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Quantitative estimation of dust fall and smoke particles in Quetta Valley*

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Abstract: Tightening of air quality standards for populated urban areas has led to increasing attention to assessment of air quality management areas, where violation of air quality standards occurs, and development of control strategies to eliminate such violation of air quality standards. The Quetta urban area is very densely built and has heavy motorized traffic. The increase of emissions mainly from traffic and industry are responsible for the increase in atmospheric pollution levels during the last years. The dust examined in the current study was collected by both deposit gauge and Petri dish methods at various sites of Quetta Valley. Smoke particles were obtained by bladder method from the exhausts of various types of motor vehicles. The concentration of lead found in the smoke ranged from 1.5×10^{-6} to 4.5×10^{-6}.

Key words: Particulate matter (PM), Dust fall, Smoke, Lead, Gasoline
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INTRODUCTION

Over the recent decades extensive research on atmospheric particles in urban environments was carried out. Most of the following papers refer to their authors' contribution to air pollution and the effects on human health (Dzubay and Mamane, 1989; van Borm *et al*., 1989; 1990; Rojas *et al*., 1990; Paoletti *et al*., 1991; 1999; Al-Rajhi *et al*., 1996; McMurry *et al*., 1996; Querol *et al*., 1996; BéruBé *et al*., 1997; Esteve *et al*., 1997; Harrison *et al*., 1997; Zou and Hooper, 1997; Kasparian *et al*., 1998; Chan *et al*., 1999). Other articles mention effects of particulates on building stone decay (Haynie, 1985; 1986; Lanting, 1986; Leysen *et al*., 1987; Zappia *et al*., 1991; Hutchinson *et al*., 1992; Nord *et al*., 1994; Rodríguez- Navarro and Sebastián, 1996; Esbert *et al*., 1996; Torfs and van Grieken, 1997; Ausset *et al*., 1998; Grossi *et al*., 1998).

The PM (particulate matter) generated by road traffic can be categorized according to its mode of formation. Research has mostly focused on vehicle exhaust particulate emissions, because it was generally assumed that fuel combustion is the primary mechanism of particles formation, although there are a number of other processes such as mechanical abrasion and corrosion, which can also result in PM being directly released to the atmosphere. The most important processes include road surface wear, tyre wear and brake wear. Other possible processes are clutch wear and corrosion of vehicle components (Wahlin *et al*., 2006).

Particle (also called particulate matter or PM) pollution is the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small, they can only be detected using an electron microscope. Particle pollution includes that of "inhalable coarse particles" with diameters ranging from 2.5 μm to 10 μm and "fine particles" with diameters equal to or smaller than 2.5 μm.

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These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some particles, known as primary particles are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Others form in complicated reactions in the atmosphere of chemicals such as sulfur dioxides and nitrogen oxides that are emitted from power plants, industries and automobiles. These particles, known as secondary particles, make up most of the fine particle pollution in the country (United States Environment Protection Agency, http://www.epa.gov/air/particles/basic.html). The term dust fall refers to aerosols with diameter equal to or greater than 10 μm and has the capability to settle down after temporary suspension in air (Ahmad, 1975; Cadle, 1975; Espinosa *et al*., 2001). Dust fall is a typical primary air pollutant. It is a complex material, the composition of which is seldom constant with the concentration of heavy metals in it being extremely variable (Jacobs, 1960).

Bowl shaped Quetta Valley is about 1650 m above mean sea level, and is bounded by the Murdar mountain ranges with peak height of 3134 m. Chiltan (peak height 3261 m) almost parallels it by 10~16 km on the east and west of the valley, somewhat farther are the mountain ranges of Zarghoon (peak height 3519 m) and Takatoo (peak height 3401 m) enclosing the valley along the Northeast and Northwest directions (Haleem, 1991).

