CHAPTER 10

Management of particulate matter

In this chapter, to summarize the results of a field study of suspended particulate matter concentrations generated by different mining activities and then discussed the management of suspended particulate matter from mining. The total suspended particulate matter is reduced using the newly developed method at the laboratory scale. A brief about these control measures discussing in subsequence paragraphs. Thus, all the existing control measures do not appear to be very useful, due to regeneration — further addition of particulate matters after drying of water from haul road and other sources. The details of the newly developed method to reduce the TSPM at a laboratory scale have discussed in this chapter.

10.1 Introduction

Mining is a dust prone occupation, and almost every primary mining process contributes to the atmospheric load of suspended particulate matter. Particulate Matter is a collection of particles in the atmosphere from various sources such as soil, dust lifted by the wind, volcanic eruptions, and pollution **[7]**. Particulate Matter in homes, offices, and other human environments contains small amounts of plant pollen, human and animal hairs, textile fibers, paper fibers, and minerals from outdoor soil, human skin cells, burnt meteorite particles, and many other materials that may be found in the local environment **[76,92]**. Natural and anthropogenic emissions of air pollutants in terms of particulate matter with the composition of trace and ultra–trace metals linked with prolonged illness, higher use of health services, and premature death among the exposed living peoples **[61,269]**. As per national ambient air quality standard has been describing the air quality management in three scales as a macro, medium, and micro–level as in spatial and temporal scale is either long term or short term **[21,32,139,227,270]**. The significant air pollution sources are industrial emissions, including emissions from large power stations, vehicles as transportation also **[10,191]**.

Particulate matter is defined as a type of air pollutant which varies in mass and composition, consisting of complex and varying mixtures of particles suspended in the breathing air and are produced by a wide variety of natural and anthropogenic activities **[93,271]**. Their aerodynamic properties express particle size because they govern the transport and removal of particles from the air, their deposition within the respiratory system, and their associated chemical composition and sources. The dust particles causing harmful effects are divided into inert and proliferate groups **[272]**. The inert particles line stone, and smoke soot does not impair lung function unless excessive deposition over the years. Increase group of dust includes free or crystalline silica and coal dust. The silicosis giving rise to breathing difficulty, reduction of chest expansion, and susceptibility to tuberculosis is because of the silica dust. Coal dust causes focal emphysema and results in marked disability in the advanced stage **[9,273]**.

This method of dust control is gaining the public as well as industry interest and mainly two reasons:

a) dust generation has expanded significantly due to higher mechanization and the acquaintance of large–scale manufacturing advancements with meet our developing generation needs making use of residue control component unavoidable

b) developing an awareness of the condition, and stricter ecological consistency systems have put consistent weight on the mining industry for ordinary utilization of residue control practices.

The details of the method have discussed here.

10.2 Existing method of suppression for particulate matter in mining industries

To implement adequate control measures for particulate matter in residential areas, management systems are necessary. Apart from the mining company's standard environmental controls to control particulate matter during its operations, additional measures are suggested to control particulate matter in sensitive areas. These measures, which are essential to control dust from road transport, include restrictions on the trucks' overloading used for transporting the coal and frequent cleaning of the transport roads themselves. The available method of particulate matter suppression has discussed below.

a) Various control methods for particulate matter

1) Blacktopping of service roads: Roads used for transportation should blacktop with arrangements made for the various collection and dust removal. Also, transportation contractors should be cautioned not to overload their trucks, leading to spillage, generating additional dust as the spilled coal is crushed by other vehicles.
2) Dust extractors: Excavation drills should cover through dust extractors.
3) Dust masks: Excavation equipment operators should use dust masks during the working stage.
4) Road plantation: Some authorities may engage in the placement of plantations in areas in addition to roadways, such as overburden dumps and unused lands.

5) Water spraying: Transport roads should be covered under water spraying schemes, taking the help of either roadside static water sprinklers or mobile sprinklers.
6) Control of contaminants at their source using preventive and control technologies is a desirable and effective method. Besides, the atmosphere has several built–in self–cleaning processes, such as dispersion, gravitational settling, flocculation, absorption, rain washout, and the like to cleanse the environment.

b) Particulate matter control measures at the source

The following steps are useful for controlling particulate matter:

1) Catalytic converters should use for the control of hydrocarbons and emissions of carbon monoxide from motors and engines.
2) Encourage people to use public transport or walk or cycle rather than use private vehicles to cut down emissions.
3) Ensure that residences, schools, restaurants, and playgrounds could not be located near busy streets.
4) Industrial and waste disposal sites should situate outside the city, preferably on the downwind side.
5) Plants and trees should be planted along busy streets to absorb noise and remove carbon dioxide and particulates.
6) Use low–sulfur and low–ash–content fuels.
7) Unleaded petrol should use.

c) Control measures in industrial centers

The following steps are useful for pollution control in industrial centers:

1) Continuous monitoring of air pollution should be carried out so that pollution levels are known.
2) Restrict pollution that exceeds the permissible limits for every industry.
3) Incorporation of air pollution control equipment into the designs of plant layouts must be made mandatory.

d) Particulate matter control measures by the plantation

The placing of plants and trees to help control particulate matter pollution control has become quite common. The plants' leaves collect the particulate matter, mitigating air pollution by absorbing pollutants, filtering, and intercepting mixed particulate matter in the atmosphere **[274]**. To use plants for control of particulate matter, factors such as the plantation's distance from the pollutant generation source and the plantation's height and width. Kapoor and Gupta **[275]** developed a plantation reduction model subsequently analyzed by Chaulya, Chakraborty, and Singh **[276]**. The effectiveness of a plant or tree is measured by its reduction factor, which is defining as the ratio of the mass flux that would reach a certain distance in the absence of the plants and trees to the mass flux reaching the same range in the presence of the plants and trees. An essential factor in establishing a plantation is the selection of tree species. In selecting plant and tree classes for the plantation, the two most important parameters are the air pollution tolerance index and the plants and trees' expected performance index **[277]**. The tolerance index of air pollution of plant and tree classes has been evaluated through the formula recommended by Singh and Rao **[278]**:

$$Tolerance\ index = \frac{A\ (T + P) + R}{10}$$

where A is the ascorbic acid content in milligram per gram (mg g^{-1}) of dry weight, P is the pH of leaf extract, R is the relative water content (%), and T is the total chlorophyll in mg g^{-1} of fresh weight.

The performance index expected of plant and tree types can be classified using the tolerance index of air pollution and applying relevant Phyto–socio–economic factors. Plants and trees may be grading as very poor, poor, moderate, good, excellent, and best. Classes of plants and trees in four categories of good, very good, excellent, and best can recommended for planting to control particulate matters in the atmosphere.

The primary pollutant sources are very challenging to deal with, as high–polluting sources of particulate matter pollute the air and pollute the surrounding water and soil. It is essential to choose plants and trees to help control and check particulate matter through their foliage and bark and tolerate gaseous pollutants effectively **[279]**.

In the case of a mining area, plantation must be established using the tolerance index for particulate matter and should be done in and around mining areas and along both sides of the road used for transportation.

e) Particulate matter control measures by the polymers

Dust suppression is often cited as the primary application of polymer emulsion soil stabilization. Dust control is important in the mining sector and heavy industries such as petroleum refining or oil and gas extraction. Dust suppression is not limited to roads only but may also apply to stockpiles, slopes, and transit goods. These industries also use polymer emulsions to stabilize slopes and access routes to industry sites.

f) Particulate matter controlling devices

Air pollution may be minimized by adopting the following measures:

1) Ensure that sufficient oxygen is available in combustion chambers and that temperatures are adequate to ensure complete combustion, eliminating much smoke, which consists of partly burned ashes and dust.
2) Equipment used to remove particulates from the exhaust gases of electric power generation plants and industrial plants are shown below, and should be used, where appropriate:
3) Mechanical devices, such as scrubbers, cyclones, baghouses, and electrostatic precipitators.
4) Wet scrubbers can additionally reduce sulfur dioxide emissions.
5) Operators of control methods that retain hazardous materials must ensure that these wastes are disposed of safely.

All the available methods for particulate matter suppression of operations and control that deal with industrial fumes through chemical treatment must ensure that collected pollutants are disposed of appropriately.

