CHAPTER 2

LITERATURE REVIEW

Today, air pollution has become an issue of great environmental importance. The haze episodes in July-September 1991 and August-October 1994 (Environmental Quality Report,1991 and 1994) which occurred in Malaysia and neighbouring countries and the chronic obstructive pulmonary disease cases (Krishna,1994; Ponka,1991) suggest the desirability and importance of clean air. Contaminated air not only drastically and adversely affects the health of human beings but also hampers economic activities. The recent July-October 1997 haze episode was caused by massive forest fires in Indonesia (The New Straits Times, 31-7-1997). Of equal serious effects and implications is air pollution caused by industrial activities. Throughout the world, various reports have been made about the health of people being adversely affected by surrounding industrial activities (Clement et al., 1991). With increasing industrialization, many inorganic pollutants are continuously emitted, thereby polluting the atmosphere and causing serious health hazards (Manahan, 1994). Various industrial operations emit dust, gases, vapours and mist which in combination with naturally occurring airborne materials constitute air pollution substances.(Stern et al.,1984).

2.1 DUST POLLUTION

Dust pollution in particular is more common than other solid forms of air pollution. Practically every form of human activities generates a certain amount of dust. This is especially so where industrial activities are concerned. Examples of these are cement manufacturing, stone quarrying and coal-fired thermal power generation. These industrial processes spew dust and fine particulate matter into the atmosphere and hence deteriorating the ambient air quality as well as causing ecological damage (Nriagau and Davidson, 1986) and affecting human health and welfare (Walton,1974).

2.2 THE NEED TO REGULATE DUST POLLUTANTS

In order to protect the health and welfare of workers, the concentration of air pollutants such as particulate matter in industrial areas must not exceed certain maximum permissible levels. The term particulate matter refers to the loadings of solid and liquid particles present in the atmosphere. The main anthropogenic sources of particulate matter are coal combustion, earthworks and various industrial processes. Particulate matter exists in a range of sizes and can absorb many chemicals present in the ambient air. High concentration of particulate matter have been associated with increases in respiratory diseases and gastric cancers, poor atmospheric visibility and the soiling of buildings. The recent haze episode in Malaysia reiterates the importance of regulating particulate matter in the ambient air. The study by Rashid and Griffiths(Rashid and Griffiths,1995) recorded an elevated loading of fine particles(with aerodynamic diameter $d_a<2.5\mu m$) during local haze episodes. This fine fraction contributes significantly to the haze phenomenon. In fact, the Malaysia's Air Pollution Index includes respirable particulate matter of size 10 µm in diameter(PM10) as one of the five parameters to assess and monitor the quality of ambient air. In the United States of America, pursuant to the Clean Air Act 1970, the National Ambient Air Quality Standards (NAAQS) sets and regulates the maximum permissible levels(as of 1995) for carbon monoxide(CO), ozone(O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter (PM10) and lead (Pb). PM10 are small enough to be breathed into the lungs. However, environmentalists in the United States have called for setting ambient standards on even smaller particles, those less than 2.5 μm since morbidity and mortality rates appear to be closely linked to particulate matter in that size range i.e.PM2.5 (Ortolano, 1997). The shifts to a PM2.5 regulation from a PM10 regulation need to be critically evaluated from human health, technology and economical view-points.

A brief explanation as to how these standards that determine maximum permissible levels have been arrived at may be in order. At the outset, public concerns on an issue lead to the development of air quality criteria on which the standards are based. These criteria refer to the concentration limitations of pollutants reflecting the latest scientific knowledge on the effects, the loadings(concentrations) and the dispersal of air pollutants on a receptor with reference to its dose-response curve. It is evident that scientific investigations are heavily involved in determining the air quality criteria. At a certain concentration of the pollutant, the ability of the receptor to tolerate that pollutant breaks down. With considerations on a certain margin for safety, the detection limits of equipment and the socio-political factors, the air quality standard of that air pollutant is then determined. As some sets of rules which are legal, authoritative and enforeceable in a court of law, that standard generally sets the maximum permissible level of an air pollutant necessary to protect against the kind and extent of all identifiable effects on human health and well-being including biodiversity, aesthetics and recreation (DOE-UM,1986).

