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Earthquake and respiratory pollutants

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Abstract:

Among natural disasters, earthquakes rank as some of the most destructive. The release of particulate pollutants and chemicals during earthquakes, both from natural events and subsequent demolition works, can have severe health repercussions. Acute pulmonary consequences include infections, inhalation injurie,s and airway obstructions, while chronic pulmonary effects encompass interstitial diseases such as silicosis and asbestosis, obstructive diseases, and cancers. It is crucial for both earthquake victims and search and rescue workers to have protection through effective engineering measures, management strategies, and personal protective equipment. The impact of disasters such as earthquakes on breathable air varies based on the geological structure of the region, local industrial, agricultural, and animal husbandry activities, as well as the existing infrastructure. This review will delve into the interrelation between earthquakes and respiratory pollutants under three sub-topics: respiratory pollutants, acute and chronic health outcomes, and preventive health measures.

Keywords:

Earthquake, health effects, occupational and enviromental lung diseases, respiratory pollutants

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Introduction

On February 6, 2023, our country experienced two consecutive major earthquakes, impacting an area spanning approximately 1,200 km across ten provinces. Beyond the immediate ramifications, earthquakes have lasting effects in both socioeconomic and health spheres. Undoubtedly, the respiratory system is among the most adversely affected. Earthquake victims, search and rescue teams, debris removal crews, and field workers face significant risk in this regard.[1–3] According to the "Air Pollution Report Card: Black Report 2022" by the Right to Clean Air Platform, air pollution levels in earthquake-affected cities are 2.5 times higher than Türkiye's limits and 7.5 times higher than the World Health Organization (WHO) guideline values. This surge in pollution is primarily attributed to debris dust and the widespread use of open fires for heating.[4] The Environmental Impact Assessment report further notes that pollution levels at the station in central Iskenderun, Hatay were 10–20 times above the WHO reference value on certain days.[5]

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The impact of disasters like earthquakes on air quality varies based on the geological structure of the affected area, local activities including industry, agriculture, and animal husbandry, as well as the infrastructure present. For example, in a region hosting an atomic power plant or a nuclear research center, an earthquake could lead to the release of radioactive materials. Therefore, it is crucial to determine the specific risks for each region through up-to-date mapping before such disasters occur.

Respiratory Pollutants

Respiratory pollutants can be vategorized into two main groups: particulate pollutants and gaseous pollutants. The US Environmental Protection Agency defines respiratory particulate pollutants or particulate matter (PM) as a collective term for a mix of solid and liquid droplets suspended in the air. PM can vary in size and shape and can be composed of several different components such as acids (e.g., sulfuric acid), inorganic compounds (like ammonium sulfate, ammonium nitrate, and sodium chloride), organic chemicals, biological materials (e.g., pollen and mold spores), soot, metals, and soil or dust particles.[6] PM 10 refers to respirable particles that are usually 10 micrometers in diameter and smaller. Their sources includes dust from construction sites, landfills, agriculture, forest fires, brush/waste burning, industrial emissions, windblown dust from open lands, and biological particles such as pollen and bacteria. PM 2.5 represent fine respirable particles that are usually 2.5 micrometers in diameter or smaller. They primarily originate from combustion emissions, including those from gasoline, oil, diesel fuel, and wood. Ultrafine PMs measure up to 0.1 micrometers. Notably, over 90% of the solids in diesel exhaust have diameters smaller than 1 μm. Contemporary fossil fuel combustion technologies, especially those associated with diesel, produce particles that can adsorb greater quantities of reactive oxygen species due to functional groups on their surfaces, increasing the toxicity of ultrafine PMs. Nanoparticles are substances with sizes smaller than 0.02 micrometers.[7] Debris generated during and after earthquakes is predominantly construction waste, which includes materials like concrete, sand, gravel, bricks, ceramics, natural rocks, rubble, asphalt, wood, various metals, glass, fluorescent lamps, plastics, carpet fragments, and insulation materials.[8]

