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Original Paper

Air Quality Management for Electroplating Industry for Mumbai Metropolitan Region, Maharashtra

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Abstract

Electroplating is considered to be a major polluting industry because it discharges toxic materials and heavy metals through effluent like wastewater, air emissions and solid wastes. There are many registered electroplating units in Mumbai Metropolitan Region (MMR). The quantities of gaseous wastes generated from these industries were estimated and the existing control and treatment techniques for these gaseous wastes were evaluated. Further, Air Quality Modeling (AQM) study was also carried out to predict the concentration of acid mist with the help of emission, characteristics of stack and meteorology. A Gaussian plume model based SCREEN View software was used to predict concentrations for two industries which showed that the acid mist emissions from stack were under the consented limits. Further, health impact survey was performed at 1km radius of the industry to study the effects of air pollution on human health. It showed that 47%, 40% and 57% workers near the electroplating industries are suffering from chest pain, eye irritation and breathlessness respectively. Clustering of electroplating industries in the MMR will improve the waste management in the region. Installation of efficient air pollution control equipment like wet scrubbers can eliminate the hazards caused due to acid mist emissions from electroplating industries.

Keywords

Electroplating, acid mist, health impact monitoring, fugitive emissions

1. Introduction

Air pollution has become a popular issue in the terms of social aspects (Muthukaruppan et al., 2010). Plantation is carried out to mitigate the air pollution issue in the region (Bora & Joshi, 2014; Thakar & Mishra, 2010). Electroplating is the process of deposition of a fine layer of one metal on another through electrolytic process to impart various properties and attributes, such as abrasion & wear resistance, corrosion protection, enhanced surface hardness, lustre, colour, aesthetics and value addition (Akolkar, Suresh, Varalaxmi, & Kumari, 2015). Electroplating uses electric current and electrochemical reaction for making metal coatings (Selhi & Nikhil, 2014).

It is considered to be a major polluting industry because it discharges toxic materials and heavy metals through wastewater (effluent), solid wastes and air emissions into the environment. The effluent from electroplating industries have high concentration of heavy metals like Iron, Chromium, Copper and Nickel (Singh, 2014). There are many registered electroplating units, located in Mumbai Metropolitan Region (MMR). These plants are divided into region I, II, III, IV. Many of these industries are operated at a small scale and hence environmental compliance and waste management is not given due importance. Due to the high treatment costs, the wastewater, solid waste and gaseous emissions from these industries are released without any prior treatment leading to deterioration of nearby land, air and water. Small scale entrepreneurs owning these electroplating industries and the employees there are either ignorant of health impacts or environmental effects of effluent discharge or are worried that it would be a financial burden to them (Singh, 2014). Electroplating industry has been generating a huge amount of waste in the forms of wastewater, spent solvent, spent process solutions and sludge (Freeman, 1988). Solid waste includes residues such as cleaning powder, buffing compounds generated during the pre-treatment process and spent anodes during the plating process. Liquid wastes includes spent chemicals and solutions such as acids, alkali, cleaning agents, bath chemicals comprising plating chemicals as well as additives such as brighteners, levellers etc. and rinse waters. Gaseous wastes include solvents and vapours from hot pre-treatment and process baths. Acid alkali mist and Volatile Organic Compounds (VOCs) are the gaseous wastes from electroplating industries. In some cases, mists and VOCs may contain metals in addition to process chemicals. Mist is produced when gases generated at the electrodes during the process rise to the surface as bubbles, then burst, and spray fine particles of the plating solution into the atmosphere above the surface (Mason, Lorimer, Saleem, & Paniwnyk, 2001). Air emissions from electroplating industries may contain toxic organic materials such as trichloroethylene and trichloroethane (Singh, Ram, & Kumar, 2016). Around 30% of the used solvent and degreasing chemicals release VOC (Cushine, 1985) (United States Environment Protection Agency, 1980). The minimization of the air emissions to be adopted is related to the optimum bath temperature control and the preventive maintenance of the suction and filtration unit or scrubber (Ramesh Babu, Udaya Bhanu, & Seeni Meera, 2009).

