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3D Modelling of Nylon Particle Arresting System to Mitigate Indoor Air Pollution

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Abstract - *The rubber industry generates a significant amount of airborne nylon particles, posing a serious health hazard to workers and contributing to environmental pollution. To address this issue, one of the main challenges is the development of efficient and cost-effective methods for producing nylon particles with the desired properties. Nylon particles must be small enough to capture, but they must also be large enough to be easily filtered out of the air. A novel nylon particle arresting system has been designed. This system effectively captures and removes nylon particles from the air, creating a cleaner and safer work environment.*

Key Words: **Nylon Fiber, Rubber Particles, Air Pollution, Tyre, Recycling, Human Health.**

1. INTRODUCTION

Every year huge numbers of tyres of four and two wheelers have been replaced with new one. Hence there is need to process the used tyres on daily basis because of large quantity. India is the world's third largest producer and fourth largest consumer of natural rubber. The automobile industry is the largest consumer of rubber in India. India produces 6.5 lakh tyres every day. Looking to the rate of growth of the automobile industry, the tyre production will increase exponentially in future. It was reported that around 80.1 million cars and utility vehicles and 236.4 million two wheelers will be on the roads by 2035. It was estimated that every year near about 1.6 billion waste tyres is generated worldwide. India contributes 6% of the waste tyre. India has big market of tyre recycle. Tyre recycle industry in India imports around 300000 tonnes of tyres every year. They are subject to thermochemical treatments and separation in high temperature to produce of rubber, nylon, industrial oil and other derivatives.

Pollution from these tyre recycling industries is a big concern. Every year many rubber or tyre recycling industries were shut down after finding that the units were flouting environmental norms and were responsible for high levels of pollution [1].

Gujrat Rubber Polymer is one such unit where the used tyres are processed. The major objectives of the processing unit are to extract rubber and the nylon from it. This extracted or recycled rubber is used to manufacture tyres. The nylon strands separated from the tyre rubber is also reused in various applications.

The air pollution is one of the greatest scourges of this era. It not only account for its impact on climate change but also its impact on public and individual health due to increasing morbidity and mortality. There are many pollutants that are major factors in disease in humans. Among them, Particulate Matter (PM), particles of variable but very small diameter, penetrate the respiratory system via inhalation, causing respiratory and cardiovascular diseases, reproductive and central nervous system dysfunctions, and cancer [2]. The effect of PM is illustrated in the table 1 [3].

Table-1 Particle size and its penetration

Particle size (μm)	Penetration degree in human respiratory system
>11	Passage into nostrils
7-11	Passage into nasal cavity
4.7-7	Passage into larynx

Research was carried in the residential indoor rooms for the air pollution and it was observed that Synthetic fragments and fibres accounted, on average, for 4% of the total identified particles, while nonsynthetic particles of protein and cellulose constituted 91% and 4%, respectively. Polyester was the predominant synthetic polymer in all samples (81%), followed by polyethylene (5%), and nylon (3%) [4]. The significance of recycling of waste rubber in protecting the environment and conserving energy is discussed. Various kinds of recycling approaches to waste rubber are summed up. [5]

Chronic exposure studies suggest relatively broad susceptibility to cumulative effects of long-term repeated exposure to fine particulate pollution, resulting in substantive estimates of population average loss of life expectancy in highly polluted environments. [6]

In this research work the causes of airborne nylon particles were investigated and the solution to arrest these air

pollutant nylon particles was designed and submitted to the industry for implementation. This will help in reducing the indoor air pollution.

2 Materials and Methods

In this work, the process of the recycling tyre was investigated. The major focus was on identifying the causes of airborne nylon particles in the indoor environment. After extensive floor study, major nylon airborne locations were identified.

2.1 Effect on human health

As per the World Health Organization (WHO) estimates, particulate matter (PM) air pollution is leading cause of mortality worldwide. Approximately 800,000 premature deaths each year is reported due to PM air pollution. Many studies reported the effect and relationship between PM air pollution responsible for respiratory illness. More focus was given to study effect of PM air pollution on the cardiovascular system. It was revealed through the research that lung function, respiratory symptoms and mortality are the major areas of concerns due to PM air pollution [7]. The size of particles plays major role in the potential for causing health problems. There are two kind of particles which are inhalable coarse particles having diameter of 2.5 to 10 µm and second one is fine particles having diameter smaller than 2.5 µm [8]. The comparison of particle size shown in fig.1 was demonstrated by Guaita R [9]