All the pollutants previosuly mentioned can increase following earthquakes, with dust and fiber being of particular significance. According to the WHO, dust comprises small solid particles, ranging from 1–100 microns in size, which remain suspended in the air for some time before settling due to their weight. Health-related examples of dust include mineral dust from the extraction and processing of minerals (e.g., silica), metallic dusts such as those from lead and cadmium and their compounds, other chemical dusts like bulk chemicals and pesticides, plant-based dusts from sources like wood, flour, cotton, and tea, as well as pollen, molds, and spores. These types of dust are prevalent during earthquake-induced destruction, such as that of roads and buildings, and during the subsequent reconstruction phases. Whether a particle in the air is inhaled is determined by its aerodynamic diameter, the velocity of the surrounding air, and the breathing rate of individuals.[9] Respirable dust size is characterized as having an aerodynamic equivalent diameter of 0.1–5.0 μm. For crystalline or amorphous dust, the diameter is less than three microns, whereas for fibers, it has a length at least three times its diameter. In our country, the threshold limit value for personal exposure to respirable inert dust in the environment is set as 5 mg/m3, as stipulated in Annex-1 of the Regulation on Control.[10] A study evaluating personal exposures to both inhalable and respirable dust at post-earthquake construction sites found that values exceeded this limit across all tasks.[11] Silica, a predominant type of dust, is a naturally occurring mineral that comprises approximately 59% of the Earth's crust's mass and is the principal component in over 95% of rocks.[12] Quartz is the most prevalent form of crystalline silica. The most common polymorphs of silica include quartz, cristobalite, and tridymite, all of which are present in rocks and soil. These silica forms can be introduced into the environment through both natural processes and human activities. Silica is ubiquitous, notably in the concrete structures of buildings, ceramics, and sanitary ware. Activities such as blasting, cutting, drilling, and grinding can especially elevate its concentrations.[13] A study conducted at a building demolition site collected 51 personal silica samples from 19 construction workers over 13 days. The findings indicated that even with Occupational Safety and Health Administration (OSHA) Table 1 engineering control methods in place, there could still be exposure to hazardous levels of respirable crystalline silica.[14]

"Asbestos" originates from the Ancient Greek word meaning "inedible" or "indestructible". It refers to a

Table 1: Heavy metals found in urban soils and their formation pathways

Arsenic	As-based insecticides used in horticulture, treated timber, or old sheep dip sites
Cadmium	Phosphate fertilizers, sludge, industrial emissions, runoff from roads
Chromium	Fixative in treated timber, industrial emissions
Copper	Cu-based fungicide, Cu roofing materials
Mercury	Industrial emissions, crematoria
Nickel	Industrial emissions
Lead	Historical use of leaded gasoline, Pb-based paints, historical use of Pb-based pesticides, Pb flashing on roofs
Thallium	Coal burning
Zinc	Galvanized metal

group of minerals composed of magnesium silicate, calcium-magnesium silicate, iron-magnesium silicate, or complex sodium-iron silicate, all of which have fibrous crystal structure.[15] The term "fiber" is used to describe longitudinal particles with uniform parallel edges and geometric faces that meet the criteria of $L/w \geq 3:1$, $L \geq 5$ μm, and $w \leq 3$ μm.[16] Lately, the term "elongated mineral particles" seems to be replacing the term "fiber". The 1920s and 1930s witnessed a significant surge in the use of asbestos, often referred to as the "magic mineral". During this period, its affordability and durability made it popular in various sectors such as shipbuilding, household appliances, art materials, filter manufacturing, automotive industries, and heat and fire-resistant textile products.[17] Exposure to asbestos van arise from materials or rocks containing asbestos, damaged or demolished buildings, fires, and even water contaminated with asbestos, especially during and after earthquakes. Such exposures can be occupational (involving groups such as construction-demolition workers, firefighters, and search-rescue teams), environmental, domestic (like during transportation), or a combination of these.[18] Since the 1980s, European Union countries have progressively restricted the production and use of asbestos, leading to a complete ban in all member countries as of January 1, 2005.[19] In our country, the "Regulation on Health and Safety Measures in Working with Asbestos," published in the Official Gazette on 25.01.2013 (No. 28539), prohibits the production and trade of both asbestos and products containing it.[20] Among other fibrous minerals, erionite is a member of the hydrated aluminosilicate mineral group. It naturally occurs as an environmental contaminant in certain volcanic tuffs. Although erionite shares a morphology similar to amphibole asbestos, its chemical and physical properties differ.[21] In our country, erionite is predominantly found in villages within the Cappadocia region, including Sarıhidir, Tuzköy, and Karain.[22] Given the higher carcinogenic effect of fibrous erionite compared to asbestos, even low concentrations of erionite can pose a significant risk. It is crucial to establish safe working environments, transportation protocols, and sustainable long-term disposal options to mitigate these hazards, especially before disasters like earthquakes occur in affected areas.[18] In our country, the threshold limit value for personal exposure to respirable asbestos dust is set at 0.1 fiber/cm^3, as stipulated in Annex 1 of the Regulation on Control Dust.[10] A 2014 study, focusing on workers involved in the demolition of old buildings, found personal exposure measurements that exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) limit value of 0.1 fiber/cm^3.[23]

