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Electrostatic precipitator to collect large quantities of particulate matter

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ELECTROSTATIC PRECIPITATOR TO COLLECT
LARGE QUANTITIES OF PARTICULATE MATTER

by

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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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ABSTRACT

Traditional aerosol samplers are limited in their abilities to collect large quantities of particulate matter due to their low flow rates, high pressure drops, and are noise intrusiveness. The goal of this study was to develop an alternate aerosol sampler using electrostatic precipitation technology that was safe and not noise intrusive to be deployed in homes. The O-Ion B-1000 was selected as the most suitable electrostatic precipitator (ESP) for achieving the goal of this study because of its affordability, the design of its collection electrode and its high flow rate. The collection efficiency of the ESP was assessed for three aerosols; Arizona Road Dust (ARD), NaCl and diesel fumes. ARD was found to have the highest average collection efficiency (65%) followed by NaCl (43%) and lastly diesel fumes (41%).

A method for recovering the particulate matter deposited on the collection electrode was developed. The dust collected on the electrode was recovered onto polyvinyl chloride (PVC) filters moistened with deionized water. Additionally, the recovery of the three test aerosols, ARD, NaCl, and diesel fumes, from the collection electrode was assessed. A gravimetric analysis was done to determine the amount of dust recovered. The collection efficiency was used to calculate the amount of mass expected on the filter for a particular aerosol. NaCl had the highest recovery at 95% recovery, followed by ARD (73%) and lastly diesel fumes (50%). Two identical ESPs were also deployed in an office and in a bedroom, 104.47 mg and 9.64 mg of particulate matter (PM) was recovered respectively.

The noise and ozone level produced by the ESP was evaluated to determine the ESP's viability as a household aerosol sampler. The ESP's high setting had a noise level

of 45.8 dB and ozone generation rate of 0.036 mg/min. The results of the calculation showed that in an averaged size unventilated room (6.10 m × 6.10 m × 2.44 m), it would take 6 hours and 53 minutes for the ozone levels to reach the recommended maximum exposure limits per National Ambient Air Quality Standards (NAAQS). Additionally, a ventilation of 230 L/min is needed in order to prevent the ozone levels generated by the ESP from exceeding maximum exposure limits per NAAQS.

Overall, the O-Ion B-1000 met the criteria of collecting 1 mg of PM in a 24 hour sampling for ARD and NaCl. Diesel fumes however, required 30 hours to collect 1 mg of PM. The noise levels generated by the ESP set on high was one dB above the Environmental Protection Agency (EPA) standards for indoor noise limit. However, the noise is proportional to inverse distance squared; the ESP should not pose a problem during household deployment. Ozone generated by the ESP was also found to be below 0.07 ppm as set by the EPA with an average ventilation of 230 L/min. The average ventilation of a household is 1500 L/min, thus the ozone generated by the ESP would not surpass 0.07 ppm. However, the ESP should not be deployed in unventilated rooms for a period of more than 6 hours and 53 minutes.

PUBLIC ABSTRACT

Traditional aerosol samplers are limited in their abilities to collect large quantities of particulate matter (PM). The goal of this study was to develop an aerosol sampler using electrostatic precipitation technology that could collect more than 1 mg of PM in 24 hours, while being safe, and not noise intrusive to be deployed in homes. The O-Ion B-1000 was selected as the most suitable electrostatic precipitator (ESP) for achieving this goal. The collection efficiency of the ESP was assessed for three aerosols; Arizona Road Dust (ARD), NaCl and diesel fumes. ARD was found to have the highest average collection efficiency (70%).

A recovery method was developed to collect dust on to a filter. The recovery of the same three test aerosols was assessed. NaCl had the highest recovery (95%). Two identical ESPs were deployed in an office and in a bedroom, 104.47 mg and 9.64 mg of PM was recovered respectively. The noise and ozone level produced by the ESP was also evaluated. The ESP had a noise level 45.8 dB (equivalent to a quiet classroom) and generated ozone at 0.036 mg/min.

Overall, the O-Ion B-1000 met the criteria of collecting 1 mg of PM in a 24 hour sampling for ARD and NaCl. Diesel fumes however, required 30 hours to collect 1 mg of PM. The ESP was also found to have low noise levels, and ozone levels below 0.07 ppm with a ventilation of 230 L/min but should not be deployed in unventilated rooms for over six hours.

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CHAPTER 1: LITERATURE REVIEW

1.1 Overview

Exposure to ambient particulate matter (PM) is associated with a variety of adverse cardiovascular and respiratory health effects. Health outcomes depend on the composition of the PM and physical characteristics, such as breathing rate and lung capacity (Kim, Kabir, and Kabir 2015).Typically, smaller particles can penetrate deeper into regions of the lung. Insoluble PM deposited in the alveolar region may take years to clear because of the absence of a protective mucus layer (Hinds 2012). Furthermore, long-term exposure to PM can lead to airway remodeling and emphysema (Padilla et al. 2010).

Filter-based aerosol samplers are typically used to collect PM, which is then analyzed chemically. These samplers collect PM onto filters with high efficiency independent of aerosol type. However, they require an air sampling pump that is often noisy because the filters have a relatively high pressure drop. Consequently, airflow rates are limited, resulting in small quantities of PM collected (less than 1 mg). Such small quantities are often not sufficient for chemical and biological assays. Elemental analysis conducted in a study of PM released during the collapse of the World Trade Center required at least 4 mg (McGee et al. 2003).

Traditionally, electrostatic precipitators (ESP) have been used extensively in industry as air purification devices. In countries such as China, flue gasses are primarily cleaned by ESPs (Qi and Yuan 2011). However, because of their effectiveness at collecting aerosols, ESPs have been adapted for airborne particle sampling. The ESPs success in collecting PM has influenced NIOSH to develop a handheld ESP as an aerosol sampler (Miller et al. 2010). ESPs use for aerosol sampling in current literature do not utilize its high flow sampling capabilities, and thus are not able to maximize the amount of PM collected.

The aim of the study was to develop an aerosol sampler capable of collecting 1 mg of dust samples within a 24 hour period, suitable for household use without disrupting the residents or exposing them to excessive amounts of ozone. The goal of this study was achieved by 1) evaluating the ESP's collection efficiency for different aerosol sizes 2) developing an effective recovery method to retrieve samples from the collection electrode of the ESP, and 3) assessing the degree of noise and ozone produced by the device to ensure it meets health and safety standards.

1.2 Health Effects from Inhaling Particulate Matter

Inhaling PM may have adverse health effects on our respiratory system. Hence, sampling of environmental aerosols is crucial in locating the source and determining the various health effects of these particles. Bio-aerosols, which are the leading cause of infectious diseases, require field samples for detection of microorganism and microbial constituents (Srikanth, Sudharsanam, and Steinberg 2008).

The National Ambient Air Quality Standards (NAAQS) includes PM as one of the six common air pollutants set by the Environmental Protection Agency (EPA). The standards regulating PM smaller than 10 µm (PM_{10}) and PM smaller than 2.5 µm ($PM_{2.5}$) are vastly different due to the difference in their ability to penetrate the respiratory system and their deposition mechanism. PM_{10} are usually generated by crushing or grinding operations, while $PM_{2.5}$ are typically generated by burning or chemical reactions (Hinds 2012). Because of the difference in penetration capabilities, the exposure level for PM_{10}

is higher than that of $PM_{2.5}$. The NAAQS comprises of a primary and secondary standard set by the EPA. The primary standard provides public health protection and has lower exposure limits compared to that of the secondary standard.

A major factor that contributing to the deposition of the PM is the aerosol size. PM_{10} can pass through the upper airways and penetrate deep in to the lungs. Fine and ultrafine particles ($PM_{2.5}$) generally can reach deeper in the respiratory system. $PM_{2.5}$ aerosols are potentially more hazardous because they are capable of reaching the alveolar region with greater efficiency than coarse particles of 2.5- 10 µm aerodynamic diameter (Harrison and Yin 2000). Thus, a particle that is not hazardous in the micrometer size range can be hazardous in the nanometer size range (Seaton et al. 1995). This becomes an issue because the level of $PM_{2.5}$ has risen significantly due vehicular exhaust emissions.

Increasing particle number concentration of inhaled PM has been associated with acute airway inflammation and impaired lung function (Strak et al. 2012). PM can contribute to cardiovascular and cerebrovascular diseases by way of systemic inflammation and direct translocation into systemic circulation (Anderson, Thundiyil, and Stolbach 2012). Indirect exposure to PM can cause alterations in hemostasis leading to increased risk of atherothrombotic events (Franchini and Mannucci 2007). $PM_{2.5}$ contributes to increase in cardiopulmonary mortality, but also facilitates the development of diabetes mellitus and causes birth defects (Feng et al. 2016).

Results from the Air Pollution and Health European Approach 2,which is aimed at studying the short-term effects of reduced air quality, showed a positive correlation between the number of individuals over the age of 65 admitted to the hospital for chronic obstructive pulmonary disease and asthma and the decrease in air quality (Atkinson et al.

2001). Lung cancer, which traditionally is more common among smokers, has also strongly been associated with the long-term effects of exposure to $PM_{2.5}$. For every 10 $\mu g/m^3$ increase in $PM_{2.5}$, the relative risk of lung cancer deaths among lifelong non-smokers increases by 15-27% (Turner et al. 2011).

1.3 Filter Based-Sampling Methods

PM samplers typically collect particles onto filters. These filter air samplers use pumps to generate airflow through either a single filter or a series of filters. The filter samplers are able to separate different size particles based on their mechanism of deposition. A major benefit of filters is that they are able to collect particles smaller than 500 nm efficiently (Verreault, Moineau, and Duchaine 2008). However, there are numerous drawbacks associated with filter based-sampling methods. The pumps used to generate airflow through the filters have high pressure drops. The high pressure drop limits the sampling flow rate of the device, resulting in a smaller yield. The high pressure drop also causes the device to be highly noise intrusive. Equipment used to operate the filter air sampler are typically large and not very portable.

While different filter-based sampling methods may be employed depending on the purpose of the experiment, all filter-based sampling methods require a pump to operate. The inclusion of a pump is a major limitation to the sampling process, due to the large pressure drop it causes. The large pressure drop severely limits the airflow rate of indoor samplers, usually between 5 L/min to 40 L/min. Other filter-based aerosol samplers that are capable of sampling at flow rates of up to 1000 L/min are more commonly used outdoors because of the larger pumps required. The larger pumps are noisy and require a large power draw, thus making them impractical for household aerosol sampling. Hence, as an indirect result of the pump, these devices have long sampling periods (24-48 hours). Certain analysis, such as trace metal analysis using microwave digestion, need large quantities (> 1 mg) of PM (Sandroni, Smith, and Donovan 2003). Furthermore, samples that require a long duration for collection are more susceptible to sampling artifacts, such as acid and basic gasses that can occur and change the chemical composition of the aerosol collected (Nie et al. 2010). While a denuder filter pack system is able to overcome the issue of sampling artifacts, the process of preparing and analyzing the denuders and filters are tedious and time-consuming (Kant Pathak and Chan 2005).

One of the byproducts of samplers that require pumps is noise. The pumps are noise intrusive and can disrupt the occupants at the sample site. Often, field sampling include locations where minimal noise intrusiveness is essential. Hence, under these circumstances, an alternative sampling method is required. Pumps also require regular maintenance to generate a consistent airflow and to remove contaminants. Potential clogs in pumps can cause the flow rate of the device to decrease and further increase the pressure drop. The cost of the device, the pump, and the maintenance adds to the total cost of sampling. Filters mounted on three-piece cassettes also all share the same drawback. The pressure from the sealed cassette can significantly affect the outcome of the sampling. If the cassette is not sealed completely, air leakage occurs. The air leakage will cause the less particles to deposit on to the filter, and contaminate the pump. On the other hand, if the pressure in the cassette is too high, the filter can rupture, once again leading to contamination and air leakage (Verreault, Moineau, and Duchaine 2008).

The large equipment used in filter-based sampling methods becomes an issue for sampling in circumstances where space is limited. The option to select different filters to collect specific aerosols is both an advantage and a disadvantage of filter based-sampling methods. This is because, during aerosol sampling, certain filters can collect particular aerosols at a higher efficiency. Conversely, it does not provide an accurate representation of the concentration of other aerosols that may be present. Under circumstances whereby the aerosol type is unknown, an equal sample of all PM present should be collected. Furthermore, certain filters can damage the structure of certain aerosols being collected, thus contributing to misidentification of the type of PM present (Verreault, Moineau, and Duchaine 2008).

Typical aerosol samplers that use filters are high volume samplers and low-pressure cascade impactors. These instruments are optimal for sampling over long periods due to the low flow rate. The low-pressure cascade impactor is employed in field settings when the concentration of specific particle sizes is required. A study on the emissions of organic aerosols in ambient air that originate from wood burning, uses the high volume sampler and low-pressure cascade impactor to collect aerosols over a 12 hour and 24 hour period, respectively (Favez et al. 2010). Assuming 100 % collection efficiency and maximum daily PM concentrations per NAAQS for a 24 hour period, the low cascade impactor that samples at 30 L/min will collect 1.511 mg of PM.

Other filter-based sampling methods includes the denuder-filter packs (DFP), which is composed of a stainless-steel filter holder and dry-annular denuders. This technique uses filters in tandem with denuders to remove acidic and alkali gases prior to the collection of the particles on to the filter (Nie et al. 2010). Another type of filter-based method is stacked-filter units (SFU). This method collects aerosols in two size fractions, similar to a dichotomous filter sampler, and operates at a flow rate of 15 L/min-17 L/min

(Trebs et al. 2008). Because of the different health effects of fine compared to coarse particles, SFU is useful when assessing the concentration of different particle sizes.

1.4 Collection of Large Quantities of Ambient Particles

Many toxicological, biological, and chemical analysis all require a minimum sample mass (typically more than 1 mg) for it to be effective due to limits of detection. Hence, most aerosol sampling conducted with filter-based samplers have a 24 hour sampling period to maximize the amount of PM collected. Often, due to the small amount of samples collected, an entire filter is extracted for toxicity studies and no chemical analysis can be performed (Wendy Hsiao et al. 2000). Further analysis of the aerosols is important to identify the minerals present as they pose a problem in aerosol mechanics and radiation calculations (Reid et al. 2003). Toxicity studies of PM also require a large sample of PM (3-7 mg) to conduct a neutron activation analysis (McGee et al. 2003).

Liquid impingers are also commonly used to collect large quantities of aerosols as an alternative to high volume aerosol samplers. Impingers are capable of operating at flow rates up to 30 L/min. The high flow rates of these devices allow for a larger number of particles to be retained in the fluid. Because they are made of glass, impingers are easy to sterilize. Typically, impingers have higher collection efficiencies in the aerodynamic size range of 0.3 µm – 10 µm (Fierer et al. 2008). Furthermore, impingers such as the Greenburg-Smith impinger collect insoluble particles that are larger than 2 µm in diameter efficiently (Wilson et al. 1980). However, with impingers, the collected PM is suspended in liquid and is potentially more difficult to remove for analysis. These sampling devices also suffer from a deteriorating collection efficiency over long periods due to reaerosolization of particles (Riemenschneider et al. 2010).

Trace metals in the open ocean stimulate oceanic primary productivity, affecting the structure and function of the biological community. To maintain the quality of marine biology, aerosol sampling is used to monitor atmospheric deposition. Once again, a large amount of the PM is required to conduct an accurate analysis. The 2008 GEOTRACES aerosol inter-calibration experiment to sample and analyze marine aerosols used high volume samplers to collect aerosols by filtering air at 1 m^3/min for over a month (Morton et al. 2013). While such methods are able to collect sufficient mass for analysis, the long sampling durations is a major drawback for studies performed under time constraints.

More technologically advanced samplers are being developed to overcome the issues of low flow rates. A high-volume aerosol-into-liquid collector has recently garnered success in addressing the issue. The sampler uses a combination of the versatile aerosol concentration enrichment system (VACES), a low-pressure drop, and a high flow rate impactor in place of a virtual impactor to collect fine and ultrafine PM in an aqueous suspension (Wang et al. 2013). For high-volume bioaerosol sampling, a modified version of Black and Shaw's wetted wall cyclone (BSWWC) was recently developed to reduce the sampling period. The modifications includes an increase in collection efficiency, a reduced pressure drop, and a higher flow rate (McFarland et al. 2010).

1.5 Electrostatic Precipitator

ESPs operate on the principle of electrostatics to collect charged particles for aerosol sampling and air purification (Hinds 2012). An ESP consists of a charging electrode and a collection electrode. The ESP charges the air by field charging using a corona discharge between the two electrodes. The charged air proceeds to bind the dust particles and ionize them. The charged particles then flow through an electric field oriented perpendicular to the flow. The electrostatic migration velocity of the charged particles causes the particles to be attracted to the collection electrode, and deposits on its surface. There are a variety of types of ESPs, each individually designed according to their application, such as cylindrical and plate type, vertical gas-flow and horizontal gas-flow, and dry and wet type (Mizuno 2000).

Many factors affect the efficiency with which the dust deposits on the collection electrode. The primary factors are size and resistivity of the dust particles. Dust particles that have a larger surface area will have a higher charge limit and thus, be more attracted to the collection electrode. Particles with high resistivity are more difficult to ionize. Therefore, they have a lower tendency to bind to the electrode. Secondary factors include gas temperature, pressure, and humidity that affects the corona generation and gas particle resistivity (Hinds 2012, Mizuno 2000). The longer the sampling duration, the lower the collection efficiency of the ESP. This occurs because, the layer of resistivity and thickness of the collected positively ionized dust particles increase, and negative ion generated within the dust layer neutralize some of the positive ions, a phenomena known as back corona (Bacchiega et al. 2006).

ESPs are commonly used as particulate air cleaners in factories. The initial applications of commercial ESPs were to reduce air pollution and to recover valuable byproducts from metal smelting processes (Parker 2012). Industrial size ESPs are large and have flow rates upwards of 10,000 L/min. Industrial precipitators usually use a negative corona that operates at higher voltages to achieve higher efficiency (Hinds 2012). Factories in China use ESPs as the primary method in clearing flue-gases released by coal-fired power plants (Qi and Yuan 2011). However, as new restrictions of ambient air quality standards are implemented, ESPs are currently being used for environmental air pollution control.

The primary advantage of using an ESP is that it does not require a filter and pump to operate, thus it has a low pressure drop. Because of the low pressure drop, the ESP can have a higher airflow rate compared to filter based aerosol samplers. ESPs are able to operate at flow rates above 100 L/min, and as a result, are able to collect more PM for a given period. Additionally, the low pressure drop reduces the power consumption of the ESP (Mizuno 2000). The durability of the electrodes and the small number of moving parts contribute to the low-maintenance requirements of the ESP. These factors also contribute to the long lifetime of ESPs.

ESPs are sold commercially to homeowners to lower indoor levels of PM. These air cleaners are small, portable, and have flow rates between 100 L/min to 200 L/min. The ESP, as a household air purifier, is silent and is useful for sampling over extended periods without disrupting the individuals at the sampling site. The ESPs used for household air purifications are commercially available, thus they are more affordable than sophisticated aerosol samplers. Another benefit of using ESPs as aerosol samplers is that they are able to collect a wide range of aerosol sizes and properties (Parker 2012). Therefore, ESPs are useful for circumstances where the size and characteristic of the aerosol are not known, because it collects everything.

Recently, ESPs have been seen as an effective tool for aerosol sampling. Afshar – Mohajer et al. (2017) used an ionic charging device (ICD) to conduct bulk sampling of airborne PM. The ICD, which is a type of ESP, was used for sampling over a period of a 24 hour period. The National Institute for Occupational Safety and Health are also a developing a handheld ESP for sampling aerosols in the workplace that can be analyzed using an electron microscopy (Miller et al. 2010). Cardello et al. (2002) conducted a study where they evaluated the ozone generation and collection efficiency of a personal ESP particle sampler, and found that increasing the flow rates of the ESP results in a reduction of ozone detected.

While there are many advantages of the ESP as an aerosol sampler, there are some drawbacks associated with operating the ESP. Ozone produced by ESPs can be hazardous when inhaled. Ozone is generated by the ESP from the corona discharge which excites oxygen molecules and pulls them apart. Some ozone is formed as the oxygen reverts to a more stable structure (Leusink 2011). Inhalation of ozone has be known to result in changed markers that affect autonomic control of heart rate (Devlin et al. 2012). Industrial air purifiers primarily use a negative corona to charge particles as oppose to a positive corona because it has a larger margin of operating voltages. A negative corona produces more ozone compared to a positive corona (Mizuno 2000), thus making it a health hazard in enclosed and poorly ventilated areas. Indoor air cleaners however, use positive corona, reducing the amount of ozone residents are exposed to.

1.6 Recovery of Material from ESP

Literature describing the use of ESP for sampling aerosols acknowledges the need for a recovery method that is capable of retrieving the largest amount of collected aerosols deposited on the collection electrode. With the wet ESP, a thin film of water is generated on the wall of the collection plate, removing dust as it deposit (Mizuno 2000). The PM washed by the layer of water is collected into a hopper, where the contents can be further analyzed. This recovery method is effective because it enables the device to maintain its collection efficiency by preventing dust re-entrainment and removing back corona buildup. Though this method filters dust particles from air effectively, it is difficult to separate the dust samples from the solution collected in the hopper.

A known method is to wipe the collection electrode with a pre-weighed filter moistened with isopropanol. Wiping the collection electrode with back and forth strokes using tweezers can effectively capture the samples onto the filter (Afshar-Mohajer et al. 2017). A study by Afshar- Mohajer et al. (2017) found that isopropanol as a solvent was an effective method of removing dust from the collection electrode compared to deionized water. The alcohol also dries faster, and thus reduces the period before post-weighting. However, the chemical constituents of the PM maybe altered after interacting with the alcohol. Additionally, the bleaching properties of the isopropanol can erode the collection plate, causing its collection efficiency to decrease.

