Report on Turnkey Osiris Particle Results at the Southampton Hotel, Weighbridge for 2003

Executive Summary:

The Health Protection Department have monitored air quality since 1994. This initial monitoring involved nitrogen dioxide (NO_2), volatile organic compounds (VOCs) and sulphur dioxide (SO_2). However, in 2002 further equipment was acquired which allowed particles measurement (PM_{10}). Particles include dust and smoke and have a well documented respiratory effect on human health.

Results for the period of 8 months in 2003 measured at the Weighbridge exceeded the EC and UK Air Quality objectives by 20 times. These objectives should be complied with by 2010 in the UK and allow only 7 exceedances per calendar year.

The results give additional support to the importance of the Air Quality Strategy (see www.health.gov.je).

Further work is necessary to assess levels of particulates in Jersey compared to traffic numbers, mix and speed, also meteorological conditions. Again, this is part of the Integrated Air Quality Strategy. It is recommended that the daily real time results are uploaded to an Internet website for easier public access.

Comparisons with the 2002 data show there were the same number of exceedances (ie 20) for 2002 (7 months data) and 2003 (8 months data). However the results when compared against the Air Pollution Bandings indicate that air quality was worse in 2003 with 5 days of high air pollution and 3 days of very high air pollution.

Particles: Sources and Health Effects

Particles in the atmosphere originate from a wide variety of sources. They take the form of dust; smoke of very small liquid or solid particles called aerosols. Particles may be either emitted directly into the atmosphere (ie primary particles)or formed subsequently by chemical reactions (ie secondary particles). PM_{10}, (particles are defined as having an average particle size of 10 microns in diameter (10 millionths of a metre), and have well documented respiratory effects on human health. These include effects on the respiratory and cardiovascular systems, asthma and mortality. PM_{10} particles are composed of primary combustion derived carbon-centred particles e.g. ultrafines, secondary particles from atmospheric chemistry eg ammonium nitrate, natural minerals e.g. soil, wind-blown, biological e.g. spores, bacteria and metals.

Studies have shown that most of the inflammation in the lungs could be explained by the mass of particulate instilled, however, mass could not account for all of the variability in the data. It is believed the presence of metals such as iron, zinc, lead and nickel content of PM10 had the best association with inflammation out of all of the compositional measurements analysed. Primary particulate content of PM10 was also positively associated with inflammation. Ref:

The Expert Panel on Air Quality Standards (EPAQS) concluded that particle air pollution episodes are responsible for causing excess deaths among those with pre-existing lung and heart disease. EPAQS also believe that any risk of lung cancer from the concentrations found in the streets of the UK is likely to be exceedingly small. However prolonged exposure for example 20 - 30 years to particles, which are likely to be combined with Polycyclic Aromatic Hydrocarbons (PAH) originating from unburnt or partially burnt fuel, is likely to be carcinogenic.

There is a wide range of human activities that produce particulate emissions, including; motor vehicles (mainly diesel), solid fuel burning, industrial processes, power stations, incinerators and construction activity.

Emissions from mainland Europe may make a significant contribution to secondary particles in Jersey. The UK Airborne Particles Expert Group's findings suggest that in a typical year with typical meteorology, about 15% of the UK's total annual average PM_{10} concentrations (about 50% of secondary particles) are derived from mainland Europe. In years of higher frequency of easterly winds, with large movements of air from mainland Europe, emissions in mainland Europe account for a considerably higher proportion of PM_{10} concentrations, particularly in south and east England. No work has been carried out to try and establish the contribution of secondary particles originating from Europe onto Jersey.

A UK government Air Quality Strategy Objective and a European Community Directive regulates concentrations of PM_{IO} in the UK (see below). The States of Jersey has agreed to work towards the limits set out in the European Daughter Directive 99/30/EC which deals with particles, sulphur dioxide, nitrogen dioxide, and lead. The main issues around air quality in Jersey relate to local air quality and the health impacts associated with high levels monitored mainly at road junctions and along canyon streets.

