Chapter 3
Marble Dust as an Environmental and Occupational Hazard

Salma Khalid, Mohsina Haq, and Zia-Ul-Ain Sabiha

Abstract With the increase in urbanization over the last century, mankind is enjoying sophisticated modern architecture. The use of different types of naturally occurring and synthetic materials is becoming very popular at industrial and domestic levels. Marble being a natural metamorphic rock is commonly used by our society because of its beautiful colors, easy maintenance, and lifelong durability. The other side of the picture of marble use is very ugly because of the environmental and health hazards that are caused by the marble industry.

Marble dust is produced by marble factories during the refinement and processing of raw marble into glass polished tiles, slabs, and tabletops. The dust produced during this process is added as a pollutant to the environment or is inhaled in high concentrations by the workers via the respiratory tract, thus making them more prone to chronic pulmonary diseases. These particles being highly irritant and allergic cause respiratory disease affecting both upper and lower respiratory tracts ultimately leading to decreased respiratory functions. Different literature showed that workers and residents living in areas adjacent to marble/granite factories are prone to lung disease, e. g., silicosis.

Also, dry cough and shortness of breath are the commonest complains with which these workers present. In spite of the latest advancements in medical field, only supportive treatment (antihistamine, Montelukast, and bronchodilators) can be given to these patients if preventive measures are not taken on time.

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International Agency for Research on Cancer (IARC) classified marble dust, heavy metals, and crystalline silica as carcinogens in 1997. International Labor organization (1919) protects workers' right and thus demands effective prevention techniques, safe working places, and awareness programs regarding commonly addressed health issue for the workers working in industries. If effective treatment is not given to workers who have developed the above-mentioned health issues on the right time, they might develop an end-stage lung disease (chronic lung disease/ lung cancer). Different epidemiological studies show that workers exposed to marble dust have an increased risk of developing chronic asthma, chronic bronchitis, and impaired lung functions and even lung cancer.

Marble dust, other than having serious health issues, can have a considerable economic impact as well; like decrease in working productivity, increase in health expenditure per person, and increase in mortality and morbidity. Health being the basic right of man, strict preventive measures should be taken for and by these workers as they constitute a substantial number of chronically affected patients of respiratory tract.

3.1 Introduction

With the increase in urbanization over the last century, mankind is enjoying sophisticated modern architecture. The use of different types of naturally occurring and synthetic materials is becoming very popular at industrial and domestic levels. Marble being a natural metamorphic rock is commonly used by our society because of its beautiful colors, easy maintenance, and lifelong durability. Today, half of the world's marble extraction is mostly from six countries; Italy, China, India, Spain, Egypt, and Turkey. However, marble is produced by many other countries too (Ciccu et al. 2005).

The other side of the picture of marble use is very ugly because of the environmental and health hazards that are caused by the marble industry (Corinaldesi et al. 2010). Mechanical breakdown and other procedures of marble dealing have not only considerable effects on the environment but also on workers' health and safety and the communities residing in nearby villages. Cumulative impacts include lack of environmental protection, rehabilitation measures, community engagement, and inappropriate and unsafe operational procedures (Bui et al. 2017; Gorman and Dzombak 2018; Nuong et al. 2011). Well, in fact, the recognized truth is that the marble industry provides much-needed opportunities for employment to the poorest families of the nearby communities (Paracha 2009).

This particular industry in its present state is confronting different challenges along with the devastating conditions of the worker like fatal injury including rock fall, fires, explosions, mobile equipment accidents, falls from height, gas explosion, suffocation, and entrapment. Less common but recognized causes of fatal injury include flooding of underground workings, wet-fill release from collapsed bulkheads, and air blast from block caving failure (Donoghue 2004). In addition to this, workers are also exposed to toxic chemicals and dust that take a toll on their health (Ashraf and Cawood 2017). There is no mechanism to provide compensation to ailing or injured mine workers, to the families of those killed on the job, or to rural communities affected by mining operations (Azad et al. 2013). Linked to these issues, the International Labor Organization (ILO) estimated that about 2.3 million people die due to occupational accidents and occupational diseases, 317 million suffer from serious nonfatal occupational injuries, and 160 million suffer from occupational illnesses and most of them belong to rural areas in less developed countries (Takala et al. 2014).