In Malaysia, while efforts to reduce air pollution have been made through the Environmental Quality (Clean Air) Regulations 1978, the recurring haze episodes demonstrate unequivocably that much still left to be done. For economic reasons, it may not be possible to keep the ambient air of industrial areas completely free from pollutants like fugitive dust, these pollutant emissions can certainly be reduced to a minimum or an acceptable level. This level is generally the maximum allowable or permissible level that should not be exceeded at any one time. With the advancement of clean technology, systematic approach in management and manufacturing processes, there may come a time where zero-emission may be achievable and become a reality. This would certainly be a revolutionary technological achievement and voluntary environmental management system would perhaps complement Environmental Quality (Clean Air) Regulations 1978 of Malaysia.

It is also important to know the nature of dust pollutants and their loadings in order to evaluate their nuisance problems, health effects and toxic stress (Filby and Shah, 1974). Hence, the analytical techniques of ambient and industrial dust pollutants are essential to assess and monitor the nature, loadings, origin and chemical composition with the greatest reliability and in the shortest time (Fox, 1985).

2.3 PARTICLE SIZE ANALYSES

The size of a spherical homogeneous particle is uniquely defined by its diameter. However, in reality, many particles of concern in dust pollution studies are not perfectly spherical in shape. Hence, the need for derived diameters. These diameters are determined by measuring a size-dependent property of the particle and relating it to a linear dimension. The most widely used of these derived diameters are the equivalent spherical diameters.

2.3.1 Definitions of Particle Size Diameters:Volume Diameter, Surface Diameter, Aerodynamic Diameter, Stoke's Diameter, Projected Area Diameter, Feret's Diameter and Martin's Diameter

Several definitions of particle size are reported in the literature (Allen,1981; de Nevers,1995; Reist,1993). The use of any particular definition essentially depends on the type of particle property one is interested in and on the particle-sizing instrumentation being used. Some of the more common ones are as follows:

(a) Volume diameter

This is the diameter of a sphere which has the same volume as the particle.

(b) Surface diameter

This is the diameter of a sphere which has the same surface area as the particle.

(c) Aerodynamic diameter

This is the diameter of a unit density sphere (density=1 g/cm^3) which has the same settling velocity as the particle.

(d) Stoke's diameter

This is the diameter of a sphere of the same density as the particle which has the same settling velocity as the particle.

(e) Projected area diameter

This is the diameter of a circle which has the same area as the projected area of the particle resting in a stable position.

(f) Feret's diameter

This is the mean value of the distance between pairs of parallel tangents to the projected outline of the particle. In the microanalysis of an individual particle, the diameters(maximum, minimum and mean) are calculated on the basis of feret's diameter(Yap et al.,1995). These projections are the pairs of parallel tangents which enclose the particle.

(g) Martin's diameter

This is the mean chord length of the projected outline of the particle which separates the particle into two equal portions.

2.3.2 Particle Size Measurement Studies

The study of particle size is of central importance in dust pollution studies. The deposition of airborne particles on surfaces is dependent on particle size (Baron and Willeke, 1993). This is of considerable significance in, for instance, the selection of dust control equipment (Cheremisinoff,1993), the choice of air quality monitoring equipment (Rahmalan et al., 1994) and the subsequent deposition of dust particles in the lungs (Zailina et al.,1994).

Bonin and co-workers (Bonin et al.,1995) carried out optical measurements of particle size at the chromium plating tank and exhaust system at a commercial hexavalent chromium plating plant. The particles were examined at three locations in the exhaust system: namely, directly at the hexavalent chromium plating surface, at the exit of a cyclone separator located in the exhaust system approximately three to four meters downstream of the bath and in the exhaust stack, downstream of the induced draft fan and all abatement devices. Particle size measurements were made using a laser-based particle-sizing instrument, the Insitec Particle Counter, Sizer, Velocimeter(PCSV) fine-particle diagnostic tube which was capable of measuring the size of particles from 0.3μm to 25 μm in diameter. They found that the particle diameters at the bath surface ranged from 0.3μm to 25 μm which really represented the measurable size range of the instrumentation used in the study. The complete particle size distribution was likely to lie outside these limits. Downstream of the cyclone exit and mesh pad filters, particle maximum sizes were approximately 5 μm and 0.7 μm respectively.