Background

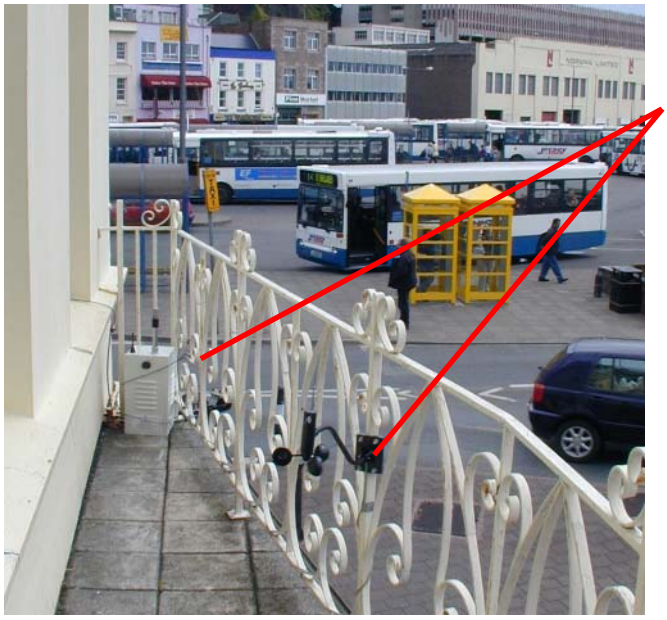
The Turnkey Osiris Particle Monitor (Optical Scattering Instantaneous Respirable Dust Indication System) (see the photograph) was purchased in March 2002. It was designed to continuously monitor particle levels in particular Total suspended particles (TSPs), PM_{10} (Particles with an aerodynamic diameter of 10 microns) $PM_{2.5}$ and $PM_{1.0}$.

A wind direction and speed monitor was also provided to give meteorological information. The Osiris is served by a GSM modem which allows Officers from this Department to dial it

up at any time and download the results using the Air Q 32 Software (see Appendix 5). It is hoped shortly that Turnkey will be providing a computer programme which will allow results to be automatically uploaded to an internet site. This would provide easier public access to the data.

The Osiris is also fitted with a filter, which traps particles as they are sized and counted. The filter was changed at 4.45pm on 23rd February 2004 and sent to TES Bretby UK Ltd for further analysis. A new pre weighed filter was placed into the unit. The filter analysis allows the weight of particles to be determined and compared with the Osiris' computer calculated weight (ie to assess the accuracy of the Osiris). The analysis by TES Bretby of the filter also allows the sources of particle and percentage contribution to be determined. The results are provided in Appendix 2.

The unit is sited on a balcony approximately 4 m above the pavement and approximately 5 m from Mulcaster Street/Esplanade (see the photograph below). The Osiris samples particles as 15 minute averages.



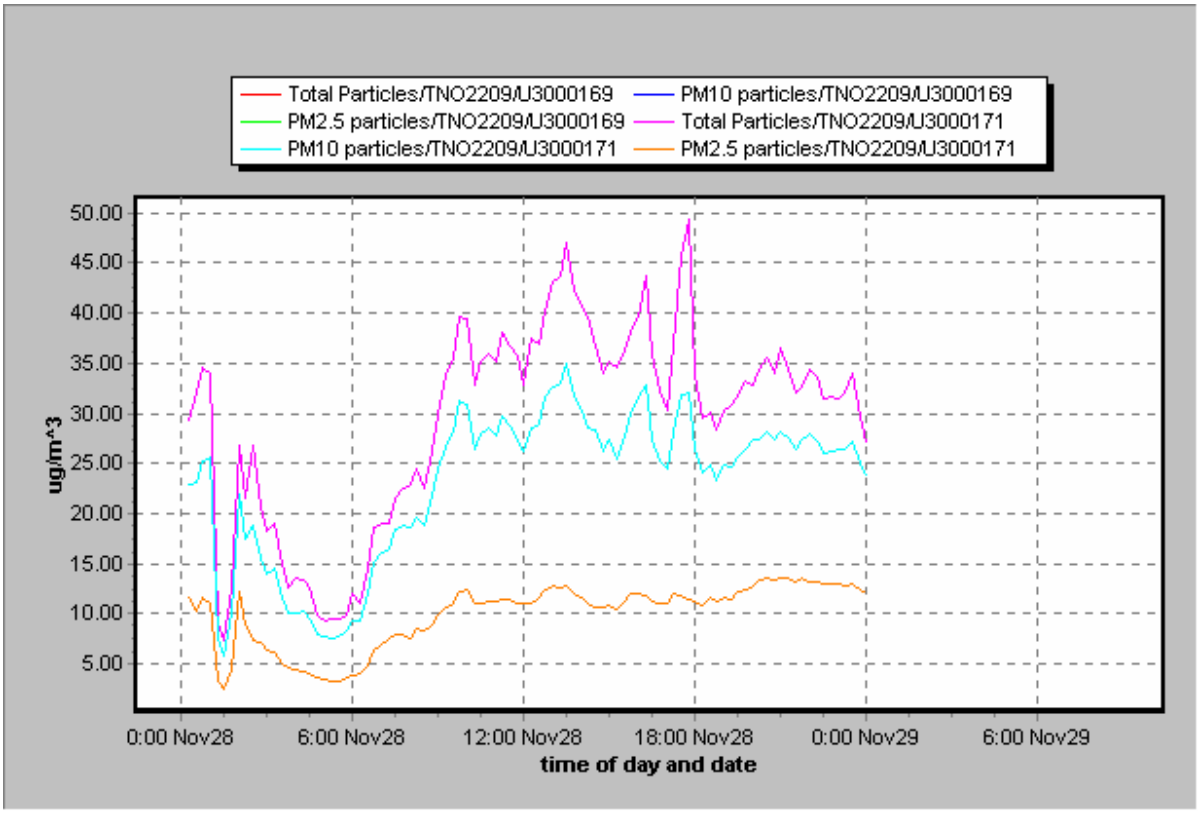
Osiris particle monitor and weather station