Mechanical breakdown like grinding, cutting, drilling, crushing, explosion, or strong friction results in emission of dust. All over the world, the marble industry is considered a high waste-producing industry. It is estimated that round about 70% of the precious marble is wasted as marble dust during the procedures of mining and polishing. This wasted marble is dumped in roads, rivers, and agricultural fields and causes environmental pollution and generation of marble dust (El-Gammal et al. 2011; Gazi et al. 2012). This polluted environment directly or indirectly affects health by polluting the air quality (Nakao et al. 2018). The dust that penetrates inside the lungs is particulate matter (PM), and usually 15–20% of cases of common chronic obstructive pulmonary disease (COPD) are linked with prolonged occupational exposure to dust, vapors, gases, and fumes over a long period of time (Azizah 2019; Borup et al. 2017; Faisal and Susanto 2017; Sudrajad and Azizah 2016) (Fig. 3.1).

The particulate matter ($PM_{2,5}$) enters the alveoli and causes inflammation and reduces lung function. The maximum harmful exposure to particulate matter is measured (10 mg/m_3) for 8 h. The dust particulates are divided into two categories, namely PM_{10} and $PM_{2.5}$ (Khoiroh 2020) (Table 3.1). Dust clouds in a working place

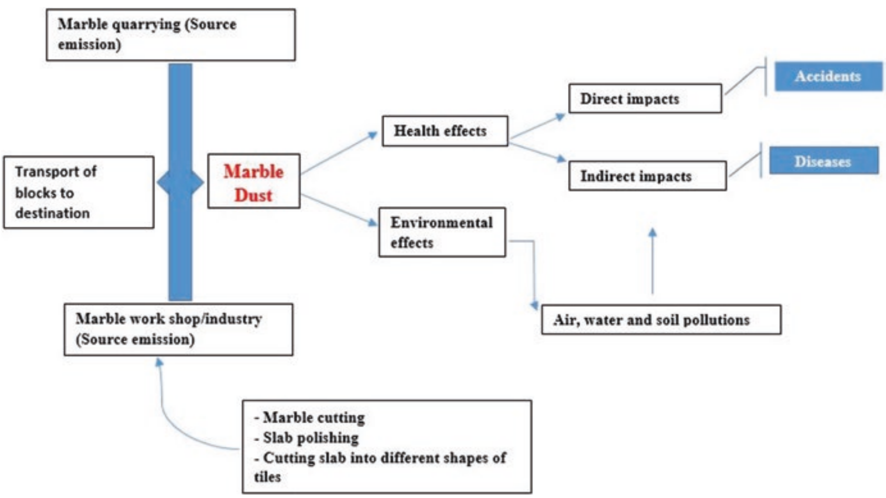

Fig. 3.1 Exposure of workers to marble dust as occupational hazard

Table 3.1 Exposure to dust concentration and rate of intake in different media

Variable	Exposure concentration in different parameters	Rate of intake
Concentration in media	Mg/l (Water)	l/hour, l/day
	mg/m^3 (Air)	Mg/inhaled per minute or per hour
	Mg/100cm^2 (Contaminated surface)	Mg/kg body weight ingested per day or per meal
Quantity available for absorption (Potential dose)	Mg inhaled, total	
	Mg inhaled/kg body weight	
	Mg ingested total	
	Mg ingested per kg body weight	
	Mg-on skin total	
	Mg/cm$_2$ skin area	

reduce visibility and deposited dust may cause slipperiness, increase the risk of accidents, and lead to degradation of materials and environmental pollution due to its deposition on various structures, machinery, and equipment (Park 2005).

In addition, fine dust covers the ground and prevents rainwater from percolating into the soil. Marble dust also destroys plants by covering their leaves and reducing exposure to sunlight which indirectly affect the health (Noreen et al. 2019).

To avoid the occupational factors and conditions hazardous to the health and safety of workers, such as occupational diseases and workplace accidents, the protection and promotion of the health of workers are necessary. Nowadays, it is considered an occupational health multidisciplinary and comprehensive approach that includes general health, the worker's physical, mental, and social well-being, and personal development (Humans and Cancer 2006).