The disposal of untreated effluent from electroplating industries into the environment can cause toxicity to aquatic flora and fauna, sewage toxicity, ground and surface water pollution and it can also cause problems in biological treatment process employed for treatment of sewage (Nair, Chandrakar, & Nandkumar, 2016).

In this study, electroplating industries of MMR region were assessed for various gaseous pollutants with the help of stack monitoring. The health of people residing in 1km radius from the electroplating industry was monitored to check for the health hazards caused due to improper waste management.

2. Study Area

The study focuses on the electroplating industries confined in Mumbai Metropolitan Region (MMR). The study area shown in Figure 1 highlights the MMR, Maharashtra. The MMR spreads over 4,355 sq. km. consists of 8 Municipal Corporations along with more than 1,000 villages in Thane and Raigad Districts. Mumbai Metropolitan Region Development Authority (MMRDA) is responsible for the development of the MMR. Due to rapid urbanization, the region was illegally developed in a haphazard manner. It has many registered electroplating units. These units are divided in region I, II, III, IV.

Project synopsis focuses on the industries located in region II of MMR. Two electroplating industries from region II of MMR were visited and the general information about these industries is given in Table 1. The main source of wastes from electroplating units are identified as drag out losses, concentrated liquid wastes, spent acid bath, spent alkali baths, spent passivation dip and rinse water. The effluents from electroplating industries have high concentration of heavy metals like Iron, Chromium, Copper and Nickel. As example, in India, river quality Yamuna river quality has deteriorated due to discharge of untreated or inadequately treated industrial effluents from nearby electroplating industries into the river (Singh, 2014).