Plinke and co-workers (Plinke et al., 1995) conducted a study on dust generation from handling powders in industry. Dust generation was characterised in experiments using titanium dioxide, limestone, glass beads and lactose with size distribution of $d_a < 5\mu m$, $5 < d_a < 25\mu m$ and $d_a > 25\mu m$ in aerodynamic diameter dropped from heights of 0.25m, 0.7m and 1.25m at material flows of 0.1, 0.3 and 0.6 kg/s. They concluded that the amount and size of the dust particles generated in an industrial process depended, among other factors, on the partcle size distribution of the original material.

Bullock and Laird (1994) undertook a pilot study of the particle size distribution of dust in the paper and wood products industry. They used a Marple personal cascade impactor(Andersen Samplers) to assess the particle size distribution to which the workers were actually exposed at a a flowrate of 2L/min. Their results showed that workers in the paper and wood products industry can be exposed to dust composed of up to 75% by weight of particles less than 2 μm in aerodynamic diameter as measured by the personal cascade impactor.

2.4 ANALYTICAL TECHNIQUES IN DUST POLLUTION STUDIES

Researchers throughout the world have employed various analytical techniques in the analysis of dust pollutants as explored in Section 1.4 Amongst the published methods include atomic absorption spectrometry (Noller and Bloom,1977; Sutter and Leroy, 1978; Geladl and Adams, 1978; Pickford and Rossi, 1978), inductively coupled plasma-atomic emission spectrometry (Lynch et al., 1980;McQuaker et al., 1979;Scott et al., 1976), neutron activation analysis (Lambert and Wilshire, 1979), X-ray fluorescence spectrometry (Nielson, 1977; Kingston and Pella, 1981; Giauque et al., 1974), proton-induced X-ray emission and Auger electron spectrometry (Linton et al., 1977) and mass spectrometry (Davies, 1977).

However, the three most commonly used analytical techniques are atomic absorption spectrometry, inductively coupled plasma-atomic emission spectrometry and neutron activation analysis. These techniques are reviewed below.

2.4.1 Atomic Absorption Spectrometry (AAS)

The AAS is one of the commonly used technique in dust analysis. Cornejo and co-workers (Cornejo et al., 1995) studied an AAS method for the multi-elemental analysis of airborne particulate matter collected on polycarbonate filters. The concentrations of calcium, magnesium, sodium, potassium and zinc were determined by flame AAS with a micro injection system while cadmium, copper, lead, nickel and vanadium were determined by graphite furnace AAS. The standard reference material used was vehicle exhaust (CRM No.8) from the National Institute of Environmental Studies (NIES), Japan. This reference material was selected because of the high content of carbon (80%) and the quantity of the elements that come from urban sources.

The AAS technique requires sample digestion. The following digestion methods were employed.The first method was as follows: A total of 100mg of the CRM No.8 was introduced inside a quartz tube and 9ml of concentrated nitric acid and 0.6ml of concentrated perchloric acid were added. The tube was placed in an aluminium block and heated on a hot plate from 20 to 140 °C during 70 minutes and then from

140 to 210 °C over 90 minutes. The solution was then reduced to approximately 50µL and was removed from the hot plate. The resulting clear, colourless sample solution was left to cool completely and then diluted to 10 ml with 1M hydrochloric acid. The second method was similar to the first method except that the sample was digested with 6ml of concentrated nitric acid and 0.4ml of concentrated perchloric acid. After the digestion, the sample solution was transferred into a polytetrafluoroethylene(PTFE) beaker and 2ml concentrated hydrofluoric acid were added. The beaker was heated gently at about 100°C to allow the hydrofluoric acid to evaporate. The residue was then diluted to 10ml with 1M hydrochloric acid. The third method was as follows: The CRM No.8 was first digested with a mixture of 400µL of concentrated nitric acid and 40µL of concentrated perchloric acid and the mixture was heated to 140°C. The sample solution was then cooled to room temperature and 500µL of concentrated nitric acid and 100µL of concentrated perchloric acid were added again, heating from 140 to 210°C for 90minutes. If the nitric acid is evaporated, further nitric acid should be added to the sample in 500µL aliquots. The resulting solution was then diluted to 10 ml with de-ionised water. It was found that a good recovery was obtained for all the elements. Recovery values over 100% were obtained for those elements which were easily contaminated (such as sodium and potassium). The other elements presented recovery values within the expected range. Full digestion of the samples was obtained for the three digestion procedures. The analytical results were in agreement with certified values. However, the calcium values for the three digestion procedures showed major differences. The possible explanation was that the conditions were not appropriate to dissolve all forms of calcium present in the samples. The same explanation could also apply to the low values of zinc in the second digestion method. From all the methods tested,