Quetta, the capital and largest city of Balochistan Province, has population of about 1.4 million. Increasing automobiles traffic in the city and use of agriculture land for constructing buildings have spoiled the environment of the city. The major sources of air pollutants entering the municipal district of Quetta area are old poorly maintained diesel engined local buses running between city and suburbs, two stroke petrol engine rickshaws fueled by lubricating oil, the oily exhaust smoke and benzene constitute the main hazards (Faiz *et al*., 1996). Since there is no control of exhaust gases, they emit black smoke of incomplete combustion fuel all over the city (Kalabokas *et al*., 2001). In addition to motor vehicles, industrial enterprises situated within the city, thermal power station, stone crusher plants, and brick kilns contribute substantially to the atmospheric pollution of Quetta, which has no surface water sources in the form of sea, river, stream, canal, lake (the only lake has almost dried of due to the drought), spring, etc., and is also situated in arid zone therefore, dry weather is also a reason of air dust. Roadside burning of rubbish occurs to some extent, producing smoke obnoxious. Poisonous phosgene (carbonyl chloride) and hydrogen chloride gases from the burning of PVC plastic are added to the existing pollution.

During summer, the tendency towards stagnation (Leopold, 1947) under the influence of stable air in the centre of Quetta Valley with accumulation of primary pollutants (e.g., SO_2, NO) and secondary pollutants (e.g., NO_2 and peroxyacetylnitrates, PAN) along-with aerosols which are suspended fine particles such as water droplets, dust and soot, the dangers they pose range from eye and throat irritation to global warming and under the influence of sunlight contribute to the smog.

This paper is focused on the dust fall and smoke and presents a methodology to study solid particles in urban atmospheres.

MATERIALS AND METHODS

The dust samples were collected by gravitational dust sampling method (Warner, 1976; Hicks *et al*., 1980; Cadle *et al*., 1986) 24 h a day in the month of October, 2005. During collection of dust fall samples with the help of Petri dish and deposit gauge methods, the weather was dry. Smoke samples were obtained with the help of bladders attached to automobile exhausts. Time factor and heavy and light transport vehicles were specially considered. All plastic ware used during the experiments and for storage of reagents and standards was precleaned with 20% HCl, thoroughly rinsed with deionised water, stored in plastic bags to prevent contamination before being used.

Deposit gauge method

Deposit gauges were setup with collecting bowls and bottles at ten suitable places selected in various parts of the city. The deposit gauges were placed about 3 m above ground level to avoid interference from animals and the public. After one month the deposited materials were analyzed.

Petri dish method

Ten suitable places were selected for placing

Petri dishes approximately 200 m to 1500 m apart from each other within the city. The sites selected were about 3 m above ground level, to avoid the interference by animals and the public. Every 24 h, the dishes were collected in the same order in which they were placed; the contents of the dishes were weighed.

Bladder method

Smoke particles were collected by tying the bladders near the exhausts of motorcycles, rickshaws, cars, wagons and buses. The bladders were weighed before and after filling. The bladders were tightly closed for about 24 h, and then the air was released very carefully (so that no smoke particles were driven out), and then weighed. The bladders were rinsed several times with 20% nitric acid, and collected after each sample, and bladder content was assayed for lead on atomic absorption spectrometer. In this method, the weight of smoke particles released from the different vehicles per unit time as well as quantity of lead in the smoke was calculated.

The emission of smoke particles is greater especially at the intersections. Therefore, the emission of smoke particles was estimated at different intersections within the city. This was estimated by counting the number of different types of vehicles passing a crossing point per hour. It was estimated that each vehicle spent 10 s in the vicinity of a crossing point. From the above information, we were able to estimate the emission of smoke particles at different sites in the city.

RESULTS AND DISCUSSION

The sites selected for this study were on the main as well as on the side roads. Tables 1 and 2 show the mass of air dust collected by deposit gauge method and Petri dish method respectively at various sites of city for 30 d. These measurements were taken for comparison in the central city area at congested places and in clean and thinly populated area such as cantonment. It is evident from the table that the mass of dry deposition is fairly indicative of the emission sources of particulate material. The highest deposition levels are found on locations where smoke and automobile exhaust emissions are present in higher amounts and where automobiles traffic is held up for long period of time. The main road crossings (b, e, j) (see city map, Fig.1) in the city centre where the buildings are large, the wind velocity is low which results in comparatively high depositions of particulate materials.