1.7 Shortcomings of Literature

Currently, the noise of air sampling pumps required to operate filter-based aerosol samplers restrict the quantity of PM collected in homes to less than 1 mg for a 24 hour sampling period. Moreover, the particles collected on the filter are difficult to remove. Consequently, there is an insufficient amount of PM collected to conduct certain assays, such as toxicological assay and chemical assays. Other methods that use a high-volume aerosol-into-liquid collector can obtain large amounts of PM. However, the dust that collects in the aqueous suspension may undergo chemical changes. Researchers are exploring the option of ESPs as an alternative to traditional aerosol samplers. Low or no airflow ESPs have been used to resolve issues with extracting PM onto filters as samples deposited on a collection electrode. Indoor high-flow rate (more than 100 L/min) ESPs are commercially available and inexpensive but have not been used for aerosol sampling. Despite the available literature that discusses the use of ESPs for aerosol sampling, the absence of critical information remains. Research describing ESPs are inadequate, as they neither contain the collection efficiency of the device based on aerosol size nor the percent recovery of the dust from the collection electrode. Current literature also does not discuss if the level of ozone generated by their ESPs is below the recommended exposure limit per NAAQS.

1.8 Objectives

The objective of this thesis was to develop an aerosol sampler capable of collecting 1 mg of dust samples over a 24 hour period in a household without disrupting the occupants. Another aspect of the experiments performed, was to determine if the collection efficiency of the ESP varied by particle size. Three different aerosols, Arizona Road Dust, NaCl, and diesel fumes were used to conduct this experiment because of their different particle size range. The PM recovery experiments was performed to develop and assess sample recovery methods (dry vs wet). Because the PM ultimately had to be removed from the collection electrode onto the filter, a recovery method that was able to efficiently extract PM onto the filter was vital. Additionally, the recovery method was assessed for the percentage of PM recovered from the collection electrode versus the amount that was deposited on it. Lastly, the ozone and noise experiment was conducted to determine the amount of ozone generated by the device and the noise level created during sampling. The ozone and noise level experiments were important to ensure that the device being deployed did not pose a health risk to or disrupt the occupants.

CHAPTER 2: EVALUATION OF ELECTROSTATIC PRECIPITATOR TO COLLECT LARGE QUANTITIES OF PARTICULATE MATTER

2.1 Introduction

Ambient aerosols have been an increasing cause of concern across the globe as inhaling particulate matter (PM) can contribute to cardiovascular and cerebrovascular diseases by mechanism of systemic inflammation, and direct translocation into systemic circulation (Anderson, Thundiyil, and Stolbach 2012). Inhaling high concentrations of PM have been associated with chronic obstructive pulmonary disease and in the long-term, increases the risk of developing lung cancer (Turner et al. 2011). Short-term effects of inhaling PM have been associated with asthma symptoms especially in children with pre-existing conditions (Guarnieri and Balmes 2014). Consequently, aerosol samples need to be collected and analyzed to understand the potential adverse health effects of PM and ultimately target strategies to reduce exposures. Often, large quantities (> 1 mg) of PM are needed to conduct trace metals analysis using microwave digestion (Sandroni, Smith, and Donovan 2003). A study of the toxicity of PM collected after the collapse of the World Trade Center on September 11 required a large sample of PM (3 mg - 7 mg) to conduct a neutron activation analysis (McGee et al. 2003). The same study on the harmful PM released as a result of the destruction of the World Trade Center also required at least 4 mg of PM to conduct an elemental analysis using ICP-MS (McGee et al. 2003).

There are difficulties in collecting more than 1 mg of PM with traditional filter based-sampling methods. Traditional filter samplers that collect particles onto a filter as air is drawn through with an air sampling pump can be used to collect large quantities of PM. However, the flow rate must be high to collect enough mass. There are numerous drawbacks with this method. Firstly, the pumps can be noisy to operate due to the high pressure drop through the filter. This is detrimental to indoor sampling as it may disrupt the occupants from performing their daily routine. Another limitation of this sampling method is the high pressure drop across the sampler associated. Because, of the high pressure drop, aerosol samplers such as the multistage virtual impactor used to sample PM in homes have limited flow rates (3.11 L/min) (Jones et al. 2007). Therefore, only a small amount of PM is collected. The low quantity of mass collected becomes an issue as to obtain accurate results, there must be sufficient samples for analysis. To overcome this problem, filter based aerosol samplers typically must operate for long sampling periods to increase the amount of PM collected. However, prolonged sampling can expose dust samples to sampling artifacts. Atmospheric sulfate, nitrate, acid, and base gases could potentially alter the chemical composition of the particles (Nie et al. 2010). Extended periods of sampling also increases the possibility that particles could be exposed to a change in temperature and/or humidity (Kant Pathak and Chan 2005).

Other forms of aerosol samplers circumvent the need for filters by collecting aerosols in liquid. Liquid impingers have been used to collect large quantities of aerosols (Willeke, Lin, and Grinshpun 1998). The AGI Impinger (Ace Glass Inc., Vineland, N.J.) and sampling pumps (Gilian Aircon II,Sensidyne LP,St. Petersburg, FL, U.S.A.) , used to collect aerosols in sawmills and swine barns, yielded a sample volume of 200 L. These impingers have higher flow rates (12.5 L/min) compared to traditional aerosol samplers (< 5 L/min) (Duchaine et al. 2001, Fierer et al. 2008). Aside from impingers, another aerosol sampler that does not require a filter is a high-volume aerosol-into-liquid collector. This sampler uses a high-flow rate impactor to collect fine and ultrafine particulate matter in an aqueous suspension (Wang et al. 2013). However, these novel devices are only capable of collecting aerosol particles in a liquid suspension. PM collected in the form of a liquid suspension is potentially more difficult to remove for sample analysis and alters the form of the sample (i.e soluble components will move to the liquid phase). Furthermore, these samplers require a pump to generate airflow, which adds complexity to the entire aerosol sampling device setup.

Alternatively, ESPs may be a more effective way to collect large quantities of PM compared to other techniques (Mizuno 2000). In ESPs, PM is collected by electrostatics onto a dry surface without a noisy sampling pump needed to overcome high pressure drops of the media. The ionic charging device used by Afshar-Mohajer et al. (2017) to conduct a study of bulk sampling of airborne PM, is a type of ESP that induces airflow via ionic current. The ICD was evaluated for bulk sample analysis over short periods (24 hour period). It was found that the ICD collects coarse particles (> 1 μm) more efficiently without the noise associated with filter based aerosol samplers (Afshar-Mohajer et al. 2017). Another type of ESP such as the O-Ion B-1000 has a fan to move large amounts of air past charging electrodes and on to the collection plates.

ESPs are widely used in industry to remove harmful airborne particles. In developing countries like China, flue gases released by coal-fired power plants are primarily cleaned by ESPs (Qi and Yuan 2011). In Japan, ESPS are used to collect dust in pulverized coal combustion boilers (Noda and Makino 2010). There are ESPs used to sample aerosols but not to collect large quantities of PM. Mainelis et al. (2002) designed and tested an ESP as a bioaerosol sampler, researchers at NIOSH developed a handheld ESP for aerosol sampling (Miller et al. 2010) and Cardello et al. (2002) evaluated the performance of a personal ESP particle sampler. ESPs with fans are able to operate at high flow rates (140 L/min - 160 L/min) (Mizuno 2000), thus drastically reducing the sampling period. Without the need of a sampling pump, an ESP is able to sample with minimal noise intrusiveness. Additionally, maintenance of an ESP is minimal due to the small number of moving parts (Mizuno 2000). A disadvantage of ESPs is that their collection efficiency becomes lower for ultrafine particles with decreasing particle size (Zhuang et al. 2000). The combination of low maintenance and low power consumption makes it a cost-effective solution to sample aerosols. Currently, ESPs used as aerosol samplers do not have fans and typically have flow rates of 10 L/min. Similar to traditional aerosol samplers, the low flow rates would result in small amount of PM being collected (< 1 mg).

The objective of this study was to use an ESP to collect a large amount (> 1 mg) of airborne particles over 24 hours in homes with a minimal disruption to the residents. First, we selected a commercially available ESP based on the attributes of cost effectiveness, low noise intrusiveness, ease of particle removal from collection electrode and portability. The collection efficiency of the selected ESP was evaluated for three aerosols: sodium chloride (NaCl) salt, Arizona Road Dust (ARD), and diesel exhaust fume. We then developed a method to recover collected PM and evaluated the noise and ozone levels generated by the ESP.

2.2 Materials and Methods

2.2.1 ESP Selection

We searched online and identified four commercial ESPs for further consideration (Table 1). We evaluated these four ESPs for their cost effectiveness, low noise intrusiveness, ease of particle removal from collection electrode, and portability. Both the ICD by Inspirotec and Envion Ionic Pro Turber Ionic Air Purifier do not have fans and rely strictly on ionic currents to generate airflow. The absence of a fan in both these ESPs limits the airflow rate and ultimately the amount of dust that can be collected on the electrode. Both ESPs are expensive, $149 and $135 respectively. These ESPs both have an easy-to-remove and easy-to-clean collection electrode, making the particle recovery process easier. Finally, because these ESPs do not have fans, they are more compact. The compact size of the ESPs is advantageous for sampling in small spaces such as in homes. The remaining two ESPs, the O-Ion B-100 and the HFD-120-Q, both have fans. All four ESPs produce ozone; however, only the ICD has an ozone remover, which is essential in sampling in poorly ventilated locations.

The O-Ion B-1000 ESP was selected for this study primarily because of the simplicity of the collection electrode. The collection electrode of the O-Ion B-1000 ESP was designed with the purpose of making it easy for cleaning. The device is also easy to operate in a residential setting. The device's low maintenance and affordability meant that sampling could be performed with a low budget. Another critical factor in selecting the O-Ion B-1000 is that it was portable. The small dimensions of the device (0.43 m × 0.14 m × 0.17 m) allowed it to be easily transported and stored. Furthermore, the device could be used for field sampling where space is limited. Although the carbon filter and the UV-light of the device may affect the results of the sampling, these components can be easily removed. In addition to removing the UV- light and carbon filter, the O-Ion B-1000 ESP was modified by installing a switch to turn the charging electrode on and off without turning the fan off. The airflow of the device was measured using a flow rate meter (VelociCalc 8360, TSI Inc., Shoreview, MN, USA) directly at the outlet of the ESP for the high and low setting. The measurement was taken after 20 s for a total of three measurements on each setting.

2.2.2 Particle Collection Efficiency and Particle Loss

We measured the collection efficiency of the O-Ion B-1000 by particle size for three polydispersed aerosols: NaCl, Arizona Road Dust (ARD), and diesel fumes. We selected NaCl as a common laboratory aerosol that results from natural sources and represents water-soluble particles for recovery experiments (Sandu et al. 2010). The generation conditions for NaCl were selected to produce a similar size aerosol as diesel fume. Diesel fume consisted primarily of fine and ultrafine particles (< 1 µm) and was selected to represent relatively non-water-soluble particles from commercial busses in residential areas (Figler et al. 1996). ARD consisted primarily of coarse particles (> 1 µm) and was selected to represent a crustal dust that may occur in homes through resuspension of soil tracked in from outdoors or from intrusion of windblown dust (Curtis et al. 2008). The three test aerosols were used to encompass a wide range of aerosol particle size that might be present in homes. However, our model system is simple compared to particles found in homes because the source of household aerosols vary according to individual lifestyle and circumstance, and thus there is a range of particle size and type that would be difficult to duplicate with laboratory experiments.

As shown in Figure 1, test aerosol was injected into the mixing zone (0.64 m × 0.64 m × 0.66 m) of a test chamber. The three polydisperse aerosols were generated using three different aerosol generation methods as shown in Figure 2. The NaCl aerosol was generated by spraying 0.9% NaCl irrigation solution (2F7123, Baxter Healthcare Co., Deerfield, IL) using a vibrating mesh nebulizer (Aeroneb Solo System, Aerogen, Ireland) (Figure 2(I)), and then dried by passing the aerosol through a silica dryer. The dried NaCl aerosols were diluted by clean air in the mixing chamber until the desired concentration was reached. A fluidized bed aerosol generator (3400A, TSI Inc., Shoreview, MN, USA) was used to aerosolize ARD (Fine Grade, Part No. 1543094., Powder Technology Inc., Arden Hills, MN, USA). The concentration of the ARD particles in the sampling chamber were regulated by adjusting the mass flow controllers. The diesel fume aerosols were generated by a diesel electric generator (DG6LE, Red Hawk Equipment LLC, Akron, NY, USA) with a valve to control concentration, and another valve to release waste fumes (Figure 2(III)).

Aerosols from the generation system were injected into a mixing zone and diluted with clean air that was produced as room air was passed through two high efficiency particulate air (HEPA) filters. The diluted aerosol was mixed with a small fan and then passed through a perforated plate to a sampling zone (0.53 m × 0.64 m × 0.66 m). A condensation particle counter (CPC) (Model 3007, TSI Inc, Shoreview, MN, USA) was used to monitor the particle concentration in the chamber. A three-way valve was used to alternately sample aerosol upstream and downstream of the ESP. Aerosol number concentration by size was measured using a scanning mobility particle sizer (SMPS, composed of an Electrostatic Classifier Model-3082 and a Nano Water-Based

Condensation Particle Counter Model-3788, TSI Inc., Shoreview, MN, USA) for particles smaller than 1 µm and using an aerodynamic particle sizer (APS, Model3321, TSI Inc. Shoreview, MN, USA) for particles larger than 1 µm.

For each aerosol type, clean air was allowed to flow through the system for 15 minutes, after which the generator was turned on, and the concentration in the sampling chamber was allowed to reach steady state (i.e., concentrations oscillated within ± 5%). Number concentrations by size were then measured for three conditions: (1) upstream of the ESP with the electric field off (2) downstream of the ESP with the electric field off (3) downstream of the ESP with the electric field on. For each condition, the SMPS was set to measure one size distribution over three minutes, and simultaneously the APS was set to measure three size distributions, each over one minute. We define the step of measuring concentrations for each condition as a trial; this step was repeated three times.

Hence for each condition there were three trials, consisting of one SMPS measurement and three APS measurements. The diameter of all three aerosols were converted to geometric diameter using the shape factor 1.50 and particle density 2.65 g/cm^3 for ARD, shape factor 1.08 and particle density 2.20 g/cm^3 for NaCl, and shape factor 2.20 and particle density 0.87 g/cm^3 for diesel fumes (Sousan et al. 2016). The three APS measurements for each trial were averaged. Collection efficiency and particle loss of the ESP were calculated as:

$$Collection\ Efficiency = 1 - \frac{C_{down,on}}{C_{down,off}} \quad (1)$$

$$Particle\ Loss = 1 - \frac{C_{down,off}}{C_{up,off}} \quad (2)$$

where $C_{down,off}$ is the number concentration downstream of the ESP with electric field off, $C_{down,on}$ is the number concentration downstream of the ESP with electric field on, and $C_{up,off}$ is the number concentration upstream of ESP with electric field off. The collection efficiency and particle loss for each trial was averaged and the standard deviation was calculated.

2.2.3 Particle Recovery

We developed a method to recover PM from the electrode of the O-Ion-B1000 ESP. The new method was based on a method described by Afshar-Mohajer et al. (2017) in which PVC filters wetted with isopropanol were used to wipe PM from the collection electrode of the Ionic Charging Device (Inspirotec, Inc., Chicago, IL, USA). We conducted an experiment to compare PM yield using dry filters and filters wetted with DI water. Dry filters were used to avoid any physiochemical change to the PM. We replaced isopropanol with DI water because the isopropanol oxidizes the surface of the electrode (O-Ion Technologies 2016).

Two trials were conducted, one for dry and one for wetted filters. For each trial, we loaded the clean electrode with ARD using the experimental setup shown Figure 3. ARD was used for this experiment as ESPs typically have higher collection efficiencies for larger particles due to more field charging (Hinds 2012). The ARD was generated with a fluidized bed as described above to achieve an average concentration of 370 $\mu g/m^3$. The ESP was operated for 30 minutes to collect at least 1 mg of ARD.

Nine 47-mm PVC filters (FPVC547, Zefon International, Inc., Ocala, FL, USA) were used in this experiment. One filter was used as a blank. One was wetted with DI and left to dry as a control. The control was used to determine if the DI water would potentially contribute to any increase in the mass of the filter. Three filters were wetted with DI water and then used to wipe the collection electrode loaded in one trial. Another four filters were used to wipe the collection electrode loaded in the other trial. The electrode was wiped with an up-and-down motion for a total of four cycles on each of the four sides of the collection electrode or until no observable PM could be seen on the filters. The filters were pre- and post-weighed using a microbalance (MT-5, Mettler-Toledo, Columbus, OH, USA). They were maintained in a temperature and humidity controlled room for 72 hours prior to being weighed. From this experiment, we determined that the wet method yielded more PM and consequently was used for further tests described below.

We measured particle recovery using the wetted filter method three times for each aerosol type, using the setup shown in Figure 3 and the same generation methods described in the particle collection efficiency experiment (Figure 2). For each trial, a clean collection electrode was placed in the ESP. A personal DataRAM (PDR-1500, Thermo Scientific, Franklin, MA, USA) was used to measure the real-time aerosol concentration in the sampling chamber. Clean air was allowed to run through the chamber for 15 minutes to achieve real-time concentrations less than 2 $\mu g/m^3$. Then, the aerosol generation system was adjusted to achieve a real-time concentration of approximately 1000 $\mu g/m^3$, knowing that it would be possible to collect at least 1 mg in 30 minutes for all aerosols. The ESP was operated for 30 minutes. Simultaneously, we measured the actual particle mass concentration in the sampling chamber with a 37-mm PVC filter (FPVC537, Zefon International, Inc., Ocala, FL, USA) in a cassette sampler operated at an airflow of 10 L/min pulled by an air sampling pump (Gilian 12, Sensidyne,LP, St.

Petersburg, Fl, USA). The 37-mm PVC filter was used because it was expected that less particles would deposit on it. At the end of each trial, the collection electrode was removed from the ESP. Particles were recovered from the electrode using the wetted filter method.

The actual mass concentration in the sampling chamber was calculated using the equation:

$$C_a = \frac{m_{37}}{Q \times t \times CE} \quad (3)$$

where C_a = actual concentration in chamber, m_{37} = mass collected on the 37-mm PVC filter, Q = flow rate, t = time, and CE = average collection efficiency of device for aerosol being collected. Using the actual concentration of the sampling chamber from equation 3, the mass expected on the ESP collection electrode was calculated using the equation:

$$m_{expected} = Q_{ESP} \times C_a \times t \times CE \quad (4)$$

where $m_{expected}$ = mass expected and Q_{ESP} = flow rate of ESP. Recovery of the mass collected was calculated using the equation:

$$R = \frac{m_{collected}}{m_{expected}} \quad (5)$$

where R = recovery, $m_{collected}$ = mass collected.

2.2.4 Field Testing

Two O-Ion B-1000 ESPs were deployed for field sampling at two locations. The first ESP was placed in the center of a room in a household, and the second ESP was placed in the center of an office. The ESPs were left to sample for 30 days prior to the PM recovery. Once the sampling was completed, the ESPs were retrieved from the field, and the collection electrodes were slowly removed to ensure no dust was dislodged. Prior to wiping the collection electrodes, twenty 47-mm PVC filters were left in a temperature and humidity controlled room for two days and then pre-weighed using a microbalance (Mettler MT5 MT-5 analytical Microbalance, Mettler-Toledo, Columbus, OH). A total of eight wet 47-mm PVC filters were used to wipe the collection electrode from the office, two on each side. A total of twelve wet 47-mm PVC filters were used to wipe the collection electrode used in the household aerosol sampling, and three filters were used on each side. The 47-mm PVC filters were left in the temperature and humidity controlled room for seven days to dry completely prior to being post-weighed.

2.2.5 Ozone and Noise

We measured the concentration of ozone and noise at the outlet of ESP at low and high settings. For each setting, the ESP was allowed to warm up for one minute. At 0 cm, 5 cm, and 10 cm away from the ESP outlet, ozone concentrations were measured with an ozone sensor (Portasense 2 gas leak detector, Analytical Technology Inc., Collegeville, PA, USA) and noise levels were measured with a sound level meter (SoundTrack LxT, Larson Davis, Depew, NY, USA). For each setting and distance, we measured ozone concentrations for 20 s, moved the sensor away from the ESP, allowed the sensor to zero, and then resumed measurements. Three measurements of ozone were taken for each setting and distance, and averaged to determine the ozone concentration. For noise, three measurements were taken for 30 s and averaged to determine the number of decibels produced by the ESP.

Two calculations were performed to estimate concentrations of ozone produced by the ESP if operated in homes under different ventilation conditions. The generation rate of ozone produced by the ESP was calculated using the equation:

$$G = Q_{ESP} \times O_3 \quad (6)$$

where G = mass rate of ozone produced by ESP, Q_{ESP} = airflow rate of ESP, and O_3 = the concentration of ozone measured at 0 cm from the ESP outlet. First, we calculated the time, *Δt*, for ozone concentrations to reach the maximum recommended exposure level of 0.07 ppm (Environmental Protection Agency (US EPA), 1997) if there was no ventilation in a typical indoor room. The following equation was used:

$$\frac{V}{G - QC} dC = dt \quad (7)$$

where V = volume of average sized room (6.10 m × 6.10 m × 2.44 m) (Council 1981), Q = ventilation rate, ΔC = maximum concentration as set by the Environmental Protection Agency (EPA), t = time, and C = concentration of ozone in the diluted air. The second calculation performed was the amount of ventilation needed to maintain that concentration level, given a steady state. The equation to determine the ventilation, Q needed was:

$$C_{max} = \frac{G}{Q} \quad (8)$$

where C_{max} = maximum ozone concentration (ppm)

2.3 Results

2.3.1 Particle Collection Efficiency and Particle Loss

Collection efficiency by particle size is shown in Figure 4. The collection efficiency for NaCl was highest for the smallest particles (72% at 21 nm), decreasing to 35% at 67 nm with an average collection efficiency of 45%. The collection efficiency for NaCl particles larger than 500 nm increased from 36% at 585 nm to 60% at 1850 nm. In contrast, the collection efficiency for the diesel fume was fairly constant at 41%

regardless of size and lowest of all of the aerosols tested. For ARD, the collection efficiency increased from approximately 30% at 296 nm to 95% at 4325 nm. The collection efficiency of ARD was higher for larger particles (> 1 µm).

