# DESIGN AND DEVELOPMENT OF A LOW-COST CYCLONE DUST COLLECTOR SYSTEM

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**In fulfilment of the requirement for the Degree of**
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**DECLARATION**

I declare that this project report entitled “Design and development of a low-cost cyclone dust collector system” is the result of my own study except as cited in the reference.

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| Name | : .................................... |
| Date | : .................................... |

**APPROVAL**

I hereby declare that I have read this project report and in my opinion this report is acceptable in term of scope and quality of the award of the degree of Bachelor of Mechanical Engineering.

Signature : ..................................

Name of Supervisor : ..................................

Date : ..................................

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**ABSTRACT**

Nowadays, the use of cyclone dust collector is very popular in industrial and domestic areas for cleaning and miscellaneous work. Cyclone dust collector is referred as two-stage dust collectors that attach with a vacuum cleaner. The result of previous study shows that, the increased usage of cyclone dust collector gained attention from industries. Cyclone dust collector is widely used in the industrial sector than in household because the price is too expensive. Furthermore, cyclones have often been considered as low-efficiency collectors. However, efficiency varies greatly with particle size and cyclone design. This project report discussed about market feasibility and the design parameters required to construct a low-cost and high-performance cyclone dust collector by applying the previous study cyclone models and surveys that have been collected from vacuum cleaner users. There are two main collection points which are the primary collection point is for the heavier dust and debris while the second point is for finer particulate matter. It uses centrifugal force as the primary means of particle separation. The fabrication of cyclone dust collector made up by low-cost or recycle materials such as skittle cone, plywood and others. The collection efficiency test will be done using three different particles which are pebble, soil and sawdust that have different size of diameter and density. The average size of diameter of pebble, soil and sawdust are 2000 $\mu m$, 50 $\mu m$, and 30 $\mu m$ respectively. At the end of this project report, the collection efficiency, detail design, fabrication procedure, cost and simulation of airflow of cyclone dust collector system will be determine.

# ABSTRAK

*Pada masa kini, penggunaan pengumpul habuk siklon sangat popular di kawasan perindustrian dan domestik untuk pembersihan dan kerja-kerja lain-lain. Pengumpul habuk siklon disebut sebagai pengumpul habuk dua peringkat yang dipasang dengan pembersih vakum. Hasil kajian sebelumnya menunjukkan bahawa, peningkatan penggunaan pengumpul habuk siklon mendapat perhatian industri. Pengumpul habuk siklon banyak digunakan di sektor perindustrian daripada isi rumah kerana harganya terlalu mahal. Selanjutnya, siklon sering dianggap sebagai pengumpul kecekapan rendah. Walau bagaimanapun, kecekapan sangat berbeza dengan ukuran zarah dan reka bentuk siklon. Laporan projek ini membincangkan mengenai kebolehpasaran dan parameter reka bentuk yang diperlukan untuk membina pengumpul habuk siklon dengan kos rendah dan berprestasi tinggi dengan menerapkan model siklon kajian sebelumnya dan tinjauan yang telah dikumpulkan dari pengguna pembersih vakum. Terdapat dua tempat pengumpulan utama yang merupakan tempat pengumpulan utama untuk habuk dan serpihan yang lebih berat sementara tempat kedua adalah untuk bahan partikulat yang lebih halus. Ia menggunakan daya sentrifugal sebagai kaedah utama pemisahan zarah. Pembuatan pengumpul habuk siklon terdiri daripada bahan kos rendah atau kitar semula seperti kon skittle, papan lapis dan lain-lain. Ujian kecekapan pengumpulan akan dilakukan dengan menggunakan tiga zarah berbeza iaitu batu kerikil, tanah dan habuk papan yang mempunyai ukuran diameter dan ketumpatan yang berbeza. Ukuran purata diameter batu kerikil, tanah dan habuk papan masing-masing adalah 2000 μm, 50 μm, dan 30 μm. Pada akhir laporan projek ini, kecekapan pengumpulan, reka bentuk terperinci, prosedur fabrikasi, kos dan simulasi aliran udara sistem pengumpul habuk siklon akan ditentukan.*

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$d_{pc}$ = diameter of the particle (m)

$d_{pj}$= diameter of the $j_{th}$ particle size range ($\mu$m)

$d_{50}$ = diameter of particles collected with 50% efficiency

Dc = cyclone body diameter (m)

De = diameter of outlet tube (m)

$g$ = gravitational force (N)

H = height of inlet duct (m)

$H_C$ = height of cyclone inlet duct (m)

$H_V$ = pressure drop expressed in number of inlet velocity heads

K = cyclone pressure drop constant

$L_c$ = length of cyclone body (m)

$m_j$ = mass fraction of particles in the $j_{th}$ size range (%)

$n_j$ = collection efficiency of particles in the $j_{th}$ size range (0 < $n_j$< 1)

N = number of turns inside the device

ΔP = cyclone pressure drop (N/m$^2$)

Q = system air volume flow rate (m$^3$/s)

W = width of inlet (m)

$Z_C$ = length of cyclone cone (m)

Z = length (vertical) of cyclone cone (m).