Gas pollutants are typically categorized into asphyxants and irritants. Simple asphyxiants are physical in nature. They act by displacing oxygen and are especially hazardous in confined spaces. Examples of these are methane, carbon dioxide, nitrogen, nitrous oxide, ethane, propane, acetylene, and noble gases.On the other hand, toxic asphyxiants hinder the utilization of oxygen at the cellular level, with carbon monoxide, hydrogen cyanide, and hydrogen sulfide being the most well-known examples. Irritant gases can be further categorized into water soluble (such as chlorine, ammonia, sulfur dioxide, and acid aerosols) and water insoluble (like nitrogen dioxide, phosgene, and ozone). Fires are also of significant importance during earthquakes. Combustion smoke contains carbon monoxide, acrolein, formaldehyde, hydrogen chloride, hydrogen cyanide, nitric oxide, nitrogen dioxide, and particulates.[24]

Furthermore, it is knows that urban soils can contain high concentrations of heavy metals. These concentrations result from anthropogenic contributions such as composts, fertilizers, manures, metal-containing agrochemicals, paints, vehicle emissions, past and current industrial practices, and the burning of coal and other fuels.

Table 1 below lists the heavy metals that can be found in urban soils and their formation pathways.[25]

For example, after the Adapazari earthquake, heavy metal levels significantly increased due to the reconstruction of city roads, sewage and water pipes, and the demolition of damaged buildings.[26]

The earthquake triggered numerous Natural Hazards leading to Technical Accidents (NATECH) events, based on the types of industrial activities in the region.[27–29]

Another hazardous substance is radon, released into rocks, buildings, and drinking water during earthquakes. Radon is a natural radioactive gas resulting from the radioactive decay of radium-226 found in igneous and metamorphic rocks, such as uranium ores, phosphate rock, shale, granite, gneiss, schist, and to a lesser degree, in common rocks.[30]

Radon in the soil can easily penetrate buildings through structural defects like cracks and voids in the building floor.[31]

Radon is also found in building materials, albeit in low concentrations. The International Agency for Research on Cancer (IARC) has classified radon as a group 1 carcinogen.[32] Radon is among the leading causes of lung cancer. It is estimated that radon contributes to 3% and 14% of all lung cancers in a country, depending on the national average radon level and the prevalence of smoking.[33]

Health Effects

Acute effects

Respiratory tract infections can be exacerbated by factors such as lung infections, significant temperature variations in earthquake zones, low-temperature conditions, inadequate shelter, compromised heating and ventilation due to earthquake damages, insufficient water and hygiene during acute situations, and limited transportation and medical facilities. For instance, the respiratory tract infection rate was 21% during the Yushu earthquake and 10% during the Nepal earthquake.[34,35]

While different climatic and geographical conditions can influence infection rates after the earthquake, acute respiratory tract infections can be grouped into categories like bacterial pneumonia, influenza, legionella, and tuberculosis. Apart from the general risk factors associated with the onset of community-acquired pneumonia in natural disasters, other factors such as inhalation of toxic gas and smoke, intense dust exposure, and severe hypothermia should be considered.[36] After the March 11, 2011 Great East Japan Earthquake, there was a reported 2.2-fold increase in community-acquired pneumonia cases compared to the previous year, and this rise was consistent across all age groups. As for viral infections, surges in viral agents like influenza, Coronavirus Disease 2019 (COVID-19), Adeno Virus, and Respiratory Syncytial Virus are anticipated. Notably, there was an emphasis on the post-earthquake flu epidemic, which spiked one week after the earthquake, and increased 20-fold compared to the previous year.[37] The influenza virus can cause severe respiratory symptoms, especially in the elderly, pregnant women, and pediatric age groups. Vaccination is considered the most critical measure in preventing outbreaks in situations with a high risk of infection, such as major disasters.[38]