10.3 Experimental details of the proposed method for suppression of particulate matter

The spraying of water on haul roads and other transportation areas in and around mines is essential to minimize dust from roadways. During the study of suspended particulate matter in the study area, it is observed that some of the roads used for transportation were dry, and their water sprinkling systems were not working correctly. For this reason, frequent maintenance and repair of water sprinkling systems and other water–spraying systems are required, as well as the construction of new, maximum–efficiency, water–sprinkling systems, and other water–spraying systems. Furthermore, on unpaved roads, eco–friendly chemicals should be applied to act as binding agents for particulate matter particles. Thus, it is recommending that unpaved roads be blacktopped and that all streets be regularly maintained and repaired. A hypothetical model for a management system for particulate matter control to continue air quality is showing in **Fig. 10.1**.

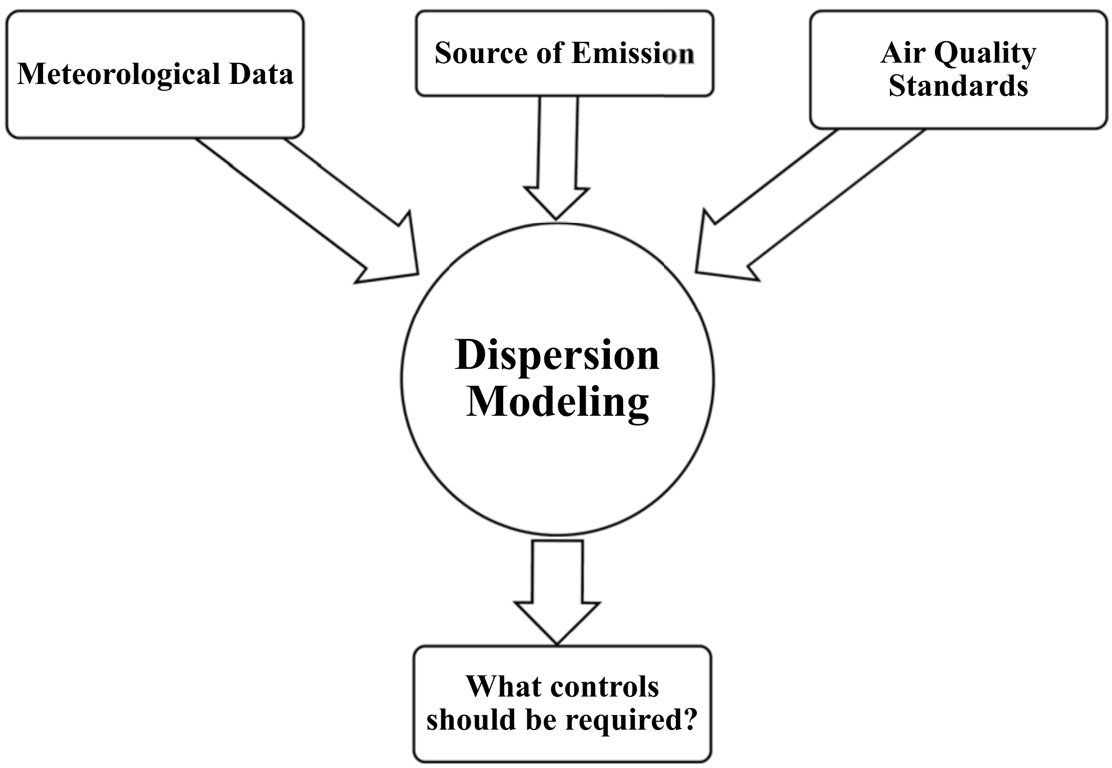

Fig. 10.1: Hypothetical system for air quality management

The process has been designed and fabricated at the laboratory scale. The experiment has been conducted using a total suspended particulate matter (TSPM) generator set up. The soap bubble generator was used with the TSPM generator to assess its performance in one unit.

The total suspended particulate matter generator unit was assembled to produce the control quantity of total suspended particulate matter inflowing air. A line diagram showed in **Figs. 10.2, and 10.3.** The total suspended particulate matter levels have been measured using the aerosol particulate profiler (Aerocet 531S, Met One Instruments Inc., Washington, USA) and aerosol mass monitor (Aerocet 831, Met One Instruments Inc., Washington, USA). When the soap bubbles are stabilizing to TSPM concentrations, the bubble was introduced into the generator's duct using a dry cell battery operated bubble generator.

The concentration of TSPM before and after introducing bubbles was measured to assess the efficiency of soap bubbles in removing TSPM. The bobbles were generated using soap containing sodium palmitate. The device mitigates the TSPM in ambient air in general and industrial areas in particular. Following components are applying for the process:

1) Soap bubble Generator
2) Liquid Soap containing Sodium Palmitate Solution

The process is developed to reduce TSPM concentration using Soap containing sodium palmitate bubble produced continuously with a power–operated soap bubble generator. Soap bubbles of small sizes generate the soap bubble generator, which is run continuously by electric power.

The soap bubble is continually generating from liquid sodium palmitate soap solution. The volume of soap containing sodium palmitate solution used is minimal. Thus, it reduces and saves water consumption. Other methods used as spray utilize chemicals to remove the dust. In the different dust control processes, a large water volume is used as a spray to settle down or remove dust from the air. In such a process, the use of chemicals adds harmful substances to the environment, which may be detrimental to human health.

On the other hand, in the present process, soap solution is used, which has no harmful effect on human health. This method for reducing suspended particulate matter in the air comprising the steps of:

1) generating bubbles from a liquid suspension of salt of long–chain fatty acid
2) releasing the bubbles of salt of long–chain fatty acid into the air; wherein, the salt of long–chain fatty acid is sodium palmitate; and the bubbles are releasing at a velocity of 2–7 ml min^{-1}, more specifically at a velocity of 5 ml min^{-1}.

Thus, the method for reducing suspended particulate, wherein sodium palmitate is suspending in a liquid, more particularly in water and reducing suspended particulate, wherein sodium palmitate is suspending in the water at a ratio of 1:10. The bubbles of sodium palmitate effectively reduce suspended particulate matter in the air with a wind speed of 1–5 Km h^{-1} as an experiment performed at the laboratory **[280]**.

