Reduction of Particulate Matter on Road using Dust Accumulator

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Abstract

Increasing air pollution is always matter of problem for entire world, especially for Asian Countries because of the population and developing industries in the countries. This is the main reason for increase in AQI (Air Quality Index) of various regions of India. AQI reflects, how polluted the air in current situation is? AQI implies amount of pollutants that are present in air. Pollutants are PM₁₀, PM₂.₅, SO₂, O₃, NO₂, CO where SO₂, O₃, NO₂ & CO are the pollutants which are mostly affected by the chemical activities by industries where as PM₁₀ and PM₂.₅ are the particulate matters of size 10 micron and 2.₅ micron respectively. These two are responsible for respiratory diseases like asthma and lung diseases. Hence it is utmost necessary to reduce these particulate matters from the road, which will help in reducing AQI of the environment. There are many devices available in the market to reduce these pollutants which work to achieve the aim. An attempt is made in this research to reduce the pollutants from the air which is installed on the vehicle with the system, which collects the particulate matter very efficiently. Here in this paper a pilot scale equipment is manufactured which helps individual vehicle to contribute in reducing AQI and also it will be flexible and economical solution to absorb dual emissions.

Keywords:- Air Pollution, Air Quality Index, Particulate Matter, Dust Accumulator

1. Introduction

Air pollution is sensational issue in today’s era. Air has many harmful constituents such as SO₂, NO₂, CO, water vapors, smog [1] and also dusts particles which range in the size between 1 to 100 micron [2]. Hence contribution to reduce air pollution, a device is manufactured which helps in reduction of particulate matter on the road using air refiner. The Air refiner is a device that controls the dust which spread due to vehicle movement on road by pulling the dust inside using vacuum action. The vacuum action created by the fan, pulls the dust inside. It is more economical & feasible solution already available in market at present. Those devices are stationary and constant located at certain places. These can work for that particular location and due to this the idea of installation of invented device on vehicles came from. The concept behind this idea is that, when the dust will spread by moving vehicle tire and at the same time dust will be collected using this device. And this way individual vehicle can contribute in reduction in air pollution by reducing the particulate matter on road.
2. Literature Review

There are many devices which are installed to improve the quality of air on road which costs around Rs. 6.5 to 7 lakh (INR). These device claims that after a few hour of operation, 30-40% reduction in PM$_{2.5}$ level are observed [3]. Also there are air purifier used at home and other public places which cost around Rs. 10000 (INR) [4].

Recently in Delhi two devices were installed on the bank of road to reduce the dust & particulate matter like PM$_{2.5}$ and PM$_{10}$. The device is ‘Fine Dust Eater’. It reduces 20-25% of the polluted air per km. The cost of device was around Rs.100000 INR. Filters are attached in it which needed to replace once in 6-8 month. The replacement cost of Rs. 15000-18000 per filters [3]. Another equipment is ‘WAYU’, which is air purifier installed in 2019 at Delhi. It was fitted near road side on footpath. It can clean 2500 meter cube air per hour. The cost of the device is up to Rs. 60000 and maintenance cost of Rs.1500 per month [4].

Dust suppressant are the chemicals used on unpaved road. Dust suppressants are mixed with the gravel mixture and aggregate so that the proper binding can be possible. Then the commonly used dust suppressants like calcium chloride (CaCl$_2$) and magnesium chloride (MgCl$_2$) are hygroscopic salts that draw moisture from the air. After this the air form a solution in road gravel which keeps road surfaces constantly damp, even in hot dry condition. Particle binds together, get compacted and hard so that the dust does not spread. They bind with the help of moisture [5].

Jatayu cleaning machine is invented in India. It has to mount on any truck as it is portable and has proved to clean roads instantly. It can be used in any weather. Handling of this equipment is very friendly with its properties like it is strong enough, hard and attractive. Collection capacity is no bar in this, since Jatayu collects everything in quick change reusable bags. It can work with less man power and it is very economic. Its functionality and working can be improved with more equipment and accessories and will lead to better results [6]. The drawback is that it can clean the environment where this individual truck will move.