Table 1 Mass of air dust collected by deposit gauge method

Observation station (marked on map)	Average mass of PM (g/24 h)	*RSD*
b	0.29	2.9
d	0.37	4.3
e	0.39	2.5
h	0.41	1.5
l	0.40	3.8

Table 2 Mass of air dust collected by Petri dish method

Observation station (marked on map)	Average mass of PM (g/24 h)	*RSD*
a	0.25	1.7
b	0.39	2.1
c	0.22	1.5
d	0.31	1.1
e	0.32	1.8
f	0.31	2.4
g	0.20	1.8
h	0.26	1.4
i	0.25	1.3
j	0.31	2.1

The probable contribution of particulate matter at Quetta City came mainly from stone crusher plants, brick kilns, solid waste disposals and their incinerations, fuel combustion, industrial effluents, soil dusts due to strong ground turbulence due to wind, poor sanitation and locomotive exhausts, especially smoke due to poor maintenance of vehicles. In addition to all these emission sources, dry weather conditions lead to heavy accumulation of pollutants in the atmosphere, especially when the only mechanism for removing pollutants is dry deposition by turbulent diffusion and gravitational sedimentation, as it seldom rains in the city in the major part of the year. From last few years during summer, the dust storms are raised from the desert (Dasht-e-Lut, Iran) and dust clouds in the absence of wind cover the whole region and sprinkle dust over the valley for 3~4 d cutting off the sunlight and decreasing the visibility to the extent where

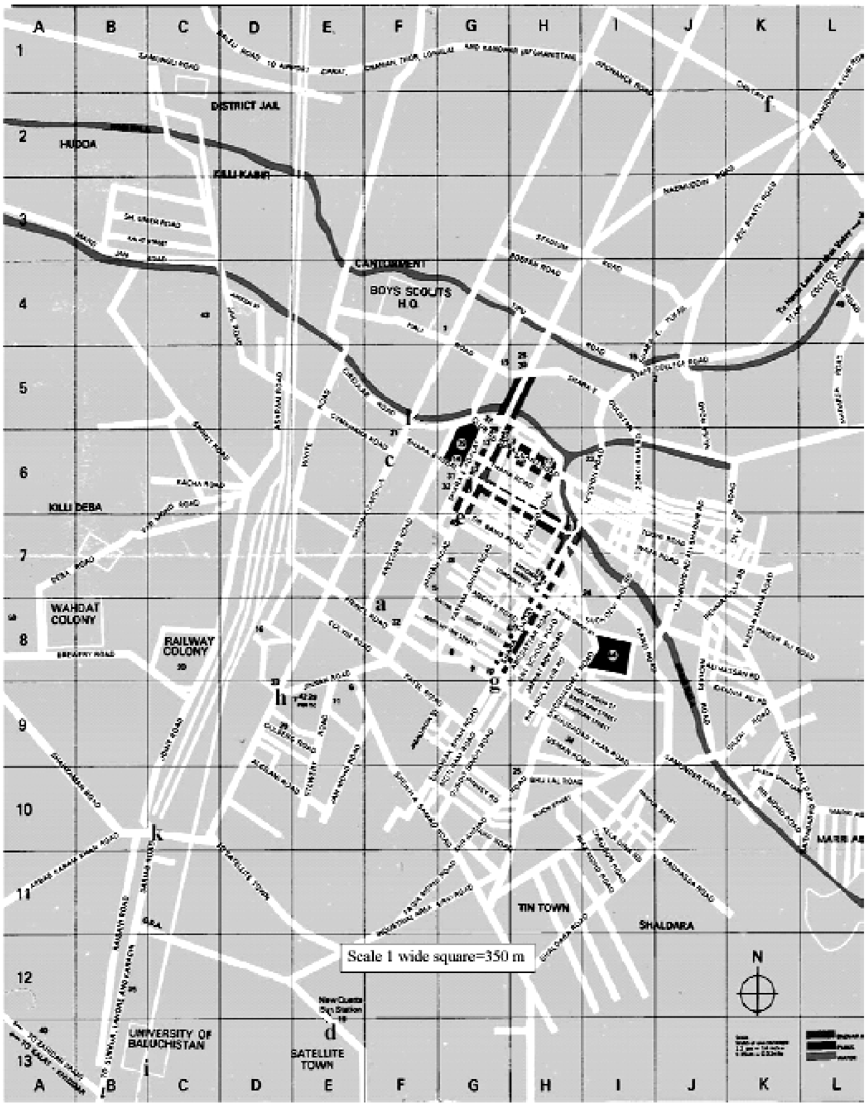

Fig.1 Map of Quetta City showing the sampling locations

the air traffic ceases. This sort of dust clouds is caused by the severe drought for the past six years.