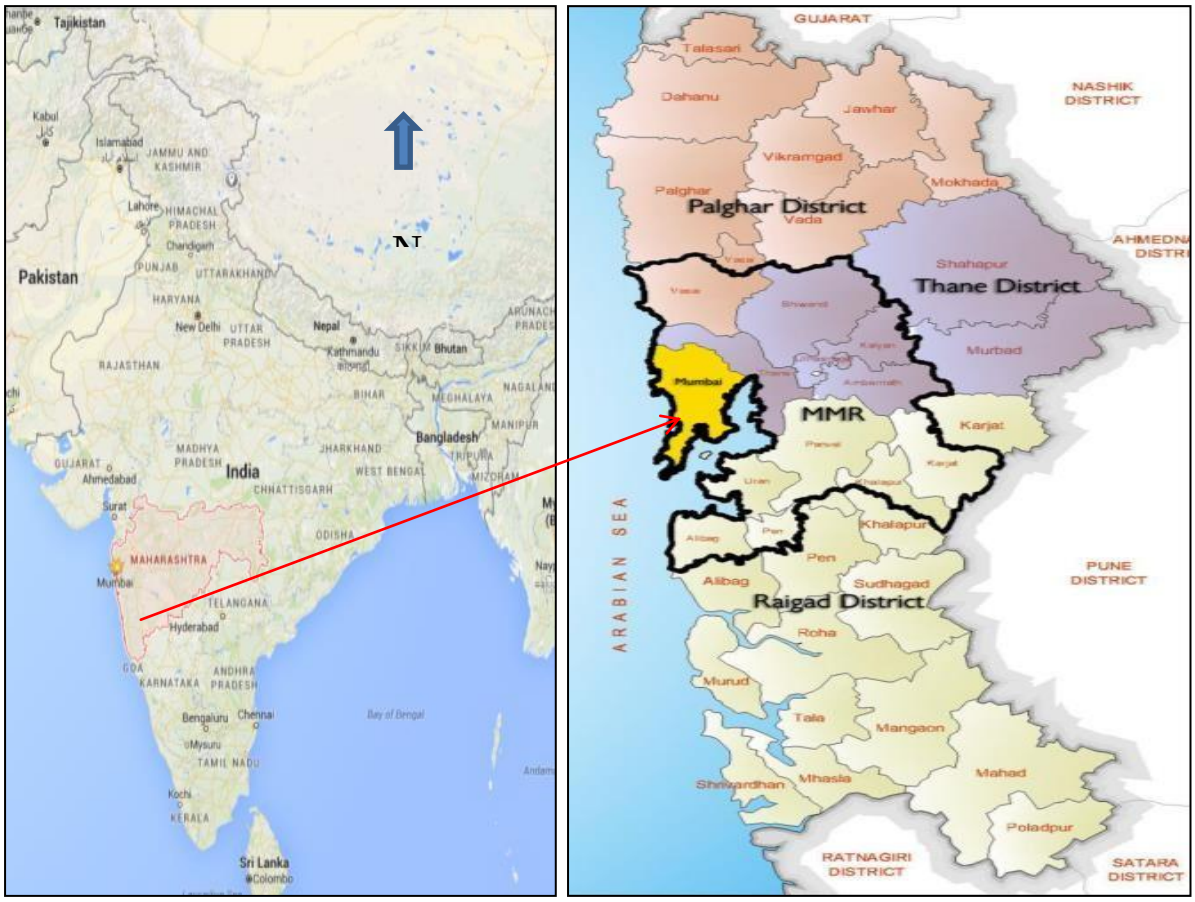

Figure 1. Mumbai Metropolitan Region

Table 1. General Information of the Industries Visited

S.No.	Name of the Industry	Water consumption (lpd)	Waste Water Generation (lpd)	Solid and Hazardous Waste Generation (kg/m)	Existing Pollution Control Methods
1	Industry A	2000	400-500	10	Hood system for pickling unit
2	Industry B	3000	2000	30	Hood system and Wet Scrubber

Note. Industry names have been hidden for confidentiality.

3. Methodology

The data for the study was collected in two stages, i.e., air quality study and its health impact. The focus of the study was to check for the air pollution levels due to acid mist. Two industries were selected to carry out air pollution studies based on emissions and meteorology. Ground level concentrations were predicted. Air quality study was conducted to obtain the existing acid fume concentration in the work place. It also gives an idea about dispersion of pollutant from stack within a certain range. A Gaussian plume based modeling software SCREEN view was used to find out the dispersion of emission from stack which aided in prediction of concentration of pollutants around stack. SCREEN View software also gives an idea about the modifications required in the technology to reduce the emission concentration from stack. This software was used with the help of general meteorological condition for finding ground level concentration of effluent from a stack at a particular hour.

A questionnaire was prepared to establish a relation between the waste management of electroplating industries and its impact on the health and well-being of the workers. The suitability of the work place for the workers was checked, along with the health complications the workers have due to the acid mist. Survey was done around the region of Industry A electroplaters and Industry B, located at Jogeshwari and Goregaon respectively. Health monitoring study was done on 47 people around the periphery of 500 m of the industries. Survey was conducted on people of 15-60 years of age residing in the vicinity of the industry. Maximum people surveyed were of the age 26-35 years which is the working population of the region. Workers who are routinely exposed to the emissions are susceptible to adverse health impact (Singh, 2014). Heavy metal exposure has been known to cause developmental retardation, different types of cancers, kidney damage, and even death in some instances of exposure to very high concentrations (Glover-Kerkvliet, 1995). A bio-monitoring study, conducted to assess the exposure in the electroplating industry showed that exposure to chromium and nickel compounds in the electroplating industry occurs via combination of inhalation, dermal and ingestion routes (Beattie et al., 2017).

4. Results and Discussion

The results obtained from the air pollution modelling study and human health impact assessment are discussed in Section 4.1 and 4.2, respectively.