Particle loss by particle size is shown in Figure 5. Particle loss for NaCl was inconsistent and ranged from 30% at 21 nm to 63% at 1722 nm, with an average particle loss of 42%. Similar to its collection efficiency, diesel fumes had a fairly consistent particle loss of 30% and had the lowest particle loss of all three aerosols. Particle loss for ARD was highest for large particles (> 1 µm). The particle loss of ARD for particles larger than 1 µm was relatively constant with an average particle loss of 79%. Additionally, ARD had a significantly higher particle loss compared to NaCl and diesel fumes.

2.3.2 Particle Recovery

Table 2 shows the weight of the PVC filter prior to being moistened with DI water, and after being moistened with DI water and left to dry. From Table 2, it can be seen that there was no change in mass collected.

Table 3 shows the results of the total mass collected using both wet and dry filters. The highest amount of mass collected was from the first wet filter (4.23 mg), while the least mass collected was from the second dry filter (0.27 mg) (Table 3). Comparing the total mass collected from Table 3, it could be observed that there was more mass collected on the wet filter. Moreover, only three wet filters were required to completely retrieve the PM from one collection electrode whereas, four dry filters were required to complete the same task. The wet filters also collected almost 1 mg of sample mass more than the dry filters. In both tables, the first filter collected the most amount of PM, 4.23

mg and 2.39 mg respectively. From Table 3, it can be seen that every consecutive filter used collected less dust.

Figure 6a and Figure 6b show the percent recovery for all three aerosol types based on mass median diameter (MMD) and number median diameter (NMD) respectively. From Figure 6, it can be observed that NaCl (95%) has the highest recovery followed by ARD (63%) and then by diesel fumes (48%). For both Figure 6a and Figure 6b, ARD had the highest MMD (2.3 µm) and NMD (0.49 µm) respectively. Diesel fumes had the largest standard deviation of recovery (11%). While the MMD for each aerosol type differed greatly, the NMD for NaCl and diesel fumes were similar (0.12 µm and 0.10 µm respectively).

2.3.3 Field Testing

Table 4 shows the amount of particulate matter collected during the field sampling of the ESP at the office and the household respectively. From Table 4, it can be seen that the total mass collected from the household was 10.8 times the amount of mass collected from the office. The 30 day sampling period allowed more dust to deposit on the collection electrode compared to the aerosols collected during the lab recovery experiments.

2.3.4 Ozone and Noise

Table 6 and Table 7 show the results of the ozone experiment. Under both high and low settings of the ESP, the ozone level did not decrease dramatically (> 0.05 ppm) for every 5 cm the sensor was placed further away from the outlet of the ESP. On the low setting, there was no traceable amount of ozone detected after the source was placed 10 cm away. Additionally, it could be observed by comparing Table 6 and Table 7 that the presence of the carbon filter did not affect the amount of ozone generated. After the sensor was moved 5 cm away from the source, the level of ozone did not decrease on the low setting and only decreased by less than 0.02 ppm when on the high setting. While set to high, the device produced twice the amount of ozone compared to that of the low setting.

From equation (7):

$$\frac{V}{G - QC} dC = dt \qquad (7)$$

$$t = \frac{(6.10\ m \times 6.10\ m \times 2.44\ m\ )(0.07\ ppm)}{0.11\ ppm \times 0.14\ m^3/min}$$

$$t = 412.69\ min$$

$$t = 413\ min$$

G was calculated using the amount of ozone produced at the outlet of the ESP on the high setting (0.11 ppm) multiplied by the flow rate of the ESP (0.14 m^3/min). *V* = volume of average sized room (6.10 m × 6.10 m × 2.44 m) (Council 1981), and *Q* = 0 because there is no ventilation. Hence, the amount of time required for the ESP to generate the maximum level of ozone for an averaged size room by NAAQS is 413 minutes.

Setting, C_{max} = 0.07 ppm and G = 0.016 (ppm·m^3/min) into equation (8):

$$Cmax = \frac{G}{Q} \qquad (8)$$

$$Q = \frac{\frac{0.016\ m^3}{min} * ppm}{0.07\ ppm}$$

$$Q = 0.23\ \ m^3/min$$

$$Q \approx 230\ L/min$$

Thus, the ventilation needed in order for the ozone generated by the ESP to never reach the maximum ozone level as set by NAAQS is 230 L/min.

The noise level of the ESP on both high and low setting was around 45 ± 2 dB. The device on the high setting produced a slightly higher noise level (45.8 dB) than when it was on the low setting (43.1 dB).

2.4 Discussion

The O-Ion B-1000 was successful in achieving the goal of the study which was to collect large quantities (> 1 mg) PM within a 24 hour period in a quiet environment. Field testing of the ESPs showed that it was possible to collect more than 1 mg of PM within a 24 hour period as seen from the mass recovered from the household in Table 4. The mass recovery experiment yielded 73% recovery for ARD, 95% recovery for NaCl, and a 50% recovery for diesel fumes. The average noise level of the device set to high was 45.8 dB. The average noise level of the device set to high was 45.8 dB, which is less than a working refrigerator (50 dB) (Roode 2016). The EPA noise level limit for indoors is 45 dB. The noise produced by the device is slightly higher (46 dB), however, noise is proportional to the inverse distance squared. Hence, the O-Ion B-1000 should not pose noise issues when deployed more than two feet away from household occupants.

The collection efficiency of the ESP varied by particle type and size (Figure 4). From 40 nm to 400 nm, collection efficiency of NaCl, diesel, and ARD were lowest and roughly the same at about 45%. This finding is consistent of typical collection efficiency trends of ESPs, whereby the collection efficiency is usually at the lowest between about 0.1 µm and 1 µm (Mizuno 2000). Neither diffusion charging nor field charging dominates for particles in this size range, which results in lower charge and lower collection efficiencies (Miller et al. 2010). For particles larger than 400 nm, the collection efficiency of the ARD increased with increasing particle size as field charging became the predominant form of charging. With field charging, increasingly large particles achieve greater electrical mobility towards the electrode (Hinds 2012).

For particles smaller than 100 nm, the predominant mode of particle deposition is diffusion charging (Miller et al. 2010). With diffusion charging, the migration velocity in an ESP is proportional to the Cunningham correction factor for smaller particles (Mizuno 2000). The collection efficiency for NaCl particles smaller than 40 nm increased with decreasing particle size, due to diffusion charging being the predominant mode of particle charging and migration to the collection electrode. The difference in collection efficiency for ARD and NaCl particles larger than 400 nm may be because NaCl had a higher electrical resistivity than ARD. The higher resistivity would make it more difficult to particles, resulting in a lower collection efficiency. However, the resistivity of all three aerosols could not be confirmed due to the insufficient literature currently available regarding their electrical conductivity.

Table B-1, Table B-3, and Table B-5 show the collection efficiencies for each trial of ARD, NaCl, and diesel fumes respectively. The collection efficiency from the first to the third trial of ARD from the Table B-1 did not show any significant reduction. Similarly, the was no significant reduction from the first to the third trial for NaCl and diesel fumes as seen in Table B-3 and Table B-5 respectively. Hence, experimental design did not pose an issue with particle loading.

The particle losses increased with increasing particle size (Figure 5), consistent with impaction being the primary mode of particle loss. Because of the high flow rate of the ESP, the larger particles had high inertia, causing them to deviate from the airflow streamlines and deposit somewhere within the ESP. ARD primarily consists of coarse particles. Hence, from Figure 5 it was not surprising that ARD had the highest percentage of particle losses. The high particle losses for the larger particles (> 2 µm) of NaCl further reinforces impaction as the primary factor for particle loss. In Figure 5, NaCl particles had a higher particle loss than diesel fumes despite having smaller particles, possibly because our assumptions for the shape factor and particle density of NaCl when converting from mobility to geometric diameter were inaccurate. Thus, NaCl may be smaller than shown. Particles larger than 7 µm were not shown in Figure 4 and 5 due to the lack of particle concentration in that size range possibly due to particle losses.

The NMD for diesel fumes and NaCl were similar due to their comparable particle size range. However, from Figure 6a, it can be seen that the MMD for NaCl was significantly higher than that of diesel fumes. The difference in MMD for NaCl and diesel fumes shows that while their particles may have similar aerodynamic diameter, the mass of NaCl particles were considerably higher. The large difference in MMD between all three aerosol types also explains their varying collection efficiency and particle losses as seen in Figure 4 and Figure 5.

The composition and aerosol properties influenced the percent recovery of the aerosol. NaCl had the highest recovery percentage because it was the most soluble in water. The high solubility of NaCl in water made it easier to remove the particles from the collection electrode and for the particles to adhere to the filter. Conversely, moist filters used to collect diesel fume particles did not make a difference in recovery because they were not water soluble. Furthermore, the chain-like structure of diesel fumes has more contact points, making it difficult to remove. Diesel fumes deposited on the electrode become viscous and difficult to remove. Filters moistened with alcohol may improve diesel fume recovery, however, the use of alcohol would damage the collection electrode. Alcohol or any other bleaching agent would oxidize the surface of the collection electrode, reducing the collection efficiency. ARD had the most consistent recovery because, similar to NaCl, it was water soluble and thus easy to remove. However, ARD had very large particles, and during the removal of the collection electrode from the ESP, these particles may have become dislodged. This typically occurred when the collection electrode was highly saturated with particles. This particle loss during the recovery process may have caused recovery to be lower than anticipated.

The mass of PM recovered from the household was much larger than that of the office during field deployment. The difference in mass collected at the two locations may be due to the higher concentration of aerosols in the household. This higher concentration of aerosols may be present because the household was exposed to outdoor aerosols more frequently than the office was. While 104.5 mg was a large amount of PM collected, the amount of dust that could potentially deposit on the collection electrode from the household could be higher than what was weighed. However, due to the collection electrode being highly saturated with dust, more re-entrainment of particles likely occurred. The highly saturated collection electrode also increases back-corona which results in a decrease in PM collected on the electrode such as that predicted by a back-corona model (Bacchiega et al. 2006). Also, the large amount of dust collected on the electrode meant that more dust particles would be repelled from the electrode due to the repulsions of like charges.

The wetted filter method yielded the highest recovery. The adhesive and cohesive properties of water allowed the water-soluble dust removed from the collection electrode to adhere to the wet filter more effectively. With wet filters, every consecutive filter used to wipe the electrode collected less dust. Conversely, with dry filters, the largest amount of PM was collected with the first filter. Every consecutive dry filter after the first filter, gradually recovered more mass. After using the first dry filter to recover the PM, the remaining PM on the electrode might have become more compact from the pressure of the first filter, making PM more difficult to remove with the second filter. For subsequent filters, perhaps the up-and-down motion of wiping with the filters progressively dislodged increasing quantities of dust.

Given sufficient building ventilation, the buildup of ozone in a home would be less than the NAAQS of 0.07 ppm. The NAAQS set by the EPA was used as it includes the primary factor of public health protection, and the secondary factor of public welfare protection. Furthermore, the EPA uses the same standards as the NAAQS to form the air quality index categories. From the calculation in equation (9), it would take 6 hours and 48 minutes for the ESP to generate enough ozone in an unventilated room to reach 0.07 ppm. Because the sampling period for this device was 24 hours, it would not be advised for the ESP to be deployed in an average sized or smaller unventilated room. The minimum unventilated room size for the ESP to be safely deployed was 3.6 times the size of the original room. From the calculation in equation (10), the minimum ventilation needed for the ESP to not exceed the NAAQS was 230 L/min. The minimum ventilation rate in dayrooms are 142 L/min (Standard 2001) and according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the typical ventilation rate of a household is 1500 L/min. Therefore, additional ventilation may be required for the average room when the ESP is being operated, but for an average household, it is not needed.

The product specifications "of ozone less than 0.05 parts per million by volume of air circulating through the product" (O-Ion Technologies 2016) was substantially lower than our measurements of 0.11 ppm ozone at the outlet of the ESP on the high setting. This discrepancy may be due to the product only being tested for the low settings of the ESP by manufacturers. The higher ozone concentration of the ESP on the high setting compared to the low setting despite having a higher flow rate could be due to the stronger electric field generated. We can operate the ESP on low settings to reduce ozone generation, however, we would collect less mass over a given time period due to the reduced time. Tests of efficiency would also need to be measured for lower airflow. An alternative solution to reduce the ozone generated by the ESP is to have an ozone an ozone destruction catalyst.

2.5 Limitations

The experiment to determine the collection efficiency of the ESP was based solely on particle size, and not on the aerosol resistivity, ρ_a. The mass recovery experiments conducted were over a period of 30 minutes, and it was assumed that no dust was lost while removing the collection electrode from the ESP. The influence of previously deposited particles on the collection efficiency was not tested. Both collection efficiency and mass recovery experiments were conducted over a short period of time (less than 1 hour for each test) at a high aerosol concentration. This did not simulate field-sampling conditions where aerosol concentration might be low (below 100 $\mu g/m^3$). Additionally, particles collected over long sampling periods were prone to chemical alteration due to ambient acid and base gases. With prolonged sampling, changes in humidity can affect the resistivity of the particles, and can ultimately change the particle collection efficiency. Previously, ESPs have been used as aerosol samplers for collecting a wide range of aerosol types, but have not been used to collect large quantities of mass.

2.6 Conclusion

In comparing the results of the ESP with traditional aerosol based samplers, it was found that ESPs are a viable solution for sampling aerosols in addition to possessing multiple advantages. Particles with a higher mass were found to not only have a higher particle loss, but also a higher collection efficiency. The recovery of the PM from the collection electrode showed that given the ESPs collection efficiency and the conditions (1 mg of sample in 24 hours), it was possible to achieve the goal of the study with the exception of diesel fumes (requires 30 hours to collect 1 mg). Lastly, the ESP ozone concentrations are expected to be lower than NAAQS recommends, given a minimum ventilation of 230 L/min.

CHAPTER 3: CONCLUSION

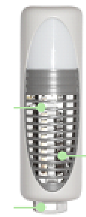
Comparing the results of the ESP with traditional aerosol based samplers, it was found that the ESP is a viable solution for sampling aerosols in addition to possessing multiple advantages. The simplicity of the collection electrode, its cost effectiveness, and the high flow rate of the O-Ion B-1000 made it valuable for aerosol sampling applications. Larger particles were found to not only have a higher collection efficiency, but also have a higher particle loss. The collection efficiency of ARD was the highest at 65% followed by NaCl at 45% and lastly diesel fumes at 41%. For most aerosols, wet filters were able to maximize recovery. Results from the particle recovery found that it was possible to retrieve 73% of ARD, 95% of NaCl, and 50% diesel fumes from the collection electrode.

The goal of this study was to develop an aerosol sampler using electrostatic precipitation technology to collect 1 mg of PM within a 24 hour period. The recovery of the PM from the collection electrode showed that given the ESP's collection efficiency, and the condition of collecting 1 mg of sample within 24 hours, it was possible to achieve the goal of this study, with the exception of diesel fumes which required 30 hours to collect 1 mg. Furthermore, the field sampling recovered an excess of 2.5 mg of PM per day from the ESP. However, only 9.64 mg was recovered from the office over a 30 day period, averaging a recovery of 0.32 mg/day. This falls short of the goal to collect 1 mg in total of PM. The conditions of sampling, such as aerosol type, aerosol concentration, and humidity also affect the amount of dust that can be collected by the ESP.

The ESP was found to below 0.07 ppm for household sampling given a minimum ventilation of 230 L/minute. For the ESP to be deployed in an unventilated room, the size of the room should be four times the size of an average room to avoid potential health effects from generated ozone. The carbon filter was found to not have any effect on the amount of ozone produced and was used primarily to trap dust particles that may have escaped the electric field of the ESP. The peak noise level of the ESP when sampling was 45.8 dB, which is equivalent to a quiet classroom, and thus the ESP would most likely not disrupt the daily activities of the occupants. The ESP is an effective alternative to traditional aerosol samplers because of its ability to sample at higher flow rates with minimal noise levels. The low cost of maintenance and its availability are additional attractive features of ESPs for aerosol sampling. With an ESP, aerosol sampling periods could be greatly reduced while maintaining the quality of samples being recovered.

Future research of ESPs as viable options to collect large quantities of PM should factor in the resistivity of the aerosol being collected. Particles with a higher resistivity are more difficult to ionize, and thus do not effectively adhere on to the collection electrode. At higher flow rates, the particle loss for larger particles (> 2.5 µm) increases, reducing the collection efficiency of the device. Hence, research into flow rates higher than 200 L/min should also be conducted to determine the optimal flow rate to collect the most PM. Sampling for long durations makes the collected aerosols more susceptible to sampling artifacts (Nie et al. 2010), and in doing so, changes the chemical structure of the particles. Therefore, field sampling of the ESP at locations with known low aerosol mass concentrations should also be performed over longer periods of time (> 24 hours). Sampling for long periods with the ESP would help determine the variability of the expected amount of PM collected versus the actual amount of PM collected.

Table 1: Electrostatic precipitators considered for in-home PM collection

Model	Cost $	Pros	Cons	Image
Inspirotec, 0.21 m × 0.14 m	149.00	• Have previous studies for reference • Collection electrode easily removed • Contains Ozone remover catalyst • Compact	• No Fans • Primarily used for collection of biological particles • Used for testing sample collection not air purification	
Envion Ionic Pro Turbo Ionic Air Purifier, Envion, 0.19 m × 0.72 m × 0.24 m	134.99	• Compact • Quiet • Easy to remove collection electrodes	• No Fans • Contains only 3 collection electrodes • Difficult to remove dust particles	
O-Ion B-1000, ION Technologies, 0.43 m × 0.14 m × 0.17 m	57.95	• Collection electrodes meant for wiping. • Two fan speeds • Carbon filter and UV- C light may potentially be removable	• Carbon filter may remove certain particles • Contains UV-C light that might potentially alter the chemical composition of particles	
HFD-120-Q, Honeywell, 0.73 m × 0.28 m × 0.25 m	120.36	• Three fan speeds • Clean air delivery rate for dust: 100 (fraction of particles remove × CFM) • Able to sample up to 15.79 m^3	• Large surface area of collection electrodes • Contains 2 filters in addition to the Ionizer which may impede collection on electrodes • Difficult to disassemble	

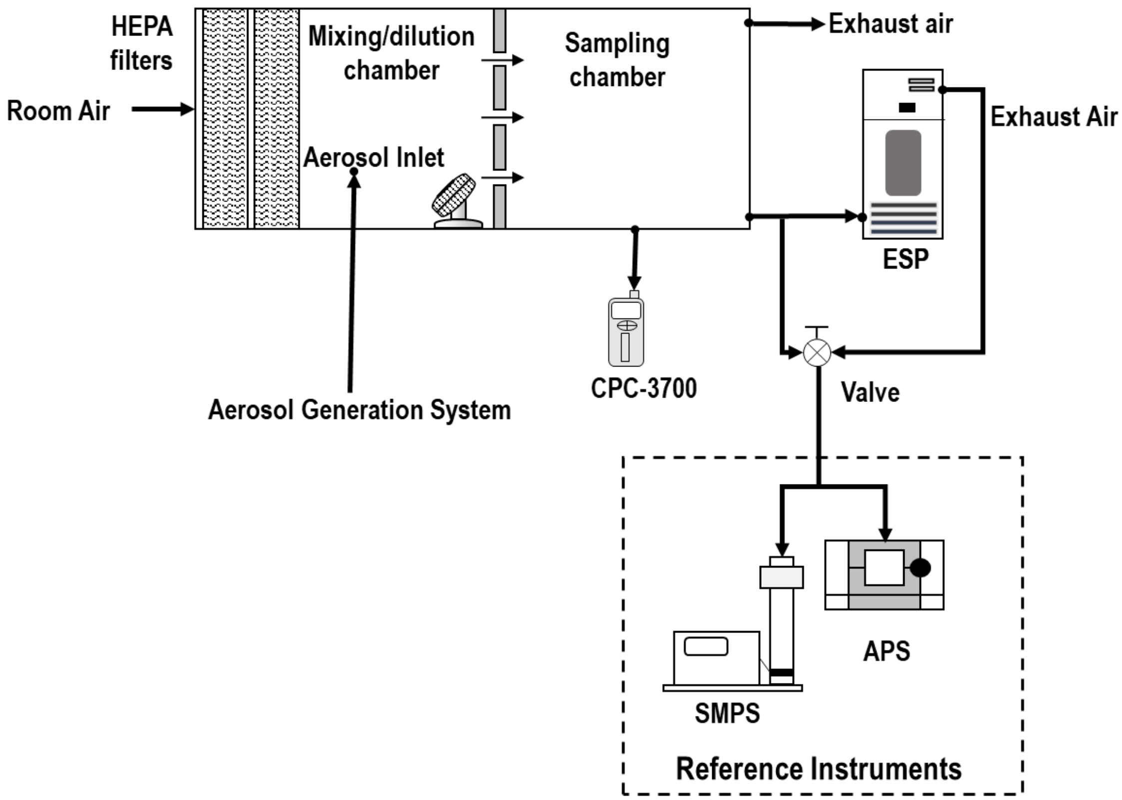


Figure 1: Experimental setup used to measure collection efficiency by particle size