Different smoke samples at fixed time interval from various motor vehicles were collected. The weights of smoke particles are summarized in Table 3. The total numbers of different types of vehicle, which pass different intersections per hour, are listed in Table 4.

It was reported that the average content of lead in gasoline is 0.19 g/L and estimated that 70%~80% of the gasoline lead content is emitted to the atmosphere in automobile exhaust fumes (Rodriguez-Flores and Rodriguez-Castellon, 1982).

The quantity of lead in smoke was found high in heavy vehicles like buses as shown in Table 5. The dangers involved after inhaling these smoke particles are obvious. The National Environment Standard Pakistan (http://www.cpp.org.pk) shows the value of lead in air to be 50 mg/m^3 equivalent to 0.05×10^{-6}.

Table 3 Mass of smoke particles released by different vehicles

Sample No.	Vehicle type	Average mass (g/s) (n=20)	*RSD*
1	Auto-cycle	0.02	1.8
2	Auto-rickshaw	0.07	2.5
3	Motor car	0.05	2.5
4	Wagon	0.04	3.6
5	Bus	0.05	2.9

Table 4 The number of vehicles passing different intersections per hour

Stations (marked on map)	Average number of vehicles (h) (n=12)*	*RSD*
b	413	4.5
h	373	5.1
j	370	3.5
k	401	3.5
l	388	4.9

* Data collected for daytime only

Table 5 Quantity of lead (Pb) in the smoke of particular vehicles

Sample No.	Name of vehicles	Lead ($\times10^{-6}$)
1	Auto-cycle	1.5
2	Auto-rickshaw	3.0
3	Motor car	3.5
4	Wagon	4.0
5	Bus	4.5

The gasoline in Pakistan contains lead as tetraethyl lead used as anti-knocking material, and is emitted from automobile exhausts along-with other contaminants. The atmospheric pollution due to lead has toxic effects on animals as well as on plants.

CONCLUSION

The high concentration of lead in air shows that safety standards for road transport are inadequate. Stringent rules are required to implement the safety standards. The severe drought in the past decade and human activities are mainly responsible for the increased amount of particulate matter. It is suggested that appropriate measures such as wet scrubbers, electrostatic precipitators, fabric filters or mechanical collectors should be installed on the chimneys of brick kiln, crushing plants, etc. In addition, construction, repair works on road, streets should be monitored so that the rate of emission and deposition of particulates could be minimized and Quetta Valley could be protected from this potential health hazard.

References

Ahmad, N., 1975. Air pollution survey of the Peshawar University area. *Pak. J. Sc.*, **27**:149-152.

Al-Rajhi, M.A., Al-Shayeb, S.M., Seaward, M.R.D., Edwards, H.G.M., 1996. Particle size effect for metal pollution analysis of atmospherically deposited dust. *Atmospheric Environment*, **30**(1):145-153. [doi:10.1016/1352-2310(95)00164-T]

Ausset, P., Bannery, F., DelMonte, M., Lefevre, R.A., 1998. Recording of pre-industrial atmospheric environment by ancient crusts on stone monuments. *Atmospheric Environment*, **32**(16):2859-2863. [doi:10.1016/S1352-2310(98)00063-6]

BéruBé, K.A., Jones, T.P., Williamson, B.J., 1997. Electron microscopy of urban airborne particulate matter. *Microscopy and Analysis*, **11**(1):11-13.

Cadle, R.D., 1975. The Measurement of Air Born Particles. John Wiley & Sons, New York.