4.1 Results of Air Pollution Study

The Occupational Safety and Health Administration (**OSHA**) is responsible for administering and enforcing the federal OSH Act of 1970. These regulations set out uniform national standards for workplace safety and health practices throughout the country. According to OSHA, the maximum allowed concentration of acid mist is 7 mg/m^3. Acid mist is a mist containing a high concentration of acid or particles of any toxic chemical. The input data consisted of emission rates, stack height, stack diameter, exit velocity and temperature of gases, ambient air temperature and wind speed.

4.1.1 Industry A Electroplaters

Industry A electroplaters had filter bags installed to control the air pollution caused due to fugitive emissions. This industry has a hood system connected to the pickling unit to control source emission/fugitive emission but the hood system was not provided at electrochemical bath. Air quality studies were conducted to analyse the emissions from the stack of Industry A Electroplaters. The input data is given in Table 2.

Table 2. Input Data

Source Type	Point
Emission rate (g/s)	0.049
Stack height (m)	3.04
Stack inside diameter (m)	1.0
Stack exit velocity (m/s)	1.4
Stack gas exit temp (k)	310
Ambient air temp (k)	293
Wind Speed (m/s)	1

The modelled results, as shown in Table 3, and the graph, as shown in Figure 2, gave details of the automated distances and concentrations at 100 m intervals from the stack. As the stack was short and large, it was found that ground level concentrations at 1m distance from the stack were the highest. The concentrations were found to be inversely proportional to the distances.

Table 3. Modelled Results

Distance (m)	Concentration (μg/m3)
1	71.57
100	57.7
200	25.2
300	17.21
400	11.90
500	8.69

As given in Table 3, the maximum concentration of acid mist at ground level was 71.57 μg/m^3 which is less than the prescribed limits. Hence, it can be concluded that the bag filters installed by Industry A Electroplaters for controlling fugitive emissions were working efficiently. And the hood provided for controlling acid mist emissions was beneficial. To decrease the emissions further, the stack height needs to be increased and the stack diameter should be decreased.

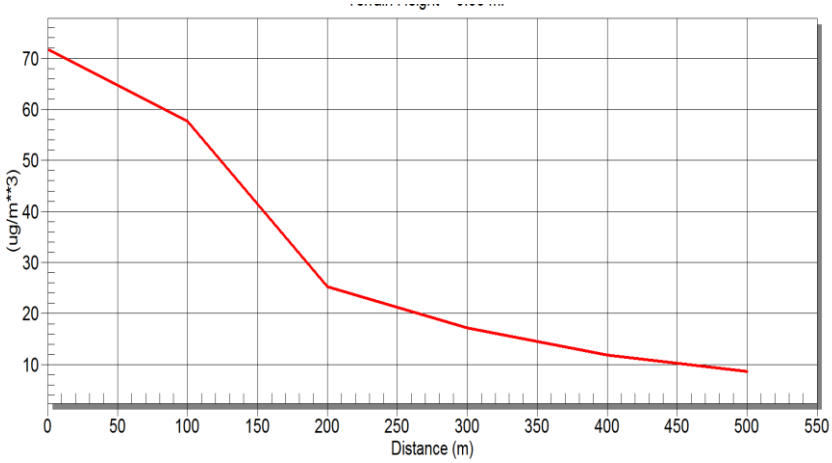

Figure 2. Automated Distances vs. Concentration

4.1.2 Industry B

Industry B is located in Goregaon East and specializes in jewelry coating. The pollution control unit here had hood systems connected to wet scrubber to control source emission/fugitive emission. The input data for Industry B is given in Table 4. The emission rates for Industry A and Industry B were found to be almost the same. However, the emission levels at the ground level differed for the two industries due to the difference in the stack heights.