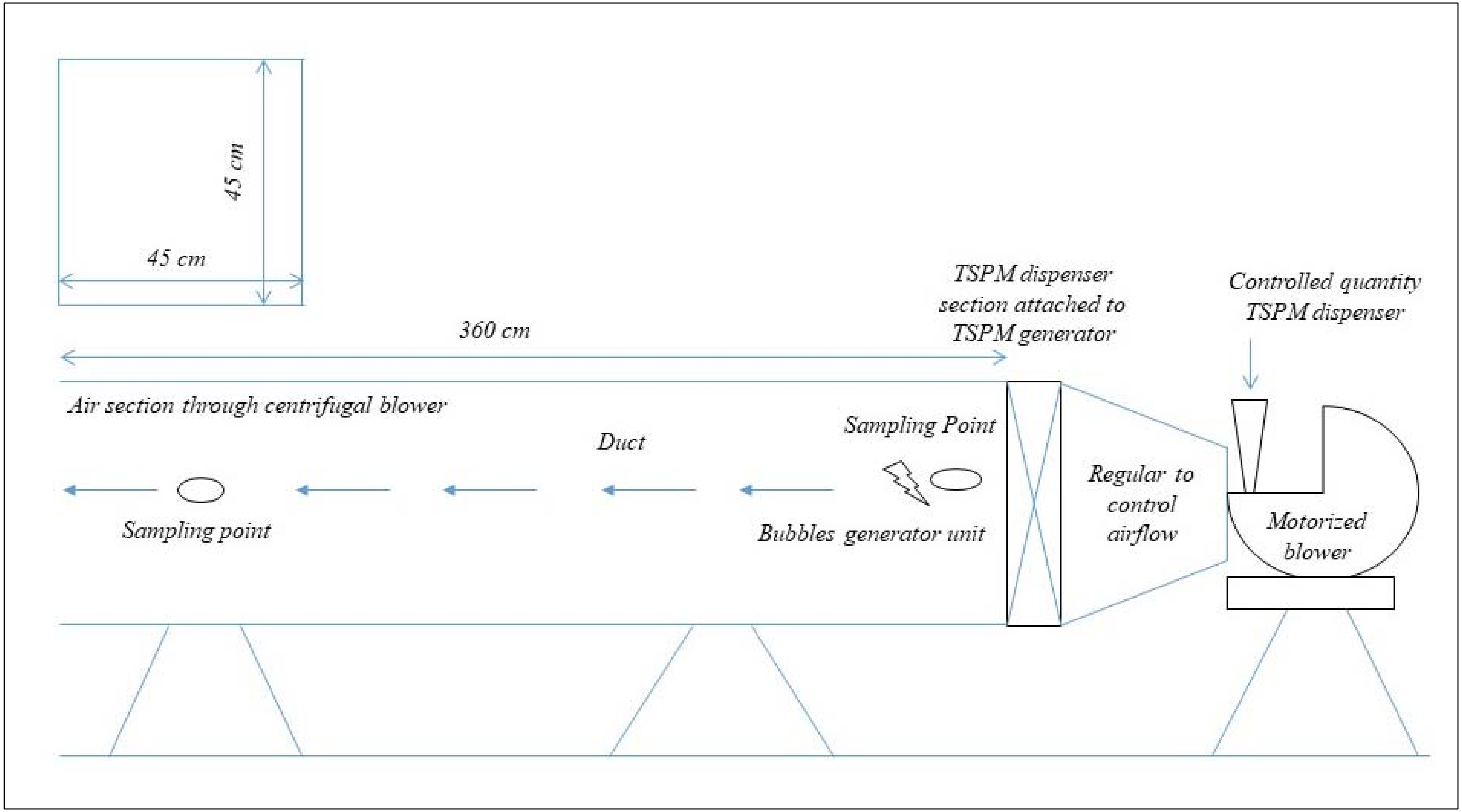

Fig. 10.2: Line diagram of the experimental setup of reduction for the total suspended particulate matter

Fig. 10.3: Dust scrubbing set up to study the effect of bubbles on TSPM suppression

10.4 Concentration of suspended particulate matter and laboratory investigation of particulate matters suppression

Infield, the monitoring of suspended particulate matter concentrations from different mining activities is investigated and given in **Table 10.1**. **Table 10.1** reveals that the highest concentration time of the blasting in the surrounding area varies from 2.00 to 4.00 mg m^{-3} with an average value of 2.75±0.10 mg m^{-3}. The lowest SPM concentration at the point of the coal loading and followed by drilling, unloading of overburden, haul road, coal yard dump, and loading source of overburden.

The laboratory investigation of particulate matter reduction details and control of models, as shown in **Fig 10.3**. The adjustable wind speed velocity maintained the TSPM concentration of desired value and dust fixed rate in the total suspended particulate matter (TSPM) generator experimental unit **(Fig. 10.2)**. TSPM generator experimental unit has been maintained the TSPM concentration with the help of the adjustable wind speed velocity and dust fixed rate. The experiment has been performing to the different wind speed velocity as follows:

1) WS_1 = 1 Km h^{-1},
2) WS_2 = 2 Km h^{-1},
3) WS_3 = 3 Km h^{-1}, and
4) WS_5 = 5 Km h^{-1}

The TSPM concentration value measured 112.0 µg m^{-3} in 1 km h^{-1} wind speed velocity. The $PM_{2.5}$ and PM_{10} concentration levels were measured 51.0 µg m^{-3} and 91 µg m^{-3}, respectively, and during other wind speed velocities for monitoring of particulate matter, concentration level was shown in **Fig. 10.4**.

The investigation of the impact of soap bubbles on particulate matters and different wind velocity is monitored and summarized in **Table 10.2**.

The bubbles performance on particulate matter at 1 km h^{-1} wind speed is shown in **Figs. 10.5–10.7** and similar observations at different wind speed, i.e., 2.0 km h^{-1}, 3.0 km h^{-1}, and 5.0 km h^{-1} are also shown in **Figs. 10.8–10.16**.

The total percentage effects of bubbles on particulate matter at various wind speed is shown in **Fig. 10.17**. It may be revealed from **Figs. 10.5–10.7** that the impact of soap bubbles reducing the $PM_{2.5}$, PM_{10}, and TSPM was concentration levels 51.0±1.0 to 37.0±0.8, 90.2±1.0 to 62.2±1.0, and 112.0±1.5 to 75.0±1.2 μg m^{-3} in 1 km h^{-1} wind speed velocity, respectively.

It may also be observed from **Fig. 10.17** that the soap bubbles reduce dust concentration on an average of 25±10%. Thus, reducing particulate matter by the bubbles of sodium palmitate effectively reduces particulate matter in the air by 10–35% at the laboratory scale. As result shows that the soap bubble is more effective in reducing larger size dust than smaller size dust, and graphical representation is shown in **Figs. 10.5–10.16**. This proposed method is economical and no adverse effect on the living being surrounding the area.

Table 10.1: Suspended particulate matter concentration during different mining activities

Mining operations	**SPM Concentration (mg m^{-3})**
Loading at source (overburden)	0.93–1.25 (1.00±0.08)
Loading at source (coal)	0.85–1.05 (0.94±0.05)
Unloading (overburden dump)	1.05–1.35 (1.12±0.06)
Unloading (coal dump yard)	0.90–1.30 (1.03±0.07)
Drilling (working)	1.20–1.60 (1.32±0.05)
Blasting	2.00–4.00 (2.75±0.10)
Haul road (working)	0.85–1.35 (1.05±0.06)

Note: mg m^{-3} = milligram per cubic meter; ± = Standard deviation

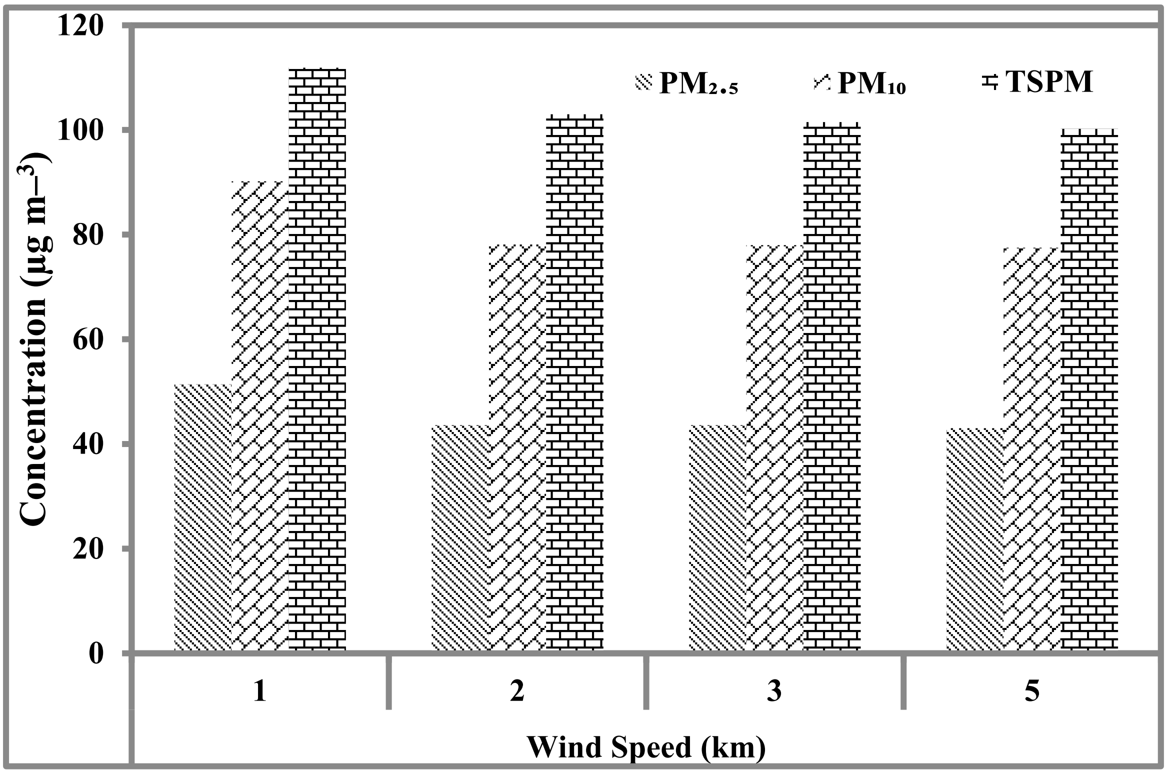

Fig. 10.4: The one–hour average concentration of particulate matters with different wind speed in the laboratory

