Science of the Total Environment 864 (2023) 161135

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Discussion

# Environmental hazards posed by mine dust, and monitoring method of mine dust pollution using remote sensing technologies: An overview

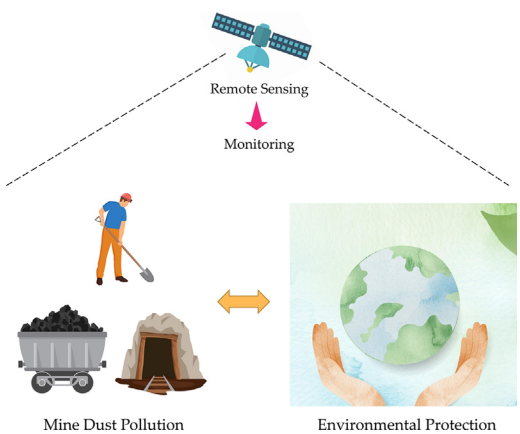
Haoxuan Yu, Izni Zahidi*

*Civil Engineering Discipline, School of Engineering, Monash University Malaysia, Bandar Sunway 47500, Malaysia*

## HIGHLIGHTS

- Combining literature research and meta-analysis, the environmental hazards posed by mine dust are presented.
- The health hazards of mine dust pollution are presented, to remind residents, miners and researchers to protect themselves.
- It is proposed to apply changes in aerosol optical depth to infer the progress of mine dust management on a regional scale.

## GRAPHICAL ABSTRACT




## ARTICLE INFO

Editor: Frederic Coulon

*Keywords:*
Mine dust pollution
Public health
Environmental exposure
Remote sensing
Mining engineering

## ABSTRACT

The over-exploitation of mineral resources has led to increasingly serious dust pollution in mines, resulting in a series of negative impacts on the environment, mine workers (occupational health) and nearby residents (public health). For the environment, mine dust pollution is considered a major threat on surface vegetation, landscapes, weather conditions and air quality, leading to serious environmental damage such as vegetation reduction and air pollution; for occupational health, mine dust from the mining process is also regarded as a major threat to mine workers' health, leading to occupational diseases such as pneumoconiosis and silicosis; for public health, the pollutants contained in mine dust may pollute surrounding rivers, farmlands and crops, which poses a serious risk to the domestic water and food security of nearby residents who are also susceptible to respiratory diseases from exposure to mine dust. Therefore, the second section of this paper combines literature research, statistical studies, and meta analysis to introduce the public mainly to the severity of mine dust pollution and its hazards to the environment, mine workers (occupational health), and residents (public health), as well as to present an outlook on the management of mine dust pollution. At the same time, in order to propose a method for monitoring mine dust pollution on a regional scale, based on the Dense Dark Vegetation (DDV) algorithm, the third section of this paper analysed the aerosol optical depth (AOD) change in Dexing City of China using the data of 2010, 2014, 2018 and 2021 from the NASA MCD19A2 Dataset to explore the mine dust pollution situation and the progress of pollution treatment in Dexing City from 2010 to 2021. As a discussion article, this paper aims to review the environmental and health risks caused by mine dust pollution, to remind the public to take mine dust pollution seriously, and to propose the use of remote sensing technologies to monitor mine dust pollution, providing suggestions for local governments as well as mines on mine dust monitoring measures.

* Corresponding author at: Jalan Lagoon Selatan, 46150 Bandar Sunway, Selangor Darul Ehsan, Malaysia.
*E-mail address:* Haoxuan.Yu@monash.edu (H. Yu), Izni.Mohdzahidi@monash.edu (I. Zahidi).

http://dx.doi.org/10.1016/j.scitotenv.2022.161135
Received 10 November 2022; Received in revised form 15 December 2022; Accepted 19 December 2022
Available online 23 December 2022

## 1. Introduction and background

### 1.1. Mine dust pollution and its environmental & health risks

As the world's resources continue to be exploited, mining activities are giving rise to increasing environmental damage and pollution, of which mine dust pollution is considered to be one of the biggest threats to environment and public health (Entwistle et al., 2019; Hendryx et al., 2020a): Mine dust pollution not only leads to serious environmental damage, but also increases the probability of respiratory diseases among mine workers and nearby residents (Zhang et al., 2021a; Chen et al., 2019), as well as infects nearby rivers (Mwaanga et al., 2019), farmlands and crops (Guo et al., 2019), leading to threats to domestic water quality and food safety.