Table 4. Input Data

Source type	**Point**
Emission rate (g/s)	0.0427
Stack height (m)	6.1
Stack inside diameter (m)	0.80
Stack exit velocity (m/s)	2.98
Stack gas exit temp (k)	310.00
Ambient air temp (k)	293.00
Wind Speed (m/s)	1

The diameter of the stack in Industry B. was smaller and hence there was proper dispersion of the emissions and the concentration at the ground level near the stack was significantly lower compared to Industry A Electroplaters. The modeled results for Industry B are given in Table 5.

Table 5. Modeled Results

Distance (m)	Concentration (μg/m^3)
1	0.00
100	37.63
200	14.30
300	11.97
400	8.98
500	6.84

From Table 5 and Figure 3, it can be concluded that the higher stack height and smaller diamater leads to better dispersion of gaseous pollutants and the pollutant concentration found at the ground level near the stack is almost negligible. Highest concentration was observed at a distance of 100m from the stack and was found to be 37.63 μg/m^3 which is significantly lower than the standards prescribed by OSHA. This implies that the industry is taking sufficient air pollution control measures for treating the acid mist that is generated during the electroplating process.

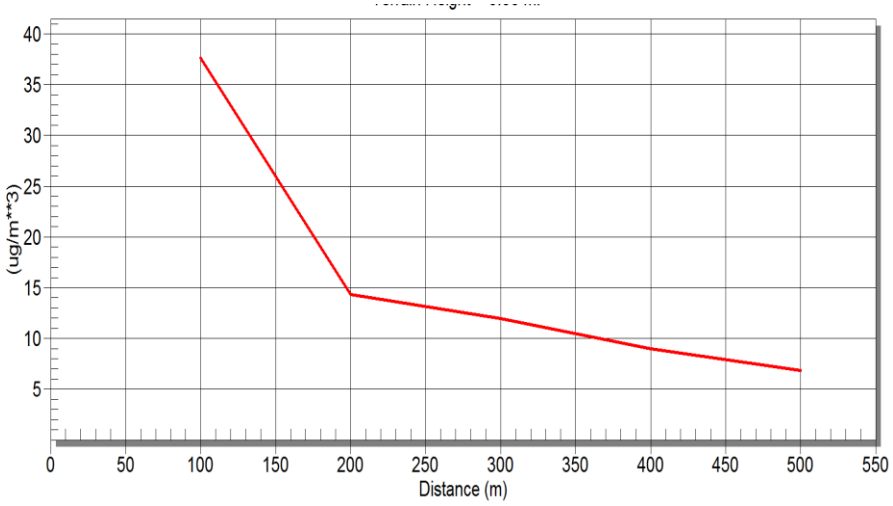

Figure 3. Automated Distances vs. Concentration

4.2 Results from Questionnaire for Health Impact Studies

The results obtained from the questionnaire survey for the health impact study has been summarized in this Section.