reactions with small quantities of concentrated nitric acid and concentrated perchloric acid in an air pressure digestion system was the best procedure for the determination of the elements by AAS.

Banerjee and co-worker (Banerjee and Pandey, 1989) used AAS to determine the concentrations of toxic metals in the ambient air of a cement plant.The suspended particulate matter in the vicinity of an electrostatic precipitator installed in the cement plant was collected using a high volume sampler at a number of sites within 10km radius of the cement plant. The micropollutants studied were antimony, arsenic, beryllium, cadmium, cobalt, lead, lithium, manganese, molybdenum, nickel, silver, bismuth and rubidium. The microfilter sheet containing the suspended particulate matter of each sampling site was divided into two equal halves.Each half of the filter sheet was treated in a Teflon digestion bomb using 10ml acid mixture of hydrochloric acid, hydrofluoric acid and nitric acid placing in an oven at 180°C for 30 minutes. The solutions were then made up to 100ml volume in a medium of 0.1M EDTA to suppress the interference of chloride, phosphate, carbonate, iodide and acetate. It was reported that the concentrations of the potentially hazardous elements (antimony, arsenic, beryllium, cadmium, lead, manganese, molybdenum and nickel) were below the limits prescribed for these elements and was concluded that an electrostatic precipitator significantly reduced the potential environmental hazards.

In another study by Chakraborti and Raeymaekers (Chakraborti and Raeymaekers, 1988), the concentrations of eight heavy metals including cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc on dust of streets, household, restaurants, top of leaves and 5 soil samples of Calcutta city were measured by AAS and ICP-AES. The street dust samples were collected by gently sweeping the street by a brush until sufficient samples had been collected. The dust was then swept into a dust pan and transferred to a polyethylene bag. Dust samples of the household, restaurants and top of leaves were collected by a soft brush. The samples of dust (1-2g) were then digested with concentrated nitric acid and concentrated hydrochloric acid.

Cadmium, cobalt, lead, manganese and nickel were determined by graphite furnace AAS while copper and zinc by flame AAS. These elements along with chromium were also analyzed by ICP-AES. A standard sediment NBS 1645 was analysed to judge the suitability of the dissolution procedure by concentrated nitric acid/hydrochloric acid. The results showed that the recovery was about 25 % lower for chromium and 10-15% lower for cadmium, copper, lead, manganese, nickel and zinc. The authors concluded that the analysis results might be 25% underestimated for chromium and 10-15% for the other metals.

Despite its simplicity, speed and adequate sensitivity (Byrne, 1983), the AAS technique is subject to matrix and inter-elemental interferences.

2.4.2 Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)