3.1.1 Potential Hazards from Marble Quarrying to Waste

Marble dust is produced from marble quarrying by cutting of rocks to marble factories during refinement and processing of raw marble into glass polished tiles, slabs, and tabletops. The dust produced during this process is added as a pollutant to the environment or is inhaled in high concentrations by the workers via the respiratory tract, thus making them more prone to chronic pulmonary diseases (Rajgor and Pitroda 2013). These particles being highly irritant and allergic cause respiratory disease affecting both upper and lower respiratory tracts ultimately leading to decreased respiratory functions (Chen et al. 2012). Different literature showed that workers and residents living in areas adjacent to marble/granite factories are prone to lung disease, e.g., silicosis (Nij et al. 2003). People with silicosis have a higher risk of developing tuberculosis (Álvarez et al. 2015). Similarly, various epidemiological studies indicate that workers exposed to marble dust have an increased risk of occupational asthma, impairment of lung function, chronic bronchitis, renal impairment, and nasal inflammation (Angotzi et al. 2005; Armaeni and Widajati 2016; Leikin et al. 2009; Morton and Dunnette 1994; Pulungan 2018). Workers are exposed to marble dust, heavy metals, and crystalline silica, which are classified as known carcinogens by the International Agency for Research on Cancer (IARC) in 1997 (Golbabaei et al. 2004; Scarselli et al. 2008; Yaghi and Abdul-Wahab 2003; Yassin et al. 2005). Marble dust is abrasive in nature and causes allergies to the skin (Scleroderma) and eye irritation. Workers with these diseases can go undiagnosed and untreated, and worst of all, effective preventive measures are not taken because of a lack of awareness of the problem. Also, dry cough and shortness of breath are the commonest complains these workers present. In spite of the latest advancements in medical field, only supportive treatment (antihistamine, Montelukast and bronchodilators) can be given to these patients if preventive measures are not taken on time.

3.1.2 Exposure to Marble Dust Concentration

Different processes involved in marble quarrying to marble workshop produce marble dust cloud into the atmosphere. Occupationally, these workers are exposed to high content of dust in their workplace during their routine working hours (Bickis 1998), which is known as "primary airborne dust" (WHO 1999). This dust comprises of particle sizes in the range of 1–400 μm, and particles larger than 100 μm easily settle down near the source. All these dust particles are divided into three size ranges, i.e., larger than 20 μm are termed large particles and 20–1 μm and less than 1 μm as fine and ultrafine particles, respectively (Leonard 1979). The particle size of a dust cloud may be different from that of the powder originated from its source. The determinants include the amount (mass), distribution of particle size, falling height from parental rock, material flow and moisture content and air movement in the workplace, etc. (Bickis 1998). Exposure of an individual to the workplace and their integration with the exposed media, dust concentration, and in relation to time can be calculated by the following equation.

3.1.3 Calculation of Exposure

$$Ej = \int_{t1}^{t2} Cj.(t)\,\mathrm{dt}$$

Where

Ej = exposure of the individual
$\int$ = integrated with exposure media

C = concentration of marble dust
d = exposure dose (mg/kg/day)
t = for a time period (Detels et al. 2011)

The main crystalline composition of minerals present in marble dust includes magnesium calcium bis (carbonate) (MgCa $(CO_3)_2$) and calcium magnesium aluminum catena- alumosilicate (Demirel 2010).

3.1.4 Inhalable and Respirable Marble Dust

The US Environmental Protection Agency (EPA) defined respirable dust as particulate matter less than 10 μm in diameter. Respirable dust enters into the lungs and causes pneumoconiosis in workers on prolonged exposure. In the working place, the quality of air must be maintained by keeping the concentration of respirable dust 2 mg/m^3 (Speight 2020) (Table 3.1). Marble dust other than having serious health issues can have a considerable economic impact as well, like decrease in working productivity, increase in health expenditure per person, and increase in mortality and morbidity. Health being the basic right of man, strict preventive measures should be taken for and by these workers as they constitute a substantial number of chronically affected patients of the respiratory tract.

3.2 Health Hazards at Workplace and in the Surrounding

Exposure to dust has always remained a known cause of occupational lung diseases. Different regulatory authorities have always tried to produce and maintain occupational guidelines and standards to minimize the exposure of workers to such inhalable particles that can ultimately result in end-stage lung conditions.

There are different routes through which workers are exposed to these occupational hazards. These routes are percutaneous routes, respiratory routes, and oral routes (Davidson and Davidson 1984; Gray and Harrison 2004; WHO 1999).