Difference has been observed in levels of recorded marginal improvement of particulate matter concentration before and after vacuum cleaning. In order to study the effect of vacuum cleaning, Delhi based Centre for Science and Environment (CSE) used portable aerosol monitors on a kilometre long stretch in Delhi’s Mayur Vihar Phase-I area. Delhi government has been practicing vacuum cleaning of roads in order to control dust pollution and try to bring down the overall pollution level in the city. The overall ambient air of the region is saturated with pollutants. It includes traffic, smoke from Ghazipur landfill, construction of flyover, metro rail and housing complexes. The vacuum cleaner truck used was in compliance with the Central Motor Vehicles Act. It was retrofitted with a sweeping device and a suction machine within. The attached brush wipes dust particles and the dust is collected by suction machine. The machine has capacity to remove 4 M$^3$ of dust in eight hours. The collected dust is dumped to the Ghazipur landfill sites where they carry out a diagnostic exposure monitoring of particulate matter of less than 2.5 micron size (PM$_{2.5}$) on that stretch. Data Collected shows improvement in air quality post-vacuuming. Vacuum cleaning helps in reduction of particulate concentration by 10% along roadside. The PM$_{2.5}$ concentration an hour before cleaning was 562 microgram per cubic metre (PCM) and after cleaning it was found out to be 517 microgram PCM an hour, which is comparatively less. Exposure before cleaning was three times more than after vacuuming. It nearly reduced 2.8 times post process. [7].

Government use Air quality index (AQI)[8] in order to communicate with public and aware them about how much the air is polluted or what will be the scenario in the future [9] [10] [11] [12]. Rise in AQI risk the health of people. Different countries have their own air quality indices, corresponding to different national air quality standards [12].
Increase in Air Quality Index (AQI) levels, leads to several health issues as shown in table 1. As the value of AQI increases the severity of pollution and damage to health can occur.

**Table 1. Details of Air Quality Index**

| Air Quality Index Levels (Health Concerns) | AQI Range | Description |
|-------------------------------------------|-----------|-------------|
| Good                                      | 0 to 50   | Satisfactory. Very less health risk. |
| Moderate                                  | 51 to 100 | Acceptable. Some pollutants can cause health issues. |
| Unhealthy For Sensitive Group             | 101 to 150| People sensitive to air pollution can experience the health effect. |
| Unhealthy                                 | 151 to 200| All can face health issues. |
| Very Unhealthy                            | 201 to 300| Critical condition, everyone will have health issues. |
| Hazardous                                 | 301 to 500| Danger: Serious Health effect to entire population. |

As per the report of USEPA (2018), AQI is calculated by two methods viz. Daily Ozone AQI & Hourly Ozone AQI. The daily ozone AQI is calculated by taking the maximum 8 hour concentration and then converting it to AQI. 17 to 18 hours averages are considered in each day, 6 of 8 hours (75%) is considered from 8 hours average for a valid calculation. In addition, 75% or 13/17 of the 8-hour averages is necessary to get a valid daily ozone AQI calculation. If calculating hourly ozone AQI for hours >1 old, these calculations are done using the midpoint 8 hour average ozone concentration which is then converted to AQI [13].

Respirable suspended particulate matter (RSPM) refers to microscopic particles of solid or liquid matter suspended in the air with diameter of less than or equal to 10 micrometres. They are produced from combustion process, vehicles and industrial sources [12]. Due to RSPM, lungs get affected and many diseases related to lungs occur.

### 3. Methodology

The mentioned device is very much useful to reduce the air quality index in the region. The concept used behind the setup is suction process which works as like as vacuum cleaner. Application of this equipment on road is much easier. It is because; there is no need to collect the settled dust but have to collect the exhausted dust from the environment. The dust which spread because of motion of vehicles which is trapped by the dust accumulator with vacuum action. So, it will ultimately reduce the dust particles around the vehicle and will ultimately reduce the AQI around the vehicle which fulfills the objective of reduction in AQI.