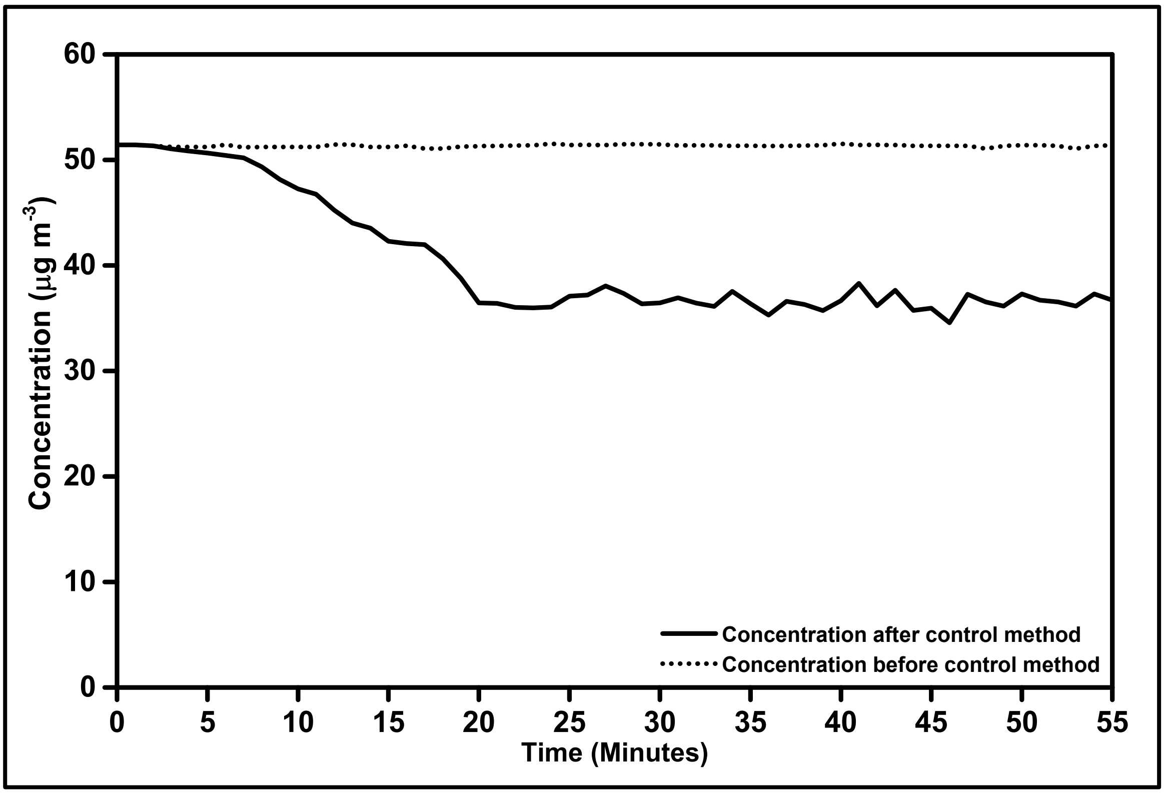

Fig. 10.5: $PM_{2.5}$ reduction by using bubbles with wind speed 1 km h^{-1} in the laboratory

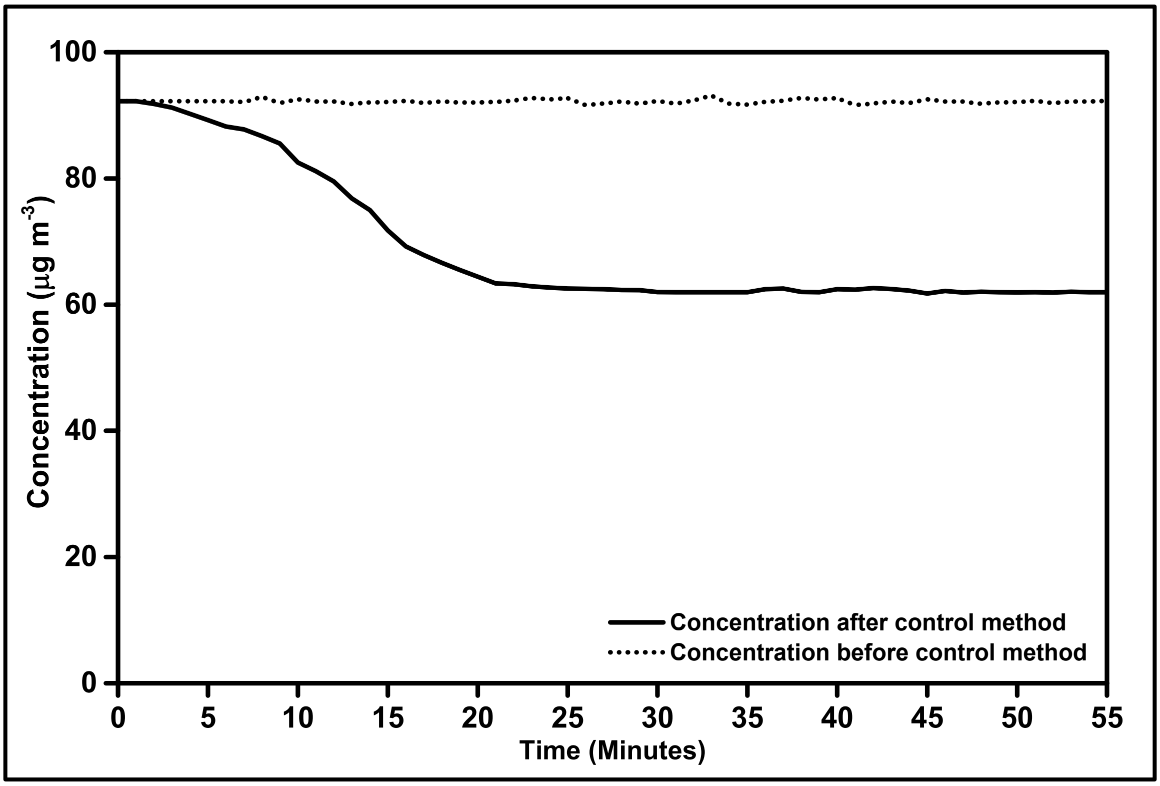

Fig. 10.6: PM_{10} reduction by using bubbles with wind speed 1 km h^{-1} in the laboratory

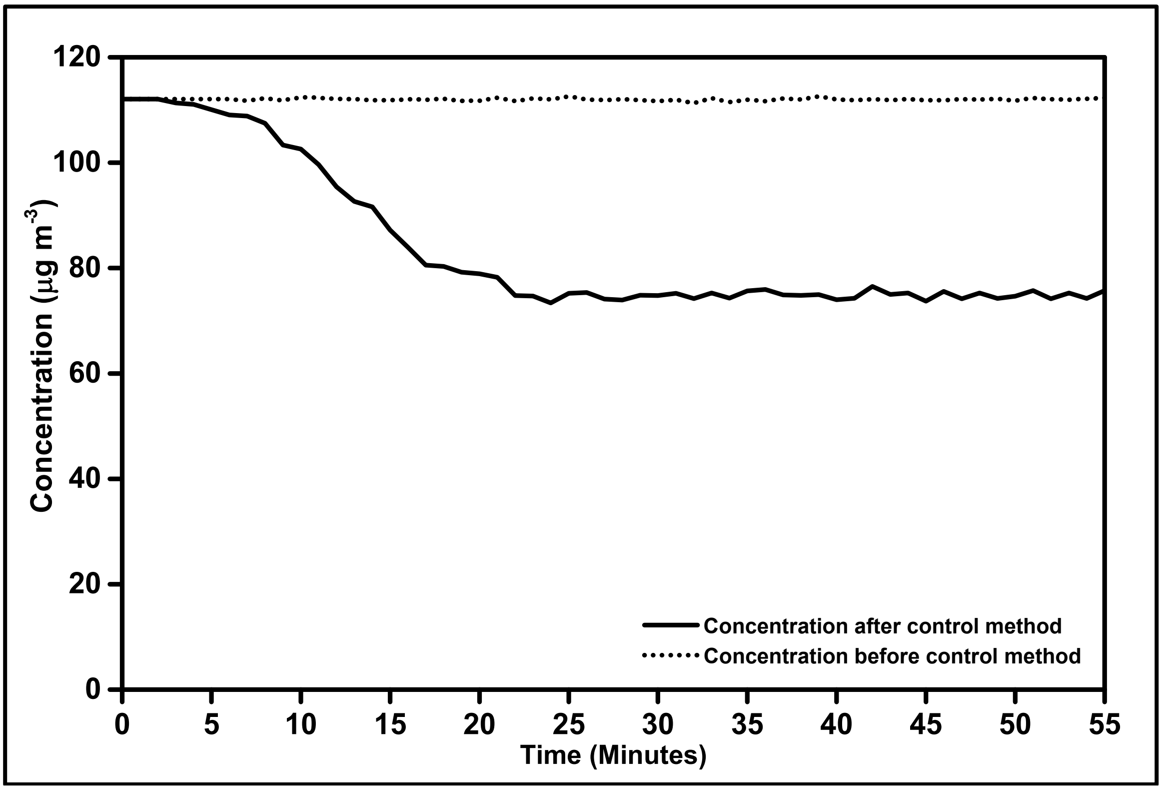

Fig. 10.7: TSPM reduction by using bubbles with wind speed 1 km h^{-1} in the laboratory