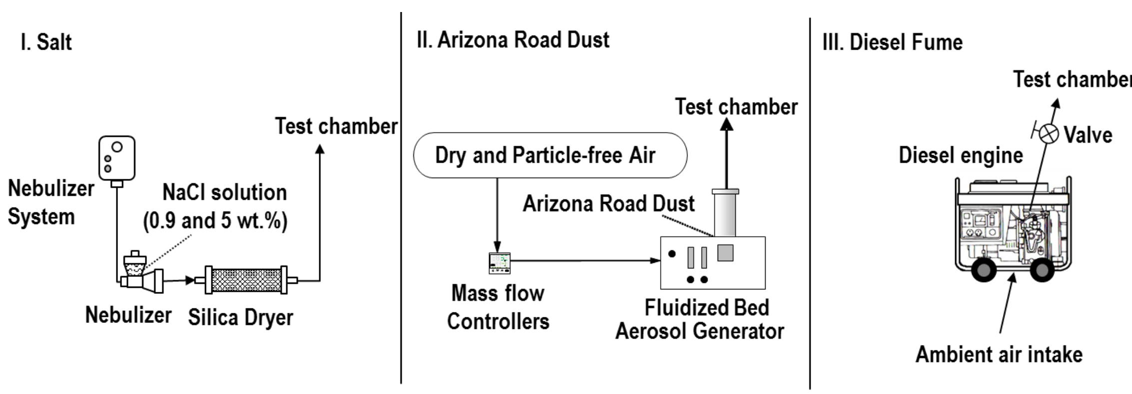


Figure 2: Experimental setups used to generate test aerosols

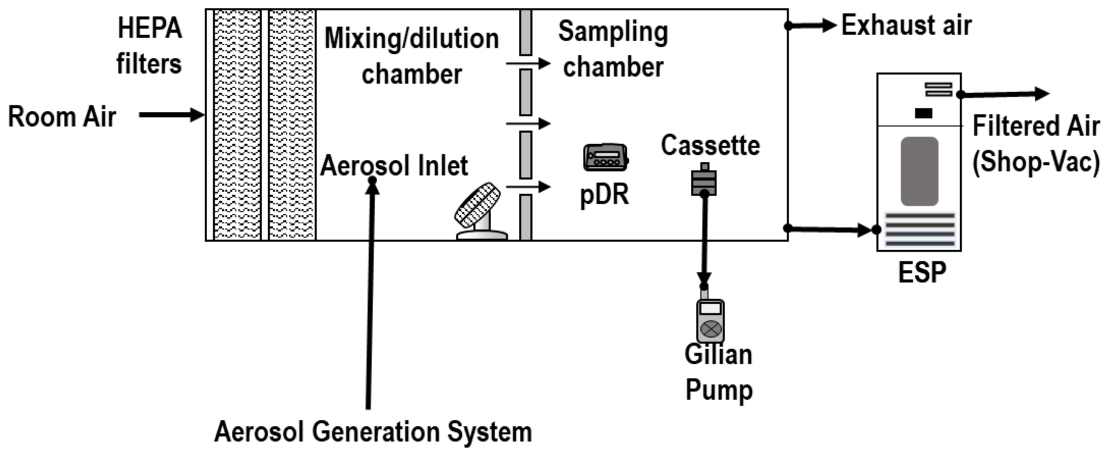


Figure 3: Experimental setup used to measure recovery of particulate matter

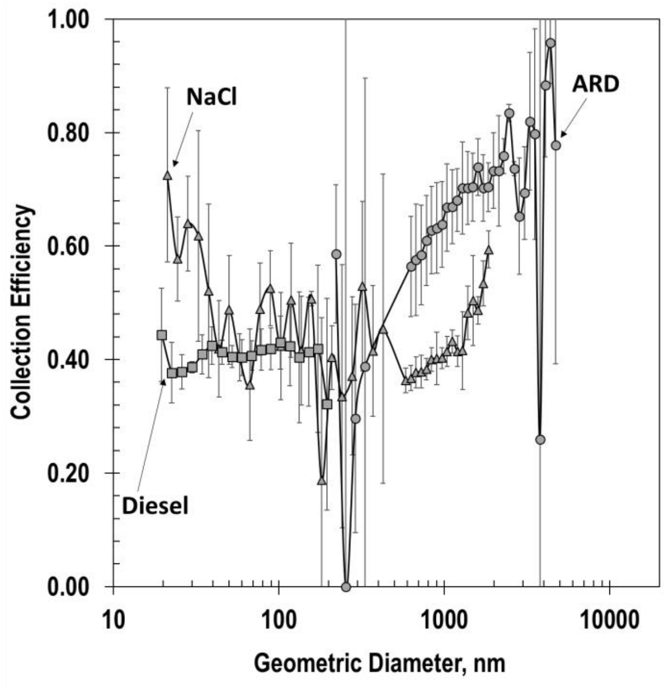


Figure 4: Collection efficiency of ESP for ARD, NaCl, and diesel fumes in relation to particle geometric diameter. Error bars correspond to one standard deviation

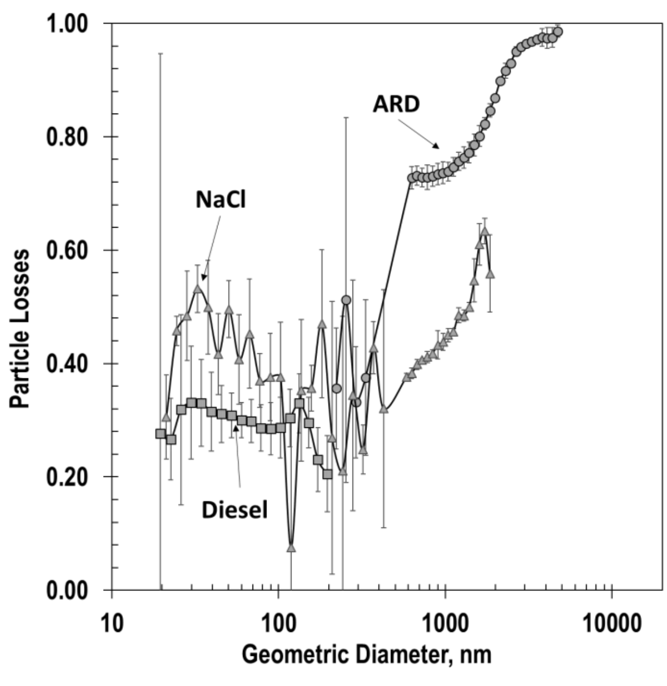
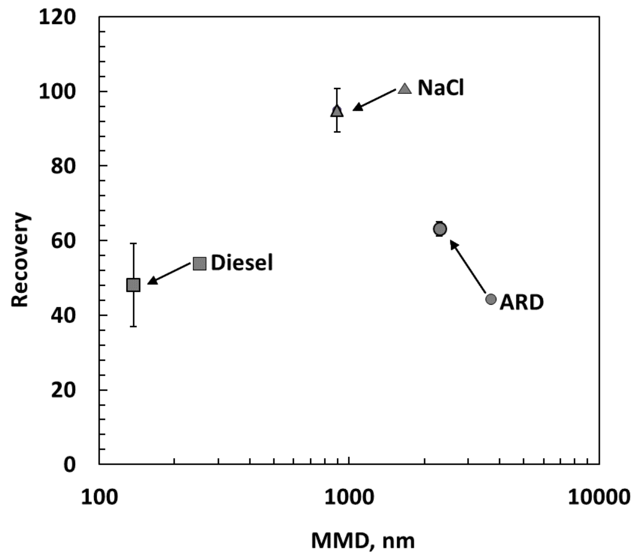


Figure 5**:** Particle loss of ESP for ARD, NaCl, and diesel fumes in relation to particle geometric diameter. Error bars correspond to one standard deviation

a)



b)

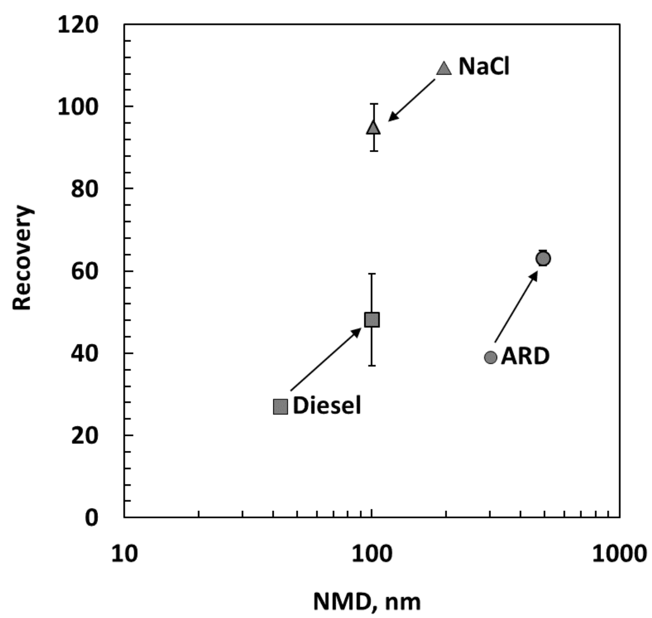


Figure 6: Percent recovery of ARD, NaCl and diesel fumes from collection electrode in relation to concentration. a) Recovery by MMD b) Recovery by NMD. Error bars correspond to one standard deviation

APPENDIX A: SUPPLEMENTAL TABLES FOR CHAPTER 2

Table A-1: Mass of filter before and after being moistened and left to dry

Pre-Weight	Post-Weight	Mass Collected (mg)
1.10	1.10	0.00

Table A-2: Mass of ARD recovered from wet filter versus dry filter

Filter	Wet filter (mg)	Dry filter (mg)
1	4.23	2.39
2	0.89	0.27
3	0.44	0.82
4	-	1.12
Total	**5.56**	**4.6**

Table A-3: Mass recovered from field-testing of ESP in office versus in household

Filter	Office (mg)	Household (mg)
1	1.07	24.32
2	0.62	6.99
3	1.28	3.65
4	0.34	17.45
5	2.00	5.06
6	1.28	2.71
7	2.67	14.78
8	0.37	5.85
9	-	0.72
10	-	15.89
11	-	4.52
12	-	2.53
Total	**9.64**	**104.47**

Table A-4: Noise level of O-Ion B-1000 low setting versus high setting

Trial	Low Setting (dB)	High Setting (dB)
1	42.7	45.5
2	43.5	45.9
3	43	45.9
Average	**43.1**	**45.8**

Table A-5: Ozone level of O-Ion B-1000 with carbon filter at outlet, 5 cm, and 10 cm away

Trial	Low Setting, Outlet (ppm)	Low Setting, 5 cm (ppm)	Low Setting, 10 cm (ppm)	High Setting, Outlet (ppm)	High Setting, 5 cm (ppm)	High Setting, 10 cm (ppm)
1	0.04	0.04	0.00	0.11	0.08	0.04
2	0.04	0.04	0.00	0.12	0.09	0.05
3	0.04	0.04	0.00	0.12	0.09	0.05
Average	**0.04**	**0.04**	**0.00**	**0.12**	**0.088**	**0.047**

Table A-6: Ozone level of O-Ion B-1000 without carbon filter at outlet, 5 cm, and 10 cm away

Trial	Low Setting, Outlet (ppm)	Low Setting, 5 cm (ppm)	Low Setting, 10 cm (ppm)	High Setting, Outlet (ppm)	High Setting, 5 cm (ppm)	High Setting, 10 cm (ppm)
1	0.05	0.05	0.	0.10	0.10	0.04
2	0.05	0.05	0	0.11	0.10	0.04
3	0.05	0.05	0	0.12	0.10	0.04
Average	**0.05**	**0.05**	**0**	**0.11**	**0.10**	**0.04**

APPENDIX B: COLLECTION EFFICIENCY AND PARTICLE LOSS OF ESP

The following tables are the raw data from the SMPS and APS for the collection efficiency and particle loss of the ESP. For tables B-1to B-6 samples 1, 2, and 3 are measured downstream of the ESP with the electric field off. For tables B-1to B-6, samples 4, 5, and 6 are measured downstream of the ESP with the electric field on. For tables B-7 to B-12, samples 1, 2, and 3 are measured upstream of the ESP. For tables B-7 to B-12, samples 4, 5, and 6 are measured downstream of the ESP with the electric field off. From tables B-1 to B-6, CE01, CE02 and CE03, is the collection efficiency of the ESP, and CEAvg and CEStd is the average of the collection efficiency and standard deviation of the collection efficiency respectively. Tables B-7 to B-12, PL01, PL02 and PL03, is the particle loss of the ESP, and PLAvg and PLStd is the average of the particle loss and standard deviation of the particle loss respectively.

Table B-1: Collection efficiency of ARD by number concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	CE 01	CE 02	CE 03	CE Avg	CE Std
17.92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20.67	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
23.84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27.50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31.70	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
36.54	0.00E+00	0.00E+00	4.43E+01	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
42.11	4.06E+01	1.98E+01	0.00E+00	1.98E+01	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
48.51	1.92E+01	0.00E+00	1.86E+01	0.00E+00	0.00E+00	3.77E+01	0.00	0.00	0.00	0.00	0.00
55.85	1.76E+01	5.34E+01	1.76E+01	1.76E+01	0.00E+00	0.00E+00	0.00	1.00	1.00	0.67	0.58
64.27	1.75E+01	6.78E+01	3.45E+01	1.75E+01	0.00E+00	8.62E+01	0.00	1.00	-1.50	-0.17	1.26
73.93	8.29E+01	5.00E+01	9.95E+01	3.31E+01	6.66E+01	3.30E+01	0.60	-0.33	0.67	0.31	0.56
85.00	9.76E+01	1.03E+02	1.62E+02	8.10E+01	3.27E+01	1.30E+02	0.17	0.68	0.20	0.35	0.29
97.65	9.66E+01	1.24E+02	2.90E+02	1.61E+02	1.61E+01	1.93E+02	-0.67	0.87	0.33	0.18	0.78
112.10	1.88E+02	9.65E+01	2.58E+02	2.09E+02	9.64E+01	1.93E+02	-0.11	0.00	0.25	0.05	0.19
128.63	2.65E+02	4.38E+02	3.41E+02	1.95E+02	6.49E+01	1.79E+02	0.26	0.85	0.48	0.53	0.30
147.47	2.49E+02	3.48E+02	2.99E+02	2.16E+02	1.99E+02	2.54E+02	0.13	0.43	0.15	0.24	0.17
169.00	3.57E+02	3.41E+02	4.09E+02	2.21E+02	1.53E+02	3.87E+02	0.38	0.55	0.05	0.33	0.25
193.57	3.91E+02	2.66E+02	3.72E+02	1.94E+02	1.77E+02	3.53E+02	0.50	0.34	0.05	0.30	0.23
221.67	4.84E+02	2.98E+02	3.71E+02	1.85E+02	9.29E+01	2.04E+02	0.62	0.69	0.45	0.59	0.12
253.79	9.75E+01	2.72E+02	3.91E+02	2.71E+02	1.17E+02	1.76E+02	-1.79	0.57	0.55	-0.22	1.35
290.52	2.71E+02	2.95E+02	2.68E+02	1.66E+02	1.66E+02	2.51E+02	0.39	0.44	0.07	0.30	0.20
332.71	2.89E+02	1.34E+02	2.03E+02	8.83E+01	4.44E+01	2.43E+02	0.69	0.67	-0.20	0.39	0.51
628.47	2.08E+02	1.92E+02	2.19E+02	1.08E+02	6.55E+01	9.83E+01	0.48	0.66	0.55	0.56	0.09
675.36	2.00E+02	1.90E+02	2.13E+02	1.04E+02	6.15E+01	9.11E+01	0.48	0.68	0.57	0.58	0.10
725.75	1.94E+02	1.78E+02	2.00E+02	9.59E+01	5.73E+01	8.60E+01	0.51	0.68	0.57	0.58	0.09
779.90	1.75E+02	1.63E+02	1.90E+02	8.20E+01	5.06E+01	7.40E+01	0.53	0.69	0.61	0.61	0.08
838.08	1.60E+02	1.49E+02	1.70E+02	6.96E+01	4.28E+01	6.73E+01	0.57	0.71	0.60	0.63	0.08
900.61	1.42E+02	1.32E+02	1.51E+02	6.40E+01	3.82E+01	5.51E+01	0.55	0.71	0.63	0.63	0.08
967.81	1.25E+02	1.15E+02	1.33E+02	5.40E+01	3.25E+01	4.92E+01	0.57	0.72	0.63	0.64	0.08
1040.01	1.11E+02	1.01E+02	1.15E+02	4.52E+01	2.57E+01	3.84E+01	0.59	0.75	0.67	0.67	0.08
1117.61	9.10E+01	8.51E+01	9.90E+01	3.55E+01	2.22E+01	3.39E+01	0.61	0.74	0.66	0.67	0.07
1200.99	7.60E+01	7.08E+01	8.30E+01	2.87E+01	1.90E+01	2.59E+01	0.62	0.73	0.69	0.68	0.06
1290.60	6.26E+01	6.26E+01	7.11E+01	2.34E+01	1.32E+01	2.18E+01	0.63	0.79	0.69	0.70	0.08
1386.89	5.35E+01	4.88E+01	5.80E+01	1.87E+01	1.10E+01	1.84E+01	0.65	0.77	0.68	0.70	0.06
1490.36	4.43E+01	3.76E+01	4.66E+01	1.56E+01	8.74E+00	1.42E+01	0.65	0.77	0.70	0.70	0.06
1601.56	3.39E+01	3.16E+01	3.80E+01	1.00E+01	6.43E+00	1.08E+01	0.70	0.80	0.72	0.74	0.05
1721.05	2.50E+01	2.32E+01	2.68E+01	8.29E+00	5.34E+00	8.86E+00	0.67	0.77	0.67	0.70	0.06
1849.45	1.73E+01	1.70E+01	1.96E+01	5.89E+00	4.32E+00	5.76E+00	0.66	0.75	0.71	0.70	0.04
1987.44	1.25E+01	1.19E+01	1.28E+01	3.49E+00	2.34E+00	4.19E+00	0.72	0.80	0.67	0.73	0.07
2135.72	7.81E+00	7.97E+00	7.68E+00	2.18E+00	1.31E+00	2.75E+00	0.72	0.84	0.64	0.73	0.10
2295.06	5.54E+00	3.97E+00	5.66E+00	1.34E+00	8.32E-01	1.54E+00	0.76	0.79	0.73	0.76	0.03
2466.29	3.68E+00	2.91E+00	3.20E+00	6.72E-01	4.48E-01	5.12E-01	0.82	0.85	0.84	0.83	0.02
2650.30	1.66E+00	1.66E+00	2.11E+00	4.48E-01	4.16E-01	5.76E-01	0.73	0.75	0.73	0.74	0.01
2848.03	1.18E+00	9.92E-01	1.28E+00	5.44E-01	2.56E-01	4.16E-01	0.54	0.74	0.68	0.65	0.10
3060.52	7.68E-01	8.32E-01	6.40E-01	1.92E-01	2.24E-01	2.56E-01	0.75	0.73	0.60	0.69	0.08
3288.86	5.76E-01	4.80E-01	4.16E-01	9.60E-02	3.20E-02	1.28E-01	0.83	0.93	0.69	0.82	0.12
3534.23	3.84E-01	3.52E-01	3.20E-01	1.60E-01	3.20E-02	3.20E-02	0.58	0.91	0.90	0.80	0.19
3797.92	6.40E-02	2.88E-01	2.88E-01	1.28E-01	0.00E+00	6.40E-02	-1.00	1.00	0.78	0.26	1.10