With the concept of "One Health" (Frank, 2008), mine pollution, especially the mine dust pollution (Dang and Shan, 2018; Xiu et al., 2020a), is getting more and more attention. Although mine dust pollution is receiving increasing attention, the public's understanding of the hazards and risks of mine dust pollution is more real, which has led to health issues due to the lack of public awareness of self-protection under mine dust in recent years (Li et al., 2015; Tang et al., 2017). Thus, the second section of this paper combines literature research, statistical studies, and meta-analysis to introduce the public mainly to the severity of the current worldwide mine dust pollution and its environmental hazards and health risks to the environment, mine workers (occupational health), and residents (public health), in the following three parts:

1. The negative impacts of mine dust pollution on the environment (e.g. vegetation reduction, natural landscapes damage and weather change);
2. The negative impacts of mine dust pollution on the mine workers (e.g. occupational diseases);
3. The negative impacts of mine dust pollution on public health (e.g. respiratory diseases, domestic water pollution and food security threat).

### 1.2. Mine dust pollution and its monitoring

At the same time, it is also important to monitor mine dust pollution in mining areas. At present, for mine dust pollution assessment, particulate matter monitoring techniques (e.g. PM10, PM5, PM2.5, etc.) are most commonly used in mines to monitor mine dust (Miler and Gosar, 2019; Wang and Jiang, 2021); while for mine dust treatment solutions, vegetation restoration and planting (Gil-Loaiza et al., 2018) are considered to be the most effective methods of mine dust control, while dust suppressants (Liao et al., 2018; Shi et al., 2021), biopolymers (Chen et al., 2015; Toufigh and Ghassemi, 2020) and geo-polymerization techniques (Kasap et al., 2022a; Koohestani et al., 2021; Li et al., 2020) are also widely used for mine dust prevention and treatment. Such assessments and solutions to mine dust pollution could indeed provide a quantitative analysis of the extent of mine dust pollution and mitigate the pollution problem to a certain extent, which is positive; however, governments could not get effective feedback from these studies on mine dust pollution situation and the progress of pollution treatment on a regional scale (Baluchová et al., 2019), especially for mining cities such as Dexing City in China and Kuantan in Malaysia. Thus, it is crucial to analyse the dust pollution situation and the progress of treatment on a regional scale. Therefore, it is significant to introduce remote sensing technologies to monitor mine dust pollution on a regional scale in mining areas and even mining cities.

Aerosol optical depth (AOD) is defined as the integral of the extinction coefficient of a medium in the vertical direction and describes the reduction of light by an aerosol. It is one of the most important parameters of an aerosol and a key physical quantity characterising the degree of atmospheric turbidity (Wei et al., 2020). AOD is often used to forecast the concentration of ground-level atmospheric particles and monitor urban air quality on a regional scale (Bai et al., 2022). At the same time, in mining cities, AOD can be used as a reference for the level of urban mine dust pollution and the progress of the mine dust treatment: Generally, the higher the AOD, the worse the air quality (Kumar et al., 2007), which indicates more dust pollution from the mining areas. Therefore, in mining cities, the change of AOD can clearly reflect the change of air quality in the mining areas, and thus the mine dust pollution in the mining area and the progress of treatment can be inferred. As a result, the third section took Dengxing City in China which is a mining city as an example, analysed the AOD changes using the data of 2010, 2014, 2018 and 2021 from the NASA MCD19A2 Dataset, to explore and discuss the mine dust pollution situation and the progress of dust pollution treatment in Dexing City, providing suggestions for local governments and mining companies on mine dust monitoring measures.

### 1.3. Research objectives and novelty statement

As a discussion article, this paper focuses on introducing the public to the seriousness of mine dust pollution and awakening public awareness of mine dust pollution so that it can be effectively prevented and controlled; at the same time, this paper also advocates the use of remote sensing technologies to monitor mine dust pollution on a regional scale to the government, mining enterprises and researchers, so as to effectively assess the mine dust pollution situation and the mine dust pollution control progress in a certain area (e.g. a mining city). The main research objectives of this paper are as follows:

- In Section 2, it is planned to summarise the environmental hazards (vegetation damage, landscape damage, etc.) and health risks (occupational diseases, respiratory diseases, cancers, etc.) caused by mine dust through literature studies and reviews; in addition, in the occupational health part, it is planned to explore and discuss the correlation between mine dust exposure and lung cancer through meta-analysis. The aim is to raise the awareness of the public, especially residents, mining workers and researchers who are exposed to mine dust for a long time, to mine dust pollution, and to raise public awareness of self-protection under the mine dust exposure.
- In Section 3, taking the city of Dexing (a mining city in China) as an example, it is planned to visualise the changes in air quality within Dexing City by calculating the change in aerosol optical depth (AOD), so as to judge and speculate on the mine dust pollution situation and dust pollution control progress within the main mining areas of Dexing City on a regional scale. The aim is to propose the use of remote sensing technologies to monitor mine dust pollution, providing suggestions for local governments as well as mines on mine dust monitoring measures, so that governments and mining companies could get effective feedback on the dust pollution control progress from this monitoring method.

