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AIR QUALITY MONITORING AND CONTROL

Prepared for: Western Pacific Regional Centre for the Promotion of Environmental Planning and Applied Studies (PEPAS)
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FOREWORD

The World Health Organization has been developing a global air monitoring project since the early seventies. Starting as a pilot project in 1972, the project began to expand rapidly in 1975 with financial support from the United Nations Environment Programme; today about 50 countries participate as part of the Global Environmental Monitoring System.

To assist Member States with the training of staff for air monitoring operations interregional courses are organized periodically as part of the project. One of these was held in Bangkok in 1977 at Chulalongkorn University. The lecture notes from this course form the basis of this document.

These notes had been prepared by staff from the WHO Collaborating Centre on Air Pollution Monitoring for the Western Pacific Region in Brisbane, Australia, and they also subsequently prepared the final draft for this manual. An earlier draft had been reviewed by Dr Verduyn, Ministry of Health and Family, Brussels, Belgium, Dr Sundaresan, National Environmental Engineering Research Institute, Nagpur, India, Mr R. Haddad, Pan American Centre for Sanitary Engineering and Environmental Sciences, Lima, Peru, Dr Kirov, Western Pacific Regional Centre for the Promotion of Environmental Planning and Applied Studies, Kuala Lumpur, Malaysia, and Mr Kohler, World Meteorological Organization, Geneva, Switzerland. Where possible all advice given has been incorporated and their contribution is herewith gratefully acknowledged.

This document is intended primarily for technical staff involved in the day to day operations of an air monitoring network. The information presented in the text is for a large part concerned with various aspects of air monitoring. In order however to place the subject of air monitoring in its proper perspective with regard to the whole subject of air quality management, additional chapters have been added on "Sources of Air Pollution and Trends", "Effects of Air Pollution" and "Transport, Dispersion, Transformation and Degradation of Pollutants". The purpose of this manual is to elaborate on various technical details of an air monitoring operation for the purpose of improving the quality and to promote a more uniform approach among various national agencies. Note should also be taken of various other WHO publications in the field of air pollution which have been listed in the bibliography along with other pertinent references. In this connexion, the reader's attention is particularly drawn to WHO Offset Publication No. 24, Selected Methods of Measuring Air Pollutants, which presents the most commonly used procedures for measuring the more common types of air pollution.

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It is expected that users of this manual will draw our attention to the difficulties they encounter in applying the techniques mentioned in this document, and make suggestions for improvement. Any comments regarding this document should be addressed to Director, Western Pacific Regional Centre for the Promotion of Environmental Planning and Applied Studies, P.O. Box 2550, Kuala Lumpur, Malaysia.

1. INTRODUCTION

1.1 General Considerations

Before any study of measurement techniques in Air Pollution monitoring can be undertaken, it is first necessary to gain an understanding of the problems involved, and to consider the basic theory of the equipment to be used.

In ambient air pollution monitoring the material to be measured (that is, the pollutant) is present in extremely low concentrations, in the range of parts per million (10^{-6}) or parts per billion (10^{-9}). In terms of weight per volume, this is equivalent to milligrams or micrograms per cubic metre. The significance of this may be better appreciated by considering that 1 part per million of a gas is equivalent to one cubic metre of it mixed into air space 100 metres long, 100 metres wide and 100 metres high. This pollutant must be identified and measured accurately and specifically.

Further, the pollutant is not contained in a pure, consistent medium, the air mass will contain in addition, varying quantities of water vapour solid particles and other pollutants which may or may not interfere with the analysis. Any analytical method used must record that pollutant only, or, at least, any interference caused by another pollutant must be capable of being measured or nullified.

The air sampled must also provide a proper representation of the area under study. If the air sample is not representative, then the results obtained will not indicate air quality in the area, regardless of how accurate, specific and sensitive the analysis is, or how competent the analyst. This subject is covered in depth in WHO Offset Publication No. 33, "Air Monitoring Design for Urban and Industrial Areas".[1]

Finally, proper techniques of sample collection and analysis must be employed. Suitable techniques are discussed in considerable detail in WHO Offset Publication No. 24, "Selected Methods of Measuring Air Pollutants".[4]

Air monitoring can be divided into two components, air sampling, which involves the removal of a known volume of air from the atmosphere, and analysis of the air sample to determine the concentration of an air pollutant in that sample.

In general terms, air sampling can be done by collecting a series of known volumes of air, one after the other and analyzing the result of each sample. Such a procedure is generally referred to as a manual method and involves transporting the samples from the sampling location to the central laboratory for analysis.

In another procedure, air is continuously drawn from the atmosphere and led into some type of detector device which analyzes the air continuously. Such instruments usually provide an electrical signal which is recorded using a strip chart recorder or some other data recording device. Such methods are called continuous methods or automatic methods. For the purpose of this manual, we shall refer to manual methods and automatic methods.

