Journal of Environmental Radioactivity 102 (2011) 1065–1069

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Development of a new aerosol monitoring system and its application in Fukushima nuclear accident related aerosol radioactivity measurement at the CTBT radionuclide station in Sidney of Canada

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ARTICLE INFO

Article history:
Received 7 July 2011
Received in revised form
5 August 2011
Accepted 8 August 2011
Available online 26 August 2011

Keywords:
High-volume aerosol sampler
Aerosol radioactivity monitoring
Fukushima nuclear accident

ABSTRACT

A high volume aerosol sampler ("Grey Owl") has been designed and developed at the Radiation Protection Bureau, Health Canada. Its design guidance is based on the need for a low operational cost and reliable sampler to provide daily aerosol monitoring samples that can be used as reference samples for radiological studies. It has been developed to provide a constant air flow rate at low pressure drops ($\sim$3 kPa for a day sampling) with variations of less than $\pm$1% of the full scale flow rate. Its energy consumption is only about 1.5 kW for a filter sampling over 22,000 standard cubic meter of air. It has been demonstrated in this Fukushima nuclear accident related aerosol radioactivity monitoring study at Sidney station, B.C. that the sampler is robust and reliable. The results provided by the new monitoring system have been used to support decision-making in Canada during an emergency response.

1. Introduction

Since 1998, Health Canada (HC) has been contributing to the International Monitoring System (IMS) associated with the Verification Regime overseen by the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The IMS consists of seismic, infrasonic, hydroacoustic and airborne radionuclide monitoring components (Kalinowski, 2006). As airborne radionuclide monitoring is considered to be the most certain way to detect a clandestine nuclear weapon test, a radionuclide monitoring system consisting of 80 globally distributed radionuclide monitoring stations has been implemented within the IMS. The stations enable a continuous worldwide observation by sampling of airborne radionuclide particles and gaseous xenon isotopes to detect atmospheric and underground tests, respectively. Within this network, Health Canada's Radiation Protection Bureau (RPB) operates four CTBT-certified IMS particulate monitoring stations (Sidney, BC; Yellowknife, NWT; Resolute Bay, NU; and St John's, NFL), two experimental noble gas systems (Yellowknife and St. John's), and one test station in Ottawa, ON. The particulate monitoring stations are equipped with aerosol samplers ("Snow White") produced by Senya Oy, Finland (Toivonen et al., 1997). In fact, it was the monitoring station in Sidney, BC (49.3N, 123.2W) that detected the first radioactive isotopes reaching Canada from the Fukushima nuclear crisis releases.

The gamma-ray spectra collected from these stations are sent over secure data links to the CTBT International Data Centre (IDC) in Vienna for radionuclide identification and activity analysis. It is also mandatory to ship all collected aerosol filters to IDC for a historic archive which means that they are not available to national authorities for other studies. In order to have parallel samples at each station for Canadian radiological study purposes, a new high volume air sampler, namely "Grey Owl", was designed and developed at RPB. It was co-located at all Canadian CTBT stations as well as some stations of the Canadian radiological monitoring network to improve aerosol sampling capabilities. The Grey Owl sampler design guidance incorporates the following key principles: a low operational cost and reliable sampler in parallel with the Snow White to provide daily aerosol monitoring samples that can be used as reference samples for Canadian radiological study. A photograph of the latest model of the Grey Owl sampler is shown in Fig. 1.

2. Aerosol sampling and gamma-ray spectral measurement

2.1. Sampling unit description

The air sampling unit is composed of a rectangular inlet and sampling head similar to that of the Snow White, a pumping unit and then flow rate measurement units. The inlet is designed to be

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doi:10.1016/j.jenvrad.2011.08.007

Fig. 1. The Grey Owl II sampler installed at Sidney station British Columbia.

rectangular with rounded edges near the filter holder to avoid turbulent deposition into the frame of the filter holder. The pumping unit is composed of an axial fan (Cincinnati Fan model PB10A), powered via a variable frequency drive to control the flow rate. A thermal mass flow meter (Fluid Components International model ST98) with a low pressure drop and capable of operation to −40 °C was chosen to measure the air flow rate. The operational principle of the thermal mass flow meter is based on thermal dispersion technology utilizing the relationship between flow rates and cooling effect for direct measurement of mass flow. The flow measurement is achieved by the evaluation of the temperature difference between two temperature sensors: a heated reference sensor and a measuring sensor. The higher flow rate results in higher cooling of the sensor in the flow stream. Mass flow rate is computed based on the amount of electrical power required to maintain a constant difference in temperature between the two temperature sensors. The active flow rate control is achieved by a variable frequency drive to control the motor rotation speed. There is a linear relationship between the frequency and flow rate over a wide range (from a minimum flow rate of 500 to a maximum of 1200 m^3/h), thus a constant flow can be achieved. The axial fan is driven by a 220V 3 phase/60 Hz, 1.5 kW motor to suck air through a polypropylene filter. The filtering media is commercially available; and the same as the one used by the Snow White.