Cadle, S.H., Dasch, J.M., Kopple, R.V., 1986. Winter time wet and dry deposition in northern Michigan. *Atmospheric Environment (1967)*, **20**(6):1171. [doi:10.1016/0004-6981(86)90151-4]

Chan, Y.C., Simpson, R.W., Mctainsh, G.H., Vowles, P.D., Cohen, D.D., Bailey, G.M., 1999. Source apportionment of PM 2.5 and PM 10 aerosols in Brisbane Australia by receptor modelling. *Atmospheric Environment*, **33**(19): 3251-3268. [doi:10.1016/S1352-2310(99)00090-4]

Dzubay, T.G., Mamane, Y., 1989. Use of electron microscopy data in receptor models. *Atmospheric Environment (1967)*, **23**(2):467-476. [doi:10.1016/0004-6981(89)90590-8]

Esbert, R.M., Dìaz-Pache, F., Alonso, F.J., Ordaz, J., Grossi, C.M., 1996. Solid Particles of Atmospheric Pollution Found on the Hontoria Limestone of Burgos Cathedral (Spain). Proceedings of the 8th International Congress on Deterioration and Conservation of Stone. MoK ller Druck und Verlag Gmbh, Berlin, p.393-399.

Espinosa, A.J.F., Rodriguez, M.T., DelaRoza, F.J.B., Sanchez, J.C.J., 2001. Size distribution of metals in urban Aerosols in Seville (Spain). *Atmospheric Environment*, **35**(14): 2595-2601. [doi:10.1016/S1352-2310(00)00403-9]

Esteve, V., Rius, J., Ochando, L.E., AmigoH, J.M., 1997. Quantitative X-ray diffraction phase analysis of coarse airborne particulate collected by cascade impactor sampling. *Atmospheric Environment*, **31**(23):3963-3967. [doi:10.1016/S1352-2310(97)00257-4]

Faiz, A., Weaver, C.S., Walsh, M.P., 1996. Air Pollution from Motor Vehicles, 1st Ed. World Bank, Washington DC, USA, p.20433.

Grossi, C.M., Esbert, R.M., Dìaz-Pache, F., 1998. Decay and durability of building stones in urban environments. *Materiales de Construccion*, **48**(252):5-25.

Haleem, N.M., 1991. Pollution interactions (ozone variation) on climate of Quetta. *Sci. Tech. and Devel.*, **10**(3):15-19.

Harrison, R.M., Smith, D.J.T., Pio, C.A., Castro, L.M., 1997. Comparative receptor modelling study of airborne particulate pollutants in Birmingham (United Kingdom), Coimbra (Portugal) and Lahore (Pakistan). *Atmospheric Environment*, **31**(20):3309-3321. [doi:10.1016/S1352-2310(97)00152-0]

Haynie, F.H., 1985. Size distribution of particles that may contribute to soiling of material surfaces. *Journal Air Pollution Control Association*, **35**:552-554.

Haynie, F.H., 1986. Theoretical Model of Soiling of Surfaces by Airborne Particles in Aerosols: Research, Risk Assessment and Control Strategie. *In*: Lee, S.D. (Ed.), Proceeding of the Second US-Dutch International Symposium. Lewis Publishers, Williamsburg, Virginia, USA, p.951-959.

Hicks, B.B., Wesley, M.L., Durham, J.L., 1980. In Critique of Methods to Measure Dry Deposition. EPA-600/9-80-050.

Hutchinson, A.J., Johnson, J.B., Thompson, G.E., Wood, G.C., 1992. The role of fly-ash particulate material and oxide catalysts in stone degradation. *Atmospheric Environment*, **26A**(15):2795-2803.

Jacobs, M.B., 1960. The Chemical Analysis of Air Pollutants. Interscience Publishers, New York.

Kalabokas, P.D., Hatzianestis, J., Bartzis, J.G., Papagiannakopoulos, P., 2001. Atmospheric concentrations of saturated and aromatic hydrocarbons around a creek oil refinery. *Atmospheric Environment*, **35**(14):2545-2555. [doi:10.1016/S1352-2310(00)00423-4]

Kasparian, J., Frejafon, E., Rambaldi, P., Yu, J., Vezin, B., Weolf, J.P., Ritter, P., Viscardi, P., 1998. Characterization of urban aerosols using SEM-microscopy, X-ray analysis and Lidar measurements. *Atmospheric Environment*, **32**(17):2957-2967. [doi:10.1016/S1352-2310(98)00013-2]

Lanting, R.W., 1986. Black Smoke and Soiling. *In*: Lee, S.D., Schneider, T., Grnat, L.D., Verkerk, P.J. (Eds.), Aerosols. Lewis Publishers, USA, p.923-932.