$\nu_i$ = terminal drift transverse velocity (m/s)

$\rho$ = density of the particle (kg/m$^3$)

$\rho_p$ = particle density (kg/m$^3$)

$\rho_g$ = gas density (kg/m$^3$)

$N_e$ = number of effective turns

$\eta$ = collection efficiency (%)

$\eta_o$ = overall collection efficiency (%)

$\eta_j$ = collection efficiency for $j_{th}$ particle size range (%)

$\mu$ = air viscosity (kg/m.s)

$\nu$ = total average gas velocity in the barrel part (m/s)

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

A vacuum cleaner is one of the most essential home appliances for cleaning. It works on the principle of flow of air from high pressure to low pressure area [1]. The configuration of vacuum cleaner working principle is shown in Figure 1.1. A fan is attached to an electric motor that spins it at high speeds. The fast spinning fan creates a low-pressure region within the vacuum cleaner's suction hose. Dust and debris are sucked into the suction hose due to the pressure difference in between the outside and inside of the suction hose. Once inside the suction hose, air and debris travel to a dust collection bag made of porous woven cloth. The dust and debris get accumulated in the collection bag and air flows out through the exhaust port after passing through a filter. However, vacuum filter needs to be cleaned or changed when there are clogged inside the filter in order to maintain the performance.

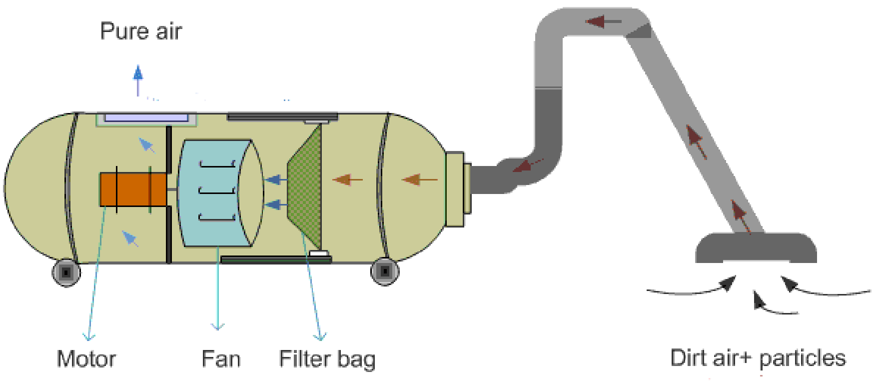


Figure 1.1: Schematic diagram of vacuum cleaner

Next, cyclone dust collector is an attachment for a vacuum cleaner in order to remove particulate matter from air streams without the use of filters, through vortex separation [2]. A cyclone is generally made up of a cylindrical upper part known as a barrel and a conical lower part called the cone as shown in Figure 1.2. The air flow enters tangentially in the top of the barrel and descends to the cone to create an outer vortex. The increasing air speed in the outer vortex results in the particles being separated by a centrifugal force from the air stream. When the air reaches the bottom of the cone, an internal vortex reverses the path and exits the top as clean air while the particles fall into the chamber of dust collection at the bottom of the cyclone.

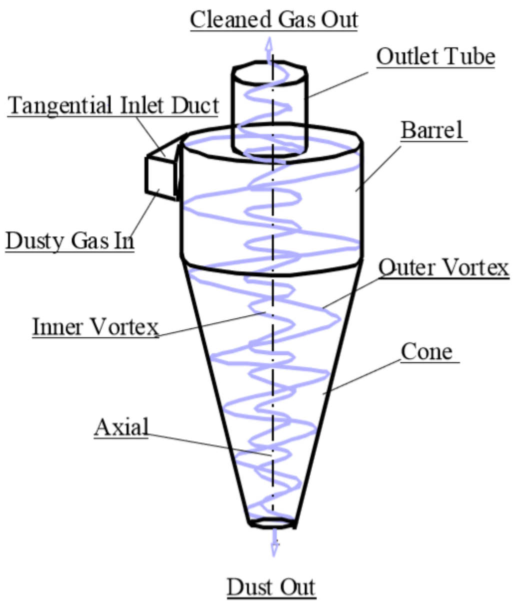


Figure 1.2: Schematic flow diagram of a cyclone [3]