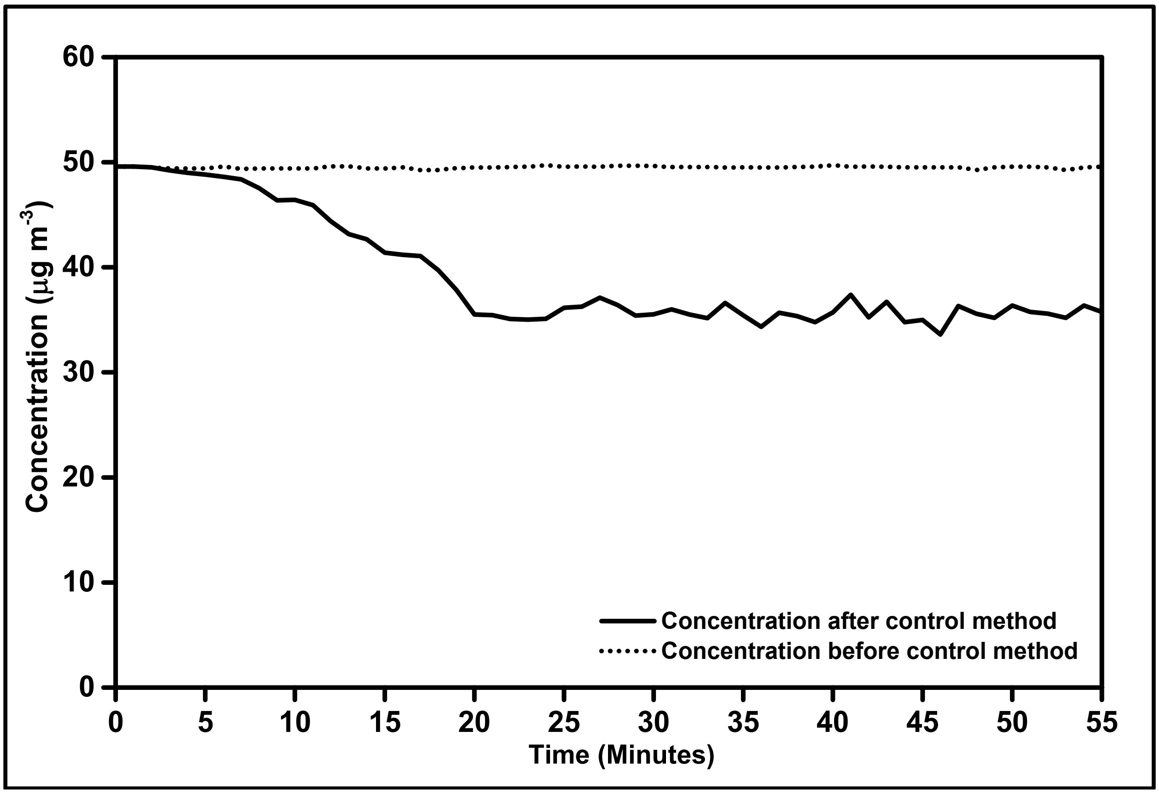

Fig. 10.8: $PM_{2.5}$ reduction by using bubbles with wind speed 2 km h^{-1} in the laboratory

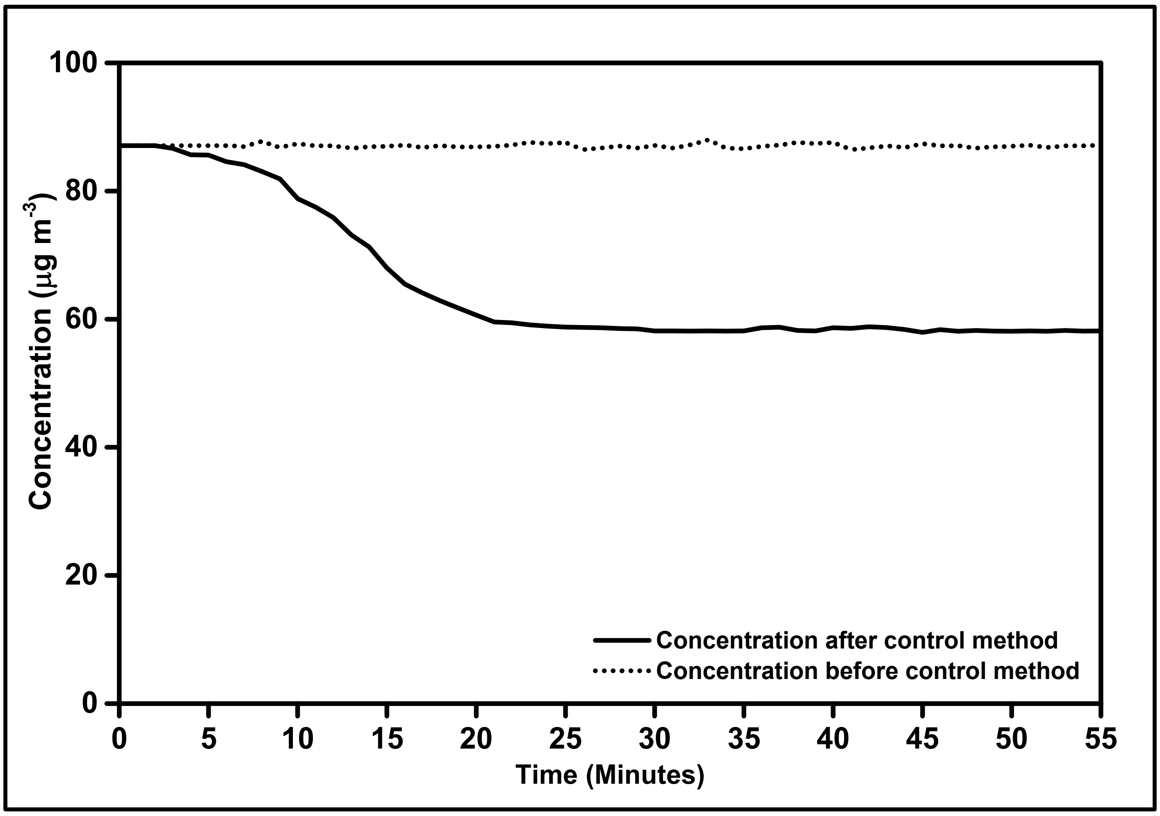

Fig. 10.9: PM_{10} reduction by using bubbles with wind speed 2 km h^{-1} in the laboratory