This paper, as a discussion article in the field of environmental health, combines literature review, meta analysis, data analysis and field surveys, with the following innovations:

- In the context of the literature review of the environmental and health threats of mine dust, Section 2 includes a meta analysis part to explore and discuss the correlation between mine dust exposure and lung cancer, which is a highlight in this paper.
- Section 3 advocates the use of remote sensing technologies for monitoring mine dust pollution, which has great practical significance. Because the application of remote sensing technologies in mine dust monitoring can reduce the efforts of researchers to sample and analyse the level of mine dust pollution; while the monitoring results (changes in AOD) can also provide feedback to governments and mining enterprises on the progress of mine dust management, which is conducive to the formulation of atmospheric environmental protection policies.

## 2. Mine dust pollution and its hazards

### 2.1. Mine dust pollution and environment damage

Mine dust is mainly generated from ore blasting operations, excavation operations, tailings pond dusting (Cavusoglu et al., 2021; Kasap et al., 2022b) and equipment dusting during the whole mining operation (Xiu et al., 2020b), which can cause environment damage, with the vegetation reduction and air pollution, and these two (Kumar, 2015a; Gumenik and Lozhnikov, 2015; Sairanen and Pursio, 2020) are considered the most serious ecological and environment damage.

#### 2.1.1. Vegetation reduction

Mine dust pollution is thought to have an inhibitory effect on the plant growth, leading to a decline in the vegetation cover (Pal and Mandal, 2017).

According to previous studies (Farmer, 1993), the deposition of mine dust (mineral dust) on vegetation can affect photosynthesis, respiration and transpiration of plants, leading to a decrease in plant productivity and also causing visible symptoms of damage to vegetation (Kumar, 2015b). Additionally, another study (Shukla et al., 2019) has represented mine dust deposition and accumulation can lead to physical damage to vegetation, clogging of stomata and reduced photosynthesis, with severe implications for the economic and nutritional value of crops in particular.

In addition, heavy metal pollutants such as those contained in mine dust can negatively affect the plant growth. The impact of heavy metals on plants is mainly through the metabolic activities of air (mine dust particles), water (waste water) and soil on plants, and the accumulation of heavy metals in plants is detrimental to growth (Asati et al., 2016). Also, some metals, including copper (Cu), manganese (Mg), cobalt (Co), zinc (Zn) and chromium (Cr), which are contained in mine dust, are essential for trace metabolism in plants, but may be toxic to plants when present in bio-available form and at high levels (Nagajyoti et al., 2010).

#### 2.1.2. Air pollution

Dust pollution from the mining operations, especially during blasting operations, often affects air quality degradation (Bakhtavar et al., 2021) in the form of suspended particulate matter (SPM) and heavy metals in aerosols:

At the beginning of the 21st century, a study (Ghose and Majee, 2001) depicted that suspended particulate matter (SPM) was the largest dust pollutant from open-pit mining, contributing to air pollution and the consequent threat to human health; while Wang et al. (Wang et al., 2022a) identified the generation of particulate matter as one of the most serious impacts of mining on air quality, and in 2021 they analysed the extent of dust pollution (concentrations of $PM_{10}$ and $PM_{2.5}$), using the example of the Haerwusu open-pit coal mine in the Northwest China, to provide the government and the mine a basis and a reference for pollution prevention and control. In addition, heavy metals (e.g. Hg) in mine dust are likely to be transported in the air and aerosols, which can cause serious air pollution and health risks (Phillips, 2016), which was subsequently verified by a study (Blondet et al., 2019): the study measured high levels of Zn, Pb, As, Cd and Sb in atmospheric fallout from the mining district of Cartagena-La Unión at Spain, with potential risks to air quality and human health. In 2022, some Chinese researchers (Wang et al., 2022b) also identified mine dust emissions as a major source of heavy metals in the air, with arsenic and chromium potentially posing a cancer risk to residents of mining areas.

Fig. 1 exposes the correspondence between mine dust pollution and environmental damage (vegetation reduction and air pollution).

### 2.2. Mine dust pollution and occupational health

Mine dust is considered the "No. 1 Culprit" for mining safety and occupational health, as mine dust pollution can be extremely harmful to the health of mine workers, making them more susceptible to cardiovascular and respiratory diseases (Hendryx et al., 2020b).