The most widely used abatement systems for particulate matter management are cyclone models 2D2D and 1D3D in the agricultural processing industry [2]. The D's in the category 2D2D refers to the cyclone's barrel diameter. The preceding numbers of the D's correspond respectively to the length of the barrel and cone sections. A 2D2D cyclone is twice the size of the barrel and cone, while 1D3D cyclone is of barrel length equal to the diameter of the barrel and a cone length equivalent to 3 times the diameter of the barrel. Previous studies have shown that 1D3D and 2D2D are the most effective cyclone collectors of fine dust as opposed to other cyclone models (particle diameters less than 100 µm) [4]. The configurations of these two cyclone designs are shown in figure 3.

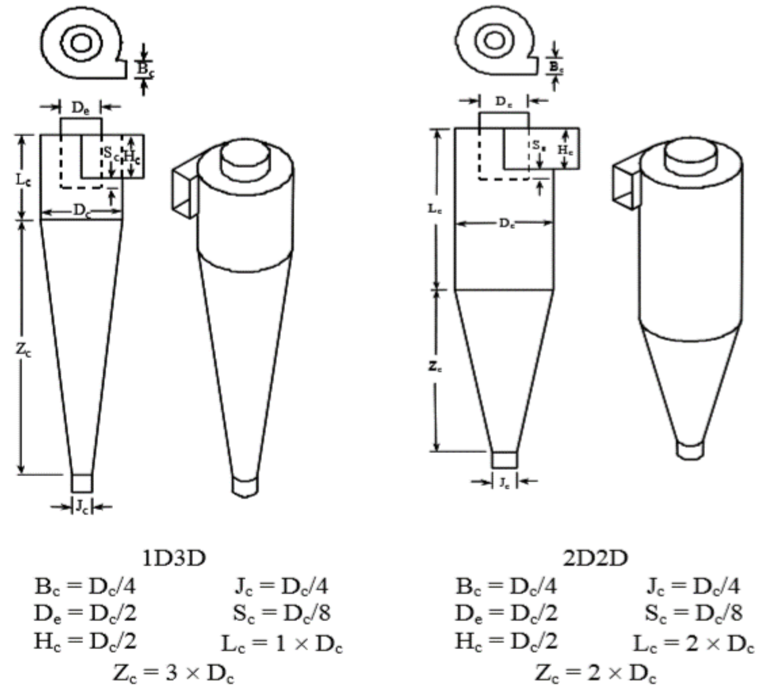


Figure 1.3: 1D3D and 2D2D cyclone configurations [3]

## 1.2 Problem Statement

Nowadays, vacuum cleaner is a must for each residence for cleaning task. There are many types of vacuum cleaners on the market that have various prices. However, there are several common problems with the normal vacuum cleaner that always occur during the cleaning process. Firstly, the vacuum cleaner lacks suction power. Usually, the reasons of the failure of a vacuum cleaner to remove dirt can be related to several basic problems. Clogged air filter may be responsible for causing a lack of suction. This part can be removed, inspected and thoroughly cleaned. If there is more serious damage to the filter, it should be replaced. If cleaning or exchange of vacuum filters frequently it can reduce efficiency of a vacuum cleaner.

Besides, in some cases a full vacuum bag will prevent the appliance from being turned on. Next, users also must replace the vacuum bag or filter to ensure their vacuum cleaner is picking up tiny dust particles. It is recommended to buy a few extra vacuum bags just in case the current vacuum bag is damaged. However, the price of vacuum bag and filter quite expensive and it's hard to find in the market stores.

Thus, to overcome this problem a device was introduced which is cyclone dust collector. In the industrial sector, cyclone dust collector is very well known and often used in the workshop, air ventilation and others. Despite, most of cyclone dust collector in market are expensive, large and not user friendly.

The aim of this project is to design and develop a low-cost cyclone dust collector that can improve collection efficiency, act as additional storage and increase the lifespan of a vacuum cleaner. Hence, the residents will be able to buy and use in daily life. By adapting and reviewing previous studies, there are various aspects that need to be highlight in the design and development of the product in order to satisfy the user.

## 1.3 Objectives

I. To perform the market feasibility studies for a low-cost cyclone dust collector system.

II. To design and develop cyclone dust collector system.

III. To evaluate the efficiency of cyclone dust collector system.

## 1.4 Scope of Project

I. This project will analyse market feasibility of a cyclone dust collector around Malaysian residents.

II. Test and experiment will be done between conventional vacuum cleaner and vacuum cleaner that attach with cyclone dust collector device.