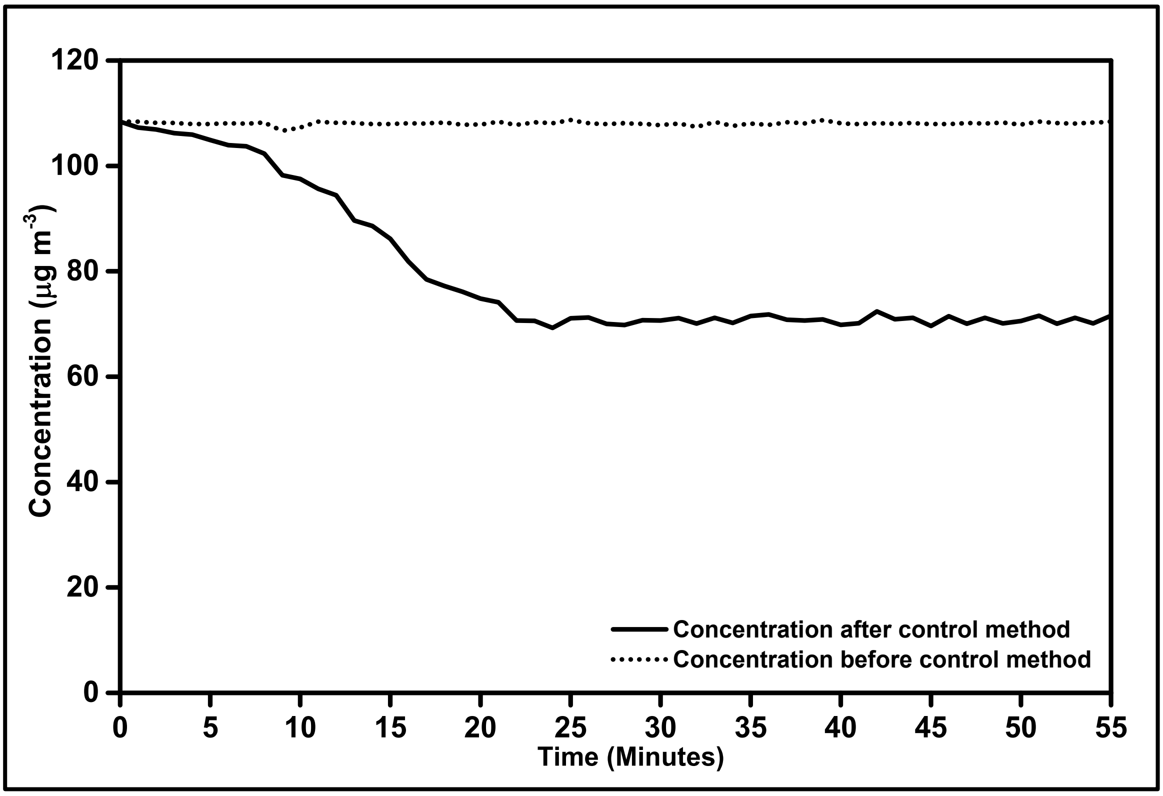

Fig. 10.10: TSPM reduction by using bubbles with wind speed 2 km h^{-1} in the laboratory

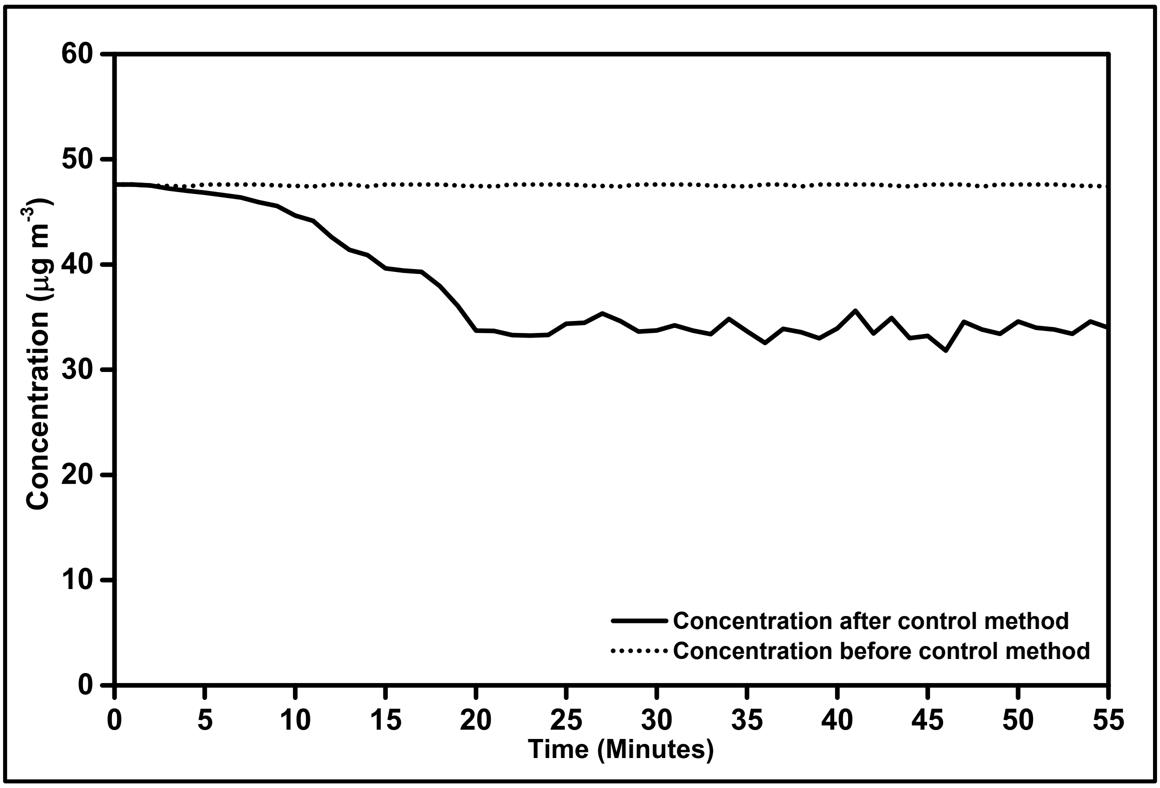

Fig. 10.11: $PM_{2.5}$ reduction by using bubbles with wind speed 3 km h^{-1} in the laboratory

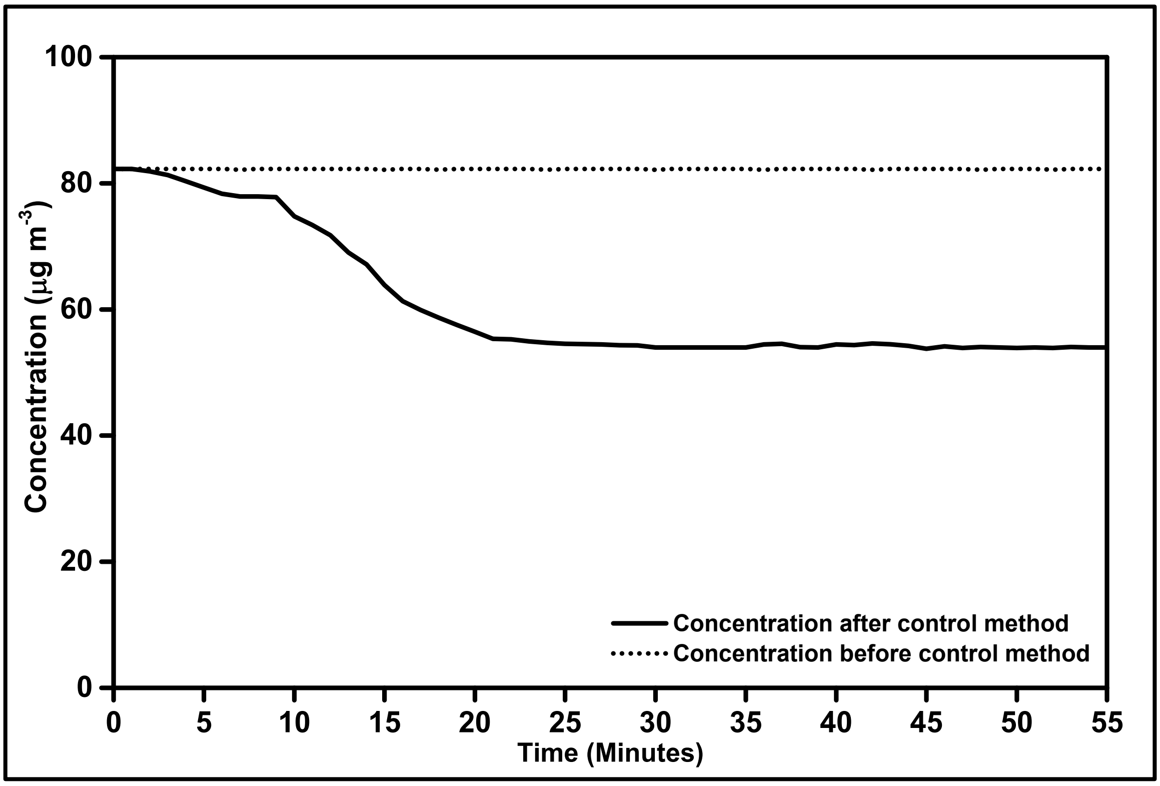

Fig. 10.12: PM_{10} reduction by using bubbles with wind speed 3 km h^{-1} in the laboratory