The most common health hazards at workplace and in the surroundings are as follows:

3.2.1 Silicosis

Overexposure to free crystalline silica's dust leads to a fibrotic lung disease that is called silicosis. This is a serious lung condition, and if not treated on time, it can prove to be fatal. It is a slow but irreversible, progressive, and fatal condition of the lungs. The severity of the disease depends upon the exposure time and the amount of free crystalline silica that is inhaled and eventually gets deposited in the alveolar region (exchange of pure oxygen takes place).

Depending upon the duration of exposure, silicosis is divided into two major types, acute silicosis and chronic silicosis.

3.2.1.1 Acute Silicosis

Acute silicosis occurs after a few months to a maximum two years of exposure to silica's high concentration. The patient experiences difficulties in breathing (dyspnea), which later on may become very severe. This respiratory insufficiency is the result of fibrosis and emphysema which ultimately causes cor pulmonale and leads to death.

3.2.1.2 Chronic Silicosis

In chronic silicosis, symptoms show up after a decade after the person is exposed to low or moderate amounts of silica. The symptoms might be mild at first, and then with the passage of time, they will slowly worsen (Davidson and Davidson 1984; Gray and Harrison 2004; Richards 2003; WHO 1999).

3.2.2 Chronic Obstructive Pulmonary Disease (COPD)

Chronic obstructive pulmonary disease is characterized by poor airflow and long-standing breathing disorder. COPD mostly presents with dyspnea, shortness of breath, and productive cough. COPD is a progressive disorder and it worsens with the passage of time slowly affecting the quality of life. A person who suffers from COPD ultimately becomes so crippled that he/she cannot carry out his/her daily routine work easily because of difficulty in breathing. Emphysema and chronic bronchitis are now collectively named under the heading "COPD"

In developing countries, COPD is also the result of occupational health hazards. Prolonged exposure causes an inflammatory response in the lungs that leads to the narrowing of air passages and ultimately affecting the normal architecture of lung parenchymal tissue. This leads to poor exchange of gases inside the lung tissue, thus affecting the breathing of a person. Workplace exposure is believed to be the cause in 10–20% of the cases. Some industries producing high levels of dust like coal mines, cotton textile, silica, and fiberglass can lead to COPD (Davidson and Davidson 1984; Gray and Harrison 2004; Richards 2003; WHO 1999).

3.2.3 Pneumoconiosis

Pneumoconiosis is defined as “the accumulation of dust in the lungs and the tissue’s reaction to its presence”. It is basically caused by the dust inhaled in the workplace; that is why it is called occupational lung disease. The severity of Pneumoconiosis depends on the amount of dust particles inhaled. The most common type of it is called “miner lung”. Other forms of pneumoconiosis depend on inhalation of excessive amounts of iron oxide resulting in siderosis, inhalation of tiny particles causing stannosis, inhalation of beryllium causing berylliosis, talc, graphite, and mica (Davidson and Davidson 1984; Gray and Harrison 2004; Richards 2003; WHO 1999).

3.2.4 Lung Carcinoma

Many dust particles such as silica, asbestos, wood dust, and radioactive particles are known as carcinogens, leading to lung cancer, mesothelioma, nasal cancers, and blood carcinomas. Some particles, like those of silica, asbestos, and radioactive particles, get deposited in the lungs, causing cancer of the lung tissue. Carcinomas due to asbestos (mesothelioma) have been linked to occupations such as that of building maintenance, ships maintenance, etc.

The establishment of carcinoma depends upon the exposure time of workers to certain chemicals. The minimum the time between exposures, the minimum is the chance of development of Ca if proper preventive measures are taken (Davidson and Davidson 1984; Gray and Harrison 2004; Richards 2003; WHO 1999).

3.2.5 Skin Disorders

Skin being the largest organ of the body helps us to protect the inside of our body from the harsh environmental factors. Occupational skin disorders are caused when there is direct contact of a worker with one or more hazardous substances. Workers can come in contact with such substances via handling tools, dipping/immersion of objects or substances in chemicals, etc. These procedures lead to disruption of the normal barrier function of the skin.

The commonest occupational skin disorders include contact dermatitis, folliculitis, skin infections, and skin cancers.