During the mining operations in underground mines, dust pollution from blasting and excavation operations is generated in the underground environment, provided that dust is not discharged in time, mine workers are exposed to mine dust (e.g. silica dust) and harmful gases and are at increased risk of occupational diseases, respiratory diseases and cancer (Gui et al., 2020); while in the mining operations of open-pit mines, dust pollution spreads more widely, affecting the occupational health of mine workers and may also have a serious impact on the surrounding environment and residents, in addition, the dust caused by mine tailings ponds at the surface is also an important source of dust pollution (Li et al., 2021).

Currently, the main effects of dust pollution (e.g. silica dust), on the occupational health of mine workers are considered to be reflected in:

1. Occupational diseases (e.g. pneumoconiosis, silicosis);
2. Cancer (e.g. lung cancer);
3. Respiratory diseases and other diseases (e.g. chronic obstructive pulmonary disease, diabetes).

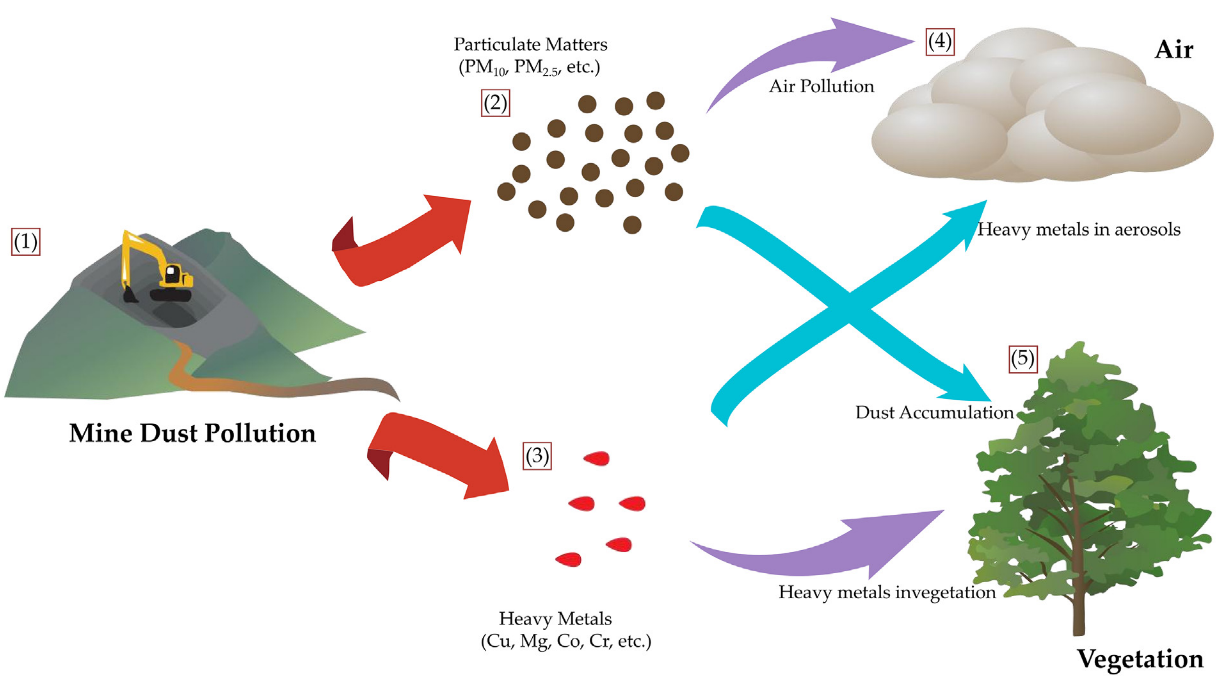



**Fig. 1.** The correspondence between mine dust pollution and environmental damage (vegetation reduction and air pollution).

*2.2.1. Occupational diseases*

For mine workers, the most common and serious occupational disease is pneumoconiosis (Liu and Liu, 2020), a general term for lung diseases caused by long-term inhalation of dust from the mining environment. Its occurrence process is complex and involves a variety of cellular and biologically active substances, including immune response, inflammatory response, structural damage and repair of cells and tissues, collagen proliferation and fibrosis (Liu et al., 2021a).

Patients who have pneumoconiosis gradually lose pulmonary function until they die: According to the 2010 Global Burden of Disease (GBD) study, approximately 125,000 global deaths are attributed to pneumoconiosis each year, so one of the most important contributors to pneumoconiosis, mine dust pollution, requires receiving more attention (Lozano et al., 2012).

A report (Laney and Weissman, 2012) revealed that between 1000 and 2000 pneumoconiosis patients are hospitalized in the United States each year, and that the mortality rate for pneumoconiosis patients in the United States was >25 % in 2007. Australia, famous for its mining industry, also has a pneumoconiosis crisis: the high dust concentration in Australian mines (especially in New South Wales) (Hendryx et al., 2019) has led to a significant increase in the probability of mine workers suffering from pneumoconiosis (Hendryx et al., 2020a). Countries such as South Africa (Nelson, 2013) and Canada (Jorgenson and Sandlos, 2021) are also facing the social situation of widespread pneumoconiosis among mine workers.