It was decided to position the Osiris at this particular site because it is believed has generally the poorest air quality compared to the other sites in Jersey. Unfortunately the Public Services Department were not been able to provide a traffic monitor at the site. Therefore there is limited data on the speed, volume or mix of traffic using Mulcaster Street. However the Nitrogen dioxide diffusion tube sited on the Police Surveillance tower suggests that the older type buses and taxis contributed to the poor results. Observations on site indicate that particle levels increase substantially with larger vehicles (eg lorries and buses).

Results

The particle results (ie TSP, PM_{10}, $PM_{2.5}$ and $PM_{1.0}$) are presented in tabular form in Appendix 3 and graphical form in Appendix 4. Unfortunately approximately 9 months data was obtained rather than 12 months due to technical problems with the equipment and computer software. Figure 1 below shows the particle levels over a 24 hour period for the 28th November 2003 ie Levels of particles increase up to lunch time and remain generally high till approximately 6.00 pm. This indicates that particle levels tend to follow traffic volume and mix.

Figure 1: Total suspended particles(TSPs), PM_{10} and $PM_{2.5}$ levels for 28thNovember 2003



The Turnkey Osiris Particle Monitor uses a heated inlet (50°C) to evaporate water vapour particles which would result in inaccurate readings, however it is believed that evaporation of volatiles/particles also occurs resulting in lower than normal results. Research has suggested that such results should be increased by up to 30% to increase their accuracy. However there are uncertainties as to whether 30% is the appropriate in all cases and areas of the UK. Details of the Osiris are provided in Appendix 1.

The European Union requires the use of a gravimetric (filter based) method to prove compliance, and the UK has suggested that its preferred Tapered element oscillating microbalance (TEOM) measuring devices are adequate if the results are multiplied by up to 1.3. It is this blanket nationwide uplift factor which may produce false exceedances. The Osiris although not as accurate as the TEOM provides useful indicative results. The twenty uncorrected exceedances in 230 days are shown in Table 1 below.

Table 1 Exceedances

Exceedance: greater than: 50 mg/m^3 as 24 hour average -
(7 exceedances allowed per year to be achieved by 31/12/10)

PM_{10} (mg/m^3)		**Result**
16/01/03	54.2	January: 2 Exceedances
26/01/03	53.2	
13/02/03	62.7	February: 2 Exceedances
16/02/03	63.8	
10/03/03	52.4	March: 15 Exceedances
13/03/03	54.1	
18/03/03	92.4	
19/03/03	94.7	
20/03/03	77.8	
21/03/03	90	
22/03/03	120.3	
23/03/03	67.1	
24/03/03	59.7	
25/03/03	65.1	
26/03/03	88.8	
27/03/03	103.9	
28/03/03	58.9	
29/03/03	54.9	
30.03.03	121.5	
03/11/03	52.4	November: 1 Exceedance

Total 20 exceedances
(uncorrected results)

In the period from the 4th May, 2002 - 7th January 2003 there have been twenty exceedances (uncorrected) of the European Union Daughter Directive 1999/30 and UK Air Quality Strategy limit value (ie 24 hour mean of 50 μg/m^3 both to be achieved by the end of 2010).