Wang and co-workers (Wang et al., 1989) used ICP-AES to analyse the multi-elemental composition of airborne particulate matter collected on glass-fibre filters. Various acid mixture digestion procedures for the pretreatment of samples were performed in a pressurised digestion system. The first method was as follows: The glass-fibre filter with airborne particulate matter was placed in a 25ml polytetrafluoroethylene(PTFE) container and 5ml of concentrated nitric acid were added. The sealed container was then transferred into a pressure bomb and heated on a heating block at 170°C for 5 hours to facilitate complete digestion. After cooling to room temperature, the solution was transferred into a 25ml calibrated flask and diluted to 25 ml volume with distilled water. The second and third methods were similar to the first method of digestion procedures, with variations involving the use of acid mixtures and heating temperatures. The samples of the second method were digested with a 5ml mixture of concentrated nitric acid and perchloric acid (3+7 v/v). The samples of the third method were digested with a 5ml mixture of concentrated nitric acid, perchloric acid and hydrofluoric acid (4+2+2 v/v). After digestion, the sample solution was transferred into a PTFE beaker and heated gently at about 100 °C to allow the concentrated hydrofluoric acid to evaporate off. The residue was then diluted to 25ml for measurement by ICP-AES. The fourth method was similar to the second method of digestion procedures. The glass-fibre filter loaded with airborne particulate matter was first digested with a mixture of concentrated nitric acid and perchloric acid. The intact filter was then removed and the digestion solution and 2ml of concentrated hydrofluoric acid were added to the sample solution. The resulting solution was then treated exactly as in the third method where it was heated gently at 100°C to evaporate the concentrated hydrofluoric acid and diluted to 25 ml.

It must be noted that all the above digestion methods characteristically involve solution digestion with concentrated nitric acid. Concentrated nitric acid is recognised as the most efficient acid to destroy organic material in various samples while the concentrated perchloric acid which establishes a powerful oxidising system and is a source of chloride ions could cause many metals to dissolve. This was necessary to destroy an unresolved matrix such as silicates but the digestion must be carried out in the presence of concentrated hydrofluoric acid. Wang et al.(1989) also commented that previous studies in laboratory had included an open-air concentrated nitric acid digestion method and a mixture of concentrated nitric acid-perchloric acid-hydrofluoric acid digestion method under pressure. Both methods were valid for the analysis of airborne particulate matter by ICP-AES. However, in the former, volatile elements such as arsenic, mercury and sulphur might be lost during the digestion process under ambient conditions. On the other hand, dissolution of the filter matrix due to the addition of concentrated hydrofluoric acid in the latter method could lead to very high blank values for elements such as aluminium, calcium, magnesium, potassium and sodium which were important constituents of contaminants in glass-fibre filters. The blank values obtained for aluminium, calcium and magnesium following digestion with concentrated nitric acid were higher than those obtained from the mixed-acid digestion methods of concentrated nitric acid-perchloric acid-hydrofluoric acid. It was well known that there were large amounts of aluminium, calcium and magnesium impurities in glass-fibre filters and that acid digestion with concentrated nitric acid would cause these impurities to be leached out to a significant extent. However, they found that this leaching phenomenon could be suppressed by using the digestion mixtures of nitric acid-perchloric acid (the second method) or nitric acid-perchloric acid/hydrofluoric acid (the fourth method). They were also of the view that the exceptionally high blank values of aluminium, calcium and magnesium for the third method were clearly due to the complete dissolution of the filter matrix. This suggested that, in view of the importance of the accuracy of the determination of aluminium, calcium and magnesium with respect to the environmental receptor model, the mixed-acid digestion methods of the second method and the fourth method would be the best choices for the pre-treatment of airborne particulate matter.

The operating conditions of the ICP-AES adopted by Wang et al.(1989) were as follows: Jarrell-Ash ICAP-9000 simultaneous type model, power 1.1 kW, carrier gas flowrate at 0.75L/min, auxilliary gas flowrate at 0.5L/min, cooling gas flowrate at 18L/min, observation height at 1.8cm, photomultiplier tube voltage at 800V, cross-flow type of nebuliser and Fassel torch type.

The study of Wang et al.(1989) also showed that ICP-AES was a useful technique for the multi-elemental analysis of airborne particulate matter collected on glass-fibre filters when the digestion with concentrated nitric acid-perchloric acid/hydrofluoric acid (the fourth method) was employed as the pretreatment procedure. The National Bureau of Standards standard reference material of Urban Particulate Matter(NBS SRM 1648) was employed to determine the accuracy and reliability of the results obtained. They reported that for most elements , good agreement was found between the data obtained by all four methods and the certified values. Recoveries of more than 90% were achieved. However, significantly lower recoveries (about 30-70%) were obtained for aluminium, chromium and vanadium with the concentrated nitric acid (the first method) and nitric acid-perchloric acid (the second method) digestion methods. The result was probably due to the incomplete dissolution of the silicates of these elements. On the other hand, the use of nitric acid-perchloric acid/hydrofluoric acid (the fourth method) as a digestion acid-mixture appeared to result in the complete dissolution of these silicates and hence, a recovery of more than 90% was obtained. However, the proposed method (the fourth method) was not successful for the determination of trace elements such as cadmium, chromium, lead, selenium and vanadium. This could be either because of the limitation of the instrumental detection capability or the lower concentration of these elements.