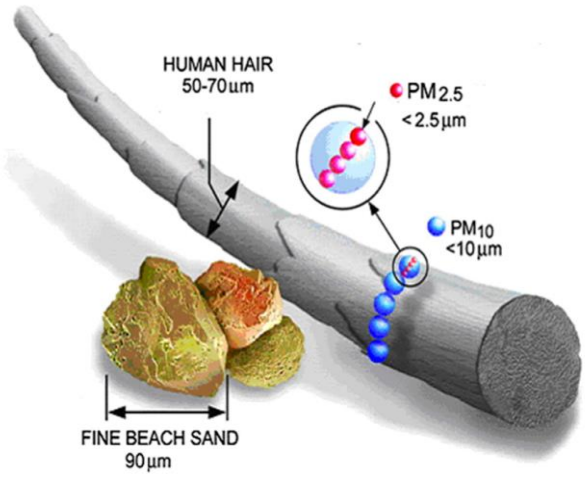

Fig.1. Size comparison of PM2.5 & PM10 [9]

It is common fact that, the PM concentration levels in indoor environment is more than those of outdoors. Several activities can generate particulates in indoor environment for example cooking, pets, walking across the carpet, household products washing machines and office equipment such as printers and photo-copiers. The construction materials of the house, the arrangement and size of rooms, and the number of windows for ventilation may be responsible for PM. [10]

2.2 Effect of particle size

It was observed that the particles having diameter less than 10 µm have the most impact on human health and other size particles have less impact. Due to their excessive penetrability, the particles can penetrate in the respiratory tract and it start with the nasal passages to the alveoli and from there into the lungs [11]. Depending on the particle size, its deposition depends. 5 and 10 µm particles deposits in the tracheobronchial tree and 1 and 5 µm particles deposits in the respiratory bronchioles and the alveoli [12]. There is gas exchange in the lungs and can even penetrate the lung. Finally, it will lead to major health problem by the blood stream. 1 µm and less size particles in general behave like gas molecules. It penetrates the alveoli and finally it may translocate into the cell tissue.[13]. There was a data which showed that 8% increase in lung cancer mortality for a 10 µg/m3 elevation in PM2.5 [14]. (Pope et al., 2002). The relationship between lung cancer mortality and air pollution have also been demonstrated [15]. (Dockery et al., 1993)

2.3 Method used to reduce air pollution

Figure 2. shows the flow diagram of tyre recycling process installed at GRP. The used tyres were dumped in the open store area. Then it was brought to washing center and sent to primary cutters. The cut tyre pieces are fed to shredder and then it is passed on to grinder where the nylon and rubber were separated. The conveyor belt with mesh were used to separate the nylon and rubber.

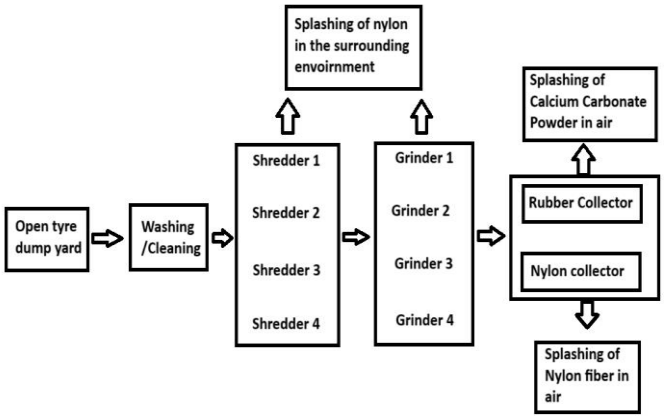

Fig.2. Flow diagram of tyre recycling process

The detailed investigation of the process helped to identify the spreader locations. Visual inspection and experiential investigation were carried out to locate exact points of air pollutions.

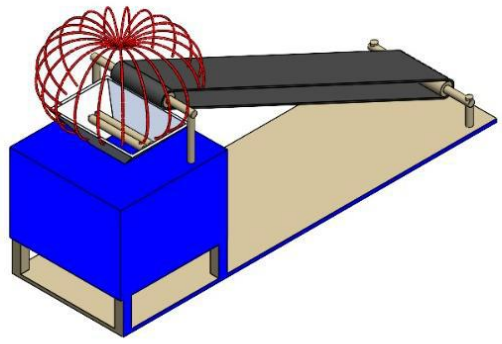

Fig.3. The umbrella Balloon to arrest splashing nylon particles

The simple solution to arrest the spreading particles were designed. An umbrella balloon was designed to catch the splashing nylon particles. These nylon fiber arresting umbrella balloons were mounted at each splashing location.