The results from the filter analysed by TES Bretby in the UK are shown in Appendix 2. The examination procedure is based on the assessment of approximately 50 individual particles selected at random. The estimated percentage is based on a comparison of the relative number of particles counted in each category. The filter was exposed for 39920 min (665 hours) and mass was 7.02mg. Examination revealed that the collected deposit was mainly carbonaceous matter with particle size of <10 microns associated with vehicular emissions. A number of amorphous dirt particles (ie irregular shaped particles containing Aluminum, Silicon, Calcium, Potassium and Iron in varying proportions) were also observed, small amounts of sodium/chlorine rich (salt) particles were also detected. Care must be taken interpreting theses results as only a very small number of particles were analysed. Unfortunately the costs are prohibitive for greater in depth analysis.

EU and UK Guidelines

Under the EC Air Quality Framework Directive (96/62/EC), all Member States have to assess their existing air quality and implement a programme of monitoring, dependent upon population, population density, emission sources and proximity of the general public to these sources.

Under the Framework Directive, a Member State MUST undertake continuous monitoring (using appropriate instrumentation) at least ONE site.

The subsequent Daughter Directives (1st for NO_2 and SO_2, 2nd for CO and Benzene, and the newly published 3rd for O_3), all prescribe exactly how and where monitoring should be undertaken. However, the mass of monitoring evidence collected strongly suggests that concentrations of CO and SO_2 are likely to be below the lower assessment threshold, and that there is little benefit in measuring O_3, as emissions from the island will have very little impact on island ozone concentrations.

NETCEN recommend, therefore, that the island undertakes continuous monitoring for NO_2 and PM_{10}. For the first year at least, this should be at the highest known pollution "hotspot" (Weighbridge). Once compliance with the Daughter Directive(s) is confirmed at this location, the site could be relocated to an area more representative of general population exposure (eg residential or urban background)

The EU Directive also details an: (24 hour limit value)

(a) Upper Assessment threshold: 60% of the limit value (30 $\mu g/m^3$) not to be exceeded more than 7 times in any calendar year.

(b) Lower Assessment threshold: 40% of the limit value (20 $\mu g/m^3$) not to be exceeded more than 7 times in any calendar year.

The upper Assessment threshold is presently being exceeded. Improvement in traffic management flow reduction will be needed to ensure the Upper Assessment threshold (UAT) is not exceeded in 2010.

Improvement should occur in the next few years with the improvement in engine design, relocation of the bus station to the Island site and road changes as part of the St Helier Life program. Concentrations of all pollutants appear to be falling with time. This is likely to be due to improved fuel composition and engine design (Ref NETCEN). However directive limits are becoming tighter and more health information is becoming available.

The UK guidelines include:

(a) **Air Pollution Bandings:** As a running 24 Hour mean

Low Air Pollution:	<50 $\mu g/m^3$ (210 results)
Moderate Air Pollution:	50 - 74 $\mu g/m^3$ (12 results)
High Air Pollution:	75 - 99 $\mu g/m^3$ (5 results)
Very High Air Pollution:	>= 100 $\mu g/m^3$ (3 results)

(b) **The UK Air Quality Strategy Objective for 31st Dec 2004**:

24 Hour daily mean: 50 μg/m^3 not to be exceeded more than 7 times per calendar year. (Exceeded 20 times based on 230 results)

Calender Year Annual Mean: 40 μg/m^3 (32.35μg/m^3 based on 230 results)

The PM_{10} particle results for the Weighbridge site exceeded the UK 24 hour limit value of 50μg/m^3 twenty times although is likely to comply with the annual mean value of 40μg/m^3. According to the Air Pollution Bandings the air pollution at the Weighbridge was low on 210 days, Moderate on 12 days and High on 5 days and very high on 3 days). There was an air pollution episode between the 18th and 30th March 2003. The reasons for this are not clear. The weather conditions during this period were mainly easterlies with little or no wind which could explain the elevated results.

