	365
Annual	–	–	60	–	80	80	80
<b>Lead</b>							
24 h	0.014	–	2	2	–	–	–
3 month	–	–	–	–	–	1.5	2
Annual	–	–	1.5	–	–	–	–
<b>Total suspended particulate matter</b>							
24 h	150	260	350	350	–	150	260
Annual	–	–	150	–	–	90	80
<b>Particulate matter &lt; 10 <math>\mu\text{m}</math> diameter</b>							
24 h	60	–	–	–	340	–	–

countrywide air quality monitoring programme in Pakistan.

### Proposed air quality guidelines for Pakistan

Taking account of WHO and regional standards, together with the prevailing levels of ambient pollutants in Pakistan, the proposed air quality guidelines for the 6 most com-

mon pollutants, along with averaging times for reporting, are summarized below and on Table 6.

#### Carbon dioxide

The CO concentration ranges given in Tables 4 and 5 correspond to 24-hour and 1-hour averaging times respectively. WHO provides guidelines for 1-hour and 8-hour averaging times as 30 000  $\mu\text{g}/\text{m}^3$  and 10 000  $\mu\text{g}/\text{m}^3$  respectively [4]. Most countries in

Table 3 Ambient air quality standards in some countries of the South-East Asia Region

Pollutant/ Averaging time	Indonesia	Sri Lanka	Thailand	Bangladesh	India, 1994		
	1988	1994	1995		Industrial area	Residential/ rural area	Sensitive area
	( $\mu\text{g}/\text{m}^3$ )	( $\mu\text{g}/\text{m}^3$ )	( $\mu\text{g}/\text{m}^3$ )	( $\mu\text{g}/\text{m}^3$ )	( $\mu\text{g}/\text{m}^3$ )	( $\mu\text{g}/\text{m}^3$ )	( $\mu\text{g}/\text{m}^3$ )
<b>Carbon monoxide</b>							
1 h	–	30 000	34 000	–	10 000	4 000	2 000
8 h	2 260	10 000	10 260	5 000	5 000	2 000	1 000
<b>Ozone</b>							
1 h	200	200	200	–	–	–	–
<b>Nitrogen dioxide</b>							
1 h	–	250	320	–	–	–	–
8 h	–	150	–	–	–	–	–
24 h	92.5	100	–	100	120	80	30
Annual	–	–	–	–	80	60	15
<b>Sulfur dioxide</b>							
1 h	–	200	–	–	–	–	–
8 h	–	120	–	–	–	–	–
24 h	260	80	300	120	120	80	30
Annual	–	–	100	–	80	60	15
<b>Lead</b>							
24 h	60	2	–	–	1.5	1.0	0.75
Monthly	–	–	1.5	–	–	–	–
Annual	–	0.5	–	–	1	0.75	0.5
<b>Total suspended particulate matter</b>							
1 h	–	500	–	–	–	–	–
8 h	–	–	–	500	–	–	–
24 h	260	300	330	–	500	200	100
Annual	–	100	100	–	360	140	70
<b>Particulate matter &lt; 10 <math>\mu\text{m}</math> diameter</b>							
24 h	–	–	120	–	150	100	75
Annual	–	–	50	–	120	60	50

the Regions have employed similar standards and the same levels for CO are therefore proposed for Pakistan.

#### Ozone

As given in Table 5, ambient concentrations of  $\text{O}_3$  range from 0.2 to 119  $\mu\text{g}/\text{m}^3$  based on 1-hour averages. Keeping in view the averaging times adopted in Indonesia, Sri Lanka

and Thailand and the prevailing local conditions, the suggested  $\text{O}_3$  level for Pakistan over 1-hour is 200  $\mu\text{g}/\text{m}^3$ .

#### Nitrogen dioxide

Local data in Table 5 indicate a concentration range for  $\text{NO}_2$  of 45.6–056  $\mu\text{g}/\text{m}^3$  on 1-hour averages. Most countries in the Region have standards for 1-hour and 24-hour

Table 4 Pollutant concentration ranges from studies in different cities of Pakistan [Source: 6–21]

Pollutant	Averaging time	Concentration range ( $\mu\text{g}/\text{m}^3$ ) (ppb)	
Carbon monoxide	8 h	160–4300	0.14–3.8 <sup>a</sup>
Ozone	1 h	9.2–78	4.6–39
Oxides of nitrogen	24 h	3.8–109	2–58
Sulfur dioxide	24 h	2–23	0.7–8.8
Lead	24 h	0.06–21.5	–
Total suspended particulate matter	24 h	180–1375	–
Particulate matter < 10 $\mu\text{m}$ diameter	24 h	85–835	–

<sup>a</sup>ppm.

concentrations. To keep in line with the standards enforced in these countries, the following guidelines are proposed for  $\text{NO}_2$ : 1-hour and 24-hour averages of  $300 \mu\text{g}/\text{m}^3$  and  $150 \mu\text{g}/\text{m}^3$  respectively.