China is also a mining power in the world, with a large number of mine workers diagnosed with pneumoconiosis throughout China, many researchers have scrambled in recent years to investigate and study pneumoconiosis cases in various Chinese provinces and cities: Han, L. (Han et al., 2019) counted the number of cases of pneumoconiosis in Jiangsu Province, China, from 2006 to 2017, with a total of 9243 pneumoconiosis cases reported; at the same time they counted (Han et al., 2015) the disease characteristics of pneumoconiosis patients and they concluded that 90.71 % of pneumoconiosis patients were underground workers or mine workers in 2014. And there even are studies (Liu et al., 2022) related to the prevalence of pneumoconiosis in mine workers.

According to the statistics (data from https://www.chinacdc.cn): by the end of 2018, 873,000 cumulative cases of pneumoconiosis were reported in China, accounting for about 90 % of the total number of reported occupational disease cases; since 2010, an average of 20,000 to 25,000 new cases of pneumoconiosis have been reported annually. The actual number of cases is much higher than the number of reported cases due to low occupational health inspection coverage and imperfect employment system.

As dust exposure, especially mine dust, is a direct cause of pneumoconiosis, residents, workers and researchers who are exposed to dust for long periods of time need to take special care to protect themselves, for example by wearing dust masks. Therefore, in this part we aim to make the public aware of the dangers of pneumoconiosis so as to raise public awareness of pneumoconiosis prevention.

*2.2.2. Dust pollution and lung cancer: meta-analysis*

Airborne dust exposure, especially silica dust, is often thought to have a strong correlation with lung cancer, especially in mining areas, and this claim has been becoming a consensus (Witschi, 2001).

In 1988, it was found that lung cancer mortality was higher in Japanese mines than in other areas, and he hypothesized that there was a correlation between mine dust emissions and lung cancer (Minowa et al., 1988); and a subsequent study (Mzileni et al., 1999) found that the incidence of lung cancer was significantly higher in the mining areas of Northern Province, South Africa. By 2008, Hendryx, M. (Hendryx et al., 2008) found that lung cancer mortality in the Appalachia region, the US, was increasing with the gradual expansion of mining. In 2012, high cancer mortality rates were also found in the coal mining region of Xuanwei, Yunnan, China (Cao and Gao, 2012).

There are many more studies and findings such as these (Leonard et al., 2020a; Stayner and Graber, 2011). As the effect of mine dust on lung cancer is unknown and mine dust does not directly cause lung cancer, a simple meta-analysis was done to study and investigate the effect of dust exposure (pneumoconiosis) on lung cancer and whether mine dust pollution and pneumoconiosis cause lung cancer.

- Search Strategy

We searched the relevant literature in Pubmed (https://pubmed.ncbi.nlm.nih.gov) and Embase (www.embase.com) databases for the terms ("Pneumoconiosis"[Mesh] OR Bagassosis) and ("Lung Neoplasm"[Mesh]).

We excluded papers with poor quality and poor control of confounding factors as well as review papers, and selected research literature (Hua et al., 1994; Samet et al., 1994; Ulm et al., 1999; Brüske-Hohlfeld et al., 2000; Rodríguez et al., 2000; Cassidy et al., 2007; Vida et al., 2010; Tse et al., 2012; Kachuri et al., 2014) that could control confounding factors better, with similar statistical indicators and 95 % confidence intervals across studies. In addition, we chose older literature (1994 to 2013) because dust handling and protection technologies are constantly innovating, while mining technology is evolving, mine mechanization is increasing, and fewer workers are actually working in mines nowadays, so the association between the dust exposure and lung cancer is better investigated using older literature.

- Statistical analysis

Statistical analysis was performed using the software Stata 15.1 (www.stata.com), and the dichotomous variables of each original study were expressed as the OR (Odds Ratio) and 95 % CI (Confidence Interval), and the $\chi^2$ test was used to analyse the heterogeneity between studies (test level $\alpha = 0.1$).

If $P > 0.1$ and $I^2 \leq 50$ %, the heterogeneity among the included studies was small or non-existent, and meta analysis was performed using the fixed-effects model; otherwise, the heterogeneity among the included studies existed, and meta analysis was performed using the random-effects model. Forest plots were drawn using fixed-effects models, and funnel plots were used to assess publication bias.