The most common side effects are seen in hands and arms as they are most frequently in contact with chemicals in working areas. The commonest of all the above-mentioned conditions is contact dermatitis, which clinically appears as inflammation of skin, redness, dryness, blistering, scalding-like appearance, and starts to bleeds.

Infection of hair follicles means folliculitis. This condition is common in those workers who are exposed to minerals and soluble oils. Skin cancers are common in workers who deal in UV radiation industries, nuclear power plants, and industries dealing with tar products (Davidson and Davidson 1984; Gray and Harrison 2004; Richards 2003; WHO 1999).

3.2.6 Ophthalmic Disorders

Occupational ophthalmic diseases have a long latent period. Most of them cannot be treated, but all of them are preventable. Occupational eye illness can be divided into: chemical injuries; radiation injuries; electrical injuries; heat injuries; etc.

In industries, workers deal with different kinds of chemicals, especially liquids and gases. These are of major concern causing injuries to eyes, for example, if liquid chemicals splash into a worker's eyes giving him acidic/basic burns, it ultimately leads to the scarring of cornea if not treated on time. Same way, fumes, gases, and vapors can also damage the eyes.

Different forms of radiations, for example, UV radiations, infrared radiations, and high source visible light, can also damage the sensitive area of the eye that is called Retina. In industries like glassblowing and steel making, workers are exposed to high intensity of light which can cause irreparable damage.

Electrical cataracts have been reported to be a cause of electrical injuries.

Corneal tissue scaring and corneal damage are common in workers who deal with heat as a source of energy in industries (Davidson and Davidson 1984; Gray and Harrison 2004; Richards 2003; WHO 1999).

3.2.7 Occupational Renal Disorders

There are certain industries that have direct impact on renal functions of the workers working in them, for example, industries of mercury, cadmium, lead, and silica. These industries produce nephro toxins (those chemicals that affect renal functions via direct toxic action).

The most common occupational renal disorders are acute renal dysfunction and chronic renal insufficiency.

Acute renal dysfunction is of sudden onset and develops hours to days after the exposure to a specific toxin. It causes the necrosis of tubules and is also called acute tubular necrosis ATN. It is characterized by decreased output of urine (less than 500 ml/day). On microscopic examination of urine, there are renal tubular cells, cellular casts, and little or no proteins.

Chronic renal insufficiency develops slowly over time. Symptoms develop slowly and include nausea, vomiting, loss of appetite, stomatitis, nocturia, and seizures. However, final diagnosis is based on renal biopsy (Davidson and Davidson 1984; Gray and Harrison 2004; Richards 2003; WHO 1999).

3.3 Health Hazards Due to Inappropriate Management

The poor working conditions, not only at mines but also at workshops, increase the work-related issues and also make a big chunk of the population vulnerable to occupational diseases and disorders and also increase government budget on health-related issues (Jiskani et al. 2020).

Worldwide, the prevailing key issues in the marble sector are:

- Use of old techniques/machinery
- Financial constraints
- Institution mismanagement
- Lack of experts and technical knowledge
- Lack of workers' safety measures, etc.

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The prevailing issues call for a great attention of the government as well as the stakeholders towards health protection of the workers, provision of better working environment, (Jiskani et al. 2019) workers training, and implementation of strict guidelines.

3.4 Hazard Prevention and Control

Hazard prevention and safety measures should be taken into account in the workplace either in the quarry or in the marble workshops with increased emphasis on risk management. The risk management not only benefits in a healthier and happier workforce and increased productivity but also protects the health of the workers and promotes the economic well-being of the country. It requires the involvement and cooperation of management and administrative support, workforce with technical knowledge and experience, occupational health professionals, allocation of suitable financial resources, and political will. A multidisciplinary approach should design, implement, and maintain dust emission and control strategies to prevent health hazards and occupational disease at a workplace. The impact of these concerns over the whole field of occupational health and safety has been considered in an ILO publication (Brune 1997). Several measures for the prevention of health hazards and occupational diseases are grouped under three main headings: medical, engineering, and legislative.

3.4.1 Medical Measures

It is the basic requirement of occupational health. The implementation of medical measures includes periodical examination and clinical evaluation should be carried out at least once a year. In addition to workers' health history and physical examination, specific laboratory tests must be carried out every one or two years, such as spirometry and chest radiography in quarrymen exposed to dust as well as those exposed to noise in marble processing. In preplacement examination, the fresh candidate may totally be rejected or may be given a job on the basis of a thorough physical, biological, and radiological examinations. Special test for endemic disease and medical history of worker having anemia, hyper tension, kidney disease, family history like asthma, skin bladder disorders, occupational history, and social history (exposure if any other) must be considered before induction. First aid services must be provided at work in case of accident or any causality. There should be provision of medical as well as immunization services and health insurance schemes for workers and their families. Periodic inspection of working environment should be carried out for checking temperature, lighting, ventilation, humidity, noise, air pollution, and sanitation. Occupational physician should be familiar with the raw material processes and products manufactured and dust produced at workplace and adverse health consequences. Also, it is important to maintain the workers' health and disability record too. Arrange health education and counselling programs for workers to reinforce them to use PPE (masks, gloves, and goggles) in workplace to protect their respiratory airways and lungs (Angotzi et al. 2005; Park 2005).

3.4.2 Engineering Measures

The other most significant measures for reducing health hazards in the marble industry are appropriate engineering procedures, because worldwide, this industry is known as the most labor-intensive industry. There should be adequate building design for industry, good housekeeping to boost the morale of the worker, and general ventilation and for dust, which settle down on the machinery, floor, racks, and beams should be promptly removed by vacuum cleaner or by wetting agent. The wet method should be tried to combat dust with regular water spray as moisture in processes of grinding, sieving, and mixing. Hood should be used for suction of dust, fumes, and gases into the collecting units. Mask, apron, gloves, respirator, and other protective equipment should be regularly used and general hygiene should be maintained. The workers should be educated about the type of respirator to use and when and how to use. For protection against noise pollution and other workplace factors, air plugs, ear muffs, helmets, safety shoes, gumboots, barrier creams, screen, and goggles should be reinforced and the worker should be trained for the appropriate use of the protective devices. The good machined plant will play a positive role in reducing the hazards of the contact with the harmful substances to the fullest possible extent. Dermatitis can be prevented if hand mixing is replaced by good mechanical devices. Grinding machine can be completely enclosed and combined with exhaust ventilation. Further research and periodical environmental surveys should be carried to determine whether the dust and other gases escaping in the atmosphere are within the permissible limits or not (Park 2005).

3.4.3 Legislation

Many countries around the world have comprehensive occupational health legislations, like the "Occupational Safety and Health Act (1970) legislation in the United States. In 1974, a regulation was enacted in the United Kingdom, "Health and Safety at Work Act," and further, the European Union adopted a policy in 1989 on the "Fundamental Social Rights of the Workers". The main goal of occupational health legislation is to ensure a safe and healthy working environment along with strong emphasis on primary prevention of health hazards. Proper implementation of legislation develops and promotes a positive social culture and enhances smooth operations and increases the productivity of the working environment. Different countries have different occupational safety and health practices such as legislation, guideline, enforcement, and incentives. Some nations adopted a pooling system and some have health and safety insurance system for their workers. For instance, some member states in the European Union promote Occupational Safety and Health (OSH) programs by providing grants and subsidies and tax system incentives for compliance (Elsler 2007; Esler et al. 2010). But significant variations were observed in compliance of occupational safety and health between countries, economic factors, and sizes of enterprise because the number of fatalities is more in the developing countries as compared to developed countries (World Bank 1995).

3.5 Conclusion

International Agency for Research on Cancer (IARC) classified marble dust, heavy metals, and crystalline silica as carcinogens in 1997. International Labor organization (1919) protects workers' right and thus demands effective prevention techniques, safe working places, and awareness programs regarding commonly addressed health issues for the workers working in industries. If effective treatment is not given to workers who have developed the above-mentioned health issues at the right time, they might develop an end-stage lung disease (chronic lung disease/lung cancer). Different epidemiological studies show that workers exposed to marble dust have an increased risk of developing chronic asthma, chronic bronchitis, and impaired lung functions and even lung cancer. Marble dust other than having serious health issues can have a considerable economic impact as well; like decrease in working productivity, increase in health expenditure per person, and increase in mortality and morbidity. Health being the basic right of man, strict preventive measures should be taken for and by these workers as they constitute a substantial number of chronically affected patients of the respiratory tract.

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