During natural disasters like earthquakes, managing Tuberculosis (TB), becomes challenging. In the presence of an active TB infection, ensuring isolation measures is difficult. Regular medical treatment may become inaccessible for a time, and directly supervised treatment might not be feasible. In latent TB infection, immunity play a central role. It is believed that living conditions and stress factors after natural disasters may weaken immunity and reactivate a latent TB infection into an active pulmonary TB infection. A study examining the prognosis of post-earthquake TB reported that most pulmonary TB cases were likely due to the activation of latent TB infection by the earthquake and tsunami. Risk factors for post-earthquake TB prognosis were linked with advanced age, low serum albumin level, performance status at presentation, and oxygen requirement.[39]

Furthermore, Legionella is an infectious disease caused by the bacteria Legionella pneumonia. It present a wide clinical spectrum ranging from a self-limiting febrile illness, known as Pontiac Fever, to severe and sometimes fatal pneumonia, termed Legionnaires' disease.[40] After significant natural disasters, factors like water sources, latrines, and heating ventilation conditions can become risk points for transmission. Preventative measures can help curtail outbreaks.

Table 2: Preventive measures against infectious diseases in natural disasters

Phase	Period	
I	0-Day 4	This phase involves the rescue of survivors and the initial treatment of disaster-related diseases. This is the most important period for infection prevention; risks of infectious diseases should be assessed and identified. Infected individuals should be isolated, and actions taken to curb the spread. Vaccination against Haemophilus influenza, Pneumococcus, or the Influenza virus can be considered if there is a perceived risk or if the disease has already emerged.
II	Day 4-week 4	This phase is marked by the initial surge of infectious diseases, including air, food, and/or waterborne infections. Outbreaks from pathogens endemic to the region are anticipated.
III	After week 4	Relocating individuals showing no clinical signs of infection during this phase to other areas might contribute to the spread of infections elsewhere. Detecting and countering infectious diseases after a significant disaster is paramount for epidemic control.

Preventive strategies against infectious diseases during natural disasters are categorized into three stages (Table 2).[41]

Acute inhalation injuries vary, ranging from the direct effects of toxic inhalants on the respiratory mucosa, such as bronchospasm and inflammation of the respiratory mucosa, to systemic effects resulting from particle absorption. The degree of acute damage is influenced by the inhalant's water solubility, aerodynamic properties, pH, and concentration.[42]

The clinical spectrum of exposure varies depending on the dose and concentration of the substance. However, based on the level of exposure in the respiratory tract, conditions such as tracheitis, bronchitis, or bronchiolitis can develop. Common symptoms include bronchial mucosal irritation, manifesting as coughing and non-purulent sputum. Systemic effects can also arise due to the systemic absorption of the exposed substance. After intense exposure to airborne particles, Reactive Airway Dysfunction Syndrome (RADS) can occur. RADS is a condition in patients with no prior history of respiratory disease, causing symptoms like coughing, wheezing, or shortness of breath within 24 hours after brief yet intense exposure to dust, smoke, or vapor. These symptoms can persist for three to six months. The most crutial preventative measure against acute inhalation injury is the use of personal protective equipment.[43,44]

Exacerbations of Asthma and Chronic Obstructive Pulmonary Disease (COPD) can be attributed to several risk factors: the dense dust and smoke generated from destruction and during search-and-rescue activities, poor ventilation in emergency shelters, increased respiratory tract infections in these environments, and patients' temporary inability to access their regular medical treatments. It has been reported that the number of asthma and COPD attacks triples after earthquakes.[37]

Another trigger for these attacks is patients on long-term oxygen therapy, who due to chronic respiratory failure, cannot use their treatment because of equipment loss or power outages. Consequently, these patient groups often need to be evacuated to medical facilities. As a short-term solution, providing these oxygen therapy patients with backup oxygen cylinders in anticipation of power failures may be beneficial. The primary objective should be to identify priority patient groups for attack prevention and to administer medical treatment to them. Subsequently, it is vital to ensure that the environment where this patient group resides is well-ventilated, and that personal protective equipment is provided to prevent exposure to outdoor pollutants like dust and smoke.