Table B-1: Continued

4385.77	6.40E-02	9.60E-02	2.56E-01	0.00E+00	0.00E+00	3.20E-02	1.00	1.00	0.87	0.96	0.07
4712.98	3.20E-02	3.20E-02	9.60E-02	0.00E+00	0.00E+00	6.40E-02	1.00	1.00	0.33	0.78	0.38
5064.61	0.00E+00	3.20E-02	3.20E-02	3.20E-02	0.00E+00	9.60E-02	0.00	1.00	-2.00	0.00	1.53
5442.47	6.40E-02	3.20E-02	9.60E-02	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
5848.52	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.00	0.58
6284.87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00	0.00	0.00	0.00	0.00
6753.77	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7257.66	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7799.14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
8381.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9006.31	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9678.25	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10400.32	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11176.27	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12010.11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12906.16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13869.06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
14903.80	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-2: Collection efficiency of ARD by mass concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	CE 01	CE 02	CE 03	CE Avg	CE Std
17.92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20.67	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
23.84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27.50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31.70	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
36.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
42.11	3.03E+06	1.48E+06	1.48E+06	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
48.51	2.19E+06	0.00E+00	0.00E+00	0.00E+00	4.31E+06	3.77E+01	1.00	0.00	-1.03	0.00	0.00
55.85	3.07E+06	9.30E+06	3.07E+06	0.00E+00	0.00E+00	0.00E+00	0.00	1.00	1.00	0.67	0.58
64.27	4.64E+06	1.80E+07	4.64E+06	0.00E+00	2.29E+07	8.62E+01	0.00	1.00	-1.50	-0.17	1.26
73.93	3.35E+07	2.02E+07	1.34E+07	2.69E+07	1.34E+07	3.30E+01	0.60	-0.33	0.67	0.31	0.56
85.00	5.99E+07	6.31E+07	4.97E+07	2.01E+07	7.97E+07	1.30E+02	0.17	0.68	0.20	0.35	0.29
97.65	9.00E+07	1.15E+08	1.50E+08	1.50E+07	1.80E+08	1.93E+02	-0.67	0.87	0.33	0.18	0.78
112.10	2.65E+08	1.36E+08	2.94E+08	1.36E+08	2.72E+08	1.93E+02	-0.11	0.00	0.25	0.05	0.19
128.63	5.65E+08	9.33E+08	4.15E+08	1.38E+08	3.80E+08	1.79E+02	0.26	0.85	0.48	0.53	0.30
147.47	7.98E+08	1.12E+09	6.91E+08	6.39E+08	8.15E+08	2.54E+02	0.13	0.43	0.15	0.24	0.17
169.00	1.72E+09	1.64E+09	1.07E+09	7.38E+08	1.87E+09	3.87E+02	0.38	0.55	0.05	0.33	0.25
193.57	2.84E+09	1.93E+09	1.41E+09	1.28E+09	2.56E+09	3.53E+02	0.50	0.34	0.05	0.30	0.23
221.67	5.27E+09	3.25E+09	2.01E+09	1.01E+09	2.22E+09	2.04E+02	0.62	0.69	0.45	0.59	0.12
253.79	1.59E+09	4.45E+09	4.44E+09	1.92E+09	2.88E+09	1.76E+02	-1.79	0.57	0.55	-0.22	1.35
290.52	6.64E+09	7.22E+09	4.08E+09	4.07E+09	6.15E+09	2.51E+02	0.39	0.44	0.07	0.30	0.20
332.71	1.06E+10	4.93E+09	3.25E+09	1.63E+09	8.96E+09	2.43E+02	0.69	0.67	-0.20	0.39	0.51
628.47	5.17E+10	4.76E+10	2.68E+10	1.63E+10	2.44E+10	9.83E+01	0.48	0.66	0.55	0.56	0.09
675.36	6.15E+10	5.84E+10	3.20E+10	1.90E+10	2.81E+10	9.11E+01	0.48	0.68	0.57	0.58	0.10
725.75	7.41E+10	6.81E+10	3.66E+10	2.19E+10	3.29E+10	8.60E+01	0.51	0.68	0.57	0.58	0.09
779.90	8.28E+10	7.71E+10	3.89E+10	2.40E+10	3.51E+10	7.40E+01	0.53	0.69	0.61	0.61	0.08
838.08	9.42E+10	8.80E+10	4.10E+10	2.52E+10	3.96E+10	6.73E+01	0.57	0.71	0.60	0.63	0.08
900.61	1.04E+11	9.62E+10	4.68E+10	2.79E+10	4.03E+10	5.51E+01	0.55	0.71	0.63	0.63	0.08
967.81	1.13E+11	1.04E+11	4.89E+10	2.95E+10	4.46E+10	4.92E+01	0.57	0.72	0.63	0.64	0.08
1040.01	1.25E+11	1.14E+11	5.08E+10	2.89E+10	4.32E+10	3.84E+01	0.59	0.75	0.67	0.67	0.08
1117.61	1.27E+11	1.19E+11	4.96E+10	3.10E+10	4.73E+10	3.39E+01	0.61	0.74	0.66	0.67	0.07
1200.99	1.32E+11	1.23E+11	4.97E+10	3.29E+10	4.48E+10	2.59E+01	0.62	0.73	0.69	0.68	0.06
1290.60	1.35E+11	1.34E+11	5.03E+10	2.85E+10	4.69E+10	2.18E+01	0.63	0.79	0.69	0.70	0.08
1386.89	1.43E+11	1.30E+11	4.99E+10	2.94E+10	4.91E+10	1.84E+01	0.65	0.77	0.68	0.70	0.06
1490.36	1.47E+11	1.24E+11	5.16E+10	2.89E+10	4.69E+10	1.42E+01	0.65	0.77	0.70	0.70	0.06
1601.56	1.39E+11	1.30E+11	4.13E+10	2.64E+10	4.42E+10	1.08E+01	0.70	0.80	0.72	0.74	0.05
1721.05	1.27E+11	1.18E+11	4.22E+10	2.72E+10	4.52E+10	8.86E+00	0.67	0.77	0.67	0.70	0.06
1849.45	1.09E+11	1.07E+11	3.72E+10	2.73E+10	3.64E+10	5.76E+00	0.66	0.75	0.71	0.70	0.04
1987.44	9.82E+10	9.37E+10	2.74E+10	1.83E+10	3.29E+10	4.19E+00	0.72	0.80	0.67	0.73	0.07
2135.72	7.61E+10	7.76E+10	2.12E+10	1.28E+10	2.68E+10	2.75E+00	0.72	0.84	0.64	0.73	0.10
2295.06	6.69E+10	4.80E+10	1.62E+10	1.01E+10	1.86E+10	1.54E+00	0.76	0.79	0.73	0.76	0.03
2466.29	5.52E+10	4.37E+10	1.01E+10	6.72E+09	7.68E+09	5.12E-01	0.82	0.85	0.84	0.83	0.02
2650.30	3.10E+10	3.10E+10	8.34E+09	7.74E+09	1.07E+10	5.76E-01	0.73	0.75	0.73	0.74	0.01
2848.03	2.74E+10	2.29E+10	1.26E+10	5.91E+09	9.61E+09	4.16E-01	0.54	0.74	0.68	0.65	0.10
3060.52	2.20E+10	2.39E+10	5.50E+09	6.42E+09	7.34E+09	2.56E-01	0.75	0.73	0.60	0.69	0.08
3288.86	2.05E+10	1.71E+10	3.42E+09	1.14E+09	4.55E+09	1.28E-01	0.83	0.93	0.69	0.82	0.12
3534.23	1.70E+10	1.55E+10	7.06E+09	1.41E+09	1.41E+09	3.20E-02	0.58	0.91	0.90	0.80	0.19
3797.92	3.51E+09	1.58E+10	7.01E+09	0.00E+00	3.51E+09	6.40E-02	-1.00	1.00	0.78	0.26	1.10
4081.27	2.18E+10	8.70E+09	2.18E+09	2.18E+09	0.00E+00	0.00E+00	0.90	0.75	1.00	0.88	0.13

Table B-2: Continued

4385.77	5.40E+09	8.10E+09	0.00E+00	0.00E+00	2.70E+09	3.20E-02	1	1	0.875	0.958333	0.072169
4712.98	3.35E+09	3.35E+09	0.00E+00	0.00E+00	6.70E+09	6.40E-02	1	1	0.333333	0.777778	0.3849
5064.61	0.00E+00	4.16E+09	4.16E+09	0.00E+00	1.25E+10	9.60E-02	0.00	1.00	-2.00	-0.33	1.53
5442.47	1.03E+10	5.16E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
5848.52	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.33	0.58
6284.87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.94E+09	3.20E-02	0.00	0.00	0.00	0.00	0.00
6753.77	9.86E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
7257.66	1.22E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
7799.14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
8381.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9006.31	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9678.25	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10400.32	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11176.27	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12010.11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12906.16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13869.06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
14903.80	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-3: Collection efficiency of NaCl by number concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	CE 01	CE 02	CE 03	CE Avg	CE Std
21.21	3.43E+03	4.30E+03	2.65E+03	8.29E+02	6.06E+02	1.17E+03	0.31	0.23	0.38	0.31	0.07
24.49	3.28E+03	3.24E+03	2.84E+03	1.57E+03	1.10E+03	1.28E+03	0.48	0.43	0.46	0.46	0.03
28.27	3.07E+03	3.12E+03	3.47E+03	1.39E+03	1.05E+03	1.02E+03	0.55	0.51	0.40	0.48	0.08
32.64	3.00E+03	3.76E+03	2.89E+03	1.71E+03	7.48E+02	1.09E+03	0.57	0.49	0.54	0.53	0.04
37.67	2.76E+03	3.60E+03	3.35E+03	1.81E+03	1.40E+03	1.31E+03	0.56	0.40	0.53	0.50	0.08
43.49	3.62E+03	3.83E+03	3.47E+03	1.75E+03	2.41E+03	2.19E+03	0.45	0.33	0.46	0.42	0.07
50.20	3.49E+03	3.46E+03	3.09E+03	1.85E+03	1.42E+03	1.85E+03	0.52	0.44	0.53	0.50	0.05
57.94	3.20E+03	3.49E+03	3.55E+03	1.87E+03	1.96E+03	2.28E+03	0.48	0.42	0.32	0.41	0.08
66.87	3.31E+03	2.86E+03	2.91E+03	1.82E+03	2.13E+03	1.85E+03	0.38	0.56	0.41	0.45	0.10
77.16	3.40E+03	3.34E+03	3.35E+03	1.61E+03	2.02E+03	1.53E+03	0.32	0.39	0.40	0.37	0.05
89.03	2.94E+03	3.55E+03	3.20E+03	1.62E+03	1.52E+03	1.42E+03	0.44	0.29	0.40	0.38	0.08
102.72	2.96E+03	3.06E+03	2.18E+03	1.77E+03	1.45E+03	1.43E+03	0.33	0.31	0.49	0.38	0.10
118.48	2.72E+03	3.33E+03	2.86E+03	1.36E+03	1.31E+03	1.69E+03	0.30	-0.15	0.08	0.08	0.22
136.65	2.64E+03	2.12E+03	2.00E+03	1.64E+03	1.39E+03	9.50E+02	0.21	0.42	0.43	0.35	0.13
157.59	2.25E+03	2.20E+03	1.93E+03	1.09E+03	1.12E+03	9.40E+02	0.40	0.32	0.35	0.36	0.04
181.72	1.86E+03	1.37E+03	1.54E+03	1.16E+03	1.57E+03	1.04E+03	0.33	0.58	0.51	0.47	0.13
209.54	1.44E+03	1.73E+03	1.83E+03	9.02E+02	9.21E+02	1.15E+03	0.54	0.08	0.19	0.27	0.24
241.56	1.97E+03	1.16E+03	1.57E+03	8.20E+02	1.02E+03	1.10E+03	-0.10	0.38	0.36	0.21	0.27
278.50	1.24E+03	1.48E+03	1.15E+03	6.38E+02	8.71E+02	9.01E+02	0.48	0.11	0.45	0.34	0.20
321.04	1.13E+03	1.35E+03	1.15E+03	6.05E+02	4.05E+02	6.65E+02	0.20	0.28	0.27	0.25	0.04
370.15	7.85E+02	9.10E+02	8.08E+02	5.62E+02	4.60E+02	4.30E+02	0.42	0.48	0.39	0.43	0.05
426.75	9.16E+02	6.84E+02	9.03E+02	3.26E+02	5.87E+02	3.82E+02	0.17	0.56	0.23	0.32	0.21
585.27	6.40E+02	6.22E+02	6.08E+02	3.92E+02	4.00E+02	3.98E+02	0.37	0.38	0.38	0.38	0.01
628.94	5.25E+02	5.17E+02	5.13E+02	3.19E+02	3.31E+02	3.33E+02	0.38	0.39	0.37	0.38	0.01
675.86	4.31E+02	4.13E+02	4.04E+02	2.56E+02	2.60E+02	2.62E+02	0.39	0.40	0.40	0.40	0.01
726.29	3.28E+02	3.14E+02	3.16E+02	1.93E+02	1.97E+02	2.05E+02	0.41	0.41	0.40	0.41	0.00
780.48	2.42E+02	2.27E+02	2.32E+02	1.44E+02	1.44E+02	1.43E+02	0.41	0.42	0.41	0.41	0.01
838.71	1.78E+02	1.69E+02	1.67E+02	1.02E+02	1.02E+02	1.03E+02	0.41	0.42	0.42	0.42	0.01
901.29	1.33E+02	1.19E+02	1.20E+02	7.23E+01	7.57E+01	7.38E+01	0.41	0.44	0.46	0.43	0.02
968.53	9.45E+01	8.66E+01	8.72E+01	5.47E+01	5.32E+01	5.23E+01	0.42	0.45	0.45	0.44	0.02
1040.79	6.61E+01	6.18E+01	6.04E+01	3.67E+01	3.72E+01	3.63E+01	0.44	0.46	0.46	0.45	0.01
1118.45	4.63E+01	4.42E+01	4.44E+01	2.52E+01	2.56E+01	2.58E+01	0.45	0.46	0.46	0.46	0.01
1201.90	3.36E+01	3.23E+01	3.04E+01	1.86E+01	1.93E+01	1.84E+01	0.49	0.47	0.50	0.48	0.01
1291.57	2.22E+01	2.04E+01	2.10E+01	1.13E+01	1.24E+01	1.35E+01	0.47	0.49	0.49	0.48	0.01
1387.93	1.40E+01	1.30E+01	1.28E+01	6.53E+00	6.94E+00	7.07E+00	0.49	0.50	0.51	0.50	0.01
1491.48	8.16E+00	7.62E+00	7.20E+00	3.36E+00	3.87E+00	4.10E+00	0.50	0.57	0.57	0.55	0.04
1602.76	3.68E+00	3.65E+00	3.33E+00	1.98E+00	1.79E+00	1.70E+00	0.57	0.63	0.63	0.61	0.04
1722.34	1.44E+00	1.34E+00	1.28E+00	6.08E-01	6.72E-01	6.08E-01	0.61	0.65	0.64	0.63	0.02
1850.84	6.08E-01	6.08E-01	4.48E-01	2.56E-01	2.24E-01	1.92E-01	0.57	0.49	0.62	0.56	0.07
1988.93	9.60E-02	0.00E+00	6.40E-02	3.20E-02	9.60E-02	3.20E-02	0.77	1.00	0.87	0.88	0.12
2137.32	9.60E-02	0.00E+00	9.60E-02	3.20E-02	0.00E+00	0.00E+00	0.50	1.00	0.40	0.63	0.32
2296.79	0.00E+00	3.20E-02	0.00E+00	3.20E-02	0.00E+00	3.20E-02	1.00	0.00	0.00	0.33	0.58
2468.15	0.00E+00	6.40E-02	3.20E-02	0.00E+00	3.20E-02	0.00E+00	0.00	0.00	0.00	0.00	0.00
2652.29	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
2850.18	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3062.82	3.20E-02	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3291.34	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3536.90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3800.78	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00	0.00	0.00	0.00	0.00

Table B-3: Continued

4084.35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4389.08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4716.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5068.43	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5446.58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5852.93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6289.61	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6758.87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7263.13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7805.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
8387.34	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9013.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9685.55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10408.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11184.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12019.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12915.90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13879.53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-4: Collection efficiency of NaCl by mass concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	CE 01	CE 02	CE 03	CE Avg	CE Std
21.21	3.27E+07	4.10E+07	2.53E+07	7.90E+06	5.79E+06	1.12E+07	0.76	0.86	0.56	0.81	0.07
24.49	4.82E+07	4.76E+07	4.17E+07	2.30E+07	1.61E+07	1.89E+07	0.52	0.66	0.55	0.59	0.10
28.27	6.93E+07	7.05E+07	7.84E+07	3.14E+07	2.36E+07	2.29E+07	0.55	0.67	0.71	0.61	0.08
32.64	1.04E+08	1.31E+08	1.01E+08	5.93E+07	2.60E+07	3.80E+07	0.43	0.80	0.62	0.62	0.26
37.67	1.48E+08	1.93E+08	1.79E+08	9.68E+07	7.50E+07	7.03E+07	0.34	0.61	0.61	0.48	0.19
43.49	2.98E+08	3.15E+08	2.86E+08	1.44E+08	1.98E+08	1.80E+08	0.52	0.37	0.37	0.44	0.10
50.20	4.42E+08	4.38E+08	3.91E+08	2.34E+08	1.79E+08	2.34E+08	0.47	0.59	0.40	0.53	0.08
57.94	6.22E+08	6.78E+08	6.90E+08	3.64E+08	3.81E+08	4.43E+08	0.41	0.44	0.36	0.43	0.02
66.87	9.91E+08	8.55E+08	8.71E+08	5.45E+08	6.38E+08	5.54E+08	0.45	0.25	0.36	0.35	0.14
77.16	1.56E+09	1.54E+09	1.54E+09	7.39E+08	9.28E+08	7.02E+08	0.53	0.40	0.54	0.46	0.09
89.03	2.08E+09	2.51E+09	2.26E+09	1.14E+09	1.07E+09	1.00E+09	0.45	0.57	0.56	0.51	0.09
102.72	3.20E+09	3.32E+09	2.36E+09	1.92E+09	1.57E+09	1.55E+09	0.40	0.53	0.34	0.46	0.09
118.48	4.52E+09	5.54E+09	4.75E+09	2.27E+09	2.17E+09	2.82E+09	0.50	0.61	0.41	0.55	0.08
136.65	6.74E+09	5.42E+09	5.10E+09	4.19E+09	3.55E+09	2.42E+09	0.38	0.34	0.52	0.36	0.02
157.59	8.81E+09	8.60E+09	7.57E+09	4.27E+09	4.37E+09	3.68E+09	0.52	0.49	0.51	0.50	0.02
181.72	1.12E+10	8.24E+09	9.26E+09	6.94E+09	9.41E+09	6.25E+09	0.38	-0.14	0.33	0.12	0.37
209.54	1.32E+10	1.59E+10	1.68E+10	8.30E+09	8.47E+09	1.06E+10	0.37	0.47	0.37	0.42	0.07
241.56	2.77E+10	1.63E+10	2.22E+10	1.16E+10	1.43E+10	1.55E+10	0.58	0.12	0.30	0.35	0.33
278.50	2.68E+10	3.19E+10	2.48E+10	1.38E+10	1.88E+10	1.95E+10	0.49	0.41	0.22	0.45	0.05
321.04	3.75E+10	4.47E+10	3.81E+10	2.00E+10	1.34E+10	2.20E+10	0.47	0.70	0.42	0.58	0.17
370.15	3.98E+10	4.62E+10	4.10E+10	2.85E+10	2.33E+10	2.18E+10	0.28	0.50	0.47	0.39	0.15
426.75	7.12E+10	5.32E+10	7.02E+10	2.53E+10	4.56E+10	2.97E+10	0.64	0.14	0.58	0.39	0.36
585.27	1.28E+11	1.25E+11	1.22E+11	7.86E+10	8.02E+10	7.98E+10	0.39	0.36	0.35	0.37	0.02
628.94	1.31E+11	1.29E+11	1.28E+11	7.93E+10	8.24E+10	8.30E+10	0.39	0.36	0.35	0.38	0.02
675.86	1.33E+11	1.28E+11	1.25E+11	7.89E+10	8.03E+10	8.08E+10	0.41	0.37	0.35	0.39	0.03
726.29	1.26E+11	1.20E+11	1.21E+11	7.41E+10	7.54E+10	7.84E+10	0.41	0.37	0.35	0.39	0.03
780.48	1.15E+11	1.08E+11	1.10E+11	6.87E+10	6.85E+10	6.80E+10	0.40	0.36	0.38	0.38	0.03
838.71	1.05E+11	9.95E+10	9.85E+10	6.05E+10	6.03E+10	6.08E+10	0.42	0.39	0.38	0.41	0.02
901.29	9.71E+10	8.74E+10	8.80E+10	5.29E+10	5.54E+10	5.40E+10	0.45	0.37	0.39	0.41	0.06
968.53	8.58E+10	7.87E+10	7.93E+10	4.97E+10	4.83E+10	4.75E+10	0.42	0.39	0.40	0.40	0.03
1040.79	7.45E+10	6.97E+10	6.81E+10	4.14E+10	4.19E+10	4.09E+10	0.44	0.40	0.40	0.42	0.03
1118.45	6.48E+10	6.18E+10	6.21E+10	3.53E+10	3.58E+10	3.60E+10	0.46	0.42	0.42	0.44	0.02
1201.90	5.83E+10	5.61E+10	5.28E+10	3.23E+10	3.36E+10	3.19E+10	0.45	0.40	0.40	0.42	0.03
1291.57	4.79E+10	4.41E+10	4.53E+10	2.43E+10	2.66E+10	2.90E+10	0.49	0.40	0.36	0.44	0.07
1387.93	3.76E+10	3.46E+10	3.41E+10	1.75E+10	1.86E+10	1.89E+10	0.54	0.46	0.45	0.50	0.05
1491.48	2.71E+10	2.53E+10	2.39E+10	1.11E+10	1.28E+10	1.36E+10	0.59	0.49	0.43	0.54	0.07
1602.76	1.52E+10	1.50E+10	1.37E+10	8.17E+09	7.38E+09	6.98E+09	0.46	0.51	0.49	0.48	0.03
1722.34	7.36E+09	6.87E+09	6.54E+09	3.11E+09	3.43E+09	3.11E+09	0.58	0.50	0.52	0.54	0.05
1850.84	3.85E+09	3.85E+09	2.84E+09	1.62E+09	1.42E+09	1.22E+09	0.58	0.63	0.57	0.61	0.04
1988.93	7.55E+08	0.00E+00	5.04E+08	2.52E+08	7.55E+08	2.52E+08	0.67	0.00	0.50	0.33	0.47
2137.32	9.37E+08	0.00E+00	9.37E+08	3.12E+08	0.00E+00	0.00E+00	0.67	0.00	1.00	0.33	0.47
2296.79	0.00E+00	3.88E+08	0.00E+00	3.88E+08	0.00E+00	3.88E+08	0.00	1.00	0.00	0.50	0.71
2468.15	0.00E+00	9.62E+08	4.81E+08	0.00E+00	4.81E+08	0.00E+00	0.00	0.50	1.00	0.25	0.35
2652.29	5.97E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.50	0.71
2850.18	0.00E+00	0.00E+00	7.41E+08	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.00	0.00
3062.82	9.19E+08	9.19E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	0.00	1.00	0.00
3291.34	0.00E+00	0.00E+00	0.00E+00	1.14E+09	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3536.90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3800.78	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E+09	0.00	0.00	0.00	0.00	0.00