Comparison with other sites in Jersey and UK

Particle measurements carried out at other sites in Jersey are generally lower than at this site. Surveys have been carried out at:

(a) Halkett Place 1997 and 2000 Jan - March: Average PM_{10} levels in 1997 and 2000 were 27μg/m^3. The Weighbridge site average was 32.35μg/m^3 for the 9 month period.

(b) New Street: Levels of PM_{10} in January 2000 varied between 13 - 27 μg as a running 24 hour average and no exceedances. The Weighbridge site varied between 6.7 μg/m^3 (22/10/03)and 121.5 μg/m^3(30/03/03).

(c) Savile Street: Levels of PM_{10} varied in January - February, 2001 from 21 μg/m^3 to 59 μg/m^3 as a running 24 hour average with one exceedance. The Weighbridge site varied between 6.7 μg/m^3 (22/10/03)and 121.5 μg/m^3(30/03/03).

PM_{10} concentrations in Jersey were generally higher than the UK comparison sites (Ref NETCEN) but broadly similar to those found in London and Bristol. Levels at the Weighbridge site are broadly what could be expected at a roadside location in the UK.

Particle levels from other sources such as the power station have reduced with the use of the two cable links to France (ie up to the end of September 2003 97% of electricity used in Jersey originated from France).

The Easy link coach service began on the 19th April 2003. There are 10- 15 buses operating with poor emissions compared to the cleaner Connex buses which have Euro 3 engines. When these engines are used in conjunction with low-sulphur diesel, emissions are very low. An aim should be to fit continuously regenerating particulate traps to Euro 2 and earlier diesel engines. (The cost is approx about £2 - 3,500 per vehicle, 90% of particles can be removed). Other options are to move towards gaseous fuels such as the vehicles operated by Jersey Gas. The availability of biodiesel in Jersey in the near future should lead to improvements. In London the trilling of water diesel emulsion is occurring which is claimed to halve particle emissions and cut NOx (i.e. Oxides of Nitrogen) by 23%.

Other improvements include:

(A) 2 new cremators which comply with the UK Environmental Protection Act 1990 Process Guidance notes

(B) A new waste to energy plant to be built in 2005-2008 with improved emissions

(C) New Building By law Part L to improve insulation etc in domestic properties thereby reducing emissions.

Comparisons with the 2002 data

1. There were the same number of exceedances (ie 20) for 2002 (7 months data) and 2003 (8 months data).

2. Calendar mean for 2003: 32.35μg/m^3 and 2002: 33.10μg/m^3

3. Air Pollution Bandings**:** As a running 24 Hour mean

	2003	**2002**
Low Air Pollution:	<50 μg/m^3 (210 results)	(211 results)
Moderate Air Pollution:	50 - 74 μg/m^3 (12 results)	(17 results)
High Air Pollution:	75 - 99 μg/m^3 (5 results)	(3 results)
Very High Air Pollution:	>= 100 μg/m^3 (3 results)	

4. The upper assessment threshold was exceeded in both 2002 and 2003

The results indicate that air quality was worse in 2003 with 5 days of high air pollution and 3 days of very high air pollution.

Conclusions

1. The Turnkey Osiris particulate monitor was set up on the Southampton Hotel's balcony at the Weighbridge in May 2002 and measures particles in real time (ie Total Suspended Particles TSP, Particles of a mean aerodynamic diameter of 10 microns PM_{10}, Particles of a mean aerodynamic diameter of 2.5 microns $PM_{2.5}$ and Particles of a mean aerodynamic diameter of 1 micron $PM_{1.0}$) as 15 minute averages.

2. Particles are associated with a range of health effects. These include effects on the respiratory and cardiovascular systems, asthma and mortality. The Expert Panel on Air Quality Standards (EPAQS) concluded that particle air pollution episodes are responsible for causing excess deaths among those with pre-existing lung and heart disease. EPAQS also believe that any risk of lung cancer from the concentrations found in the streets of the UK is likely to be exceedingly small. However prolonged exposure for example 20 - 30 years to particles, which are likely to be combined with Polycyclic Aromatic Hydrocarbons (PAH) originating from unburnt or partially burnt fuel, is likely to be carcinogenic.

3. The results show that the EU Directive health limit was exceeded 20 times in the 9 months sampling period. The EU Directive allows 7 exceedances and is to be achieved by the end of 2010.