- Results

As shown in Fig. 2, studies were analysed, first with the heterogeneity analysis and no significant heterogeneity between studies ($P = 0.207$, I2 = 26.7 %), and a fixed-effects model was adopted, and patients in the silica dust-exposed group had a statistically significant effect on the development of lung cancer compared to those in the non-exposed group, with patients in the exposed group having a higher risk of developing lung cancer than those in the non-exposed group (OR = 1.34 [1.24,1.46], $P < 0.001$).

Fig. 3 shows publication bias funnel plots with a more symmetrical distribution of original studies, showing no significant publication bias. This has led us to conclude that occupational dust is an important cause of lung cancer.

*2.2.3. Respiratory diseases and other diseases*

Chronic obstructive pulmonary disease (COPD) is a lung disease characterized by restricted airflow and is associated with an abnormal inflammatory response of the lungs to harmful gases or particles. Mine dust exposure is also a direct cause of COPD which generally occurs in adults after the age of 40, especially in people with long-term exposure to dust, such as underground workers and mine workers (Silver et al., 2021).

As early as 1992, studies concluded that occupational dust was a significant cause of COPD and that the risk appeared to be greater for gold mine workers than for coal mine workers (Oxman et al., 2012). One possible explanation for the greater risk in gold mine workers is the higher silica content of gold mine dust. Also, epidemiological and pathological studies (Hnizdo and Vallyathan, 2003) have shown that silica dust exposure can cause COPD and may also lead to chronic bronchitis, emphysema and small airway diseases. And many studies (Laney and Weissman, 2014; McBean et al., 2020; Murgia et al., 2021) have also shown that the dust

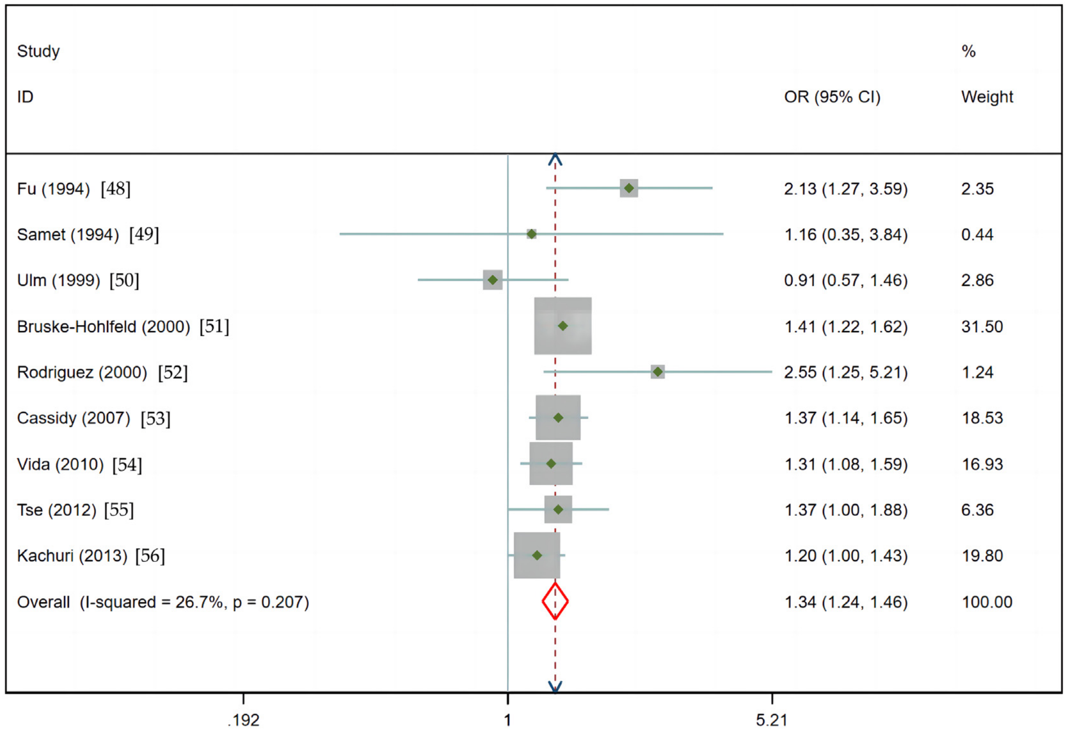



**Fig. 2.** Forest plots (which are mainly used to graph the results of quantitative synthesis of meta-analysis).

exposure (especially mine dust exposure) can lead to chronic obstructive pulmonary disease.

In addition to respiratory diseases, studies have shown that mine dust pollution may also cause an increased risk of cardiovascular disease (Landen et al., 2011) cerebrovascular disease (Tong et al., 2019), kidney disease (Hendryx, 2009), and diabetes (Ganesan et al., 2019) among mine workers. However, there is insufficient evidence to suggest that mine dust is a direct factor in causing these diseases.