Because of the light weight of splashing particles nylon fiber and rubber particles, there was need to avoid splashing of these particles. It can be done by two methods firstly by modifying the process itself and secondly by arresting the splashing particles. Modifying the process is possible but it is not economical and whole process need to be revamped. Second method of arresting the particles is easy and economical.

Figure 3 show the flying particle arresting mechanism designed to collect the flying particles in the closed chamber. When the conveyor releases the crushed tyre rubber and nylon particles in the hopper, the light weight particles fly in the air. This designed mechanism does not allow the particles to mix with air. It prevents the particles and fibers from surrounding atmosphere and hence air.

The umbrella balloon is made up of the polyester fabric material available at local market and the wire frame is designed and fabricated. The umbrella wire frame is covered with the help of fabric material. The umbrella wire frame is mounted at the top of the hopper where the conveyor releases the crushed rubber and nylon fibers. When the crushed rubber and nylon fly in the air, the umbrella arrest the particles and are collected in the collecting ring provided at the bottom of the umbrella.

3. Results and Discussion

A recent study from the World Health Organization (WHO) shows that PM concentration is linked to 7 million global deaths per annum with a high contribution from Southeast Asia and Western Pacific regions. These deaths are attributed to 6% lung cancer, 33% stroke and 36% ischemic heart disease as per WHO reports (2014) [16]. Urbanization rate of India is highest in Asian countries and it is 31%. It is predicted that by 2050, it would add 416 million urban population. Many cities of India is experiencing rapid urban growth. Because of this huge urbanization, WHO found major Indian cities are most polluted cities due to particulate matter air pollution. 106.38 and 58.59 μg/m^3 was the annual average concentrations of PM 10 and PM2.5 in Indian cities respectively reported by WHO (2018) [17]. It was also observed in a study that 1 million deaths annually are related to PM in India. This number is 1/7 of the global deaths and in South and Southeast Asian region it amounts 69% [18].

Figure 4 shows the daily PM10 concentration trend in 10 selected cities in India. In these selected cities, Varanasi, Delhi and Thane has high PM10 value of 261.92 μg/m^3 186.83 μg/m^3 and 132.51 μg/m^3 respectively. Compared with these, other cities reported 48.26 and 98.79 μg/m^3 PM10 concentration. It was also found that a small city like Solapur is recorded 200 μg/m^3 PM10 concentration because of dusty atmosphere due to dry land [19].

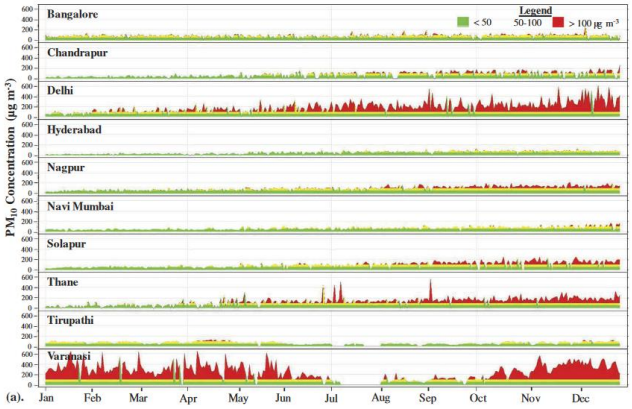

Fig.4. Air pollution data of various Indian cities

The observed results show that by employing the developed mechanism, the air pollution at all the grinder location was reduced by about 60%. In few of the locations it was observed that air pollution due to flying nylon fiber was reduced by 80%. The rubber dust spread over the surrounding floor was also observed to be reduced by about 70%.

4. CONCLUSIONS

As the human health is at risk due to air pollution and that too because of PM2.5 and PM10, there was need to either modify the processes responsible for pollution or to design a mechanism to arrest the polluting particles. In this work, a mechanism was designed to arrest the flying nylon fiber and rubber particles in an indoor tyre recycling industry located at Solapur, Maharashtra. It was observed that the air pollution due to nylon fiber was reduced by 60-80%. The air pollution due to rubber particle was reduced by 70%. This will help in protecting the human life.

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