Leopold, L.B., 1947. Meteorological factors influencing air pollution in the Los Angeles area. *Trans. Am. Geophys. Union*, **28**:73-192.

Leysen, L.A., Roekens, E.J., Storms, H., van Grieken, R.E., 1987. Classification of suspended particles in deposition samples and run-off water samples from a limestone cathedral. *Atmospheric Environment (1967)*, **21**(11): 2425-2433. [doi:10.1016/0004-6981(87)90377-5]

McMurry, P.H., Litchy, M., Huang, P., Cai, X.P., Turpin, B.J., Dick, W.D., Hanson, A., 1996. Elemental composition and morphology of individual particles separated by size and hygroscopicity with the TDMA. *Atmospheric Environment*, **30**(1):101-108. [doi:10.1016/1352-2310(95)00235-Q]

Nord, A.G., Svärdh, A., Tronner, K., 1994. Air pollution levels reflected in deposits on building stone. *Atmospheric Environment*, **28**(16):2615-2622. [doi:10.1016/1352-2310(94)90435-9]

Paoletti, L., Diociaiuti, M., de Beradis, B., Santucci, S., Lozzi, L., Picozzi, P., 1999. Characterisation of aerosol individual particles in a controlled underground area. *Atmospheric Environment*, **33**(22):3603-3611. [doi:10.1016/S1352-2310(99)00101-6]

Paoletti, L., Diociauti, M., Falchi, M., Pisant, D., Ziemacki, G., 1991. Quantitative analysis of airborne breathable particles. A comparison between different analytical techniques. *Atmospheric Environment*, **25B**(2):237-242.

Querol, X., Alastuey, A., López-Soler, A., Mantilla, E., Plana, F., 1996. Mineral composition of atmospheric particulates around a large coal-fired power station. *Atmospheric Environment*, **30**(21):3557-3572. [doi:10.1016/1352-2310(96)00108-2]

Rodriguez-Flores, M., Rodriguez-Castellon, E., 1982. Lead and cadmium levels in soil and plants near highways and their correlation with traffic density. *Environ. Pollut.*, **4B**(4):281-290.

Rodríguez-Navarro, C., Sebastián, E., 1996. Role of particulate matter from vehicle exhausts on porous building stone (limestone) sulfation. *Science of the Total Environment*, **187**(2):79-91. [doi:10.1016/0048-9697(96)05124-8]

Rojas, C.M., Artaxo, P., van Grieken, R., 1990. Aerosols in Santiago de Chile: a study using receptor modeling with X-ray fluorescence and single particle analysis. *Atmospheric Environment*, **24B**:227-241.

Torfs, K., van Grieken, R., 1997. Chemical relations between atmospheric aerosols deposition and stone decay layers on historic buildings at the Mediterranean coast. *Atmospheric Environment*, **31**(15):2179-2192. [doi:10.1016/S1352-2310(97)00038-1]

van Borm, W.A., Adams, F.C., Maenhaut, W., 1989. Characterization of individual particles in the Antwerp aerosol. *Atmospheric Environment (1967)*, **23**(5):1139-1151. [doi:10.1016/0004-6981(89)90315-6]

van Borm, W.A., Adams, F.C., Maenhaut, W., 1990. Receptor modeling of the Antwerp aerosol. *Atmospheric Environment*, **24B**:419-435.

Wahlin, P., Berkowicz, R., Palmgren, F., 2006. Characterisation of traffic-generated particulate matter in Copenhagen. *Atmospheric Environment*, **40**(12):2151-2159. [doi:10.1016/j.atmosenv.2005.11.049]

Warner, P.O., 1976. Analysis of Air Pollution. Wiley Interscience Publication, John Wiley & Sons, New York.

Zappia, G., Sabbioni, C., Gobbi, C., 1991. Carbonaceous aerosol on marble and limestone monuments. *Journal of Aerosol Science*, **22**(1):S581-S584. [doi:10.1016/S0021-8502(05)80168-5]

Zou, L.Y., Hooper, M.A., 1997. Size-resolved airborne particles and their morphology in central Jakarta. *Atmospheric Environment*, **31**(8):1167-1172. [doi:10.1016/S1352-2310(96)00307-X]