Fig. 4 exposes the correspondence between mine dust pollution and occupational health.

### *2.3. Mine dust pollution and public health*

Mine dust pollution also has a serious impact on public health. First of all, the spread of mine dust (especially in open-pit mines) can also cause respiratory diseases in residents such as COPD, emphysema, pneumoconiosis and even lung cancer in the surrounding area of the mines (Leonard et al., 2020b). In addition, mine dust can also contaminate rivers, farmlands, residential water and even drinking water around mining areas, posing a serious public health threat (Gautam et al., 2018).

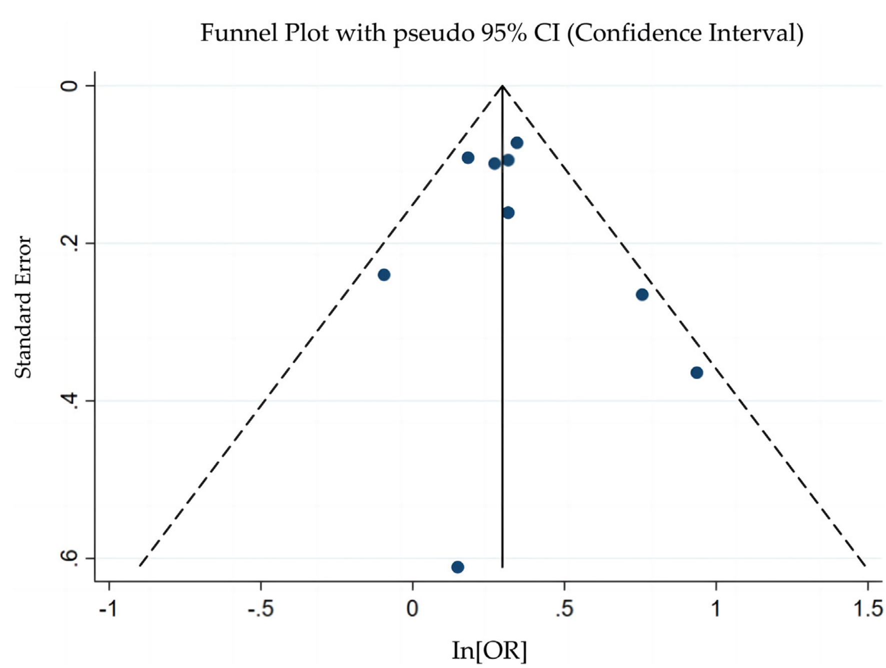



**Fig. 3.** Funnel plots (which are mainly used to exclude statistical bias).

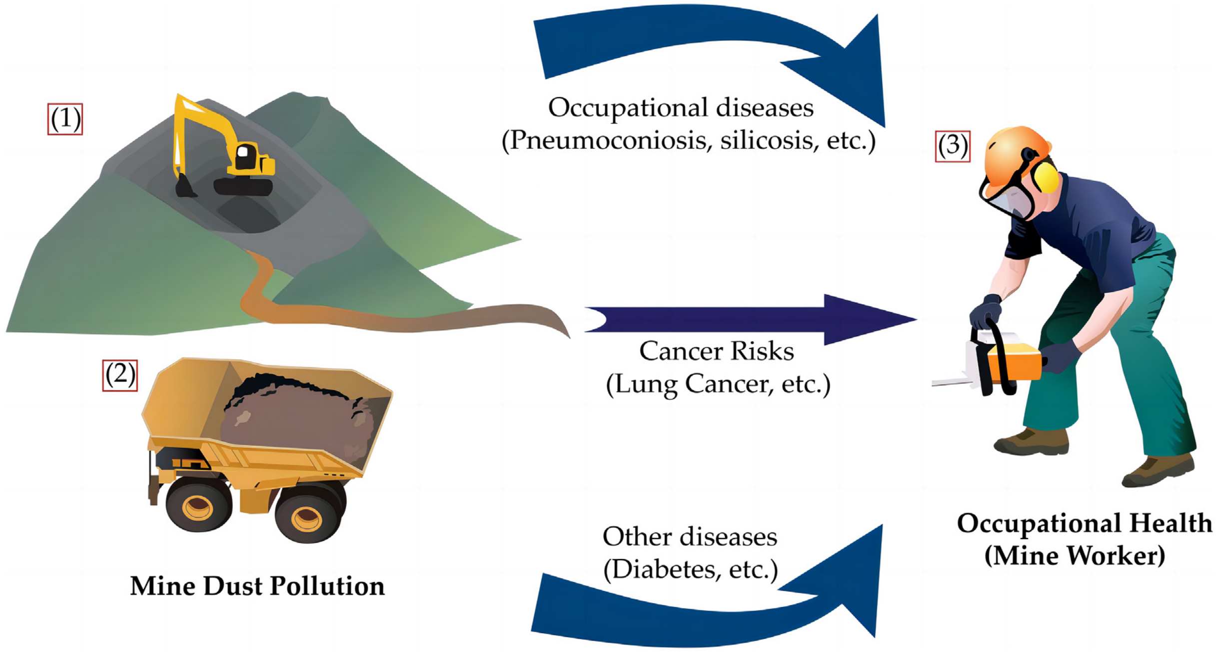



**Fig. 4.** The correspondence between mine dust pollution and occupational health.

#### 2.3.1. Water pollution

Mine dust contains heavy metals and its dispersion can pollute the rivers, while many residents near mining areas use river water as domestic water for washing dishes, clothes, etc., posing a threat to their health (Li et al., 2022a); and studies have indicated that wind-blown mine dust from mine tailings is likely the most significant cause of heavy metal contamination of water sources such as lakes and rivers (Battogtokh et al., 2014); at the same time, mine dust is thought to contaminate the drinking water of people living near the mine, just as mine wastewater discharge does (Bhuiyan et al., 2010). Many studies have also shown that mine dust pollution can cause serious contamination of water sources around mining areas, thus affecting the health of the local residents (Liu et al., 2021b; Sedibe et al., 2017).

#### 2.3.2. Food security threat

The accumulation of mine dust in crops as well as in farmland soils leads to contamination of crops by heavy metals in mine dust, causing food safety threat. And if contaminated crops are mistakenly eaten, then people's health can be adversely affected (Baghaie and Aghili, 2019).

Mine dust contamination increases heavy metal concentrations in soil, atmosphere and wheat, thereby posing a risk to metal-related human health through food intake (Maqbool et al., 2019). Many researchers apparently agreed with this statement, for example, Izydorczyk et al. (Izydorczyk et al., 2021) proposed that crop contamination from heavy metals in mineral dust that have invaded the soil can have a negative impact on human health; and Qin et al. (Qin et al., 2021) believed that mine dust pollution causes the spread of heavy metals and other pollutants, and that the adverse effects on crop quality threaten human health; Esmaeili et al. (Esmaeili et al., 2014) conducted a study in the Isfahan industrial area and found that mine dust pollution affected the concentration of Cu and Mn in soil, jeopardizing the ecology of agriculture, food security, human health and sustainable development.