Valerio and co-workers (Valerio et al., 1989) used ICP-AES to analyse airborne particulate matter collected using high volume samplers. The samples were collected in several selected sites in urban, suburban and industrial areas. Nine metals including cadmium, chromium, iron, lead, manganese, nickel, thallium, vanadium and zirconium were analysed. The particulate matter was treated with 65% concentrated nitric acid at 165 °C for 5 hours. The results confirmed the usefulness of multi-elemental analysis to identify major sources of dust pollution.

The operating conditions of the ICP-AES were as follows: ICP (Spectrometer Jolin Yvon JY38-Plasma source JY3832), argon plasma flowrate at 18L/min, argon carrier gas flowrate at 0.4L/min, sample flowrate through peristaltic pump at 0.8ml/min and power at 2kW.

The ICP-AES offers several advantages over the AAS. These include low detection limits, freedom from matrix interference, the increased speed of analysis and wide linear calibration range offered by such simultaneous and sequential systems and the possibility of simplified sample pretreatment, notably the direct aspiration of suitably homogenised samples (Buller et al., 1981; Ebdon and Cave, 1982).

2.4.3 Neutron Activation Analysis (NAA)

Ambulkar and co-workers(Ambulkar et al., 1994) employed this technique to analyze ambient air dust particulate matter from a typical cement factory in Central India. The dust were sampled by means of high volume samplers. Synthetic elemental standards were prepared by impregnating an appropriate amounts(2-10μg) of AR/GR grade salt solutions in nitrate form on Whatman No.42 filter paper. Standard reference materials from urban particulate matter (SRM 1648) and coal flyash (SRM 1633a) from the National Institute of Standards and Technology

(NIST), USA, pond sediment (CRM No.2) and vehicle exhaust (CRM) No.8) both from the National Institute of Environmental Studies (NIES), Japan were used after drying in an oven overnight. The samples (20-30 mg), comparators and an elemental standard were packed in pure aluminium foil and irradiated for 10 minutes, 1 hour and 6 hours at a thermal neutron flux of 10 n^{12} /cm^2 /s. After 40 minutes of irradiation, the samples were opened, decontaminated and counted on a 45-cm^3 HPGe detector. It was reported that thirty elements (antimony, arsenic, barium, bromine, cesium, chlorine, chromium, cobalt, europium, gallium, gold, hafnium, indium, iron, lathanum, magnesium, manganese, mercury, molybdenum, potassium, rubidium, samarium, scandium, selenium, silver, sodium, tantalum, thorium, ytterbium and zinc) had been analyzed and the values for most of these elements were within ±5-10% of the published certified values in the literature.

This technique has similarly been applied on pedestrian dust (Chutke et al., 1995) collected from various industrial, commercial, residential, transport areas and highways of Nagpur City. Thirty elements were analysed including important elements: arsenic, chromium, cobalt, copper, zinc, silver and others. The samples were collected using a pre-cleaned soft brush into a clean polythene container. The samples were air-dried, crushed, powdered and sieved to a uniform mesh size (<150 μm). A multi-elemental synthetic standard was also prepared by spiking aqueous solutions containing 2-5 μg of AR/GR grade salts on a Whatman paper strip. Several standard reference materials such as coal (SRM 1632b) from the National Institute of Standards and Technology (NIST), USA, pond sediment from the National Institute of Environmental Studies (NIES), Japan and soil-5 from the International Atomic Energy Agency (IAEA), Vienna were also analysed for quality control and data validation.. All the samples and standards were dried overnight at 110 °C. 25

mg of each sample along with comparator standards were encapsulated in pure aluminium foil and irradiated with thermal neutrons at $1.5x10^{13}$ n/cm^2 /s for one day in a reactor. After 48 hours of irradiation, the samples were counted on a 113-cm^3 HPGe detector at sucessive intervals of 2 days, 5 days and 2 weeks. It was reported that the data for standard reference materials were within ±5% of the certified values. The relative standard deviations values in all cases were less than 10% suggesting a high order of precision.