III. The cyclone model type 1D3D (by Parnell and Davis, 1979) is used as a guideline for the development of a low-cost cyclone dust collector system.

IV. The simulation and modelling of a cyclone dust collector will be done in software Computer-Aided Three-Dimensional Interactive Application (CATIA) and Ansys.

## 1.5 Organization of Thesis

This section explains how this project needs to be carried out to achieve the objectives of this project, such as the identification, processing and analysis of data and information. Chapter 1 is an introduction to this thesis and provides a summary of the background to this thesis. Chapter 2 describe about the literature review that consists of the background of the project. It also describes about the similar works that have been done by other person and is a comparison to the similar works, thus discuss the advantages and disadvantages of previous project.

Furthermore, Chapter 3 provides an overview about customer requirement and engineering characteristics, House of Quality (HOQ) and product specification. This chapter also discusses about the development method that will be used in the project such as material selection, fabrication process and market feasibility. Meanwhile, in chapter 4 provides the results of simulation, evaluation of efficiency collection and the final concept of low-cost cyclone dust collector. Chapter 5 states the conclusions drawn from the results obtained and suggests possible directions for future research.

### 1.5.1 Flowchart

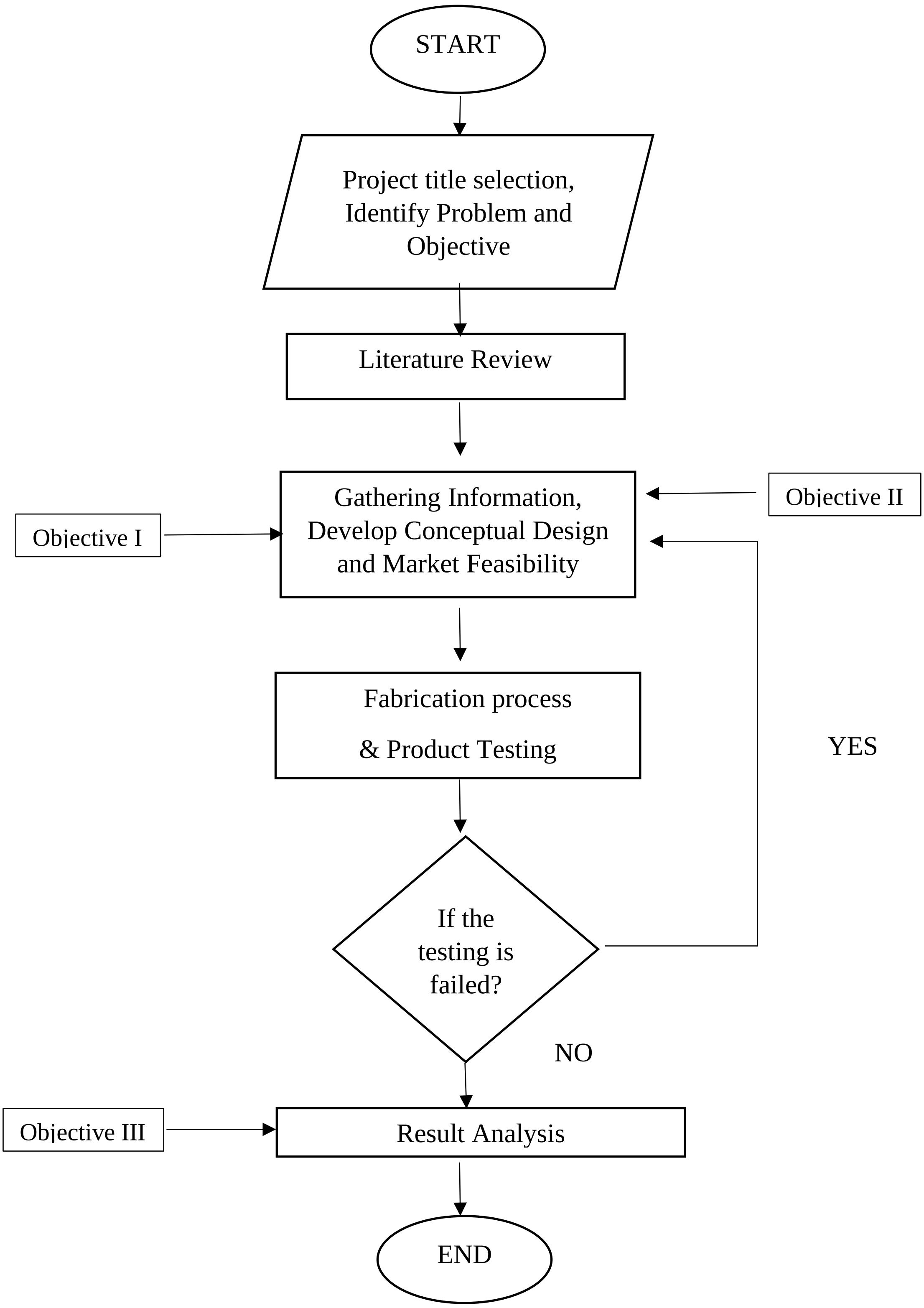


Figure 1.4: Flowchart of the project methodology

### 1.5.2 Gantt Chart

Gantt chart describes the estimate of time for each element and also the estimation of time taken to complete the entire project process. Table 1.1 below shows the Gantt chart for this project time period.

Table 1.1: Gantt chart

| No. | Activity | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Project Title Selection | ■ | ■ | ■ | | | | | | | | | | | | | |
| 2. | Literature Review | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | |
| 3. | Gathering Information | | | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| 4. | Develop Conceptual Design | | | | | | | ■ | ■ | ■ | | | | | | | |
| 5. | Fabrication process and modification | | | | | | | | ■ | ■ | ■ | ■ | | | | | |
| 6. | Testing | | | | | | | | | | ■ | ■ | ■ | | | | |
| | i. Collection Efficiency Test | | | | | | | | | | | ■ | ■ | ■ | | | |
| | ii. Product Simulation | | | | | | | | | | | ■ | ■ | ■ | | | |
| 7. | Submission Progress Report | | | | | | | ■ | | | | | | | | | |
| 8 | Preparation Final Report | | | | | | | | | | | | ■ | ■ | ■ | | |
| 9 | Submission Final Report | | | | | | | | | | | | | | ■ | ■ | |
| 10 | PSM Talk | | | | | | | | | | | | | | | | ■ |

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Cyclones have been used since the late 1800s for collecting dust from the industrial gas streams and have become the most commonly used industrial dust collectors with its simple design, low capital and maintenance costs, and adaptability to a variety of operating conditions. This is because cyclones have a good collection efficiency for particles larger than about 5 $\mu$m in diameter as they rely on inertial forces to capture particles [5].