4. The particle results follow traffic movements as particle levels increase up to lunchtime and remain high into the afternoon.

5. The relationship between meteorological conditions and particle levels is not clear. As wind speed increase particle levels reduce, however the position of the monitor is sheltered to northerly and north easterly winds.

6. The Osiris has a glass fibre filter which collects particle material, which was further analysed to determine the sources of the particles and percentage contribution. Examination revealed that the collected deposit was mainly carbonaceous matter with particle size of <10 microns associated with vehicular emissions. A number of amorphous dirt particles were also observed, small amounts of sodium/chlorine rich (salt) particles were also detected. Care must be taken interpreting these results as only a very small number of particles were analysed. Unfortunately the costs are prohibitive for greater in depth analysis.

7. Most exceedances (13) occurred in March 2003. It is not clear what caused this pollution episode.

8. PM_{10} concentrations in Jersey were generally higher than the UK comparison sites (Ref NETCEN) but broadly similar to those found in London and Bristol. Levels at the Weighbridge site are broadly what could be expected at a roadside location in the UK.

9. Concentrations of all pollutants appear to be falling with time. This is likely to be due to improved fuel composition and engine design (Ref NETCEN). However directive limits are becoming tighter and more health information is readily available.

10. Particle levels from other sources such as the power station have reduced with the use of the two cable links to France (ie up to the end of September 2003 97% of electricity used in Jersey originated from France).

11. The main issues around air quality in Jersey relate to local air quality and the health impacts associated with high levels monitored mainly at road junctions and along canyon streets.

Recommendations

1. Further long term research (until at least 2010) should be carried out to assess levels of $PM_{10}/PM_{2.5}$ in Jersey compared to traffic numbers, mix and speed and meteorological conditions to establish trends and assess compliance with the European Union Daughter Directive objectives. This forms part of the integrated Air Quality Strategy. It is recommended the results are uploaded to an internet web site for easier public access. NETCEN are quoting for the cost of setting up a website to enable this to occur.

2. Traffic data (eg volume, mix and speed) should be made available to allow more meaningful comparison with particle results.

3. Further work is needed to assess the relationships between meteorological data and particle levels.

4. It is likely reductions in particle levels will occur because of improvement in emissions from the re-location of the bus station to the Island Site and road changes associated with the St Helier Street Life program.

5. Those objectives which impact on air quality in the Department's Air Quality Strategy, Public Services Department's Sustainable Island Transport Strategy, the new Island Plan, the Strategy on Sustainable Development be implemented and supported.

6. Further work is needed to assess the contribution of secondary particles from mainland France to Jersey. Also analysis should be carried out to confirm that the 30% increase in figures associated with heated inlets is correct for this particular monitoring site.

7. An aim should be to fit continuously regenerating particulate traps to Euro 2 and earlier diesel engines. (The cost is approx about £2 - 3,500 per vehicle, 90% of particles can be removed).

8. Good quality data is needed to assess improvements in tends in air quality, usuage of public transport etc

9. The Department’s Air Quality Strategy (AQS)needs progressing and the profile of air quality raising.

Appendix 1: The Turnkey Osiris Particle Monitor

Osiris stands for *Optical Scattering Instantaneous Respirable Dust Indication System*.

The Osiris is an investigational instrument that fulfils the dual role of a portable instrument or permanent installation.

The instrument is housed in a sturdy die cast metal box with internal rechargeable battery. The external power source was connected for the long term monitoring. The internal memory was used to record PM_{10}, $PM_{2.5}$, $PM_{1.0}$ and Total Suspended Particles (TSP) as 15 minute averages for the monitoring periods. Each 24 hour period is saved in a folder for downloading to a computer and analysing with the Air Quality Programme for Windows. The Air Quality programme allows the data to be graphed and copied into Microsoft Excel for further analysis.

The instrument measures and records the concentration of airborne particles using a proprietary laser (nephelometer). An internal pump continuously draws an air sample through the nephelometer which analyses the light scattered by individual particles as they pass through a laser beam. These same particles are then collected on the reference filter. The nephelometer's dedicated microprocessor can analyse the individual particles even if there are millions of them per litre. This allows the size fractions to be determined at concentrations up to several milligrams/m^3.

The light scattered by the individual particles is converted into an electrical signal which is proportional to the size of the particle. A unique feature of the Turnkey nephelometer is that only light scattered through very narrow angles 10 degrees or less is measured. At this narrow angle the amount of light scattered is virtually the same for say black diesel or white limestone particles of the same size. That is, it doesn't depend on the material composition of the particle. On the other hand, the easier to measure right angle 90° scatter used by some earlier scattering instruments is highly dependant on material composition with white particles apparently scattering much more light than black ones of the same size.

The light scattered by airborne particles can be thought of as consisting of three components. Light reflected from the surface of the particle, light refracted through the particle and light which is diffracted from its original path by the presence of the particle. The intensity of the light scattered by reflection or refraction strongly depends on the type of particle. Thus a white limestone particle will reflect much more light than a black diesel fume particle of the same size. On the other hand the diffracted component depends only on the size of the particle and is independent of its material composition.

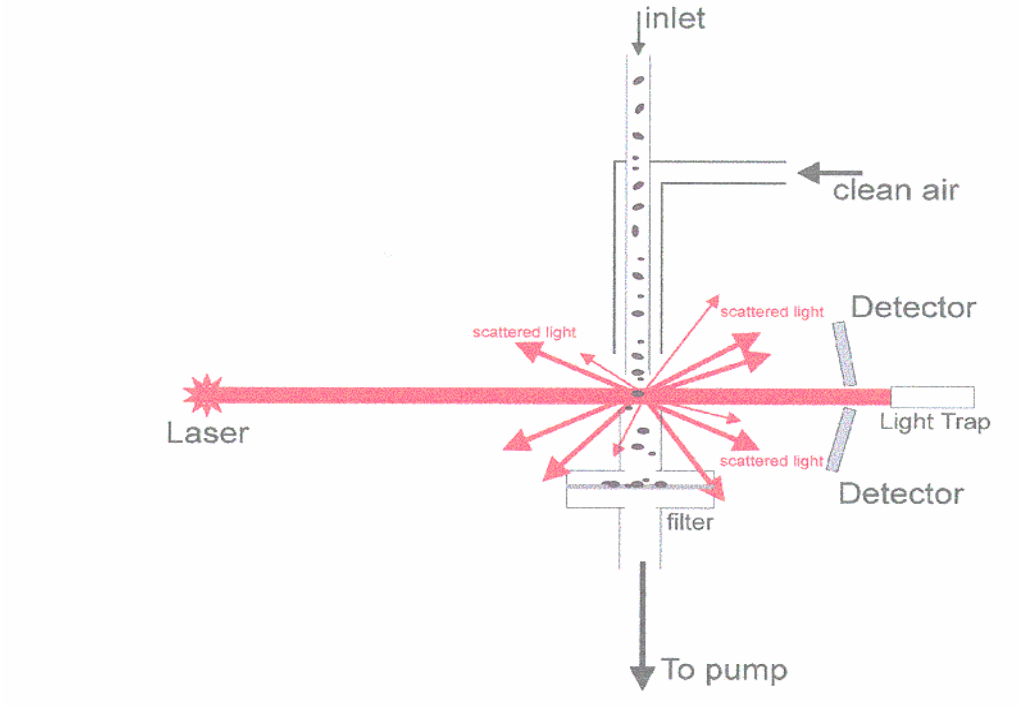
For irregularly shaped particles, light, which is reflected and refracted, tends to be scattered over all possible directions. The diffracted component, however, tends to be scattered only through very small angles. For example, for a 5 micron diameter particle, 90% of the diffracted light is scattered by less than 10 degrees from the original direction of the light beam.(42)

The intensity of the light pulse is therefore an indicator of particle size, from this the microprocessor is able to calculate the expected mass of the particle. It assumes the material density of the particle is 1.5 grams per cc, which for most airborne dusts is a good approximation but the mass calibration factor can be adjusted to compensate for different material types.

Having evaluated the mass of the particle, the microprocessor then evaluates the likely chance of deposition of the particle according to the sampling convention being used (PM_{10}, thoracic,

and so on) as shown in figure 19 below. Thus for the thoracic convention a 6 micron particle has an 80.5% chance of deposition, hence only this percentage of its evaluated mass is accumulated.(42)

Diagram of the Osiris particle monitor



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