The technique was also applied on ambient air dust particulate matter from metropolitan cities (Chutke et al., 1994). The dust particulate matter were collected using a high volume air sampler on a pre-weighed glass-fibre filter paper. The filter paper was dried in an oven at 80°C. The fine powder of dust was then removed using a Teflon-coated spatula in order to avoid any metal contamination. The standard reference materials used were urban particulate matter (SRM 1648) and coal (SRM 1632b) from the NIST, USA, vehicle exhaust (CRM No.8)from the NIES, Japan and soil-5 from the IAEA, Vienna. After drying in an oven at 80°C overnight, 20-30mg of each sample and standard were packed in an aluminium foil and irradiated for 1 day in a thermal neutron flux of 10^{13} n/cm ^{2}/s in a reactor. All samples were then counted on a 113-cm^3 HPGe detector. It was reported that for most elements, the observed values were within ±5-10% of the certified values. In all cases, the standard deviations were less than 10%.

Other analyses of the NIST coal and flyash standard reference materials by four laboratories employing NAA technique showed excellent interlaboratory agreement (Ondov et al., 1975). With the coal standard, the interlaboratory means shared coefficient of variation values: < 10% for 17 of 30 elements, < 15% for 25 of 30 elements and <25% for all 30 elements. Results with the flyash standard were slightly poorer. Except for arsenic, nickel and zinc , the mean values results agreed with the NIST values within the experimental uncertainties.

In another interlaboratory comparison employing dried solution deposits containing known elemental concentrations, NAA agreed with the theoretical results within 11% in all cases (Camp et al., 1975).

The reported advantages of NAA (Lodge, 1989) include: (1) the near absence of matrix effects from self-absorption and few inter-elemental interferences, (2) the ability to analyze thick and heterogeneous samples and (3) the relative nondestructiveness of the method ,making the samples potentially available for some additional analyses (excluding those for labile constituents and allowing for residual radioactivity).

However, NAA also has some disadvantages when compared with several other analytical techniques. These are :relatively high skill is required from the operator, handling of radioactive material is involved and the turnover time could be long in many instances, the exclusion of nickel, phosphorus and elements lighter than sodium (except F) and a very high instrumental detection limit for sulphur. In addition, cadmiun is not consistently measured (Ondov et al., 1975). Moreover, it requires access to a nuclear reactor which is already a problem in some countries and which may gradually become worse in the years to come.

2.5 CONCLUSION

The volume weighted mean diameter is selected for the present study as this study is partly implicated with the health effects of the paint dust and hence its potential deposition in the lungs since the volume of a particle is proportional to its weight.

The analytical techniques such as atomic absorption spectrometry (Chen and Risby, 1983; Kneip and Kleinman., 1982), inductively coupled plasma-atomic emission spectrometry (Sugimae, 1975), neutron activation analysis (Alia and Sansoni, 1985; Darus et al., 1970) and to a lesser extent X-ray fluorescence spectrometry (Iwatsuki et al., 1984; Adams et al., 1980) have been used to determine trace elements in airborne particulate matter collected on different types of filter media. A comparative study of these techniques suggests that ICP-AES might be the best choice for the analysis of airborne particulate matter (Sneddon, 1983).

ICP-AES technique could also possibly be applied in an equally efficient way to dust samples collected from the hopper of a dust-collecting equipment.

In the present 3-4 month study, the AAS technique is not chosen because it can only determine one element at a time and thus it renders multi-elemental analyses too laborious and too time-consuming. The NAA is not available at the Institute of Postgraduate Studies and Research, University of Malaya (IPSP,UM) due to the requirement of a nuclear reactor and also it can be very expensive for elemental analyses. The ICP-AES technique has been chosen because of its multi-elemental capability thereby saving considerable amount of time in several elemental analyses, cheaper cost and its availability at the IPSP,UM.