Next, cyclone dust collector has not changed much in their basic shape and function. The first example of "pot-bell" or low-pressure design was soon joined by high performance designs with a smaller diameter compared with the volumetric gas inlet flow [5]. These high efficiency designs accounted for a higher percentage of incoming particulates due to their higher gas flow and particle velocity. Higher velocity also resulted in an increase in pressure drop. The designs of the cyclones relate the height of the cylinder and the cone sections to the diameter of the cylinder [6].

When developing a cyclone dust collector system, cyclone pressure drops associated with cyclone operation is a significant factor to consider. Several models were developed to evaluate a pressure drop, for example Shepherd's and Lapple's, Stairmand and Stern equations [7]. Nonetheless, equations are both empirical models or involve variables and dimensionless parameters that are now not easily accounted for in practical applications. It is recognised that the cyclone pressure drop depends on the design of the cyclone and its operating parameters. Shepherd and Lapple mentioned that the cyclone pressure drop used to be made up of the following factors [2]:

I. Loss due to gas expansion when it enters the chamber of the cyclone.
II. Loss in the cyclone chamber due to wall friction.
III. Any potential friction losses that occur from the swirling flow above and beyond those caused by straight flow in the exit duct.
IV. Loss as the rotational kinetic energy in the cyclone chamber.
V. Any recovery of kinetic rotational energy as a pressure energy.

## 2.2 Classical Cyclone Design (CCD)

In the early 1950s, Lapple developed the cyclone design procedure outlined in Cooper and Alley [8], hereafter known as the Classical Cyclone Design (CCD) process. The CCD (Lapple model) system used to be viewed as a trendy approach and used to be viewed proper with the aid of some engineers. However, there are several issues related to this design procedure. First of all, in designing cyclone dimensions the CCD method does not consider the cyclone inlet velocity. Besides, the most excellent cyclone output there is an "ideal" inlet velocity for the various cyclone designs [9].

In addition, the CCD does not determine the correct number of turns for specific types of cyclones due to the inaccurate fractional efficiency curve produced via the CCD process, the overall efficiency expected by the CCD procedure is wrong [10]. In order to use the CCD process, the design engineer is presumed to have knowledge of the float conditions, particulate matter concentrations and Particle Size Distribution (PSD) and the type of cyclone to be constructed in terms of high efficiency, conventional or high throughput. The PSD ought to be in the form of mass fraction versus aerodynamic equivalent diameter of the