2.2. Advantages of the design

Instead of an orifice, which is a differential pressure measurement device that cause a minimum of 20% permanent pressure drop in the system, an insertion style thermal mass flow meter with low pressure drop is used by the Grey Owl to provide an accurate flow measurement value. As a result, the sampler maintains a constant flow rate over the whole sampling period. Fig. 2 shows the log of recorded flow rate profiles over a filter sampling period. As shown in Fig. 2(a), when rain moisten the dust collected on the filter and thus cause a higher flow restriction, the controllers can quickly adjust the frequency to maintain a constant flow rate. Fig. 2(b) shows that when the pressure drop across the filter due to dust or temperature increases, the controllers can slowly adjust the frequency to maintain the flow rate. The trade-offs of using thermal mass flow meter is a longer sampler in comparison to the Snow White, as unlike orifice the thermal mass flow meter needs a minimum of process tube length before and after the sensor to achieve an accurate measurement and thus maintaining a constant flow rate over the whole sampling period.

It is also interesting to note that the pump selected for the air filtration used by the Grey Owl is actually an industrial axial fan that draws air through a filter with large surface area and low pressure drop. Large surface areas allow a lower linear velocity at the face of the filter to sample a given volume of air and therefore require less energy per standard cubic meter (SCM) of air filtered

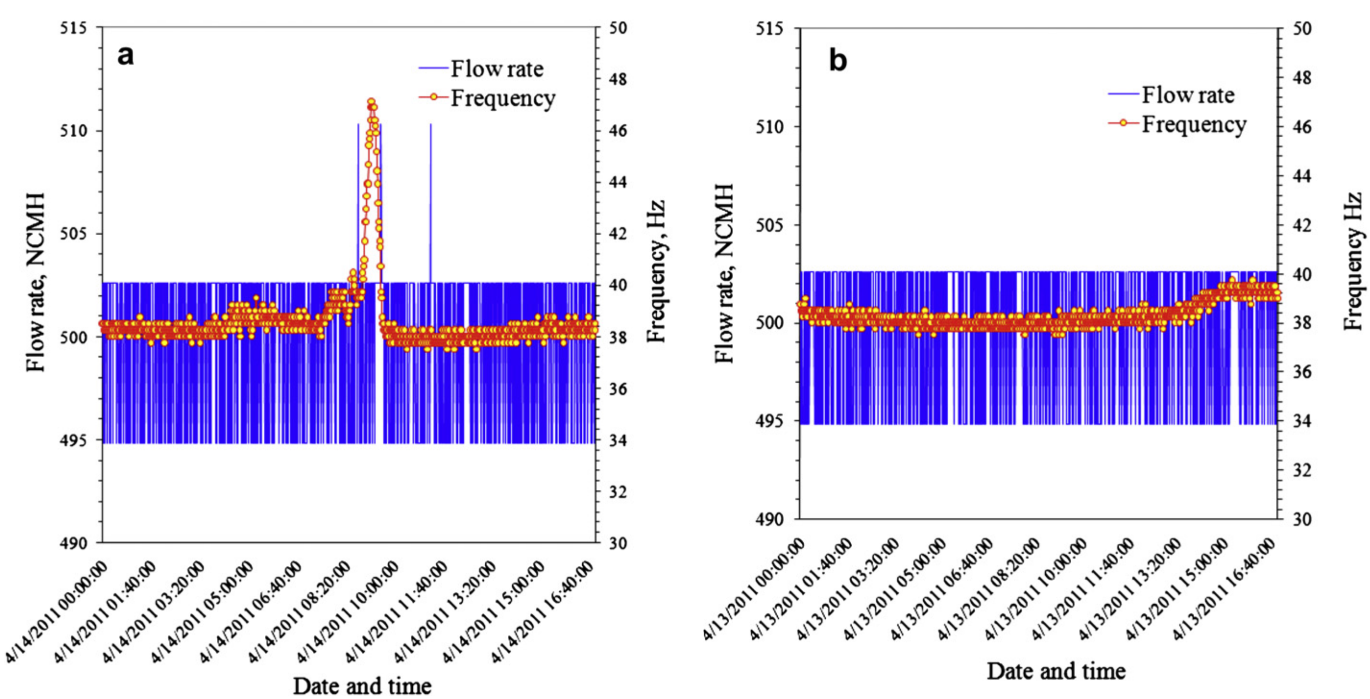

Fig. 2. Logged constant flow rate profile over a one day sampling period; (a) controller quickly adjust the frequency to maintain a constant flow rate during rain; (b) controller slowly adjust the frequency to maintain the flow rate for pressure drop across the filter due to dust or temperature increases. The units NCMH in the figure stands for normal cubic meter per hour.