#### 3.1 Dust Accumulator

The device consist of small circular dust bin (Space for dust collection) as shown in figure 1. Dust bin is divided into two compartment. In first compartment, component assembly is kept and in another part accumulated dust particles (waste) can collect. Dust bin is seperated by filter. It avoid the entry of waste in other compartment where the whole circuit assembly is mounted. This setup can be used in vehicle or can be fixed within the vehicle. This may be rechargable battery operated or one can operate with vehicle power. In a given equipment setup, a rechargeable battery is used as a power supplier. A
reverse fan is connected with electric motor which create suction to sucks the dust. This device add additional motion to the cleaning units. Air refiner (dust accumulator) is to be attached to the vehicle. When the vehicle will start, the dust emission controller will also start. Wherever the vehicle will travel, the air refiner will absorb the exhausted dust in its vicinity. When the detachable dust bin occupy the whole space with dust, it can remove to clean the occupied dust for best performance. The dust near by the vehicle will be absorbed and it will automatically decrease the AQI near the road and humans won’t have to inhale such harmful dust. It will result in less respiratory diseases. Figure 1 shows the schematic view of dust accumulator experimental setup.

![Diagram of Dust Accumulator](image)

**Figure 1.** Diagram of Dust accumulator

### 3.2 Working of Dust Accumulator

Dust accumulator consists of battery connected to a fan with a toggle switch which provide ON/ OFF along with the charging facility. There are 3 rechargeable batteries of 3.7 V each which makes total voltage of 11.1 V and can be charged till 12 V is connected to single pole double throw toggle switch. When toggle switch is connected to fan, the fan starts. A diode prevents the reverse flow and drop 0.7 V is available before fan setup. When toggle switch connects to DC power jack, circuit starts charging. A resistor is attached prior to power jack, so that required amount of voltage is provided for charging battery and LED starts to glow. Here also a diode is present before power jack which prevents reverse flow of current. The circuit diagram of the experimental setup is shown in figure 2. The device creates suction action which sucks the dust present in the surrounding and collects in front of the filter & bin.
3.3 Advantages of Dust accumulator

- The system is portable because of rechargeable system using the adaptor.
- The collected dust can be removed easily with the help of detachable bin.
- The device can be mounted within vehicle. When vehicle will start, the dust emission controller will also start.
- Wherever the vehicle will move, the dust controller will absorb the dust in its vicinity.
- The device consists of circular dump bin. It is divided in two compartments. One for component assembly and another for waste collection.
- Dust bin is separated by filter. It avoids the entry of waste in other compartment.
- By absorbing dust, improvement in AQI of the area can be achieve.

4. Results

The setup was installed in a site to check the efficiency. Following results are shown in table 2.

Table 2. Results of dust collection by using dust accumulator

| Day   | Location of site (Urban/ Rural) | Time of operation at site (In hours) | Wt. of dust collected (in gms) |
|-------|----------------------------------|-------------------------------------|--------------------------------|
| Day 1 | Urban                            | 8                                   | 2.25                           |
| Day 2 | Urban                            | 8                                   | 1.62                           |
| Day 3 | Urban                            | 8                                   | 1.97                           |
| Day 4 | Urban                            | 8                                   | 2.01                           |
| Day 5 | Rural                            | 8                                   | 10.61                          |
| Day 6 | Rural                            | 8                                   | 8.50                           |
| Day 7 | Rural                            | 8                                   | 8.38                           |
| Day 8 | Rural                            | 8                                   | 8.79                           |
| Day 9 | Rural                            | 8                                   | 9.12                           |
| Day 10| Rural                            | 8                                   | 7.38                           |
From the table 2 it is observed that, because of urban development & constructed rigid pavement, concrete/ paving blocks everywhere at site accumulated dust obtained low as compare to rural areas where the pavements are of WBM.

5. Conclusion

This device is a small set up which creates vacuum which helps in pulling of dust inside the dust collection chamber. It proven to be successful for taking dust inside the bin and accumulate with good efficiency. It helps in minimizing the harmful air inhalation by the human. It also prevents from diseases and other harmful respiratory problems like respiratory disease, skin diseases, hair diseases etc. Not only adults, new born children are also affected by dust inhalation.

Dust accumulator makes the roads environment friendly with less pollution. The pedestrians will get benefit of good quality of air during walking. Rural areas become more beneficiary where hard pavements are not available. This device will be effective for our environment. The setup is small and hence it is economical for common person. It is portable & handy, so that it can carry easily, work efficiently, handled smartly etc. It is a small try to make environment a better place to live with help of science.

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