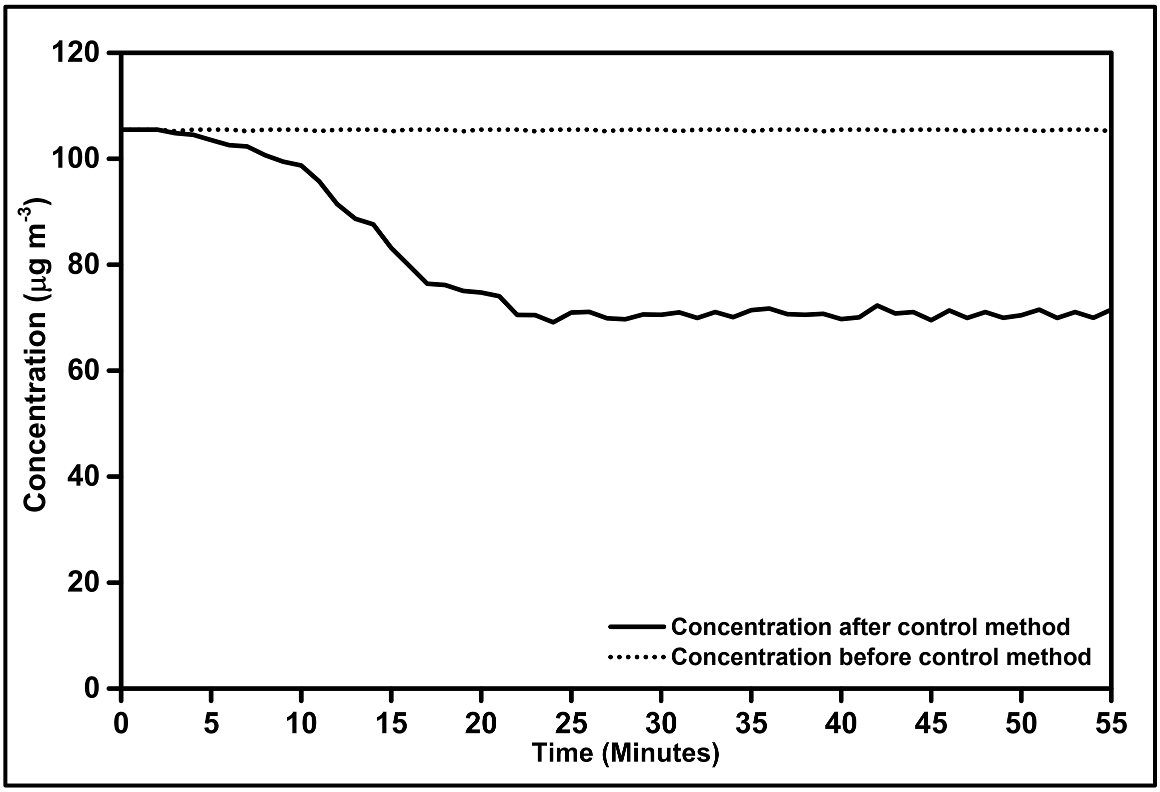

Fig. 10.13: TSPM reduction by using bubbles with wind speed 3 km h^{-1} in the laboratory

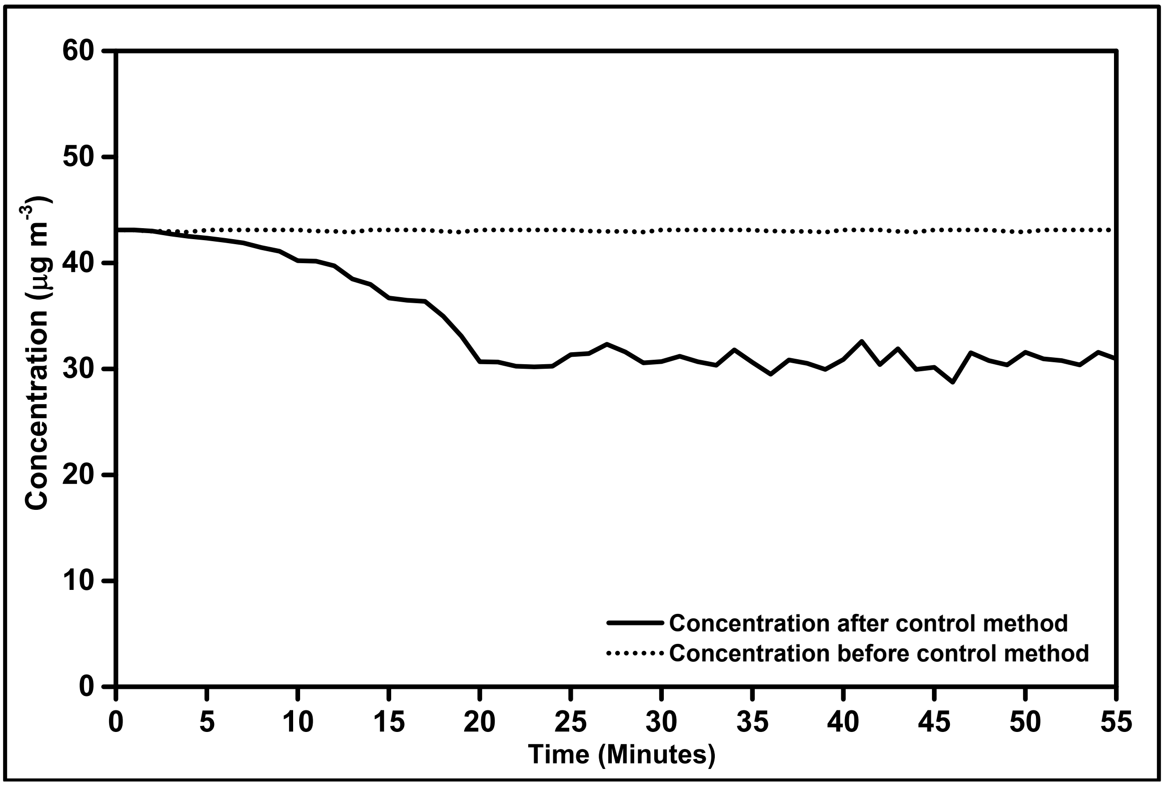

Fig. 10.14: $PM_{2.5}$ reduction by using bubbles with wind speed 5 km h^{-1} in the laboratory

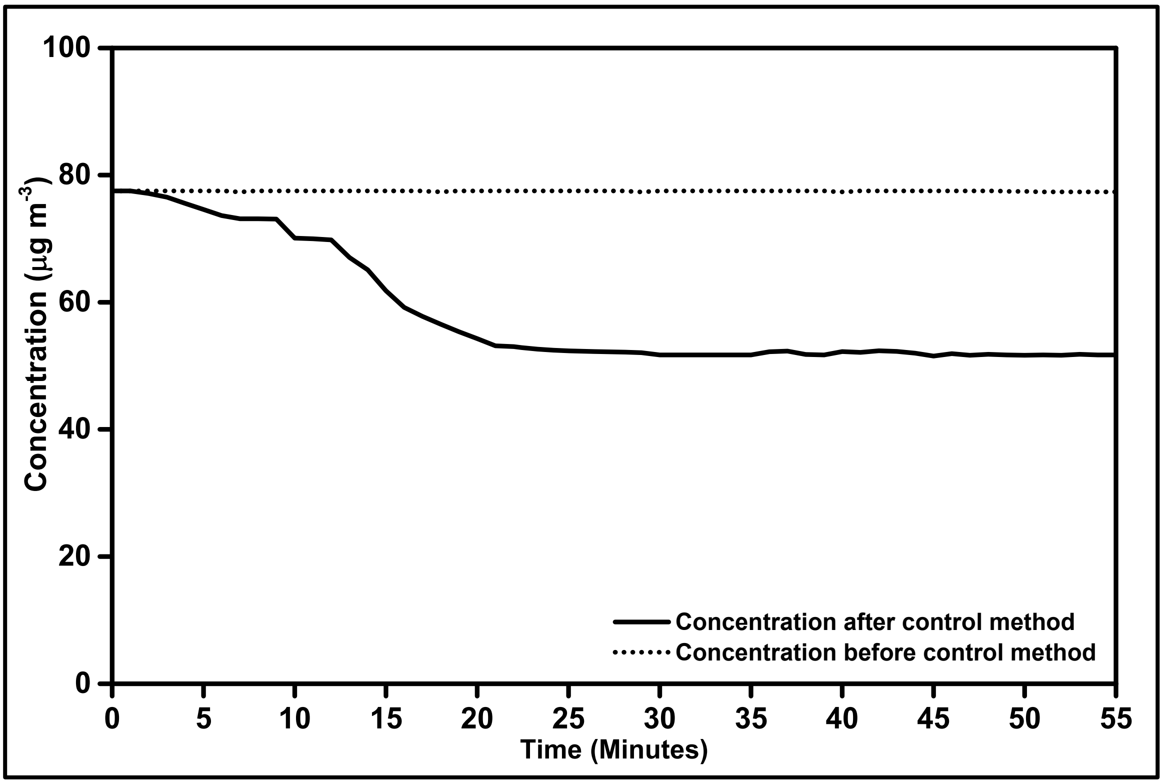

Fig. 10.15: PM_{10} reduction by using bubbles with wind speed 5 km h^{-1} in the laboratory

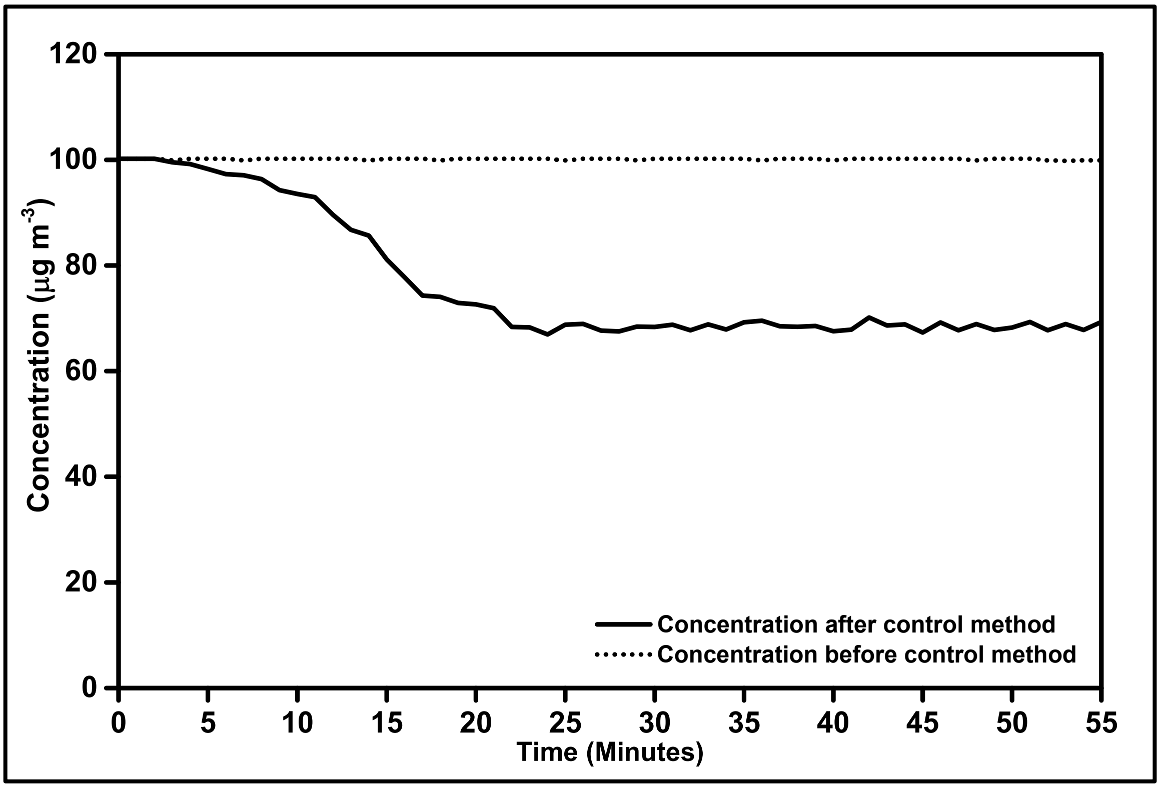

Fig. 10.16: TSPM reduction by using bubbles with wind speed 5 km h^{-1} in the laboratory

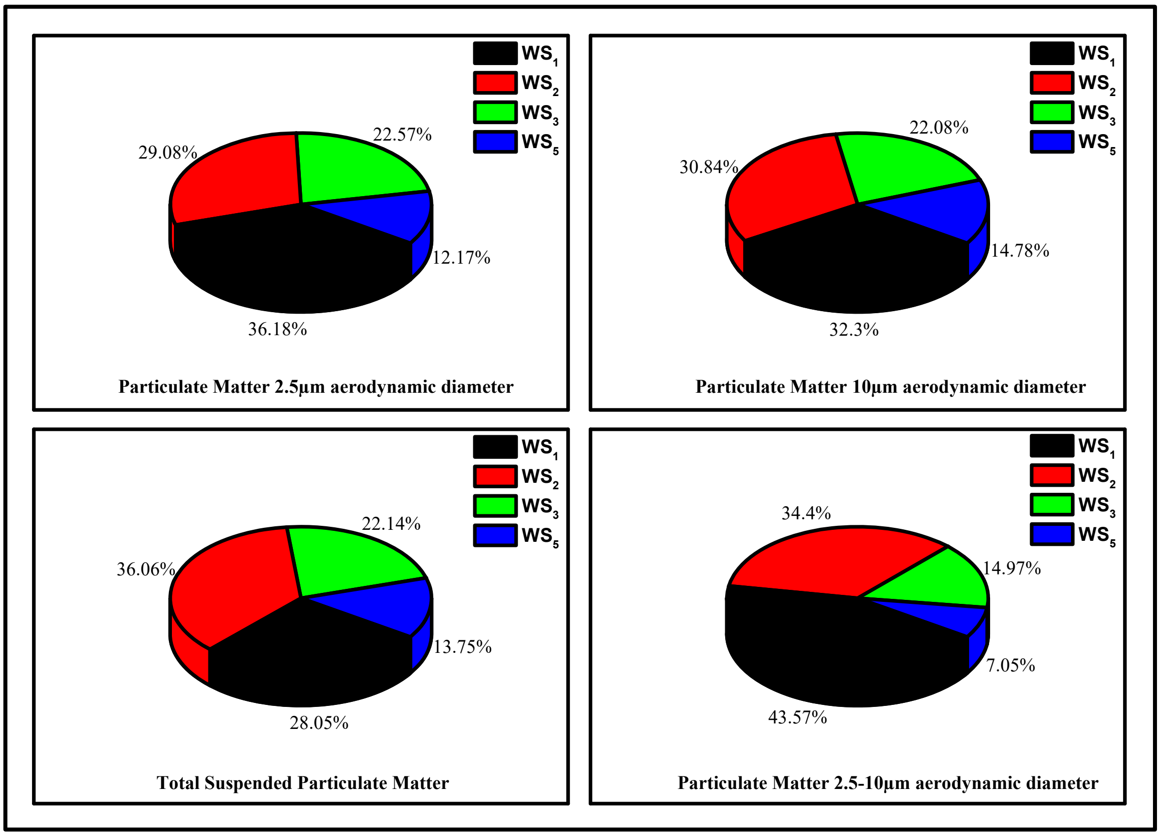

Fig. 10.17: Percentage control of TSPM in various wind speed in the laboratory

Table 10.2: One–hour average concentration of particulate matter with different wind speed and control method in the laboratory

Wind speed (Km h^{-1})	$PM_{2.5}$ (μg m^{-3})		PM_{10} (μg m^{-3})		TSPM (μg m^{-3})	
	Conc.	Conc. (Control Method)	Conc.	Conc. (Control Method)	Conc.	Conc. (Control Method)
1	51.4	37.2	90.2	62.2	111.9	72.1
2	49.6	35.4	87.1	58.1	108.4	75.4
3	47.6	33.8	82.3	57.3	105.5	76.1
5	43.1	32.7	77.5	56.2	100.2	78.2

10.5 Conclusion

A laboratory investigation was conducted to study soap bubbles' influence on the particulate matter of different sizes. The effect of soap bubbles reduces the $PM_{2.5}$, PM_{10}, and TSPM was concentration levels 51.0±1.0 to 37.0±0.8 μg m^{-3}, 90.2±1.0 to 62.2±1.0 μg m^{-3}, and 112.0±1.5 to 75.0±1.2 μg m^{-3} at 1 km h^{-1} wind speed velocity, respectively. The method, wherein the bubbles of sodium palmitate effectively reduces suspended particulate matter in the air by 10–55%. This technique is a low–cost technology and environment-friendly. The conclusions mentioned above are valid within the present experimental range. A generation and validation of this application of the work further, the study may be required before applying in the field.