A high concentration of allergens, such as house dust mites due to intense dust exposure, crowded shelter conditions, delayed access to acute medical treatments, and hygiene conditions in emergency shelters post-earthquake, can exacerbate symptoms, especially in atopic individuals.[45]

Chronic effects

Factors like air pollution, limited access to clean drinking water, cramped living conditions, food insecurity, direct exposure to sunlight, climatic variables like temperature and humidity, and challenges in accessing basic health services can complicate the management of chronic diseases. One key consideration is the indoor air quality in temporary, crowded housing. There may be significant reductions in the respiratory capacities of both those involved in debris removal and those residing in the affected region. In fact, after the terrorist attack on the

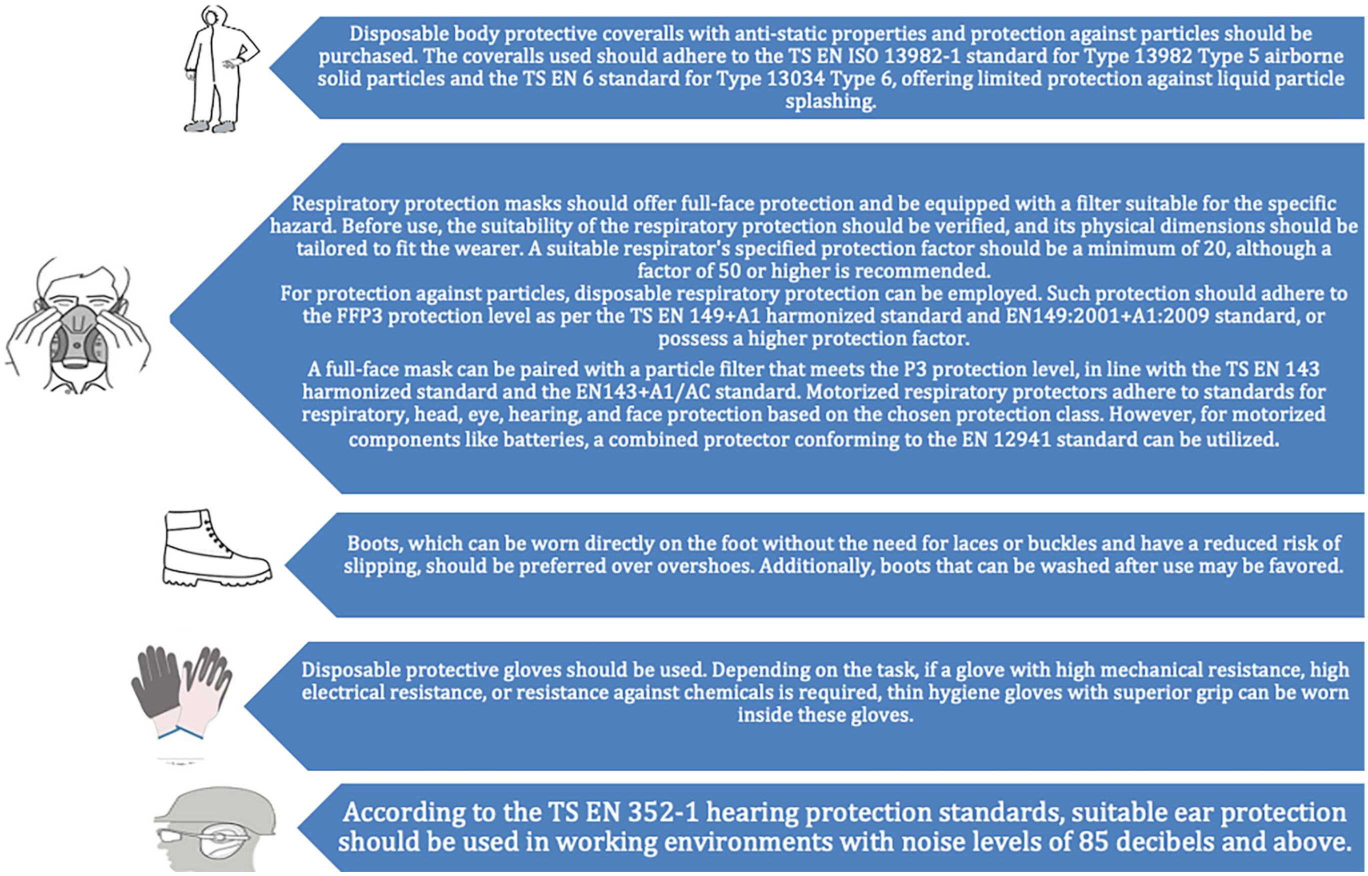

Figure 1: The personal protective equipment that should be used by workers in the earthquake debris area