There are a number of variations, for example, where part of the manual operation has been automated; there also exist instruments which analyze a series of distinct air samples, such instruments are sometimes referred to as semi-automatic.

There are advantages and disadvantages to using manual methods and automatic methods. Manual methods generally are more labour-intensive, but require less capital investment. They can be more sensitive, in that a larger volume of air can be taken in each sample. Very often they can utilize a considerable amount of existing equipment, facilities and personnel. Automatic methods require a much higher capital investment and also a higher level of operating staff. More important than that, their operating and maintenance costs are generally much higher than for a manual procedure. Their advantage however is that they provide continuous data which is a requirement for certain monitoring applications (see also WHO Offset Publication No. 33)[1]. Also for the measurement of some pollutants there are really no good manual methods, for example, for ozone.

Many monitoring networks begin as manual operations and gradually introduce some automatic instruments to suit the particular objectives for which the air monitoring is carried out. It should be noted however that for certain situations manual operations may be preferred over automatic instruments and vice versa. It would be quite erroneous to assume that either one or the other would be better under all circumstances. In other words, both have their advantages and disadvantages and these will have to be weighed in the light of the objective(s) for which the air quality monitoring network is established or further developed.

1.2 The Gas Laws

When analyzing an air sample for a pollutant gas, two measurements must be made, the weight of pollutant collected and the volume of air in which it is contained. Both of these must be determined as accurately as possible if a reliable answer is to be obtained.

1.2.1 Gas Volumes

The volume of a gas, as measured, does not provide a measure of the quantity sampled, unless temperature and pressure are prescribed, since the gas volume changes with changes in temperature and pressure. This is defined in two of the fundamental gas laws, Boyle's Law and Charles' (or Gay Lussac's) Law.

1.2.1.1 Boyle's Law and Charles' Law

Boyle's Law states: "The volume of a given mass of a gas at constant temperature varies inversely as the absolute pressure".

Charles' Law states: "The volume of a given mass of a gas at constant pressure varies directly as the absolute temperature".

These two laws may be combined and expressed mathematically:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = R$$

or

$$V_1 = V_2 \cdot \frac{P_2}{P_1} \cdot \frac{T_1}{T_2}$$

where P_1, P_2 are the gas pressures in millimetres of mercury or kilopascals

T_1, T_2 are the gas temperatures in $^\circ$ Kelvin (or $^\circ$Absolute)

V_1 = volume of the gas at pressure P_1 and temperature T_1

V_2 = volume of the gas at pressure P_2 and temperature T_2

R = the universal gas constant

1.2.1.2 Standard Temperature and Pressure

Atmospheric temperature and pressure vary continuously at all places throughout the world. In any air quality monitoring programme ambient air samples will therefore be collected over a range of temperatures and pressures. Because of this, a standard reference of temperature and pressure is required if the result, expressed in terms of a measured weight of pollutant per measured volume of air (weight/volume), is to have a consistent meaning.

Monitoring results submitted under the GEMS/Air programme are to be reported under specified conditions of 25°C temperature and 760 millimetres of mercury (or 101.3 kPa) pressure. In other places, 0°C and 760millimetres of mercury is sometimes used. In referring a gas volume to these standard conditions, it should be noted that absolute zero temperature is equal to -273°C, so that 25°C is equal to 298° Absolute, or 298 K. So, for data to be included in the GEMS/Air programme:

$$V \text{ standard} = V \text{ measured} \times \frac{P}{760} \times \frac{298}{273+t^{\circ}C}$$

(Where pressure is measured in kPa, the figure 760 would be replaced by 101.3).

This correction is necessary when pollutant concentrations are expressed on a weight/volume basis (i.e. in milligrams per cubic metre or micrograms per cubic metre), since the weight of pollutant will remain constant, while the volume of the sample will change with changes in temperature and pressure.

This correction is not necessary when pollutant concentrations are expressed on a volume/volume basis (i.e. parts per million or parts per billion), since the volume of the pollutant and the volume of sample will change with changes in temperature and pressure. However, the percentage change will be the same in each case, since all gases obey the gas laws described above. Hence, the volume to volume ratio of the two will remain the same.

When samples are collected over a 24 hour period, some difficulty may be experienced in determining the sample temperature and sample pressure to be used in the calculation. There are several courses which might be followed. A reading of temperature and pressure may be taken regularly during the 24 hour period, or continuously recording instruments measuring atmospheric temperature and pressure (thermographs and barographs) may be operated. Mean temperature and pressure may be calculated from the readings, or deduced from the recorder charts. However, it is usually of sufficient accuracy to obtain the maximum and minimum temperature and pressure recorded each day by the Bureau of Meteorology, and take the mean of these. This should not introduce significant errors in the result.

(An error of 1°C in temperature induces an error of $\frac{1}{273 + 25}$, or approximately 0.3 percent in the measured volume, and an error of 5 millimetres of mercury in pressure induces an error of $\frac{5}{760}$, or approximately 0.65 percent.)

Example: