could reverse this effect and lead to an increase in Australian drying trends. "We are really at the beginning of understanding the trends but sooner or later these emissions will be cleaned up and then a trend of increasing rainfall in the northwest and centre could be reversed. This is potentially serious, because the northwest and centre are the only parts of Australia where rainfall has been increasing in recent decades."

Dr Rotstayn stresses that climate modelling is a valuable tool for teasing out what is actually causing weather trends, rather than simply assuming that these trends are all related to greenhouse gases.

At a time when Australian science agencies are investing in new climate forecasting capabilities, the research - to be published early in 2007 in the Journal of Geophysical Research - increases confidence in the accuracy of future climate simulations for Australia. An aerosol is a haze of particles in the atmosphere. Dr Rotstayn says representing aerosols in climate models and understanding their influence on cloud formation and rainfall is one of the biggest challenges facing climate scientists.

"Because the cooling effect of aerosol pollution is possibly comparable to the warming effect of increased levels of carbon dioxide, the message from this research is that aerosols are an essential inclusion if we are to accurately describe present and future Australian climate," he says.

The new research is based on simulations performed with a new low-resolution version of CSIRO's global climate model - including a treatment of aerosols from both natural and human-induced sources.

Dr Rotstayn was lead author of the paper with contributing scientists from: the Cooperative Research Centre for Greenhouse Accounting; the University of Michigan's Department of Atmospheric, Oceanic and Space Sciences; and the US National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory in Princeton.

Source: CSIRO News Release, 12 December 2006

CORPORATE US TO REACH GREEN TIPPING POINT BY 2009?

US corporate profitability is tied to the proactive use of green ideas and building principles, according to the "Green Perspective from Corporate America" study commissioned by Siemens last year.

The study found leading US companies view "green" practices as an important component of profitable growth and have begun to incorporate them into strategic business planning.

The study also suggests American businesses will reach a "green tipping point" in early 2009, perhaps even as soon as 2007. Green philosophy and buildings will emerge as a prominent corporate trend in the next 1-3 years, with the majority of respondents believing their companies will be aligned with "green" industry practices within three years.

Almost 60% agreed that going green would lower their operating costs, with rising energy prices the key driver. Some 40% considered environmental sustainability to be "of high importance" to their organisation.

Source: WME weekly News, November 28 2006

OIL RESERVE EIGHT TIMES BIGGER THAN SAUDI ARABIA'S

All of a sudden, the oil sands in Alberta, Canada have become a veritable "black gold" mine.

Just three years ago, when the average price of crude was $29.63 a barrel, producers didn't find the profits to be worth the costs of processing the oil sands. But improvements in mining technology have dramatically reduced the cost of extraction, rocketing bottom lines skyward. According to the Oil Sands Discovery Centre in Alberta, it now costs an average of just $13.21 to process each of the 2.5 trillion barrels of oil embedded in the sands – a reserve 8 times bigger than Saudi Arabia's... containing more oil than all OPEC nations combined.

Source: InvestmentU web site, January

Development and Evaluation of a Low Cost Particulate Monitor for User-Defined Conditional Sequential Sampling

J. Harrison, N. Key, S. Kingham and A.P. Sturman

ABSTRACT

This paper presents the design and evaluation of a low-cost particulate monitor, the Samplemaster 7000, designed for user-defined conditional sequential sampling. The sampler is a portable unit which can be quickly and easily assembled, and is easy to operate. It was field tested initially using sequential sampling for 24 hours from midnight to midnight and showed good correlations with standards measures. It was then set up for conditional sampling based on wind speed and direction, with excellent results.

INTRODUCTION

There are a variety of methods available for monitoring particulates based on different techniques that are available at a range of costs. The aim of this paper is to describe a low cost gravimetric sampler that allows sequential sampling based on user-defined criteria. For information which reviews or compares samplers and sampling techniques the reader is referred to (Baldauf, 2001; Chang, 2001; Green, 2001; MfE, 2003; Vega *et al.*, 2003; Yanosky, 2001). As the focus of this paper is on a gravimetric method, it is worth noting the relative advantages and disadvantages of gravimetric methods. The two main advantages are that the equipment associated with gravimetric methods can be relatively low cost, and consistency with USEPA reference method specifications (MfE, 2003). The disadvantages are that they rarely include information on temporal distributions of data and can incur significant labour costs associated with changing, conditioning and weighing filters (MfE, 2003).

Consequently, a low cost gravimetric sampler that can account for some temporal changes and that can reduce filter related labour costs is attractive. Samplers that have attempted to address some of these concerns are the ACCU™ system for TEOM® monitor and the Partisol-Plus Model 2025 Sequential Air Sampler. The ACCU™ system allows for the collection of up to seven gases or particulate samples which can be subsequently analysed or weighed. The timing of collection can be based upon time, real-time PM concentration (from the TEOM®), wind speed/direction, or other analog input. The Partisol allows for the collection of up to sixteen samples, but does not allow the collection to recommence on a filter that has already been used. Neither of these samplers would be considered a low-cost sampler. The TEOM® with the ACCU™ system costs somewhere in the region of NZ$37,000 (AUS$32,000) while the Partisol-Plus Model 2025 Sequential Air Sampler costs around NZ$23,000 (AUS$20,000). It is anticipated that the Samplemaster will cost somewhere in the region NZ$12-17,000 (AUS$10-15,000) depending the exact specification required.

The purpose of this study was to develop a low cost gravimetric sampler that allowed sequential sampling based on user-defined conditional criteria. These criteria could include such things as:

- only sample 9am to midday;
- only sample when the wind is coming from the east;
- only sample when wind speed is below three metres per second;

or any other criteria that is measurable. In addition, the sampler should be robust and flexible to the requirements of users. The sampler needs also to be able to collect on a filter already used, if defined criteria are met again.

This paper will describe the sampler in the methods section, before evaluating its performance in field trials in the results section.

Figure 1. Photo of the Samplemaster 7000 system.

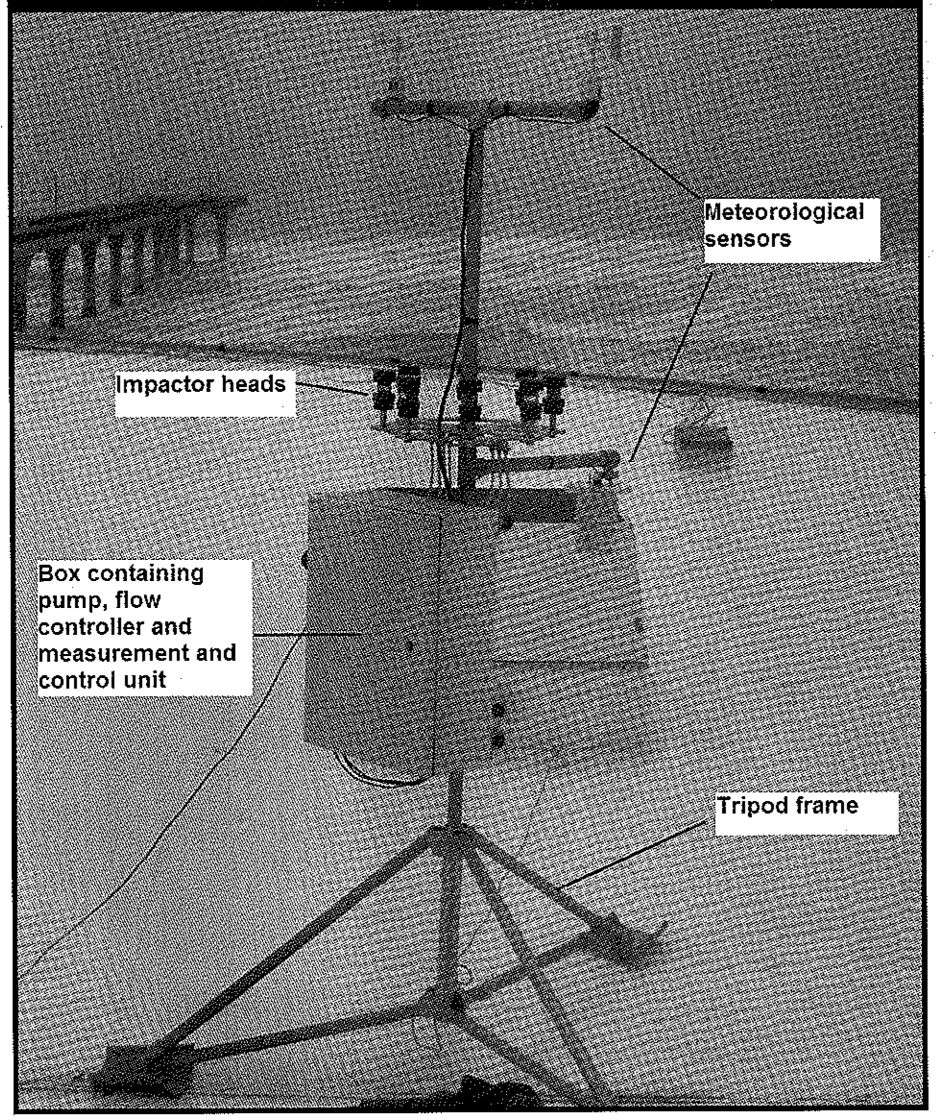


Figure 2. Schematic of the Samplemaster 7000 system.

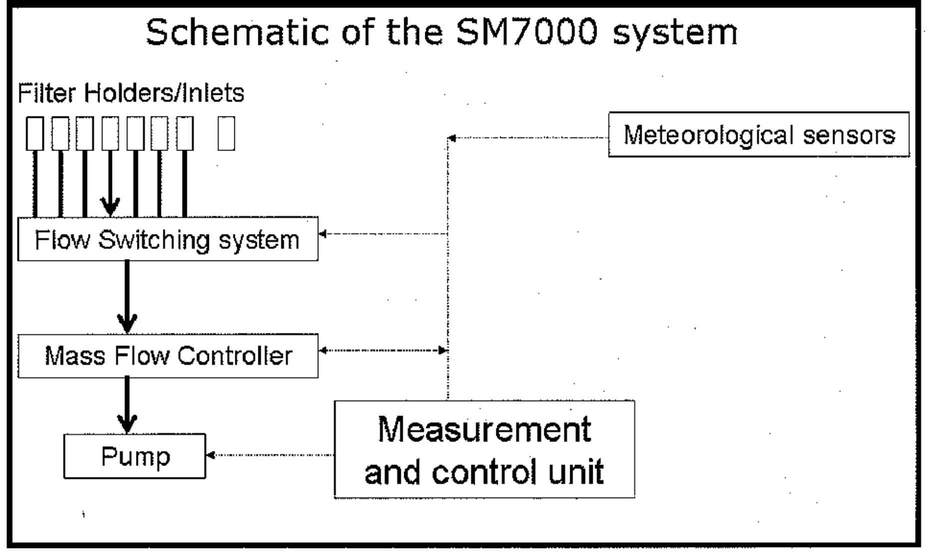
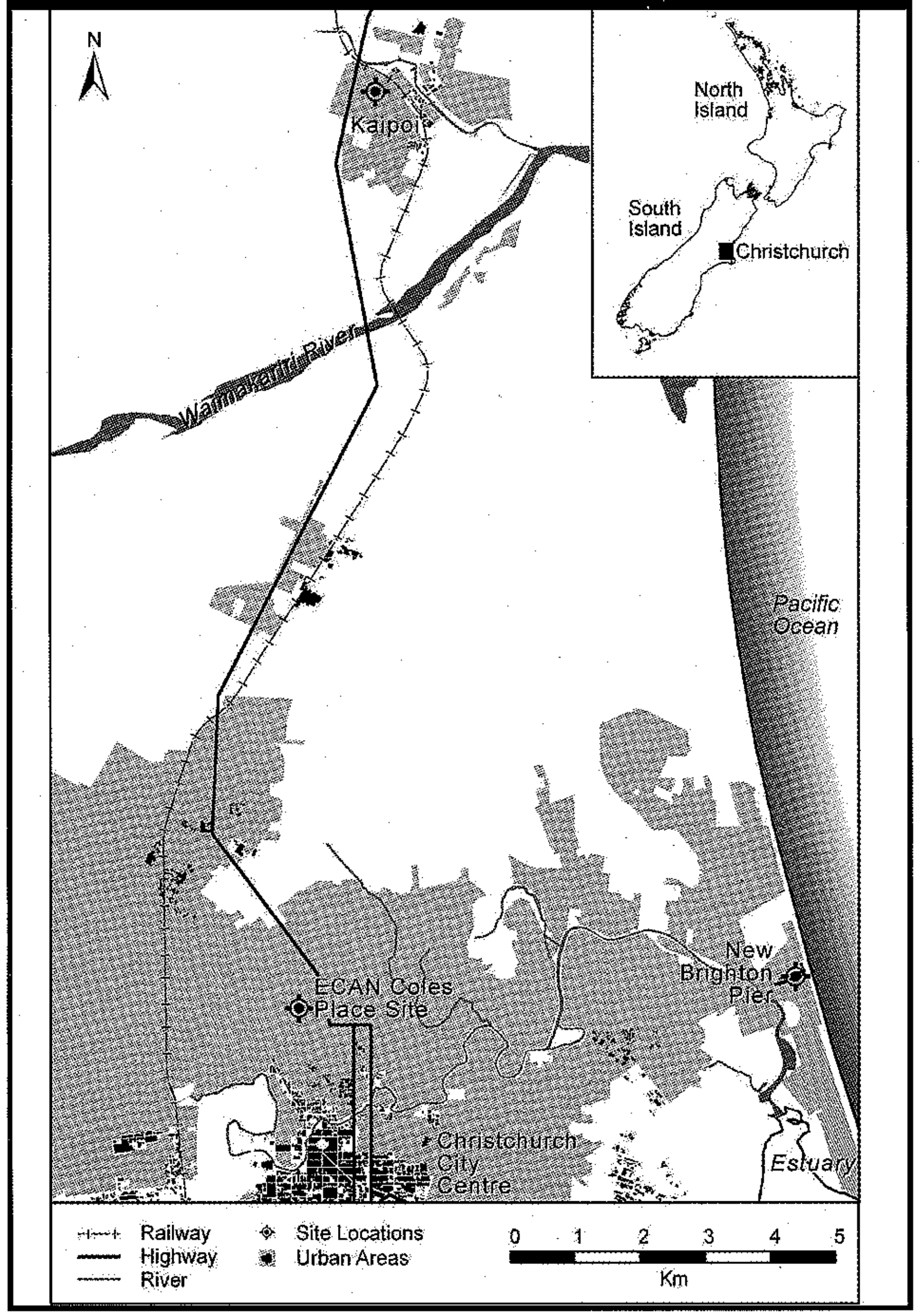


Figure 3. Area map showing location of sample sites.



Methods

Description of the Samplemaster 7000

The Samplemaster 7000 is a flexible sampling system that allows for sequential or conditional sampling of a selected pollutant. It is based on a simple tripod frame upon which sampling apparatus can be attached, along with a pump, flow controller and meteorological or other sensors (Figure 1). It was originally set up as a low volume gravimetric particulate sampler, and this set up is the basis for this paper.

The Samplemaster 7000 has a total of eight inlet attachment points positioned 2m above the tripod base, seven of which are connected to the flow control system (Figure 2). The eighth inlet is used to house a field blank for quality control. The seven active inlets can be used, one at a time, to measure either PM10, PM2.5, or for sorbent tubes and equivalent type sampling. Standard MiniVol (www.airmetrics.com) PM10 inlets were used for this study.

A key factor in gravimetric sampling is the control of flow rates (John and Wang, 1991). The Samplemaster 7000 uses a mass flow controller, thereby eliminating the need for calculations to convert flow rates to standard conditions. In the configuration used for this study, the mass flow controller was manually set to a standard flow of five litres/min, although there is the flexibility in the system to allow flow rates up to 15 litres/min with the current pump and flow controller. The flow rate can also be changed depending on measured environmental conditions, or time. The use of these higher flow rates may be desirable for studies where particulate concentrations are expected to be low. Data from the mass flow controller is recorded to track any deviations of flow from the desired value. Flow rates other than five litres/min cannot be used when measuring either PM10 or PM2.5 due to the present inlet design (which is set up with MiniVol heads) which relies on known flow rates and greased impactor plates to separate out the desired size fraction.

A further key factor in gravimetric sampling is the method used to determine mass of aerosol on the filter. In this study, Whatman GF/A 47mm diameter filters were used. Filters were placed in a sealed desiccator (with silica gel crystals used as desiccant) for a period of at least 24 hours before weighing (both before and after exposure). Prior to weighing, filters were allowed to equilibrate in the weighing room for a period of no less than 20 minutes. Environmental conditions were monitored in the weighing room using a Kestrel 4000 pocket weather meter; and all weighing was conducted within the following environmental constraints: air temperature: 20°C ±1.5°C; relative humidity 35% ± 7.5%. The balance used was a Sartorius Genius, model MEP215P with integrated ionisation function (used to eliminate any static charge on filters). The weighing room used was an internal room (i.e. has no walls in direct contact with the outside of the building) for temperature stability, and it was located on

Table 1. Field trialling of the Samplemaster 7000.

Type of trial	Location	Dates	Measured
Comparison with regional council (ECan) TEOM® (with FDMS)	Coles Place, Christchurch	23 - 30 June 2005	PM10 concentration
Comparison with regional council (ECan) TEOM® (with FDMS)	Peraki St, Kaiapoi	15 - 21 June 2006	PM10 concentration
Conditional on wind direction	Roof of New Brighton Library, Christchurch	27 - 30 June and 6 - 13 July 2006	PM10 concentration and absorption

the ground floor, with the balance situated on a masonry block bench to minimise vibration disturbance.

The integration of meteorological sensor data into the measurement and control system allows filters to be sampled either sequentially, based on pre-set timings, or conditionally, in the latter case depending on the meteorological conditions of interest, for example wind direction (for source apportionment studies), wind speed (for threshold studies), temperature, relative humidity, etc. If required, the sampler will return to a filter that has already been used. For example, a user may want to know the particulate levels that result from certain meteorological and environmental conditions, such as when the wind is below three ms^{-1} and coming from the sea. Data can be recorded at whatever interval is considered appropriate, with sufficient storage for 32,000 data points. The unit can also be linked by cell modem or other appropriate telemetry option to allow viewing of real-time meteorological data, or even to change the sampling program remotely.

Preliminary field trials

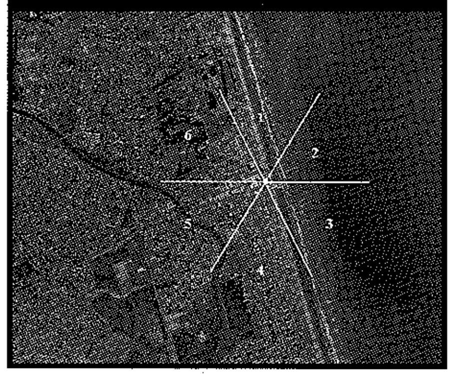
The preliminary sampling was undertaken on a sequential basis at a user defined interval of 24 hours with a start time of midnight to allow for comparison to the Regional Council's (Environment Canterbury) TEOM (with FDMS, Filter Dynamics Measurement System which reduces the loss of volatiles as a result of heating the air sample) (Table 1). Two periods of sampling were conducted to benchmark performance of the Samplemaster 7000 to reference methods administered by Environment Canterbury. The first period was for seven days from 23 to 30 June 2005 at Coles Place in the St Albans suburb of Christchurch, New Zealand. Coles Place is the main monitoring site used by the Regional Council (Figure 3 and Table 1). It is a good site as there are no nearby large buildings or other structures that may affect airflow. The second period was from 15 to 21 June 2006 at Peraki St in the small town of Kaiapoi, approximately 15km north of Christchurch (Figure 3 and Table 1). The Peraki St site is not such a good site as there are some moderately large buildings nearby, as well as a large hedge and a chimney stack approximately 30m away to the south-west. As the purpose of this sampling was to compare to standard methods, this is not seen as a problem. The concentrations recorded by TEOM samplers were compared with those recorded by the Samplemaster 7000.

Conditional sampling field trial

The conditional sampling program used in the main field trial of this study controlled which inlet was sampled depending on the wind direction (Table 1). With this program, the user is able to specify six wind direction sectors, which relate to inlets/filters 1-6. The seventh filter is used to sample when wind speeds are below a user defined cut off point (in this case $0.2ms^{-1}$) in which case the wind direction is no longer reliably measured. Wind direction was sampled every five seconds, and a rolling 30 second average was used to determine when to change the sampled inlet. This was done to avoid rapid and frequent changes of the sampled inlet in unstable wind conditions. Also, the nature of wind direction measurement using a wind vane is such that overshoot can result in incorrect interpretation of wind direction if only considering one instantaneous sample.

The Samplemaster 7000 was set up on top of the library building on the water front at New Brighton, Christchurch from June 27 - 30 and July 6 -13 2006. The library building is a large structure with a roof that angles in from both sites to where the Samplemaster 700 was located. This may potentially disturb wind patterns, and confirmation of any wind disturbances around the building would require a detailed study. The six wind direction sectors were: 1: 330-030, 2: 030-090, 3: 090-150, 4: 150-210, 5: 210-270, and 6: 270-330. Sectors 1, 2 and 3 sample air from the direction of the sea and sectors 4, 5, and 6 from land (see Figure 4). Bearing in mind the problem of potential wind disturbance, it was expected that the sectors would be coarse enough to still give a good representation of true origin. ECan (the Regional Council) does not collect PM10 at the library, so it is not possible to compare the Samplemaster values with those collected by any other systems. In this study we know that sectors 1, 2 and 3 sample air coming from the sea and therefore we would expect a large proportion of the PM10 to be sea salt. They would therefore contain lower levels of elemental carbon and result in lighter colour filters relative to the PM10 concentrations. When the wind direction is from inland (sectors 4-6) we might expect a similar relationship between blackness of filter and PM10 concentration to that observed elsewhere where Spearman correlation values of between 0.5 and 0.6 have been reported (Fischer *et al.*, 2000; Kingham *et al.*, 2000). However it should be noted that in the areas this research took place the main source of PM10 was traffic, whereas Christchurch also has significant

Figure 4. Aerial photo of the location of the Samplemaster 7000 system at New Brighton, with wind sectors marked.



particulate emissions from domestic heating (Spronken-Smith *et al.*, 2002). Less research has been done on such relationships when the wind direction is from the sea (sectors 1-3) although you may expect a clearer relationship if the only source is sea salt. It is therefore of research interest to see what impact this has on the relationship between PM10 concentration and blackness of filter. A proxy of the amount of elemental carbon in PM10 can be gained by taking a measure of blackness of filter (Fischer *et al.*, 2000; Kingham *et al.*, 2000) and so to provide such measures, the reflectance of the PM10 was measured. The reflectance was transformed into an absorption coefficient to take into account the volume of air sampled, using the following equation (ISO, 1993):

$$\text{Absorption} = ((A/2)/V)\text{Ln}(R_0/R_S) \times 10^5$$

where A is the loaded filter area (m^2), V the sampled volume (m^3), R_0 the reflection of the field blank (%), and R_S the reflection of the sampled filter (%).

Results

Lab testing

In order to confirm the flow control system was delivering the required flow rates at the inlets (and not simply at the measurement point of the mass flow controller), a Buck calibrator was used in the lab. The Buck calibrator was connected directly to each of the inlet positions to confirm correct flow rate. As new, factory calibrated, meteorological sensors were used for this study, testing of the meteorological sensors was not undertaken. In future, checks should be conducted at least annually.

Preliminary field trials

Preliminary field trials were carried out in June 2005 and June 2006. For 2005, a

Figure 5. Comparison of Samplemaster 7000 and TEOM with FDMS for PM10, June 2005 at Coles Place, St. Albans.

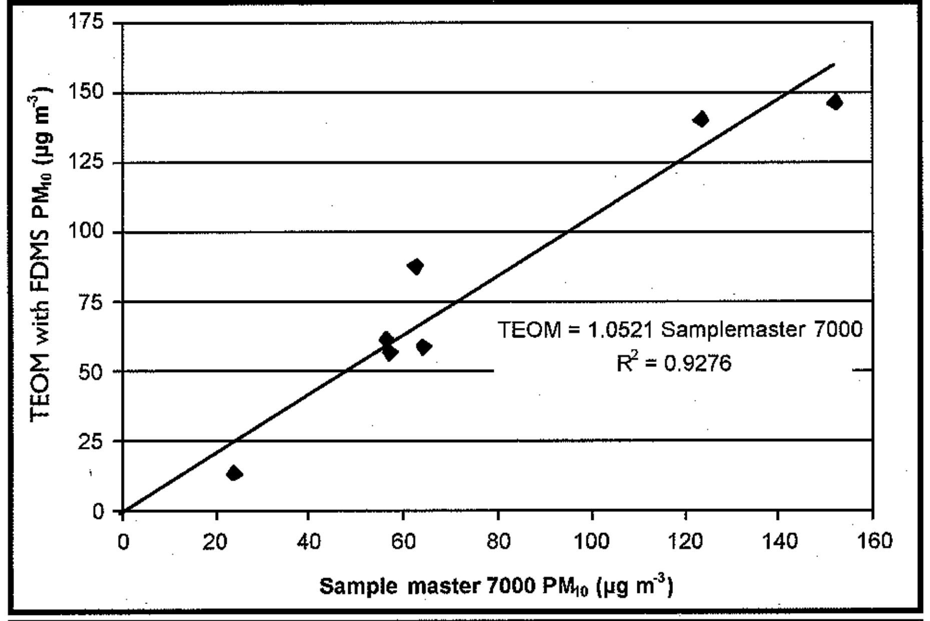


Figure 6. Comparison of Samplemaster7000 and TEOM with FDMS for PM10, June 2006 at Peraki St, Kaiapoi.

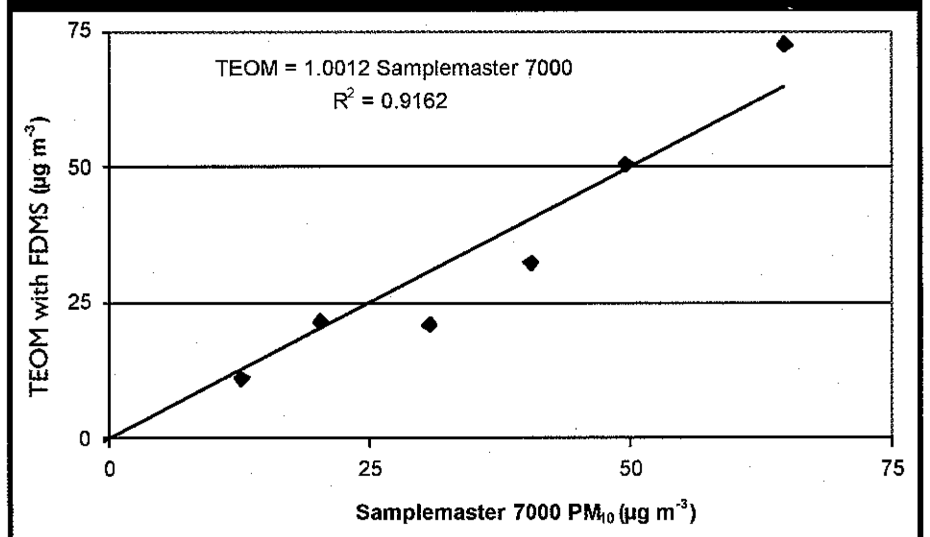
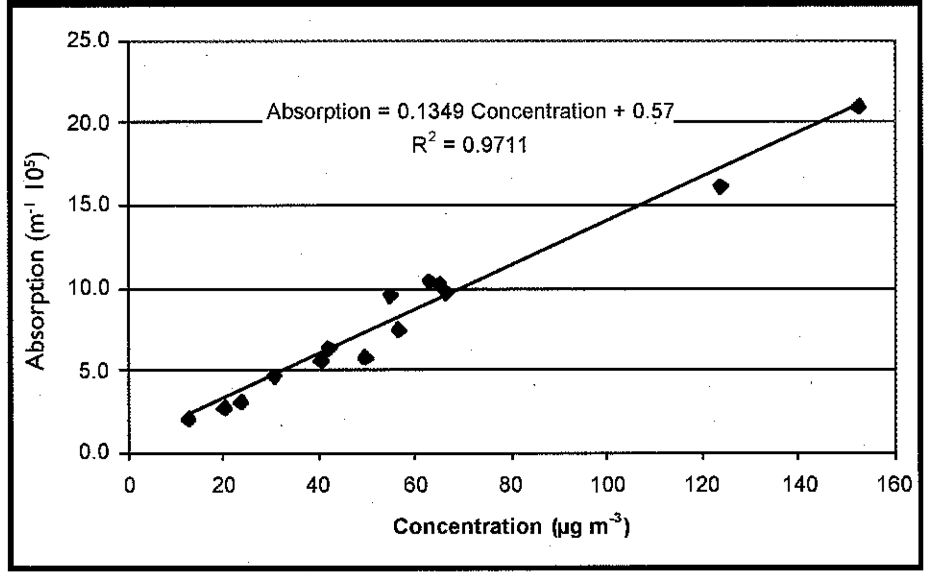


Figure 7. Relationship between Samplemaster 7000 PM10 filter concentration and reflectance for Coles Place and Peraki St sites.



best fit regression line of the relationship between the Samplemaster 7000 and TEOM measurements achieved an R^2 of 0.93 (Figure 5). For 2006, the R^2 was again 0.93 (Figure 6). These high R^2 are unsurprising, as the current set up of the Samplemaster 7000 uses MiniVol sampler heads and the MiniVol has been shown to record similar values to other samplers (Baldauf, 2001). The relationship between PM10 concentrations and reflectance was investigated and a very high R^2 of 0.97 was found suggesting a strong relationship between blackness of filter and PM10 concentration (Figure 7).

Conditional sampling field trial

The conditional sampling field trial took place in July 2006. As previously indicated it is not possible to compare the Samplemaster 7000 results with ECan data as there was no ECan equipment at the Library site. However, it is worth examining the raw data values along with the volumes sampled (if the volumes are low, there may be too little on the filter to accurately measure the particulate levels), and the absorption coefficient (Table 2).

While the quantity of data points and problems with low sample volume in some of the samples mean it is difficult to draw many firm conclusions, a few tentative comments can be made. It seems from the mean values, (Table 2) that when the wind is coming from the sea the absorption value is lower relative to its corresponding concentration value than when it comes from the land. This seems to confirm the fact that there is less elemental carbon in sea salt-dominated PM10 than when the main source is likely to be from anthropogenic sources, supporting the suggestion that the more varied the nature of particulate sources present, the lower the correlation between concentrations and absorbance. However, the main firm conclusion we can draw from this is that the Samplemaster 7000 effectively monitored PM10 levels conditional upon the direction from which the wind was coming.

Discussion

Samplemaster 7000 performance

The Samplemaster performed well in preliminary field trials when the sampler merely operated sequentially for 24 hours , with R^2 values of 0.92 and 0.93. In many ways this would be expected as the sampler heads are from a MiniVol sampler which has been shown to compare well to EPA reference methods (Baldauf, 2001).

The issue of passive deposition is worth discussion, as there was an initial concern that leaving filters in their holders exposed to the air may result in passive deposition, which is why the eighth inlet position was incorporated for quality control. The initial findings suggest that passive deposition under the conditions experienced in this study is below the level of detection, and therefore of limited cause for concern.

With some samplers there is an issue of loss of volatiles (Zhang and McMurry, 1987; Zhang and McMurry, 1992). With the Samplemaster 7000, filters are only ever exposed at ambient temperatures, so the loss of volatiles is governed by the temperature conditions over the sampling period. Practically speaking, filters are likely to be exposed to higher temperatures (and therefore experience some loss of volatiles) during the desiccation and weighing process.

Advantages of the Samplemaster 7000

The advantage of this sampler over the ACCU™ system for TEOM® and Partisol monitors is that it will be significantly cheaper in cost. The ACCU™ is an add-on to the relatively expensive TEOM® system, while the the Partisol has filter changing mechanisms that increase the overall cost of the unit. The Samplemaster 7000's flexibility that allows bits to be added or removed from the tripod frame means that only required features are retained and consequently costs are kept down.

The Samplemaster 7000 also has an advantage over the Partisol in that it can swap back and forth between filters, which the Partisol is unable to do. This is of real practical benefit if repeated sampling under specified meteorological conditions is required. This might be particularly useful if the impact of a suspected source of pollution was to be investigated. The Samplemaster 7000 could be set to record on one filter when the wind direction was from that source, and possibly also at low wind speeds.

The Samplemaster is also highly flexible. It can be used with any sample head in addition to the MinVol head with which it is currently set up. The current set up uses a pump that can operate at flow rates from 0.1-15 litres/min. For instance, it can also be used with a Cascade Impactor or RespiCon. In addition, it can be set up to sample for non–particulate pollutants and could be used with charcoal or bubble sample collectors. In addition the Samplemaster is set up to integrate meteorological sensor data into the measurement and control system. Any meteorological sensor can also be attached, which could be used as the trigger for a particular filter to be used for sampling.

In addition to its flexibility, there are a number of practical features of the Samplemaster 7000 that make it attractive. It is quick and easy to set up. The unit can be set up at a site in approximately 15 minutes by two experienced operators, or 20 minutes by one experienced operator. The robust tripod legs enable it to be located in a wide range of sites. This could be particularly useful for a screening monitoring campaign. Unlike the TEOM®, the unit does not require any air conditioning. The arrangement of the inlets is ideal for wind direction measurement, as the inlets are aligned with the direction they are sampling; and the wide spacing of the inlets means little disturbance around one inlet due to influence of the others or the mounting pole.

Future developments

Subsequent versions of the wind direction sampling program will allow sampling to be stopped on any wind sector once a 24 hour period has been reached, to allow better comparisons with standard sampling methods and also between wind sectors.

Table 2. Samplemaster 7000 PM10 filter concentrations, reflectance absorption and sampled volume for Library site with wind direction conditional sampling.

	Wind Sector	Concentration (µg m^{-3})	Absorption (m^{-1} 105)	Vol (m^3)
June 27-30	1: 330-030 - from sea	53	1.8	4.5
	2: 030-090 - from sea	114	2.5	2.1
	3: 090-150 - from sea	96	2.0	3.1
	4: 150-210 - from land	109	3.7	1.1
	5: 210-270 - from land	55	5.7	8.2
	6: 270-330 - from land	62	4.5	8.4
	Wind less than 0.2m/sec	139	5.3	1.1
July 7-9	1: 330-030 - from sea	82	2.1	8.8
	2: 030-090 - from sea	177	2.9	3.0
	3: 090-150 - from sea	189	2.0	12.0
	4: 150-210 - from land	141	6.7	4.5
	5: 210-270 - from land	57	6.3	10.2
	6: 270-330 - from land	56	4.0	10.4
	Wind less than 0.2m/sec	209	7.0	1.5

In this study, the seventh inlet was used when wind speeds were low. In the future a two dimensional sonic anemometer can be used that will improve the resolution of wind speed and direction, thereby reducing the 'low wind speed' threshold for the seventh inlet and giving a better indication of the origin of pollution at lower wind speeds. A sonic anemometer would also eliminate the need for a rolling thirty second average of wind direction, and changes could potentially be made more frequently. However, given the turbulent nature of wind, it is expected that some averaging would still be required even if a two dimensional sonic anemometer was to be used. This would be particularly necessary at low wind speeds when direction can be highly variable.

In the first week at the library site the power cut out after four days due to maintenance at the building. A residual current device (RCD) was used to protect the unit. This maintained the power at the measurement and control unit, but meant power was not automatically restored and needed to be manually re-set. There is therefore a need for a residual current device to be investigated which would allow battery power to maintain the measurement and control system, so that if mains power becomes available it will automatically re-start the pump. It is proposed to replace the RCD with a simple surge protector. Related to this, the relatively low power use of the Samplemaster 7000 means that potentially it could operate without the need for mains power. Further investigation is needed to see whether this potential can be practically fulfilled. Options include large storage batteries with power produced by solar panels and/or wind generators. Some studies may also allow for the use of a small petrol or diesel generator although care would need to be taken to prevent artificial results from the emissions a generator would create.

Developments are also underway to adapt the system to allow for two inlets to be sampled simultaneously such as PM10 and PM2.5. In addition future versions of the Samplemaster 7000 will be more compact, lighter weight and easier to handle than the prototype described here. This combined with the low noise level from the low volume pump mean this system could be used for indoor pollution studies.

CONCLUSIONS

This paper has described the development and field testing of the Samplemaster 7000, a new low cost and flexible air pollution sampling system. The field tests showed it to be a good monitor for PM10. While this system was used to sample for PM10, it can as easily be used for PM2.5, TSP or any size fraction for which an impactor can be developed and also has the ability to sample for any gas that relies on air being drawn through a filter or other collection medium. The Samplemaster 7000 has the unique ability to sample on different inlets according to a variety of user-defined conditions, that the Samplemaster 7000 itself measures. It is also able to re-sample on a previously used filter. The simplicity of the sampling system also means it is robust and relatively low cost, making it highly attractive for a range of uses.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Walter Gallagher for assistance with development of the Samplemaster 7000; Paul Bealing for assistance in the field and with figures; staff at Environment Canterbury for the monitoring data; Jeff Bluett and Guy Coulson for comments on this paper; and to the Foundation for Research, Science and Technology's *'Protecting New Zealand's Air'* project research grant No. C01X0405, the Health Research Council's *'Health and Air Pollution in New Zealand (HAPiNZ)'* project research grant No. 03/470 and the University of Canterbury for assistance with funding for this project.

REFERENCES

Baldauf, R., Lane, D., Marotz, G., and Wiener, R., 2001 Performance evaluation of the portable MiniVol particulate matter sampler. *Atmospheric Environment* **35**, 6087-6091.

Chang, C., Tsai, C., Lee, C., Chang, S., Cheng, M., and Chein, H., 2001. Differences in PM10 concentrations measured by ß-gauge monitor and hi-vol sampler. *Atmospheric Environment* **35**, 5741-5748.

Fischer, P. H., Hoek, G., van Reeuwijk, H., Briggs, D. J., Lebret, E., van Wijnen, J. H., Kingham, S., and Elliott, P. E., 2000. Traffic-related differences in outdoor and indoor concentrations of particles and volatile organic compounds in Amsterdam. *Atmospheric Environment* **34**, 3713-3722.

Green, D., Fuller, G., and Barratt, B., 2001. Evaluation of TEOM 'correction factors' for assessing the EU Stage 1 limit values for PM10.*Atmospheric Environment* **35**, 2589-2593.

ISO. (1993). *Ambient air-determination of a black smoke index*. International Organization for Standarization.

John, W., and Wang, H. C., 1991. Laboratory testing method for samplers lowered effectiveness from particle loading. *Aerosol Science and Technology* **14**, 93-101.

Kingham, S., Briggs, D., Elliott, P., Fischer, P., and Lebret, E., 2000. Spatial variations in the concentrations of traffic-related pollutants in indoor and outdoor air in Huddersfield, England. *Atmospheric Environment* **34**, 905-916.

MfE., 2003. *Monitoring of PM10 in New Zealand*. Air Quality Technical Report No 40, Ministry for the Environment, Wellington, New Zealand.

Spronken-Smith, R., Sturman, A., and Wilton, E., 2002. The Air Pollution Problem in Christchurch, New Zealand - Progress and Prospects. *Clean Air* **36**, 23-29.

Vega, E., Reyes, E., Wellens, A., Sanchez, G., Chow, J. C., and Watson, J. G., 2003. Comparison of continuous and filter based mass measurements in Mexico City. *Atmospheric Environment* **37**, 2783-2793.

Yanosky, J., and MacIntosh, D., 2001. A Comparison of Four Gravimetric Fine Particle Sampling Methods. *Journal of the Air and Waste Management Association* **51**, 878-884.

Yanosky, J., Williams, P., and MacIntosh, D., 2002. A comparison of two direct-reading aerosol monitors with the federal reference method for PM2.5 in indoor air. *Atmospheric Environment* **36**, 107-113.

Zhang, X. Q., and McMurry, P. H., 1987. Theoretical analysis of evaporative losses from impactor andfilter deposits. *Atmospheric Environment* **21**, 1779-1789.

Zhang, X. Q., and McMurry, P. H., 1992. Evaporative losses of fine particulate nitrates during sampling. *Atmospheric Environment* **26A**, 3305-3312.

AUTHORS

Justin Harrison
Department of Geography,
University of Canterbury,
Private Bag 4800,
Christchurch 8020, New Zealand
email: justin.harrison@canterbury.ac.nz

Nick Key
Department of Geography,
University of Canterbury,
Private Bag 4800,
Christchurch 8020, New Zealand

Simon Kingham
Department of Geography,
University of Canterbury,
Private Bag 4800,
Christchurch 8020, New Zealand

Andy Sturman
Department of Geography,
University of Canterbury,
Private Bag 4800,
Christchurch 8020, New Zealand

Indoor Air Concentrations Of Various Volatile Organic Compounds in a Suburban Nail Salon

L.I. Peters, D. Hawker, M.E. Bartkow, S. Tapper and W. Gore.

ABSTRACT

Nail salon technicians and customers are exposed to a multitude of hazardous compounds. Health effects of exposure to these volatile organic compounds (VOCs) may include: central nervous system depression/alteration, sensitisation and irritation. This study aimed to measure the air concentrations of various volatile organic compounds in a suburban nail salon. Sampling was conducted over a period of six days. Acetone, ethyl and n-butyl acetates, methyl methacrylate, and toluene were quantified at arithmetic mean time weighted average concentrations (TWACs) of: 9.10ppm, 0.09ppm, 0.22ppm, 3.52ppm, 0.10ppm respectively. Results obtained all fall below relevant guideline concentrations (Australian Safety and Compensation Council 2006); however methyl methacrylate and ethyl acetate were both observed well in excess of several odour threshold values (Ruth 1986).

INTRODUCTION

Nail cosmetology is a rapidly expanding industry with annual US revenues in excess of $664 million. In the United States alone, nail technicians perform over 48 million manicures every year (LoSasso *et al.* 2001). In Australia, it is not uncommon for there to be more than one salon in any given shopping centre. These salons employ a multitude of potentially hazardous substances, many of which are identified or suspected neurotoxins, teratogens and/or sensitisers (Hiipakka 1987, Singh *et al.* 1971).

Volatile organic compounds, or VOCs, are commonly found as components or main constituents of solvents, lacquers, paints and adhesives, all of which are utilised in the nail manicuring process. VOCs such as toluene, methyl, ethyl and n-butyl methacrylates, n-butyl and ethyl acetates, acetone and other ketones may be present in concentrations upwards of 98% in the formulations employed during manicure treatments and have been previously identified in salon air (Hiipakka 1987).

The effects of human exposure to these compounds are diverse. Symptomatic expressions upon exposure to these compounds in the air column have been shown to include central nervous system (CNS) depression, sensitisation and sensory irritation, among others (Australian Safety and Compensation Council 2006a-e). Toluene and n-butyl acetate are widely documented as CNS narcotics at high concentrations (Lee and Seung 1993; LoSasso *et al.* 2001). Of the effects cited in the literature the most prevalent include decreased general cognitive efficiency and peripheral neuropathy.

Methacrylate esters are of particular interest due to their more extensive use in the nail sculpting process. Methyl methacrylate monomer (MMA) is a clear, flammable liquid at room temperature. It has a strong pungent odour,detectable by the human nose at concentrations > 0.05ppmv (Ruth 1986). Polymers formed utilising MMA principally employ a powder-liquid system. This system utilises an acrylic powder made up principally of polymethyl methacrylate together with ~1% peroxide (eg cumenehydroperoxide). The reaction proceeds instantaneously at room temperatures until the polymethacrylate sheet is set by photo-bonding. This occurs within seconds, making the system ideal for nail sculpting applications.

Nail technicians, typically seated at a work station for >30min per customer, utilise this system to physically build a sculptured acrylic nail on an existing natural nail base. This process generally takes place within the breathing zones (30cm) of both the customer and the technician, thus exposing both individuals to these potentially hazardous vapours. The newly formed acrylic nail is then ground to the desired shape, primed, painted and lacquered.

Methyl methacrylate monomer and polymethacrylate dust have both been identified by The United States' National Institute for Occupational Safety and Health (NIOSH) and the Australian Safety and Compensation Council (ASCC) as sensitisers. Chronic inhalation of MMA monomer has been shown by the United States Environmental Protection Agency (USEPA 1998) to cause degeneration of olfactory epithelium. At chronic exposures to elevated concentrations of MMA, degeneration and necrotic changes have been observed in the liver, kidney, brain, spleen, and bone marrow of animal test subjects (United States Environmental Protection Agency 1992). Carcinogenicity post inhalation was ruled out after an extensive animal trial (Chan et al. 1988), however its mutagenic activity was confirmed with the use of the AMES test with positive results for the induction of mutagenesis in the bacterium Salmonella typhimurium (Hiipakka 1987). Foetal abnormalities and central nervous system alterations have also been observed in animals exposed to MMA vapour (United States Environmental Protection Agency 1992, Australian Safety and Compensation Council 2006d).

This study aims to supplement the exceptionally small body of monitoring data by investigating vapour phase concentrations of a small suite of VOCs including MMA and thus the guideline compliance (Australian Safety and Compensation Council 2006a-e) of one randomly selected Brisbane nail salon.

Site Selection

Monitoring was conducted in a typical suburban nail salon located in Brisbane, Queensland, Australia. The salon investigated is located within a shopping mall connected to a non-modified, centralised ventilation system which maintained an atmospheric temperature of between 21-24°C over the duration of the sampling regime. The salon does not have any openings or extraction systems vented to the outside environment. All exhaust gases are dispersed into the greater internals of the shopping centre through two large (~3m) high doors. The salon has nine individual treatment stations, each equipped with an array of various volatile formulations, polishes, lamps and sanding apparatuses. The salon has approximately 180m^2 of floor space and is open for business eight hours a day, seven days a week. Customer turnover averages 20-30 customers day^{-1} with workers arranged on a six day roster.

Methodology

Due to the lack of available information on compounds likely to be identified, an initial short-time weighted sample (five minutes) was taken using an SKC constant flow rate pump with an inline Tenax/Carboxen sorbent tube. Tubes were spiked with deuterated internal standards for recovery quantification, all five standards were 80-100% recovered during the sampling regime. Results of this initial screen were used in order to select more appropriate sampling equipment and for calibration of analytical instruments, however on the bases of % recovery and ease of use, the original configuration was deemed adequate and used throughout the entire sampling regime. Sampler intake was positioned 40cm away from the nail technician's face at a height of 1.25m from the ground. It was placed at one work station for eight hour day^{-1} throughout the six day sampling period. Eight hour time