World Trade Center on September 11, Reactive Airways Dysfunction Syndrome, diffuse parenchymal lung diseases, dust, smoke, and other environmental respiratory pollutants were identified as culprits for interstitial fibrosis. Studies indicate that decreases in Forced Vital Capacity (FVC) and Forced Expiratory Volume in the first second (FEV1) persist even years later.[46–51] A study from Tehran highlighted that in the realm of building demolition, the risk of silicosis mortality for many demolition workers exceeded 1/1,000 (an unacceptable risk level). Estimations of lifetime lung cancer mortality revealed a higher death risk from lung cancer among building demolition workers.[52] Research after the 9/11 attacks demonstrated that both organic and inorganic pollutants, such as fibers in dust, cement mixtures, silica, asbestos, lead, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and other compounds have been linked to diseases like rheumatoid arthritis, psoriatic arthritis, systemic lupus erythematosus, and various autoimmune diseases. After the 2011 Japanese earthquake, exposure to asbestos and silica-containing dusts was found to increase the incidence of microscopic polyangiitis.[50,51] In a study, Izbicki et al.[53] highlighted the increased incidence of sarcoidosis and sarcoidosis-like granulomatous lung disease after dust exposure in search-and-rescue teams.

Cohort studies have linked cadmium exposure in dust with prostate cancer and iodine-131 and ionizing radiation with thyroid cancer.[54] Additionally, asbestos exposure may elevate the risk of malignant mesothelioma, digestive system cancers, urogenital cancers, breast, and lung cancers.[55] Given that exposure to respiratory pollutants can act as long-term endocrine disruptors, cause genomic damage, and adversely affect growth, development, reproductive health, and even intrauterine life, it is crucial to implement preventive health practices with a proactive approach. Special emphasis should be placed on pregnant women and children. An anticipated increase in occupational diseases following physical, chemical, and bio-psychological exposure among workers in disaster areas underscores the importance of implementing both primary and secondary protective measures.

Preventive Health Practices

To mitigate the acute and chronic effects of respiratory pollutants on all demographics, including the young, elderly, children, and women, preventive practices should be prioritized within a holistic health framework. It is essential to position temporary settlements in tent cities away from demolition and debris areas, recognizing that pollutants can be dispersed for kilometers by wind and air currents. Proper disposal of biological wastes in communal living areas is crucial for preventing infectious diseases. Maintaining optimal indoor air quality and guarding against mold, fungi, and other pathogens is vital for preventing respiratory diseases.[56] For individuals temporarily or permanently engaged in damage assessment, debris work, building demolition, transportation, and scrap collection, provisions should be made for safe shelter, clean drinking and potable water, continuous immunization services, food safety, and security. Health access should be facilitated. Furthermore, providing appropriate personal protective equipment and training should regarding potential diseases and disabilities from exposures is essential. The recommended personal protective equipment for workers in earthquake debris areas is depicted in Figure 1.[57]

Efforts to control dust should adhere to legislative regulations, and both entry examinations and periodic control examinations for employees should be expedited. Some studies advocate for a series of pulmonary function tests to detect early signs of bronchial hyperreactivity and diminished respiratory reserve.[58,59] Anti-smoking measures can help preserve workers' respiratory function. While working in dusty environments, it is crucial not to smoke, consume food or beverages, or remove masks and protective clothing during the day. Additionally, workers should undress in appropriate settings at day's end to avoid carrying pollutants home.[58]

Climatic conditions that cause heat or cold stress can increase exposure to respiratory pollutants and may also hinder the consistent use of personal protective equipment. When appropriate, wetting work surfaces can prevent dust formation. Providing adequate rest breaks for workers, organizing social programs after work hours, and offering psychological support to those in need can significantly boost morale. In disaster scenarios, scheduling periodic control examinations more frequently than once a year should be considered for overall worker health.

Conclusion

The temporal and spatial ramifications of earthquakes, a type of natural disaster, often cahllenge predictive measures. Populations residing in temporary settlements within affected areas, representatives from diverse sectors serving these communities, and employees involved in dismantling, demolition, restoration, evacuation, and transportation tasks experience significant impacts. Large-scale catastropihic events produce not only economic, psychological, and social consequences but also detrimental health oucomes. In addition to facing forced internal migrations, many individuals endure the loss of their relatives, periods of mourning, disabilities, and financial concerns. Those living in temporary tent cities must also navigate the challenges posed by debris removal operations within the earthquake zone. It is essential to recognize that the health of both humans and ecosystems may suffer for years after powerful earthquakes that span vast geographies.

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