Table B-4: Continued

4084.35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4389.08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4716.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5068.43	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5446.58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5852.93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6289.61	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6758.87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7263.13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7805.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
8387.34	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9013.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9685.55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10408.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11184.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12019.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12915.90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13879.53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-5: Collection efficiency of diesel fumes by number concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	CE 01	CE 02	CE 03	CE Avg	CE Std
14.73	3.70E+01	7.26E+01	7.37E+01	3.82E+01	3.70E+01	0.00E+00	-0.03	0.49	1.00	0.49	0.52
16.98	1.95E+02	2.01E+02	3.28E+02	1.61E+02	1.95E+02	1.94E+02	0.17	0.03	0.41	0.20	0.19
19.57	1.52E+03	1.41E+03	1.67E+03	9.89E+02	7.24E+02	8.43E+02	0.35	0.49	0.49	0.44	0.08
22.55	6.46E+03	6.67E+03	8.43E+03	4.35E+03	4.19E+03	4.78E+03	0.33	0.37	0.43	0.38	0.05
25.97	2.46E+04	2.57E+04	3.05E+04	1.59E+04	1.62E+04	1.79E+04	0.35	0.37	0.41	0.38	0.03
29.89	7.71E+04	7.32E+04	8.24E+04	4.64E+04	4.55E+04	5.08E+04	0.40	0.38	0.38	0.39	0.01
34.39	1.98E+05	1.75E+05	2.01E+05	1.14E+05	1.10E+05	1.14E+05	0.42	0.37	0.43	0.41	0.03
39.54	4.11E+05	3.63E+05	3.99E+05	2.35E+05	2.21E+05	2.17E+05	0.43	0.39	0.46	0.42	0.03
45.43	7.24E+05	6.27E+05	6.72E+05	4.11E+05	3.83E+05	3.91E+05	0.43	0.39	0.42	0.41	0.02
52.16	1.09E+06	9.38E+05	9.62E+05	6.25E+05	5.61E+05	5.89E+05	0.43	0.40	0.39	0.41	0.02
59.83	1.41E+06	1.19E+06	1.20E+06	7.93E+05	7.17E+05	7.49E+05	0.44	0.40	0.38	0.40	0.03
68.54	1.54E+06	1.31E+06	1.30E+06	8.70E+05	7.85E+05	7.99E+05	0.44	0.40	0.38	0.41	0.03
78.45	1.49E+06	1.25E+06	1.20E+06	8.05E+05	7.45E+05	7.31E+05	0.46	0.40	0.39	0.42	0.04
89.68	1.18E+06	9.83E+05	9.41E+05	6.36E+05	5.98E+05	5.61E+05	0.46	0.39	0.40	0.42	0.04
102.40	7.39E+05	6.19E+05	5.89E+05	3.85E+05	3.79E+05	3.40E+05	0.48	0.39	0.42	0.43	0.05
116.78	3.34E+05	2.81E+05	2.74E+05	1.67E+05	1.79E+05	1.61E+05	0.50	0.36	0.41	0.42	0.07
133.05	1.05E+05	8.92E+04	9.10E+04	5.04E+04	6.33E+04	5.44E+04	0.52	0.29	0.40	0.40	0.11
151.42	2.20E+04	2.15E+04	2.34E+04	1.10E+04	1.48E+04	1.32E+04	0.50	0.31	0.43	0.41	0.10
172.19	4.61E+03	4.23E+03	5.10E+03	2.26E+03	3.17E+03	2.56E+03	0.51	0.25	0.50	0.42	0.15
195.71	9.54E+02	9.95E+02	1.07E+03	5.99E+02	8.81E+02	5.59E+02	0.37	0.11	0.48	0.32	0.19
222.39	3.51E+02	3.93E+02	4.72E+02	3.10E+02	1.64E+02	2.89E+02	0.12	0.58	0.39	0.36	0.23
252.68	1.09E+02	2.43E+02	1.52E+02	1.10E+02	8.85E+01	1.12E+02	-0.01	0.64	0.26	0.30	0.32
1327.87	4.42E+00	3.97E+00	3.14E+00	2.40E+00	2.91E+00	3.33E+00	0.46	0.27	-0.06	0.22	0.26
1428.05	3.49E+00	3.14E+00	1.86E+00	1.98E+00	1.57E+00	2.21E+00	0.43	0.50	-0.19	0.25	0.38
1534.59	1.92E+00	2.46E+00	1.34E+00	8.64E-01	1.28E+00	1.15E+00	0.55	0.48	0.14	0.39	0.22
1649.09	1.18E+00	1.15E+00	7.36E-01	3.52E-01	8.00E-01	6.72E-01	0.70	0.31	0.09	0.37	0.31
1771.53	9.60E-01	8.96E-01	5.12E-01	4.80E-01	2.88E-01	5.12E-01	0.50	0.68	0.00	0.39	0.35
1903.52	5.44E-01	4.16E-01	4.16E-01	9.60E-02	1.60E-01	2.56E-01	0.82	0.62	0.38	0.61	0.22
2045.05	6.08E-01	3.20E-01	1.60E-01	2.24E-01	3.20E-01	3.52E-01	0.63	0.00	-1.20	-0.19	0.93
2197.71	2.56E-01	2.24E-01	2.24E-01	9.60E-02	9.60E-02	2.56E-01	0.62	0.57	-0.14	0.35	0.43
2363.09	1.60E-01	1.60E-01	1.92E-01	9.60E-02	3.20E-02	1.28E-01	0.40	0.80	0.33	0.51	0.25
2538.01	9.60E-02	1.28E-01	6.40E-02	0.00E+00	6.40E-02	1.28E-01	1.00	0.50	-1.00	0.17	1.04
2727.24	1.92E-01	9.60E-02	1.60E-01	0.00E+00	3.20E-02	9.60E-02	1.00	0.67	0.40	0.69	0.30
2930.79	6.40E-02	1.60E-01	1.28E-01	9.60E-02	6.40E-02	9.60E-02	-0.50	0.60	0.25	0.12	0.56
3150.24	6.40E-02	6.40E-02	1.60E-01	3.20E-02	3.20E-02	0.00E+00	0.50	0.50	1.00	0.67	0.29
3385.58	3.20E-02	3.20E-02	1.28E-01	3.20E-02	0.00E+00	0.00E+00	0.00	1.00	1.00	0.67	0.58
3638.43	9.60E-02	9.60E-02	1.60E-01	0.00E+00	6.40E-02	1.28E-01	1.00	0.33	0.20	0.51	0.43
3908.76	9.60E-02	6.40E-02	1.60E-01	6.40E-02	6.40E-02	6.40E-02	0.33	0.00	0.60	0.31	0.30
4201.36	3.20E-02	6.40E-02	6.40E-02	6.40E-02	6.40E-02	0.00E+00	-1.00	0.00	1.00	0.00	1.00
4514.63	0.00E+00	6.40E-02	0.00E+00	3.20E-02	3.20E-02	3.20E-02	0.00	0.50	0.00	0.17	0.29
4851.75	6.40E-02	1.28E-01	3.20E-02	3.20E-02	0.00E+00	0.00E+00	0.50	1.00	1.00	0.83	0.29
5212.72	0.00E+00	6.40E-02	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00	1.00	0.00	0.33	0.58
5602.32	0.00E+00	6.40E-02	1.28E-01	3.20E-02	3.20E-02	3.20E-02	0.00	0.50	0.75	0.42	0.38
6020.55	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.33	0.58
6468.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6950.81	3.20E-02	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	1.00	0.67	0.58
7470.15	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
8027.48	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.33	0.58
8626.39	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00	1.00	0.00	0.33	0.58

Table B-5: Continued

9269.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9961.59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10704.80	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00	0.00	0.00	0.00	0.00
11503.46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12361.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13283.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
14275.07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
15340.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
16484.58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
17714.46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
19036.09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20456.33	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
21982.53	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
23622.60	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
25385.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27278.94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
29314.16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31501.22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-6: Collection efficiency of diesel fumes by mass concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	CE 01	CE 02	CE 03	CE Avg	CE Std
14.73	1.18E+05	2.32E+05	2.36E+05	1.22E+05	1.18E+05	0.00E+00	-0.03	0.49	1.00	0.49	0.52
16.98	9.54E+05	9.84E+05	1.61E+06	7.90E+05	9.53E+05	9.49E+05	0.17	0.03	0.41	0.20	0.19
19.57	1.14E+07	1.06E+07	1.25E+07	7.41E+06	5.43E+06	6.32E+06	0.35	0.49	0.49	0.44	0.08
22.55	7.40E+07	7.65E+07	9.66E+07	4.99E+07	4.81E+07	5.48E+07	0.33	0.37	0.43	0.38	0.05
25.97	4.31E+08	4.49E+08	5.34E+08	2.78E+08	2.84E+08	3.14E+08	0.35	0.37	0.41	0.38	0.03
29.89	2.06E+09	1.95E+09	2.20E+09	1.24E+09	1.22E+09	1.36E+09	0.40	0.38	0.38	0.39	0.01
34.39	8.06E+09	7.10E+09	8.17E+09	4.65E+09	4.48E+09	4.62E+09	0.42	0.37	0.43	0.41	0.03
39.54	2.54E+10	2.24E+10	2.47E+10	1.45E+10	1.37E+10	1.34E+10	0.43	0.39	0.46	0.42	0.03
45.43	6.79E+10	5.88E+10	6.30E+10	3.85E+10	3.59E+10	3.67E+10	0.43	0.39	0.42	0.41	0.02
52.16	1.55E+11	1.33E+11	1.37E+11	8.88E+10	7.96E+10	8.36E+10	0.43	0.40	0.39	0.41	0.02
59.83	3.02E+11	2.54E+11	2.57E+11	1.70E+11	1.54E+11	1.60E+11	0.44	0.40	0.38	0.40	0.03
68.54	4.96E+11	4.23E+11	4.18E+11	2.80E+11	2.53E+11	2.57E+11	0.44	0.40	0.38	0.41	0.03
78.45	7.19E+11	6.01E+11	5.80E+11	3.89E+11	3.60E+11	3.53E+11	0.46	0.40	0.39	0.42	0.04
89.68	8.51E+11	7.09E+11	6.79E+11	4.59E+11	4.31E+11	4.05E+11	0.46	0.39	0.40	0.42	0.04
102.40	7.93E+11	6.64E+11	6.33E+11	4.13E+11	4.07E+11	3.65E+11	0.48	0.39	0.42	0.43	0.05
116.78	5.33E+11	4.47E+11	4.36E+11	2.67E+11	2.86E+11	2.57E+11	0.50	0.36	0.41	0.42	0.07
133.05	2.47E+11	2.10E+11	2.14E+11	1.19E+11	1.49E+11	1.28E+11	0.52	0.29	0.40	0.40	0.11
151.42	7.64E+10	7.46E+10	8.11E+10	3.83E+10	5.15E+10	4.60E+10	0.50	0.31	0.43	0.41	0.10
172.19	2.36E+10	2.16E+10	2.60E+10	1.16E+10	1.62E+10	1.30E+10	0.51	0.25	0.50	0.42	0.15
195.71	7.15E+09	7.46E+09	8.02E+09	4.49E+09	6.61E+09	4.19E+09	0.37	0.11	0.48	0.32	0.19
222.39	3.86E+09	4.32E+09	5.19E+09	3.41E+09	1.80E+09	3.17E+09	0.12	0.58	0.39	0.36	0.23
252.68	1.76E+09	3.93E+09	2.45E+09	1.78E+09	1.43E+09	1.80E+09	-0.01	0.64	0.26	0.30	0.32
1327.87	1.03E+10	9.29E+09	7.34E+09	5.62E+09	6.82E+09	7.79E+09	0.46	0.27	-0.06	0.22	0.26
1428.05	1.02E+10	9.13E+09	5.41E+09	5.78E+09	4.57E+09	6.43E+09	0.43	0.50	-0.19	0.25	0.38
1534.59	6.94E+09	8.90E+09	4.86E+09	3.12E+09	4.63E+09	4.16E+09	0.55	0.48	0.14	0.39	0.22
1649.09	5.31E+09	5.17E+09	3.30E+09	1.58E+09	3.59E+09	3.01E+09	0.70	0.31	0.09	0.37	0.31
1771.53	5.34E+09	4.98E+09	2.85E+09	2.67E+09	1.60E+09	2.85E+09	0.50	0.68	0.00	0.39	0.35
1903.52	3.75E+09	2.87E+09	2.87E+09	6.62E+08	1.10E+09	1.77E+09	0.82	0.62	0.38	0.61	0.22
2045.05	5.20E+09	2.74E+09	1.37E+09	1.92E+09	2.74E+09	3.01E+09	0.63	0.00	-1.20	-0.19	0.93
2197.71	2.72E+09	2.38E+09	2.38E+09	1.02E+09	1.02E+09	2.72E+09	0.62	0.57	-0.14	0.35	0.43
2363.09	2.11E+09	2.11E+09	2.53E+09	1.27E+09	4.22E+08	1.69E+09	0.40	0.80	0.33	0.51	0.25
2538.01	1.57E+09	2.09E+09	1.05E+09	0.00E+00	1.05E+09	2.09E+09	1.00	0.50	-1.00	0.17	1.04
2727.24	3.89E+09	1.95E+09	3.25E+09	0.00E+00	6.49E+08	1.95E+09	1.00	0.67	0.40	0.69	0.30
2930.79	1.61E+09	4.03E+09	3.22E+09	2.42E+09	1.61E+09	2.42E+09	-0.50	0.60	0.25	0.12	0.56
3150.24	2.00E+09	2.00E+09	5.00E+09	1.00E+09	1.00E+09	0.00E+00	0.50	0.50	1.00	0.67	0.29
3385.58	1.24E+09	1.24E+09	4.97E+09	1.24E+09	0.00E+00	0.00E+00	0.00	1.00	1.00	0.67	0.58
3638.43	4.62E+09	4.62E+09	7.71E+09	0.00E+00	3.08E+09	6.17E+09	1.00	0.33	0.20	0.51	0.43
3908.76	5.73E+09	3.82E+09	9.55E+09	3.82E+09	3.82E+09	3.82E+09	0.33	0.00	0.60	0.31	0.30
4201.36	2.37E+09	4.75E+09	4.75E+09	4.75E+09	4.75E+09	0.00E+00	-1.00	0.00	1.00	0.00	1.00
4514.63	0.00E+00	5.89E+09	0.00E+00	2.94E+09	2.94E+09	2.94E+09	0.00	0.50	0.00	0.17	0.29
4851.75	7.31E+09	1.46E+10	3.65E+09	3.65E+09	0.00E+00	0.00E+00	0.50	1.00	1.00	0.83	0.29
5212.72	0.00E+00	9.06E+09	0.00E+00	0.00E+00	0.00E+00	4.53E+09	0.00	1.00	0.00	0.33	0.58
5602.32	0.00E+00	1.13E+10	2.25E+10	5.63E+09	5.63E+09	5.63E+09	0.00	0.50	0.75	0.42	0.38
6020.55	0.00E+00	0.00E+00	6.98E+09	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.33	0.58
6468.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6950.81	1.07E+10	0.00E+00	1.07E+10	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	1.00	0.67	0.58
7470.15	1.33E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
8027.48	0.00E+00	0.00E+00	1.66E+10	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.33	0.58
8626.39	0.00E+00	2.05E+10	0.00E+00	0.00E+00	0.00E+00	2.05E+10	0.00	1.00	0.00	0.33	0.58

Table B-6: Continued

9269.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9961.59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10704.80	3.93E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.93E+10	1.00	0.00	0.00	0.33	0.58
11503.46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12361.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13283.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
14275.07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
15340.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
16484.58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
17714.46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
19036.09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20456.33	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
21982.53	0.00E+00	0.00E+00	3.40E+11	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
23622.60	0.00E+00	4.22E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
25385.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27278.94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
29314.16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31501.22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-7: Particle loss of ARD by number concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	PL 01	PL 02	PL 03	PL Avg	PL Std
17.92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20.67	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
23.84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27.50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31.70	2.32E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
36.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.43E+01	0.00	0.00	0.00	0.00	0.00
42.11	4.02E+01	2.01E+01	0.00E+00	4.06E+01	1.98E+01	0.00E+00	0.00	0.00	0.00	0.00	0.00
48.51	1.92E+01	1.86E+01	1.86E+01	1.92E+01	0.00E+00	1.86E+01	0.00	1.00	0.00	0.33	0.58
55.85	1.79E+01	0.00E+00	1.79E+01	1.76E+01	5.34E+01	1.76E+01	0.01	0.00	0.01	0.01	0.01
64.27	6.82E+01	3.42E+01	0.00E+00	1.75E+01	6.78E+01	3.45E+01	0.74	-0.98	0.00	-0.08	0.87
73.93	1.49E+02	5.01E+01	6.63E+01	8.29E+01	5.00E+01	9.95E+01	0.45	0.00	-0.50	-0.02	0.47
85.00	1.95E+02	2.44E+02	1.96E+02	9.76E+01	1.03E+02	1.62E+02	0.50	0.58	0.17	0.42	0.22
97.65	2.90E+02	1.29E+02	2.66E+02	9.66E+01	1.24E+02	2.90E+02	0.67	0.04	-0.09	0.21	0.40
112.10	3.13E+02	2.09E+02	5.06E+02	1.88E+02	9.65E+01	2.58E+02	0.40	0.54	0.49	0.48	0.07
128.63	5.76E+02	3.73E+02	5.53E+02	2.65E+02	4.38E+02	3.41E+02	0.54	-0.17	0.38	0.25	0.38
147.47	6.13E+02	4.13E+02	6.78E+02	2.49E+02	3.48E+02	2.99E+02	0.59	0.16	0.56	0.44	0.24
169.00	6.30E+02	5.28E+02	7.01E+02	3.57E+02	3.41E+02	4.09E+02	0.43	0.36	0.42	0.40	0.04
193.57	6.92E+02	5.84E+02	8.14E+02	3.91E+02	2.66E+02	3.72E+02	0.43	0.54	0.54	0.51	0.06
221.67	6.31E+02	5.19E+02	6.30E+02	4.84E+02	2.98E+02	3.71E+02	0.23	0.43	0.41	0.36	0.11
253.79	5.68E+02	3.34E+02	8.19E+02	9.75E+01	2.72E+02	3.91E+02	0.83	0.19	0.52	0.51	0.32
290.52	4.77E+02	4.38E+02	3.51E+02	2.71E+02	2.95E+02	2.68E+02	0.43	0.33	0.24	0.33	0.10
332.71	4.62E+02	1.76E+02	4.17E+02	2.89E+02	1.34E+02	2.03E+02	0.37	0.24	0.51	0.38	0.14
628.47	7.68E+02	7.58E+02	7.47E+02	2.08E+02	1.92E+02	2.19E+02	0.73	0.75	0.71	0.73	0.02
675.36	7.61E+02	7.42E+02	7.40E+02	2.00E+02	1.90E+02	2.13E+02	0.74	0.74	0.71	0.73	0.02
725.75	7.15E+02	6.97E+02	6.92E+02	1.94E+02	1.78E+02	2.00E+02	0.73	0.74	0.71	0.73	0.02
779.90	6.53E+02	6.43E+02	6.42E+02	1.75E+02	1.63E+02	1.90E+02	0.73	0.75	0.70	0.73	0.02
838.08	6.05E+02	5.86E+02	5.88E+02	1.60E+02	1.49E+02	1.70E+02	0.74	0.74	0.71	0.73	0.02
900.61	5.41E+02	5.29E+02	5.28E+02	1.42E+02	1.32E+02	1.51E+02	0.74	0.75	0.71	0.73	0.02
967.81	4.83E+02	4.65E+02	4.66E+02	1.25E+02	1.15E+02	1.33E+02	0.74	0.75	0.71	0.74	0.02
1040.01	4.26E+02	4.12E+02	4.11E+02	1.11E+02	1.01E+02	1.15E+02	0.74	0.75	0.72	0.74	0.02
1117.61	3.67E+02	3.54E+02	3.64E+02	9.10E+01	8.51E+01	9.90E+01	0.75	0.76	0.73	0.75	0.02
1200.99	3.18E+02	3.07E+02	3.18E+02	7.60E+01	7.08E+01	8.30E+01	0.76	0.77	0.74	0.76	0.02
1290.60	2.82E+02	2.70E+02	2.76E+02	6.26E+01	6.26E+01	7.11E+01	0.78	0.77	0.74	0.76	0.02
1386.89	2.37E+02	2.31E+02	2.34E+02	5.35E+01	4.88E+01	5.80E+01	0.77	0.79	0.75	0.77	0.02
1490.36	2.03E+02	1.94E+02	2.01E+02	4.43E+01	3.76E+01	4.66E+01	0.78	0.81	0.77	0.79	0.02
1601.56	1.77E+02	1.70E+02	1.73E+02	3.39E+01	3.16E+01	3.80E+01	0.81	0.81	0.78	0.80	0.02
1721.05	1.43E+02	1.38E+02	1.41E+02	2.50E+01	2.32E+01	2.68E+01	0.83	0.83	0.81	0.82	0.01
1849.45	1.17E+02	1.16E+02	1.17E+02	1.73E+01	1.70E+01	1.96E+01	0.85	0.85	0.83	0.85	0.01
1987.44	9.82E+01	8.94E+01	9.50E+01	1.25E+01	1.19E+01	1.28E+01	0.87	0.87	0.87	0.87	0.00
2135.72	8.03E+01	7.50E+01	7.50E+01	7.81E+00	7.97E+00	7.68E+00	0.90	0.89	0.90	0.90	0.00
2295.06	6.15E+01	5.83E+01	6.11E+01	5.54E+00	3.97E+00	5.66E+00	0.91	0.93	0.91	0.92	0.01
2466.29	4.85E+01	4.60E+01	4.47E+01	3.68E+00	2.91E+00	3.20E+00	0.92	0.94	0.93	0.93	0.01
2650.30	3.78E+01	3.64E+01	3.53E+01	1.66E+00	1.66E+00	2.11E+00	0.96	0.95	0.94	0.95	0.01
2848.03	2.87E+01	2.71E+01	2.75E+01	1.18E+00	9.92E-01	1.28E+00	0.96	0.96	0.95	0.96	0.00
3060.52	1.99E+01	2.10E+01	2.15E+01	7.68E-01	8.32E-01	6.40E-01	0.96	0.96	0.97	0.96	0.01
3288.86	1.48E+01	1.52E+01	1.61E+01	5.76E-01	4.80E-01	4.16E-01	0.96	0.97	0.97	0.97	0.01
3534.23	1.20E+01	1.21E+01	1.29E+01	3.84E-01	3.52E-01	3.20E-01	0.97	0.97	0.98	0.97	0.00
3797.92	9.57E+00	8.38E+00	8.77E+00	6.40E-02	2.88E-01	2.88E-01	0.99	0.97	0.97	0.98	0.02
4081.27	6.85E+00	7.14E+00	7.20E+00	3.20E-01	1.28E-01	9.60E-02	0.95	0.98	0.99	0.97	0.02