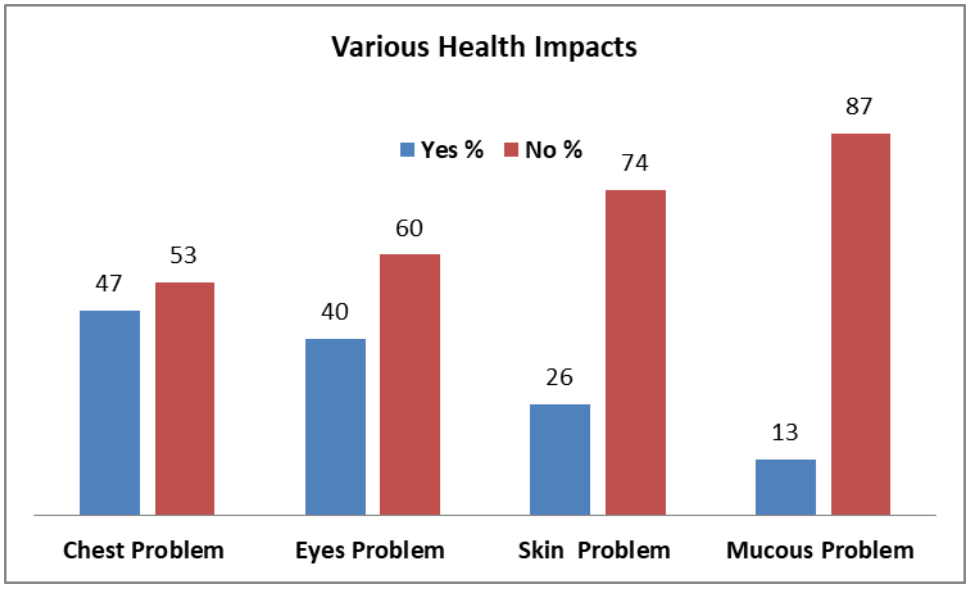

Figure 4. Percentage Responses of People on Various Health Impacts

Figure 4 gives the results of the survey and it can be seen that the chest problem (47%) is the most predominant health issue faced by the people living in the vicinity of the industry, followed by eye irritation at 40% and skin problems at 26%.

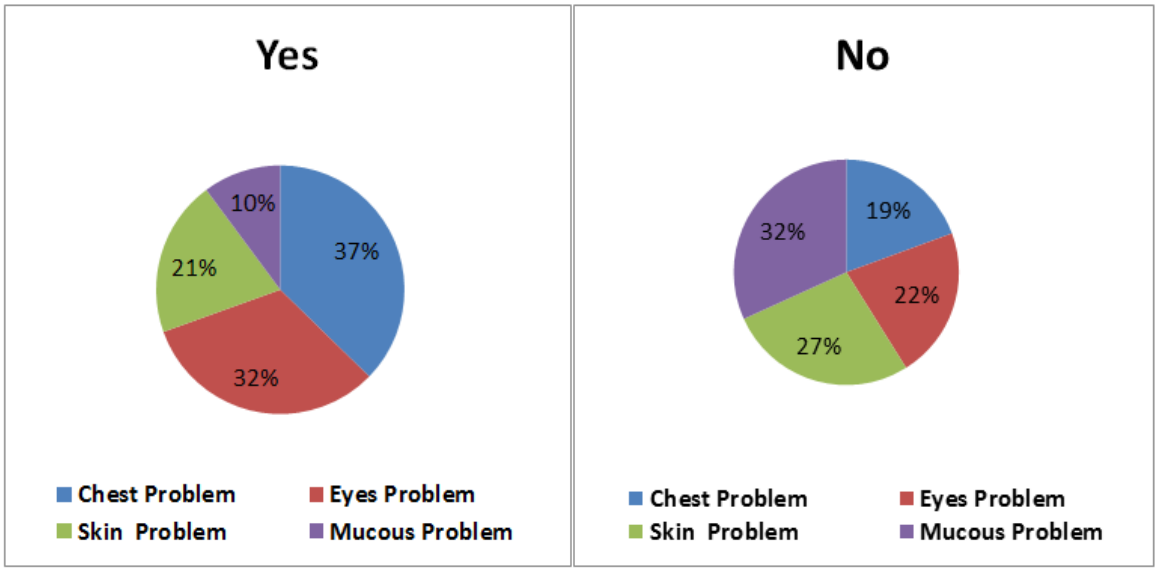

Figure 5. Percentage Representation of Response of People Who Said Yes

As seen from Figure 5, among all the people who reported of having any health issue, the maximum number of people (37%) have chest related problems while the minimum number of people (10%) have mucous membrane irritation problem. Around 32 % of the people claimed of experiencing eye irritation. This can be due to the fumes that are generated in the electroplating operations like pickling, degreasing and electrochemical bath. It was observed that the people above 35 years of age were more susceptible to health problems than the younger people.

Response for Chest Related Problems

The most common health problems in electroplating industry are related to chest. This could be due to the constant exposure to toxic chemicals and fumes which were emitted into the atmosphere without any prior treatment. Figure 6 shows results from the survey which was specifically focused on chest related problems like breathlessness, chest tightening, watering eyes and blocked/runny nose. During this survey, it was observed that many of the people were claiming to have these problems.

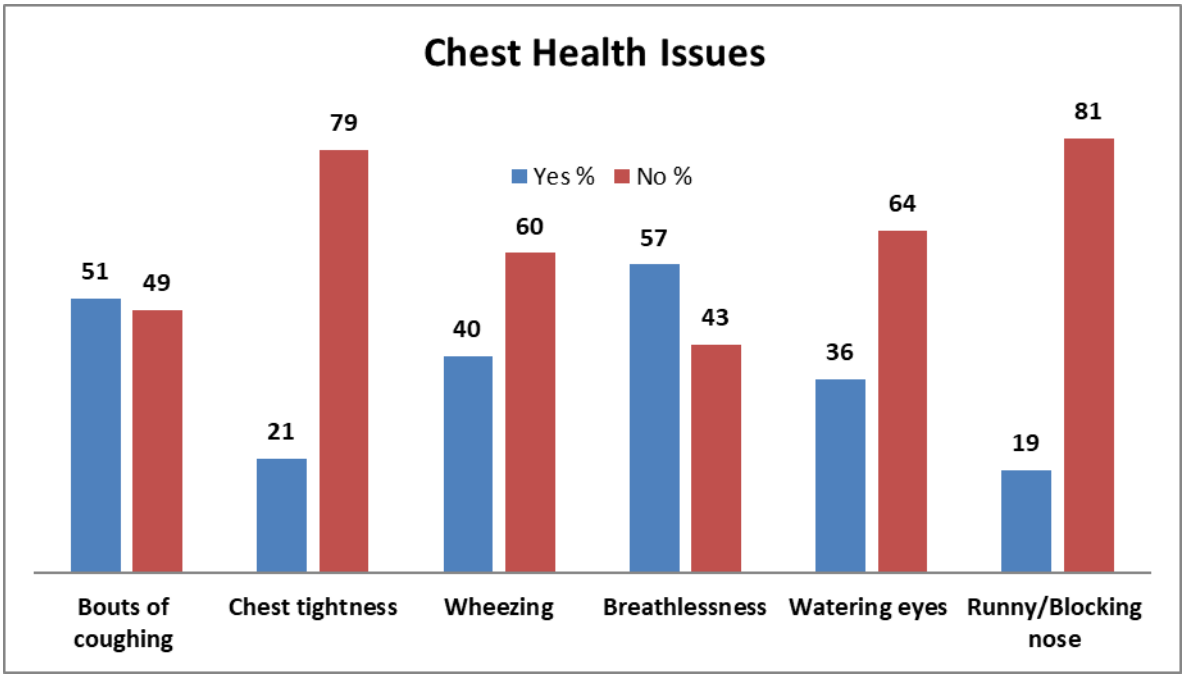

Figure 6. Percentage Responses for Chest Health Issues

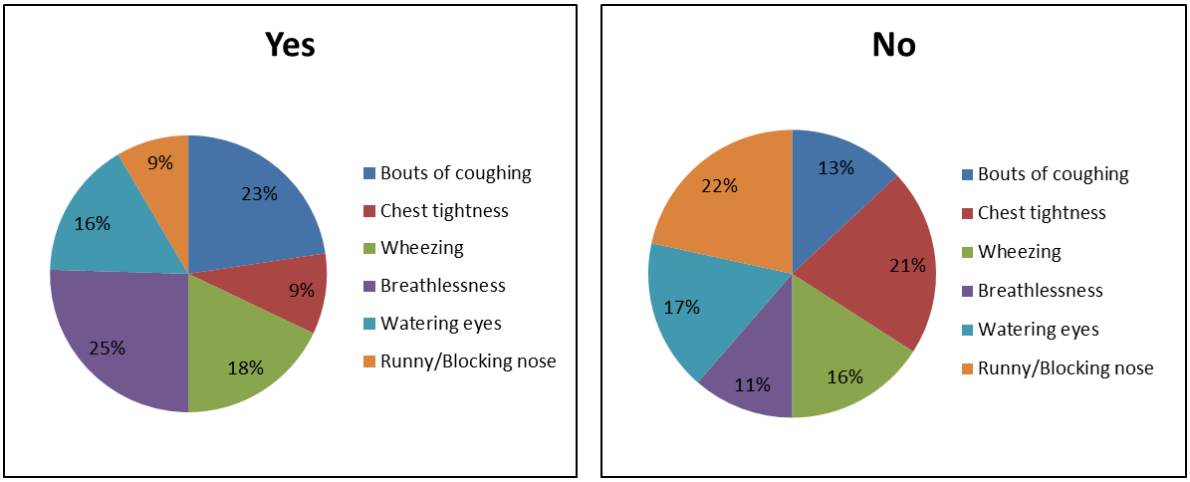

Figure 7. Percentage Representations of People Who Said Yes and Had Chest Issues

It can be observed from Figure 7 that more than half of the people approached claimed to have some form of chest problems like bouts of coughing and breathlessness. Among the people with chest problems, 9% people reported chest tightness, 23% reported bouts of coughing, 9% of them have running/ blocking nose, 16% were suffering from watering eyes, 18% were having the problem of wheezing. The maximum number of people (25%) claimed to have breathlessness while watering eyes and bouts of coughing can also be seen as major problems.

These health issues could be due to the long term exposure to acid mist which is present in high concentration in the ambient air in the region. People living near the industries which do not use scrubbers and fume hoods are at a great risk of heavy exposure to these acid fumes. It was also observed in the survey that the people were mostly suffering from chest problems and respiratory disorders as these fumes were affecting their lungs.

5. Conclusions and Recommendations

Electroplating industry generates gaseous emissions, wastewater and solid waste. Acid mist is predominant in the air emissions because of extensive use of highly concentrated acid. Very few industries have proper control technology for treating liquid effluent and gaseous emissions. Since most of these industries are operated at small scale, they cannot afford to have proper control and treatment equipment. Installing such treatment equipment will increase the cost of their products compared to the rest of the market. SCREEN View modeling software was conducted to find the acid mist dispersion concentration from the stack. It was observed that emissions from industries undertaken for study were below the consented limit of acid mist from stack given by Maharashtra Pollution Control Board (MPCB). The modeling study showed that the concentrations of acid mist at ground level were 71.57 $\mu g/m^3$ and 37.63 $\mu g/m^3$ for Industry A Electroplaters and Industry B, respectively. It can be concluded from the study that in order to have lower acid mist concentrations at ground level, higher stack height and smaller stack diameter should be provided.

From the results of the health monitoring survey, it can be concluded that majority of the people who are staying around the electroplating industries are suffering from chest problems, eye irritation and ulcers. Immediate steps need to be taken in order to protect the health of the people living in nearby areas.

Installation of scrubbers will control acid mist emissions. Also, minimizing the use of raw material, reducing the drag out losses, modification of rinsing technique, and replacement of hexavalent chrome by trivalent chrome can further reduce the negative impacts in the environment caused due to electroplating industries. Installation of air pollution control equipment like electrostatic precipitator, fabric filters, cyclone separators and settling chambers should be done for removal of particulate matter. Acid fumes hood should be used for coverage of fugitive emissions through ventilation process. However, coverage of fugitive emissions should be done by providing hood to collect acid fumes through ventilation process.

Clustering is recommended for the electroplating industries in the MMR region. Shifting all the electroplating industries to a common place will directly affect the growth and development of the industry. It will also help in stabilizing the electroplating market.

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