#### Sulfur dioxide

Ambient concentrations of  $\text{SO}_2$  are reported to be in the range of  $0.8$ – $553 \mu\text{g}/\text{m}^3$  for 1-hour averages. As  $\text{SO}_2$  may also exist in particulate form, WHO and many other countries have also specified guidelines on an annual average basis, in addition to 1-hour and 24-hour averages. Therefore, the suggested guidelines for  $\text{SO}_2$  levels for

Pakistan are 1-hour, 24-hour and annual levels of  $350 \mu\text{g}/\text{m}^3$ ,  $125 \mu\text{g}/\text{m}^3$  and  $80 \mu\text{g}/\text{m}^3$  respectively.

#### Lead

WHO and some countries including India, Sri Lanka and Iraq specify ambient lead concentration values on the basis of annual averages. Lead concentrations, as indicated in Table 4, are well above WHO guidelines. Under the present conditions, it would therefore be appropriate to adopt WHO guidelines for Pakistan for lead of an annual average of  $1.0 \mu\text{g}/\text{m}^3$ .

Table 5 Pollutant concentration ranges in ambient air of Pakistani cities [Source: 22]

Pollutant	Lahore		Rawalpindi/ Islamabad	
	(ppb)	( $\text{mg}/\text{m}^3$ )	(ppb)	( $\text{mg}/\text{m}^3$ )
Carbon monoxide	0.1–9.4 <sup>a</sup>	114–10 745	0.1–6.7 <sup>a</sup>	114–7658
Ozone	0.4–48.5	0.8–97	0.1–59.3	0.2–119
Oxides of nitrogen	24–556	45.6–1056	24–349	45.6–663
Sulfur dioxide	0.3–211	0.8–553	0.3–60.2	0.8–157.8
Particulate matter < 10 $\mu\text{m}$ diameter	90.6–1535	–	80–1406	–

<sup>a</sup>ppm.

Table 6 Draft national air quality standards for Pakistan

Pollutant/Averaging time <sup>a</sup>	Concentration ( $\mu\text{g}/\text{m}^3$ )
Carbon monoxide	
1 h	30 000
8 h	10 000
Ozone	
1 h	200
Nitrogen dioxide	
1 h	300
24 h	150
Sulfur dioxide	
1 h	350
24 h	125
Annual <sup>b</sup>	80
Lead	
Annual <sup>b</sup>	1.0
Total suspended particulate matter	
24 h <sup>c</sup>	500
Annual <sup>b,c</sup>	300
Particulate matter < 10 $\mu\text{m}$ diameter	
24 h <sup>c</sup>	200
Annual <sup>b,c</sup>	120

<sup>a</sup>Arithmetic mean.<sup>b</sup>Minimum 104 measurements per 1 year, 2  $\times$  per week, 24 hourly at uniform intervals.<sup>c</sup>Excluding duststorm days.

### Total suspended particulate matter

WHO guidelines do not suggest any value for TSP levels. Despite having a high TSP content in ambient air, Saudi Arabia does not specify TSP standards. Monitoring data reported in Table 4 show a high value for TSP in Pakistan of 180–1375  $\mu\text{g}/\text{m}^3$ . The major cause of this is the arid nature of the land and there is little hope of any major reduction in ambient TSP levels in the near future. Therefore, the following guidelines for TSP are proposed for Pakistan: 24-hour levels of 500  $\mu\text{g}/\text{m}^3$  (excluding duststorm days) and annual levels of 300  $\mu\text{g}/\text{m}^3$ . The guideline values are in line with the values adopted by countries with conditions similar to Pakistan.

### Particulate matter

Many countries in the Regions employ  $\text{PM}_{10}$  standard. The data presented in Table 5 indicate a  $\text{PM}_{10}$  range of 80–535  $\mu\text{g}/\text{m}^3$  for a 1-hour averaging time. In order to place the emphasis on improvement measures, the following values for  $\text{PM}_{10}$  levels are suggested: 24-hour average of 200  $\mu\text{g}/\text{m}^3$  (excluding duststorm days) and annual average of 120  $\mu\text{g}/\text{m}^3$ .

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