Table B-7: Continued

4385.77	5.82E+00	4.80E+00	5.82E+00	6.40E-02	9.60E-02	2.56E-01	0.989011	0.98	0.956044	0.975018	0.017039
4712.98	4.03E+00	4.26E+00	3.65E+00	3.20E-02	3.20E-02	9.60E-02	0.992063	0.992481	0.973684	0.986076	0.010734
5064.61	3.55E+00	3.01E+00	3.10E+00	0.00E+00	3.20E-02	3.20E-02	1.00	0.99	0.99	0.99	0.01
5442.47	2.85E+00	2.66E+00	2.50E+00	6.40E-02	3.20E-02	9.60E-02	0.98	0.99	0.96	0.98	0.01
5848.52	1.86E+00	2.02E+00	1.82E+00	0.00E+00	0.00E+00	3.20E-02	1.00	1.00	0.98	0.99	0.01
6284.87	1.41E+00	1.28E+00	1.18E+00	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
6753.77	1.47E+00	8.00E-01	1.09E+00	3.20E-02	0.00E+00	0.00E+00	0.98	1.00	1.00	0.99	0.01
7257.66	7.68E-01	7.36E-01	9.60E-01	3.20E-02	0.00E+00	0.00E+00	0.96	1.00	1.00	0.99	0.02
7799.14	4.80E-01	8.32E-01	2.56E-01	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
8381.02	3.84E-01	2.24E-01	3.20E-01	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
9006.31	3.20E-01	2.24E-01	4.16E-01	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
9678.25	9.60E-02	4.16E-01	4.16E-01	0.00E+00	0.00E+00	3.20E-02	1.00	1.00	0.92	0.97	0.04
10400.32	6.40E-02	2.56E-01	2.56E-01	0.00E+00	0.00E+00	3.20E-02	1.00	1.00	0.87	0.96	0.07
11176.27	6.40E-02	1.92E-01	1.92E-01	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
12010.11	0.00E+00	1.60E-01	1.60E-01	0.00E+00	0.00E+00	0.00E+00	0.00	1.00	1.00	0.67	0.58
12906.16	3.20E-02	1.28E-01	1.28E-01	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
13869.06	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
14903.80	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58

Table B-8: Particle loss of ARD by mass concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	PL 01	PL 02	PL 03	PL Avg	PL Std
17.92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20.67	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
23.84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27.50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31.70	0.00E+00	0.00E+00	2.46E+05	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
36.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.16E+06	0.00	0.00	0.00	0.00	0.00
42.11	1.50E+06	0.00E+00	1.50E+06	3.03E+06	1.48E+06	0.00E+00	-0.01	0.02	0.00	0.00	0.01
48.51	2.12E+06	2.12E+06	2.14E+06	2.19E+06	0.00E+00	2.12E+06	0.00	1.00	0.00	0.33	0.58
55.85	0.00E+00	3.12E+06	2.08E+06	3.07E+06	9.30E+06	3.07E+06	0.01	0.00	0.01	0.01	0.01
64.27	9.08E+06	0.00E+00	9.06E+06	4.64E+06	1.80E+07	9.17E+06	0.74	-0.98	0.00	-0.08	0.87
73.93	2.02E+07	2.68E+07	3.58E+07	3.35E+07	2.02E+07	4.02E+07	0.45	0.00	-0.50	-0.02	0.47
85.00	1.50E+08	1.20E+08	1.30E+08	5.99E+07	6.31E+07	9.98E+07	0.50	0.58	0.17	0.42	0.22
97.65	1.20E+08	2.47E+08	2.12E+08	9.00E+07	1.15E+08	2.70E+08	0.67	0.04	-0.09	0.21	0.40
112.10	2.94E+08	7.13E+08	4.83E+08	2.65E+08	1.36E+08	3.63E+08	0.40	0.54	0.49	0.48	0.07
128.63	7.95E+08	1.18E+09	1.07E+09	5.65E+08	9.33E+08	7.26E+08	0.54	-0.17	0.38	0.25	0.38
147.47	1.33E+09	2.17E+09	1.82E+09	7.98E+08	1.12E+09	9.58E+08	0.59	0.16	0.56	0.44	0.24
169.00	2.55E+09	3.39E+09	2.99E+09	1.72E+09	1.64E+09	1.97E+09	0.43	0.36	0.42	0.40	0.04
193.57	4.24E+09	5.91E+09	5.05E+09	2.84E+09	1.93E+09	2.70E+09	0.43	0.54	0.54	0.51	0.06
221.67	5.65E+09	6.86E+09	6.46E+09	5.27E+09	3.25E+09	4.04E+09	0.23	0.43	0.41	0.36	0.11
253.79	5.47E+09	1.34E+10	9.38E+09	1.59E+09	4.45E+09	6.40E+09	0.83	0.19	0.52	0.51	0.32
290.52	1.07E+10	8.61E+09	1.03E+10	6.64E+09	7.22E+09	6.58E+09	0.43	0.33	0.24	0.33	0.10
332.71	6.47E+09	1.53E+10	1.29E+10	1.06E+10	4.93E+09	7.48E+09	0.37	0.24	0.51	0.38	0.14
628.47	1.88E+11	1.85E+11	1.88E+11	5.17E+10	4.76E+10	5.43E+10	0.73	0.75	0.71	0.73	0.02
675.36	2.28E+11	2.28E+11	2.30E+11	6.15E+10	5.84E+10	6.55E+10	0.74	0.74	0.71	0.73	0.02
725.75	2.67E+11	2.65E+11	2.68E+11	7.41E+10	6.81E+10	7.64E+10	0.73	0.74	0.71	0.73	0.02
779.90	3.05E+11	3.05E+11	3.06E+11	8.28E+10	7.71E+10	9.00E+10	0.73	0.75	0.70	0.73	0.02
838.08	3.45E+11	3.46E+11	3.49E+11	9.42E+10	8.80E+10	1.00E+11	0.74	0.74	0.71	0.73	0.02
900.61	3.87E+11	3.86E+11	3.89E+11	1.04E+11	9.62E+10	1.10E+11	0.74	0.75	0.71	0.73	0.02
967.81	4.22E+11	4.22E+11	4.27E+11	1.13E+11	1.04E+11	1.20E+11	0.74	0.75	0.71	0.74	0.02
1040.01	4.63E+11	4.62E+11	4.68E+11	1.25E+11	1.14E+11	1.29E+11	0.74	0.75	0.72	0.74	0.02
1117.61	4.95E+11	5.08E+11	5.05E+11	1.27E+11	1.19E+11	1.38E+11	0.75	0.76	0.73	0.75	0.02
1200.99	5.32E+11	5.51E+11	5.45E+11	1.32E+11	1.23E+11	1.44E+11	0.76	0.77	0.74	0.76	0.02
1290.60	5.81E+11	5.92E+11	5.93E+11	1.35E+11	1.34E+11	1.53E+11	0.78	0.77	0.74	0.76	0.02
1386.89	6.17E+11	6.25E+11	6.25E+11	1.43E+11	1.30E+11	1.55E+11	0.77	0.79	0.75	0.77	0.02
1490.36	6.42E+11	6.66E+11	6.59E+11	1.47E+11	1.24E+11	1.54E+11	0.78	0.81	0.77	0.79	0.02
1601.56	6.98E+11	7.11E+11	7.12E+11	1.39E+11	1.30E+11	1.56E+11	0.81	0.81	0.78	0.80	0.02
1721.05	7.02E+11	7.21E+11	7.18E+11	1.27E+11	1.18E+11	1.37E+11	0.83	0.83	0.81	0.82	0.01
1849.45	7.33E+11	7.40E+11	7.39E+11	1.09E+11	1.07E+11	1.24E+11	0.85	0.85	0.83	0.85	0.01
1987.44	7.02E+11	7.46E+11	7.40E+11	9.82E+10	9.37E+10	1.00E+11	0.87	0.87	0.87	0.87	0.00
2135.72	7.31E+11	7.31E+11	7.48E+11	7.61E+10	7.76E+10	7.48E+10	0.90	0.89	0.90	0.90	0.00
2295.06	7.05E+11	7.38E+11	7.29E+11	6.69E+10	4.80E+10	6.85E+10	0.91	0.93	0.91	0.92	0.01
2466.29	6.90E+11	6.70E+11	6.96E+11	5.52E+10	4.37E+10	4.80E+10	0.92	0.94	0.93	0.93	0.01
2650.30	6.77E+11	6.57E+11	6.79E+11	3.10E+10	3.10E+10	3.93E+10	0.96	0.95	0.94	0.95	0.01
2848.03	6.26E+11	6.35E+11	6.41E+11	2.74E+10	2.29E+10	2.96E+10	0.96	0.96	0.95	0.96	0.00
3060.52	6.02E+11	6.16E+11	5.96E+11	2.20E+10	2.39E+10	1.83E+10	0.96	0.96	0.97	0.96	0.01
3288.86	5.42E+11	5.73E+11	5.47E+11	2.05E+10	1.71E+10	1.48E+10	0.96	0.97	0.97	0.97	0.01
3534.23	5.35E+11	5.68E+11	5.44E+11	1.70E+10	1.55E+10	1.41E+10	0.97	0.97	0.98	0.97	0.00
3797.92	4.59E+11	4.80E+11	4.88E+11	3.51E+09	1.58E+10	1.58E+10	0.99	0.97	0.97	0.98	0.02
4081.27	4.85E+11	4.89E+11	4.80E+11	2.18E+10	8.70E+09	6.53E+09	0.95	0.98	0.99	0.97	0.02

Table B-8: Continued

4385.77	4.05E+11	4.91E+11	4.63E+11	5.40E+09	8.10E+09	2.16E+10	0.99	0.98	0.96	0.98	0.02
4712.98	4.46E+11	3.82E+11	4.17E+11	3.35E+09	3.35E+09	1.00E+10	0.99	0.99	0.97	0.99	0.01
5064.61	3.91E+11	4.03E+11	4.18E+11	0.00E+00	4.16E+09	4.16E+09	1.00	0.99	0.99	0.99	0.01
5442.47	4.28E+11	4.02E+11	4.30E+11	1.03E+10	5.16E+09	1.55E+10	0.98	0.99	0.96	0.98	0.01
5848.52	4.03E+11	3.65E+11	3.80E+11	0.00E+00	0.00E+00	6.40E+09	1.00	1.00	0.98	0.99	0.01
6284.87	3.18E+11	2.94E+11	3.20E+11	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
6753.77	2.46E+11	3.35E+11	3.45E+11	9.86E+09	0.00E+00	0.00E+00	0.98	1.00	1.00	0.99	0.01
7257.66	2.81E+11	3.67E+11	3.14E+11	1.22E+10	0.00E+00	0.00E+00	0.96	1.00	1.00	0.99	0.02
7799.14	3.95E+11	1.21E+11	2.48E+11	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
8381.02	1.32E+11	1.88E+11	1.82E+11	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
9006.31	1.64E+11	3.04E+11	2.34E+11	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
9678.25	3.77E+11	3.77E+11	3.20E+11	0.00E+00	0.00E+00	2.90E+10	1.00	1.00	0.92	0.97	0.04
10400.32	2.88E+11	2.88E+11	2.48E+11	0.00E+00	0.00E+00	3.60E+10	1.00	1.00	0.87	0.96	0.07
11176.27	2.68E+11	2.68E+11	2.49E+11	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
12010.11	2.77E+11	2.77E+11	1.85E+11	0.00E+00	0.00E+00	0.00E+00	0.00	1.00	1.00	0.67	0.58
12906.16	2.75E+11	2.75E+11	2.37E+11	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	1.00	1.00	0.00
13869.06	0.00E+00	0.00E+00	6.68E+10	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
14903.80	0.00E+00	0.00E+00	8.29E+10	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58

Table B-9: Particle loss of NaCl by number concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	PL 01	PL 02	PL 03	PL Avg	PL Std
21.21	4.95E+03	5.59E+03	4.28E+03	3.43E+03	4.30E+03	2.65E+03	0.31	0.23	0.38	0.31	0.07
24.49	6.32E+03	5.69E+03	5.28E+03	3.28E+03	3.24E+03	2.84E+03	0.48	0.43	0.46	0.46	0.03
28.27	6.78E+03	6.36E+03	5.75E+03	3.07E+03	3.12E+03	3.47E+03	0.55	0.51	0.40	0.48	0.08
32.64	7.00E+03	7.36E+03	6.22E+03	3.00E+03	3.76E+03	2.89E+03	0.57	0.49	0.54	0.53	0.04
37.67	6.24E+03	6.05E+03	7.20E+03	2.76E+03	3.60E+03	3.35E+03	0.56	0.40	0.53	0.50	0.08
43.49	6.60E+03	5.75E+03	6.48E+03	3.62E+03	3.83E+03	3.47E+03	0.45	0.33	0.46	0.42	0.07
50.20	7.23E+03	6.16E+03	6.61E+03	3.49E+03	3.46E+03	3.09E+03	0.52	0.44	0.53	0.50	0.05
57.94	6.14E+03	5.99E+03	5.24E+03	3.20E+03	3.49E+03	3.55E+03	0.48	0.42	0.32	0.41	0.08
66.87	5.36E+03	6.53E+03	4.97E+03	3.31E+03	2.86E+03	2.91E+03	0.38	0.56	0.41	0.45	0.10
77.16	4.97E+03	5.49E+03	5.61E+03	3.40E+03	3.34E+03	3.35E+03	0.32	0.39	0.40	0.37	0.05
89.03	5.24E+03	5.01E+03	5.33E+03	2.94E+03	3.55E+03	3.20E+03	0.44	0.29	0.40	0.38	0.08
102.72	4.43E+03	4.42E+03	4.25E+03	2.96E+03	3.06E+03	2.18E+03	0.33	0.31	0.49	0.38	0.10
118.48	3.86E+03	2.89E+03	3.12E+03	2.72E+03	3.33E+03	2.86E+03	0.30	-0.15	0.08	0.08	0.22
136.65	3.33E+03	3.68E+03	3.48E+03	2.64E+03	2.12E+03	2.00E+03	0.21	0.42	0.43	0.35	0.13
157.59	3.74E+03	3.22E+03	2.99E+03	2.25E+03	2.20E+03	1.93E+03	0.40	0.32	0.35	0.36	0.04
181.72	2.76E+03	3.26E+03	3.12E+03	1.86E+03	1.37E+03	1.54E+03	0.33	0.58	0.51	0.47	0.13
209.54	3.11E+03	1.87E+03	2.27E+03	1.44E+03	1.73E+03	1.83E+03	0.54	0.08	0.19	0.27	0.24
241.56	1.78E+03	1.86E+03	2.46E+03	1.97E+03	1.16E+03	1.57E+03	-0.10	0.38	0.36	0.21	0.27
278.50	2.37E+03	1.66E+03	2.07E+03	1.24E+03	1.48E+03	1.15E+03	0.48	0.11	0.45	0.34	0.20
321.04	1.42E+03	1.86E+03	1.58E+03	1.13E+03	1.35E+03	1.15E+03	0.20	0.28	0.27	0.25	0.04
370.15	1.36E+03	1.74E+03	1.31E+03	7.85E+02	9.10E+02	8.08E+02	0.42	0.48	0.39	0.43	0.05
426.75	1.10E+03	1.56E+03	1.17E+03	9.16E+02	6.84E+02	9.03E+02	0.17	0.56	0.23	0.32	0.21
585.27	1.01E+03	1.00E+03	9.78E+02	6.40E+02	6.22E+02	6.08E+02	0.37	0.38	0.38	0.38	0.01
628.94	8.52E+02	8.49E+02	8.19E+02	5.25E+02	5.17E+02	5.13E+02	0.38	0.39	0.37	0.38	0.01
675.86	7.04E+02	6.93E+02	6.78E+02	4.31E+02	4.13E+02	4.04E+02	0.39	0.40	0.40	0.40	0.01
726.29	5.52E+02	5.32E+02	5.30E+02	3.28E+02	3.14E+02	3.16E+02	0.41	0.41	0.40	0.41	0.00
780.48	4.07E+02	3.93E+02	3.90E+02	2.42E+02	2.27E+02	2.32E+02	0.41	0.42	0.41	0.41	0.01
838.71	3.02E+02	2.91E+02	2.89E+02	1.78E+02	1.69E+02	1.67E+02	0.41	0.42	0.42	0.42	0.01
901.29	2.23E+02	2.11E+02	2.21E+02	1.33E+02	1.19E+02	1.20E+02	0.41	0.44	0.46	0.43	0.02
968.53	1.63E+02	1.57E+02	1.58E+02	9.45E+01	8.66E+01	8.72E+01	0.42	0.45	0.45	0.44	0.02
1040.79	1.17E+02	1.14E+02	1.11E+02	6.61E+01	6.18E+01	6.04E+01	0.44	0.46	0.46	0.45	0.01
1118.45	8.43E+01	8.12E+01	8.25E+01	4.63E+01	4.42E+01	4.44E+01	0.45	0.46	0.46	0.46	0.01
1201.90	6.58E+01	6.10E+01	6.03E+01	3.36E+01	3.23E+01	3.04E+01	0.49	0.47	0.50	0.48	0.01
1291.57	4.22E+01	4.03E+01	4.10E+01	2.22E+01	2.04E+01	2.10E+01	0.47	0.49	0.49	0.48	0.01
1387.93	2.76E+01	2.61E+01	2.58E+01	1.40E+01	1.30E+01	1.28E+01	0.49	0.50	0.51	0.50	0.01
1491.48	1.64E+01	1.78E+01	1.66E+01	8.16E+00	7.62E+00	7.20E+00	0.50	0.57	0.57	0.55	0.04
1602.76	8.51E+00	9.89E+00	9.02E+00	3.68E+00	3.65E+00	3.33E+00	0.57	0.63	0.63	0.61	0.04
1722.34	3.68E+00	3.87E+00	3.55E+00	1.44E+00	1.34E+00	1.28E+00	0.61	0.65	0.64	0.63	0.02
1850.84	1.41E+00	1.18E+00	1.18E+00	6.08E-01	6.08E-01	4.48E-01	0.57	0.49	0.62	0.56	0.07
1988.93	4.16E-01	3.52E-01	5.12E-01	9.60E-02	0.00E+00	6.40E-02	0.77	1.00	0.87	0.88	0.12
2137.32	1.92E-01	1.28E-01	1.60E-01	9.60E-02	0.00E+00	9.60E-02	0.50	1.00	0.40	0.63	0.32
2296.79	6.40E-02	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00E+00	1.00	0.00	0.00	0.33	0.58
2468.15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.40E-02	3.20E-02	0.00	0.00	0.00	0.00	0.00
2652.29	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
2850.18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00	0.00	0.00	0.00	0.00
3062.82	0.00E+00	0.00E+00	0.00E+00	3.20E-02	3.20E-02	0.00E+00	0.00	0.00	0.00	0.00	0.00
3291.34	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3536.90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3800.78	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-9: Continued

4084.35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4389.08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4716.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5068.43	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5446.58	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5852.93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6289.61	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6758.87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7263.13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7805.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
8387.34	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9013.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9685.55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10408.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11184.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12019.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12915.90	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13879.53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-10: Particle loss of NaCl by mass concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	PL 01	PL 02	PL 03	PL Avg	PL Std
21.21	4.72E+07	5.33E+07	4.08E+07	3.27E+07	4.10E+07	2.53E+07	0.31	0.23	0.38	0.27	0.05
24.49	9.28E+07	8.35E+07	7.75E+07	4.82E+07	4.76E+07	4.17E+07	0.48	0.43	0.46	0.46	0.04
28.27	1.53E+08	1.44E+08	1.30E+08	6.93E+07	7.05E+07	7.84E+07	0.55	0.51	0.40	0.53	0.03
32.64	2.43E+08	2.56E+08	2.16E+08	1.04E+08	1.31E+08	1.01E+08	0.57	0.49	0.54	0.53	0.06
37.67	3.34E+08	3.24E+08	3.85E+08	1.48E+08	1.93E+08	1.79E+08	0.56	0.40	0.53	0.48	0.11
43.49	5.43E+08	4.73E+08	5.33E+08	2.98E+08	3.15E+08	2.86E+08	0.45	0.33	0.46	0.39	0.08
50.20	9.14E+08	7.79E+08	8.36E+08	4.42E+08	4.38E+08	3.91E+08	0.52	0.44	0.53	0.48	0.06
57.94	1.19E+09	1.17E+09	1.02E+09	6.22E+08	6.78E+08	6.90E+08	0.48	0.42	0.32	0.45	0.04
66.87	1.60E+09	1.95E+09	1.49E+09	9.91E+08	8.55E+08	8.71E+08	0.38	0.56	0.41	0.47	0.13
77.16	2.28E+09	2.52E+09	2.58E+09	1.56E+09	1.54E+09	1.54E+09	0.32	0.39	0.40	0.35	0.05
89.03	3.69E+09	3.53E+09	3.76E+09	2.08E+09	2.51E+09	2.26E+09	0.44	0.29	0.40	0.36	0.10
102.72	4.81E+09	4.79E+09	4.60E+09	3.20E+09	3.32E+09	2.36E+09	0.33	0.31	0.49	0.32	0.02
118.48	6.42E+09	4.81E+09	5.18E+09	4.52E+09	5.54E+09	4.75E+09	0.30	-0.15	0.08	0.07	0.32
136.65	8.51E+09	9.39E+09	8.88E+09	6.74E+09	5.42E+09	5.10E+09	0.21	0.42	0.43	0.32	0.15
157.59	1.46E+10	1.26E+10	1.17E+10	8.81E+09	8.60E+09	7.57E+09	0.40	0.32	0.35	0.36	0.06
181.72	1.66E+10	1.96E+10	1.87E+10	1.12E+10	8.24E+09	9.26E+09	0.33	0.58	0.51	0.45	0.18
209.54	2.87E+10	1.72E+10	2.09E+10	1.32E+10	1.59E+10	1.68E+10	0.54	0.08	0.19	0.31	0.33
241.56	2.51E+10	2.62E+10	3.46E+10	2.77E+10	1.63E+10	2.22E+10	-0.10	0.38	0.36	0.14	0.34
278.50	5.12E+10	3.59E+10	4.48E+10	2.68E+10	3.19E+10	2.48E+10	0.48	0.11	0.45	0.29	0.26
321.04	4.68E+10	6.17E+10	5.22E+10	3.75E+10	4.47E+10	3.81E+10	0.20	0.28	0.27	0.24	0.05
370.15	6.88E+10	8.83E+10	6.66E+10	3.98E+10	4.62E+10	4.10E+10	0.42	0.48	0.39	0.45	0.04
426.75	8.59E+10	1.21E+11	9.12E+10	7.12E+10	5.32E+10	7.02E+10	0.17	0.56	0.23	0.37	0.28
585.27	2.03E+11	2.01E+11	1.96E+11	1.28E+11	1.25E+11	1.22E+11	0.37	0.38	0.38	0.37	0.01
628.94	2.12E+11	2.11E+11	2.04E+11	1.31E+11	1.29E+11	1.28E+11	0.38	0.39	0.37	0.39	0.01
675.86	2.17E+11	2.14E+11	2.09E+11	1.33E+11	1.28E+11	1.25E+11	0.39	0.40	0.40	0.40	0.01
726.29	2.11E+11	2.04E+11	2.03E+11	1.26E+11	1.20E+11	1.21E+11	0.41	0.41	0.40	0.41	0.00
780.48	1.93E+11	1.87E+11	1.85E+11	1.15E+11	1.08E+11	1.10E+11	0.41	0.42	0.41	0.41	0.01
838.71	1.78E+11	1.71E+11	1.71E+11	1.05E+11	9.95E+10	9.85E+10	0.41	0.42	0.42	0.42	0.01
901.29	1.64E+11	1.55E+11	1.62E+11	9.71E+10	8.74E+10	8.80E+10	0.41	0.44	0.46	0.42	0.02
968.53	1.48E+11	1.42E+11	1.43E+11	8.58E+10	7.87E+10	7.93E+10	0.42	0.45	0.45	0.43	0.02
1040.79	1.32E+11	1.29E+11	1.25E+11	7.45E+10	6.97E+10	6.81E+10	0.44	0.46	0.46	0.45	0.01
1118.45	1.18E+11	1.14E+11	1.15E+11	6.48E+10	6.18E+10	6.21E+10	0.45	0.46	0.46	0.45	0.00
1201.90	1.14E+11	1.06E+11	1.05E+11	5.83E+10	5.61E+10	5.28E+10	0.49	0.47	0.50	0.48	0.01
1291.57	9.10E+10	8.68E+10	8.83E+10	4.79E+10	4.41E+10	4.53E+10	0.47	0.49	0.49	0.48	0.01
1387.93	7.37E+10	6.97E+10	6.90E+10	3.76E+10	3.46E+10	3.41E+10	0.49	0.50	0.51	0.50	0.01
1491.48	5.45E+10	5.89E+10	5.50E+10	2.71E+10	2.53E+10	2.39E+10	0.50	0.57	0.57	0.54	0.05
1602.76	3.50E+10	4.07E+10	3.72E+10	1.52E+10	1.50E+10	1.37E+10	0.57	0.63	0.63	0.60	0.04
1722.34	1.88E+10	1.98E+10	1.81E+10	7.36E+09	6.87E+09	6.54E+09	0.61	0.65	0.64	0.63	0.03
1850.84	8.93E+09	7.51E+09	7.51E+09	3.85E+09	3.85E+09	2.84E+09	0.57	0.49	0.62	0.53	0.06
1988.93	3.27E+09	2.77E+09	4.03E+09	7.55E+08	0.00E+00	5.04E+08	0.77	1.00	0.87	0.88	0.16
2137.32	1.87E+09	1.25E+09	1.56E+09	9.37E+08	0.00E+00	9.37E+08	0.50	1.00	0.40	0.75	0.35
2296.79	7.75E+08	0.00E+00	0.00E+00	0.00E+00	3.88E+08	0.00E+00	1.00	0.00	0.00	0.50	0.71
2468.15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.62E+08	4.81E+08	0.00	0.00	0.00	0.00	0.00
2652.29	0.00E+00	0.00E+00	0.00E+00	5.97E+08	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
2850.18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.41E+08	0.00	0.00	0.00	0.00	0.00
3062.82	0.00E+00	0.00E+00	0.00E+00	9.19E+08	9.19E+08	0.00E+00	0.00	0.00	0.00	0.00	0.00
3291.34	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3536.90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
3800.78	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-10: Continued

4084.35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4389.08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
4716.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5068.43	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5446.58	5.17E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
5852.93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6289.61	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
6758.87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7263.13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
7805.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
8387.34	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9013.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
9685.55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
10408.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11184.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12019.17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
12915.90	0.00E+00	6.89E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13879.53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-11: Particle loss of diesel fumes by number concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	PL 01	PL 02	PL 03	PL Avg	PL Std
14.73	3.95E+01	0.00E+00	3.56E+01	3.70E+01	7.26E+01	7.37E+01	0.06	0.00	-1.07	0.00	0.00
16.98	3.93E+02	3.25E+02	1.92E+02	1.95E+02	2.01E+02	3.28E+02	0.50	0.38	-0.71	0.06	0.67
19.57	2.21E+03	2.09E+03	2.07E+03	1.52E+03	1.41E+03	1.67E+03	0.31	0.32	0.19	0.28	0.07
22.55	9.88E+03	1.08E+04	9.11E+03	6.46E+03	6.67E+03	8.43E+03	0.35	0.38	0.07	0.27	0.17
25.97	3.90E+04	4.15E+04	3.83E+04	2.46E+04	2.57E+04	3.05E+04	0.37	0.38	0.20	0.32	0.10
29.89	1.16E+05	1.23E+05	1.10E+05	7.71E+04	7.32E+04	8.24E+04	0.34	0.40	0.25	0.33	0.08
34.39	2.91E+05	2.93E+05	2.74E+05	1.98E+05	1.75E+05	2.01E+05	0.32	0.40	0.27	0.33	0.07
39.54	5.84E+05	5.78E+05	5.52E+05	4.11E+05	3.63E+05	3.99E+05	0.30	0.37	0.28	0.32	0.05
45.43	1.01E+06	9.75E+05	9.48E+05	7.24E+05	6.27E+05	6.72E+05	0.29	0.36	0.29	0.31	0.04
52.16	1.51E+06	1.42E+06	1.39E+06	1.09E+06	9.38E+05	9.62E+05	0.28	0.34	0.31	0.31	0.03
59.83	1.90E+06	1.77E+06	1.76E+06	1.41E+06	1.19E+06	1.20E+06	0.26	0.33	0.32	0.30	0.04
68.54	2.06E+06	1.91E+06	1.93E+06	1.54E+06	1.31E+06	1.30E+06	0.25	0.31	0.33	0.30	0.04
78.45	1.94E+06	1.78E+06	1.78E+06	1.49E+06	1.25E+06	1.20E+06	0.23	0.30	0.32	0.29	0.05
89.68	1.53E+06	1.39E+06	1.41E+06	1.18E+06	9.83E+05	9.41E+05	0.23	0.29	0.33	0.29	0.05
102.40	9.68E+05	8.66E+05	8.90E+05	7.39E+05	6.19E+05	5.89E+05	0.24	0.29	0.34	0.29	0.05
116.78	4.51E+05	3.96E+05	4.28E+05	3.34E+05	2.81E+05	2.74E+05	0.26	0.29	0.36	0.30	0.05
133.05	1.50E+05	1.29E+05	1.47E+05	1.05E+05	8.92E+04	9.10E+04	0.30	0.31	0.38	0.33	0.04
151.42	3.25E+04	2.79E+04	3.50E+04	2.20E+04	2.15E+04	2.34E+04	0.32	0.23	0.33	0.30	0.06
172.19	5.49E+03	5.55E+03	7.21E+03	4.61E+03	4.23E+03	5.10E+03	0.16	0.24	0.29	0.23	0.07
195.71	1.38E+03	1.26E+03	1.18E+03	9.54E+02	9.95E+02	1.07E+03	0.31	0.21	0.10	0.21	0.11
222.39	4.44E+02	3.30E+02	3.70E+02	3.51E+02	3.93E+02	4.72E+02	0.21	-0.19	-0.28	-0.09	0.26
252.68	1.32E+02	2.84E+02	1.75E+02	1.09E+02	2.43E+02	1.52E+02	0.17	0.14	0.13	0.15	0.02
1327.87	4.48E+00	6.43E+00	5.44E+00	4.42E+00	3.97E+00	3.14E+00	0.01	0.38	0.42	0.27	0.23
1428.05	3.42E+00	3.90E+00	3.46E+00	3.49E+00	3.14E+00	1.86E+00	-0.02	0.20	0.46	0.21	0.24
1534.59	2.08E+00	2.59E+00	2.14E+00	1.92E+00	2.46E+00	1.34E+00	0.08	0.05	0.37	0.17	0.18
1649.09	2.05E+00	1.28E+00	1.44E+00	1.18E+00	1.15E+00	7.36E-01	0.42	0.10	0.49	0.34	0.21
1771.53	8.64E-01	7.36E-01	7.36E-01	9.60E-01	8.96E-01	5.12E-01	-0.11	-0.22	0.30	-0.01	0.28
1903.52	5.44E-01	8.32E-01	4.16E-01	5.44E-01	4.16E-01	4.16E-01	0.00	0.50	0.00	0.17	0.29
2045.05	3.20E-01	5.76E-01	4.48E-01	6.08E-01	3.20E-01	1.60E-01	-0.90	0.44	0.64	0.06	0.84
2197.71	2.56E-01	2.24E-01	1.92E-01	2.56E-01	2.24E-01	2.24E-01	0.00	0.00	-0.17	-0.06	0.10
2363.09	3.52E-01	2.24E-01	3.20E-01	1.60E-01	1.60E-01	1.92E-01	0.55	0.29	0.40	0.41	0.13
2538.01	1.60E-01	3.20E-01	2.24E-01	9.60E-02	1.28E-01	6.40E-02	0.40	0.60	0.71	0.57	0.16
2727.24	1.60E-01	1.92E-01	2.88E-01	1.92E-01	9.60E-02	1.60E-01	-0.20	0.50	0.44	0.25	0.39
2930.79	1.28E-01	2.56E-01	3.52E-01	6.40E-02	1.60E-01	1.28E-01	0.50	0.37	0.64	0.50	0.13
3150.24	1.92E-01	1.92E-01	2.56E-01	6.40E-02	6.40E-02	1.60E-01	0.67	0.67	0.38	0.57	0.17
3385.58	1.92E-01	1.28E-01	1.92E-01	3.20E-02	3.20E-02	1.28E-01	0.83	0.75	0.33	0.64	0.27
3638.43	3.52E-01	3.20E-01	2.56E-01	9.60E-02	9.60E-02	1.60E-01	0.73	0.70	0.37	0.60	0.20
3908.76	2.56E-01	2.56E-01	6.40E-02	9.60E-02	6.40E-02	1.60E-01	0.62	0.75	-1.50	-0.04	1.26
4201.36	1.28E-01	1.60E-01	1.92E-01	3.20E-02	6.40E-02	6.40E-02	0.75	0.60	0.67	0.67	0.08
4514.63	6.40E-02	1.60E-01	9.60E-02	0.00E+00	6.40E-02	0.00E+00	1.00	0.60	1.00	0.87	0.23
4851.75	6.40E-02	1.92E-01	3.20E-02	6.40E-02	1.28E-01	3.20E-02	0.00	0.33	0.00	0.11	0.19
5212.72	0.00E+00	9.60E-02	3.20E-02	0.00E+00	6.40E-02	0.00E+00	0.00	0.33	1.00	0.00	0.51
5602.32	9.60E-02	6.40E-02	0.00E+00	0.00E+00	6.40E-02	1.28E-01	1.00	0.00	0.00	0.33	0.58
6020.55	1.28E-01	1.28E-01	6.40E-02	0.00E+00	0.00E+00	3.20E-02	1.00	1.00	0.50	0.83	0.29
6468.98	3.20E-02	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	0.00	0.00	0.58
6950.81	6.40E-02	0.00E+00	9.60E-02	3.20E-02	0.00E+00	3.20E-02	0.50	0.00	0.67	0.39	0.35
7470.15	6.40E-02	6.40E-02	3.20E-02	3.20E-02	0.00E+00	0.00E+00	0.50	1.00	1.00	0.83	0.29
8027.48	1.28E-01	0.00E+00	3.20E-02	0.00E+00	0.00E+00	3.20E-02	1.00	0.00	0.00	0.00	0.58
8626.39	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-11: Continued

9269.98	9.60E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
9961.59	6.40E-02	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	1.00	0.67	0.58
10704.80	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11503.46	3.20E-02	0.00E+00	6.40E-02	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	1.00	0.67	0.58
12361.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13283.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
14275.07	0.00E+00	3.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
15340.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
16484.58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
17714.46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
19036.09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20456.33	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
21982.53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00	0.00	0.00	0.00	0.00
23622.60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00E+00	0.00	0.00	0.00	0.00	0.00
25385.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27278.94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
29314.16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31501.22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-12: Particle loss of diesel fumes by mass concentration

Midpoint Diameter (nm)	1	2	3	4	5	6	PL 01	PL 02	PL 03	PL Avg	PL Std
14.73	1.26E+05	0.00E+00	1.14E+05	1.18E+05	2.32E+05	2.36E+05	0.06	0.00	-1.07	-0.34	0.64
16.98	1.92E+06	1.59E+06	9.39E+05	9.54E+05	9.84E+05	1.61E+06	0.50	0.38	-0.71	0.06	0.67
19.57	1.66E+07	1.57E+07	1.55E+07	1.14E+07	1.06E+07	1.25E+07	0.31	0.32	0.19	0.28	0.07
22.55	1.13E+08	1.23E+08	1.04E+08	7.40E+07	7.65E+07	9.66E+07	0.35	0.38	0.07	0.27	0.17
25.97	6.83E+08	7.27E+08	6.71E+08	4.31E+08	4.49E+08	5.34E+08	0.37	0.38	0.20	0.32	0.10
29.89	3.11E+09	3.28E+09	2.94E+09	2.06E+09	1.95E+09	2.20E+09	0.34	0.40	0.25	0.33	0.08
34.39	1.19E+10	1.19E+10	1.11E+10	8.06E+09	7.10E+09	8.17E+09	0.32	0.40	0.27	0.33	0.07
39.54	3.61E+10	3.57E+10	3.41E+10	2.54E+10	2.24E+10	2.47E+10	0.30	0.37	0.28	0.32	0.05
45.43	9.49E+10	9.14E+10	8.88E+10	6.79E+10	5.88E+10	6.30E+10	0.29	0.36	0.29	0.31	0.04
52.16	2.14E+11	2.01E+11	1.98E+11	1.55E+11	1.33E+11	1.37E+11	0.28	0.34	0.31	0.31	0.03
59.83	4.07E+11	3.78E+11	3.76E+11	3.02E+11	2.54E+11	2.57E+11	0.26	0.33	0.32	0.30	0.04
68.54	6.63E+11	6.16E+11	6.23E+11	4.96E+11	4.23E+11	4.18E+11	0.25	0.31	0.33	0.30	0.04
78.45	9.39E+11	8.60E+11	8.57E+11	7.19E+11	6.01E+11	5.80E+11	0.23	0.30	0.32	0.29	0.05
89.68	1.10E+12	1.00E+12	1.02E+12	8.51E+11	7.09E+11	6.79E+11	0.23	0.29	0.33	0.29	0.05
102.40	1.04E+12	9.30E+11	9.56E+11	7.93E+11	6.64E+11	6.33E+11	0.24	0.29	0.34	0.29	0.05
116.78	7.18E+11	6.30E+11	6.82E+11	5.33E+11	4.47E+11	4.36E+11	0.26	0.29	0.36	0.30	0.05
133.05	3.52E+11	3.04E+11	3.46E+11	2.47E+11	2.10E+11	2.14E+11	0.30	0.31	0.38	0.33	0.04
151.42	1.13E+11	9.70E+10	1.22E+11	7.64E+10	7.46E+10	8.11E+10	0.32	0.23	0.33	0.30	0.06
172.19	2.80E+10	2.83E+10	3.68E+10	2.36E+10	2.16E+10	2.60E+10	0.16	0.24	0.29	0.23	0.07
195.71	1.04E+10	9.44E+09	8.87E+09	7.15E+09	7.46E+09	8.02E+09	0.31	0.21	0.10	0.21	0.11
222.39	4.89E+09	3.63E+09	4.07E+09	3.86E+09	4.32E+09	5.19E+09	0.21	-0.19	-0.28	-0.09	0.26
252.68	2.13E+09	4.58E+09	2.82E+09	1.76E+09	3.93E+09	2.45E+09	0.17	0.14	0.13	0.15	0.02
1327.87	1.05E+10	1.51E+10	1.27E+10	1.03E+10	9.29E+09	7.34E+09	0.01	0.38	0.42	0.27	0.23
1428.05	9.97E+09	1.14E+10	1.01E+10	1.02E+10	9.13E+09	5.41E+09	-0.02	0.20	0.46	0.21	0.24
1534.59	7.52E+09	9.37E+09	7.75E+09	6.94E+09	8.90E+09	4.86E+09	0.08	0.05	0.37	0.17	0.18
1649.09	9.18E+09	5.74E+09	6.46E+09	5.31E+09	5.17E+09	3.30E+09	0.42	0.10	0.49	0.34	0.21
1771.53	4.80E+09	4.09E+09	4.09E+09	5.34E+09	4.98E+09	2.85E+09	-0.11	-0.22	0.30	-0.01	0.28
1903.52	3.75E+09	5.74E+09	2.87E+09	3.75E+09	2.87E+09	2.87E+09	0.00	0.50	0.00	0.17	0.29
2045.05	2.74E+09	4.93E+09	3.83E+09	5.20E+09	2.74E+09	1.37E+09	-0.90	0.44	0.64	0.06	0.84
2197.71	2.72E+09	2.38E+09	2.04E+09	2.72E+09	2.38E+09	2.38E+09	0.00	0.00	-0.17	-0.06	0.10
2363.09	4.64E+09	2.96E+09	4.22E+09	2.11E+09	2.11E+09	2.53E+09	0.55	0.29	0.40	0.41	0.13
2538.01	2.62E+09	5.23E+09	3.66E+09	1.57E+09	2.09E+09	1.05E+09	0.40	0.60	0.71	0.57	0.16
2727.24	3.25E+09	3.89E+09	5.84E+09	3.89E+09	1.95E+09	3.25E+09	-0.20	0.50	0.44	0.25	0.39
2930.79	3.22E+09	6.44E+09	8.86E+09	1.61E+09	4.03E+09	3.22E+09	0.50	0.37	0.64	0.50	0.13
3150.24	6.00E+09	6.00E+09	8.00E+09	2.00E+09	2.00E+09	5.00E+09	0.67	0.67	0.38	0.57	0.17
3385.58	7.45E+09	4.97E+09	7.45E+09	1.24E+09	1.24E+09	4.97E+09	0.83	0.75	0.33	0.64	0.27
3638.43	1.70E+10	1.54E+10	1.23E+10	4.62E+09	4.62E+09	7.71E+09	0.73	0.70	0.37	0.60	0.20
3908.76	1.53E+10	1.53E+10	3.82E+09	5.73E+09	3.82E+09	9.55E+09	0.62	0.75	-1.50	-0.04	1.26
4201.36	9.49E+09	1.19E+10	1.42E+10	2.37E+09	4.75E+09	4.75E+09	0.75	0.60	0.67	0.67	0.08
4514.63	5.89E+09	1.47E+10	8.83E+09	0.00E+00	5.89E+09	0.00E+00	1.00	0.60	1.00	0.87	0.23
4851.75	7.31E+09	2.19E+10	3.65E+09	7.31E+09	1.46E+10	3.65E+09	0.00	0.33	0.00	0.11	0.19
5212.72	0.00E+00	1.36E+10	4.53E+09	0.00E+00	9.06E+09	0.00E+00	0.00	0.33	1.00	0.44	0.51
5602.32	1.69E+10	1.13E+10	0.00E+00	0.00E+00	1.13E+10	2.25E+10	1.00	0.00	0.00	0.33	0.58
6020.55	2.79E+10	2.79E+10	1.40E+10	0.00E+00	0.00E+00	6.98E+09	1.00	1.00	0.50	0.83	0.29
6468.98	8.66E+09	8.66E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	1.00	0.00	0.67	0.58
6950.81	2.15E+10	0.00E+00	3.22E+10	1.07E+10	0.00E+00	1.07E+10	0.50	0.00	0.67	0.39	0.35
7470.15	2.67E+10	2.67E+10	1.33E+10	1.33E+10	0.00E+00	0.00E+00	0.50	1.00	1.00	0.83	0.29
8027.48	6.62E+10	0.00E+00	1.66E+10	0.00E+00	0.00E+00	1.66E+10	1.00	0.00	0.00	0.33	0.58
8626.39	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E+10	0.00E+00	0.00	0.00	0.00	0.00	0.00

Table B-12: Continued

9269.98	7.65E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	0.00	0.33	0.58
9961.59	6.33E+10	0.00E+00	3.16E+10	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	1.00	0.33	0.58
10704.80	0.00E+00	0.00E+00	0.00E+00	3.93E+10	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
11503.46	4.87E+10	0.00E+00	9.74E+10	0.00E+00	0.00E+00	0.00E+00	1.00	0.00	1.00	0.67	0.58
12361.71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
13283.98	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
14275.07	0.00E+00	9.31E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
15340.10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
16484.58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
17714.46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
19036.09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
20456.33	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
21982.53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.40E+11	0.00	0.00	0.00	0.00	0.00
23622.60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.22E+11	0.00E+00	0.00	0.00	0.00	0.00	0.00
25385.02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
27278.94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
29314.16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00
31501.22	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00

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