Fig. 5 exposes the correspondence between mine dust pollution and public health (water pollution and food security threat).

## 3. Mine dust assessment and its treatment progress in Dexing City, China

In this section, we took Dengxing City, China as an example, and analysed the AOD changes using the data of 2010, 2014, 2018 and 2021 from the NASA MCD19A2 Dataset, to explore and discuss the mine dust pollution situation and the progress of pollution treatment in Dexing City, providing suggestions for local governments as well as mining companies on mine dust monitoring measures.

### 3.1. Background and preparations

#### 3.1.1. Study area

Located in the northeastern part of Jiangxi Province between 24°29′14″ to 30°04′41″ North and 113°34′36″ to 118°28′58″ East, Dexing City is known as the “Copper Capital” of China. Dexing City is a famous natural resource extraction city in China, with two large open-pit mines, the Yinshan Mine and the Dexing Copper Mine (as shown in Fig. 6), as well as a number of non-ferrous metal mining and processing enterprises. The frequent mining activities have resulted in serious mine dust pollution and dispersion.

#### 3.1.2. Data source and process

The data used in this study are from the NASA MCD19A2 Dataset (https://search.earthdata.nasa.gov). The dataset is obtained by inversion of satellite sensor observations after the Multi-Angle Implementation of Atmospheric Correction (MAIAC), with good accuracy (Lyapustin et al., 2018). In this study, we used aerosol data in the Optical_Depth_055 (550 nm) band, and the data used are geometrically corrected, with the temporal resolution of 1d and the spatial resolution of 1 km.

Kaufman and Sendra (Kaufman and Sendra, 1988) proposed Dense Dark Vegetation (DDV) Algorithm based on extensive experiments, which takes advantage of the low reflectivity of multiple features (e.g. dense vegetation, etc.) in the red and blue bands, and uses the apparent reflectance of the 3.8 μm or 2.1 μm channel to find the dense dark vegetation, taking into account multiple ground cover, and fit the relationship between the surface reflectance of the red and blue channels of the dense dark vegetation and the apparent reflectance of the 2.1 μm channel (as shown in Eqs. (1) and (2)):

$$\rho_R = \rho^*_{2.1}/2 \tag{1}$$

$$\rho_B = \rho^*_{2.1}/4 \tag{2}$$

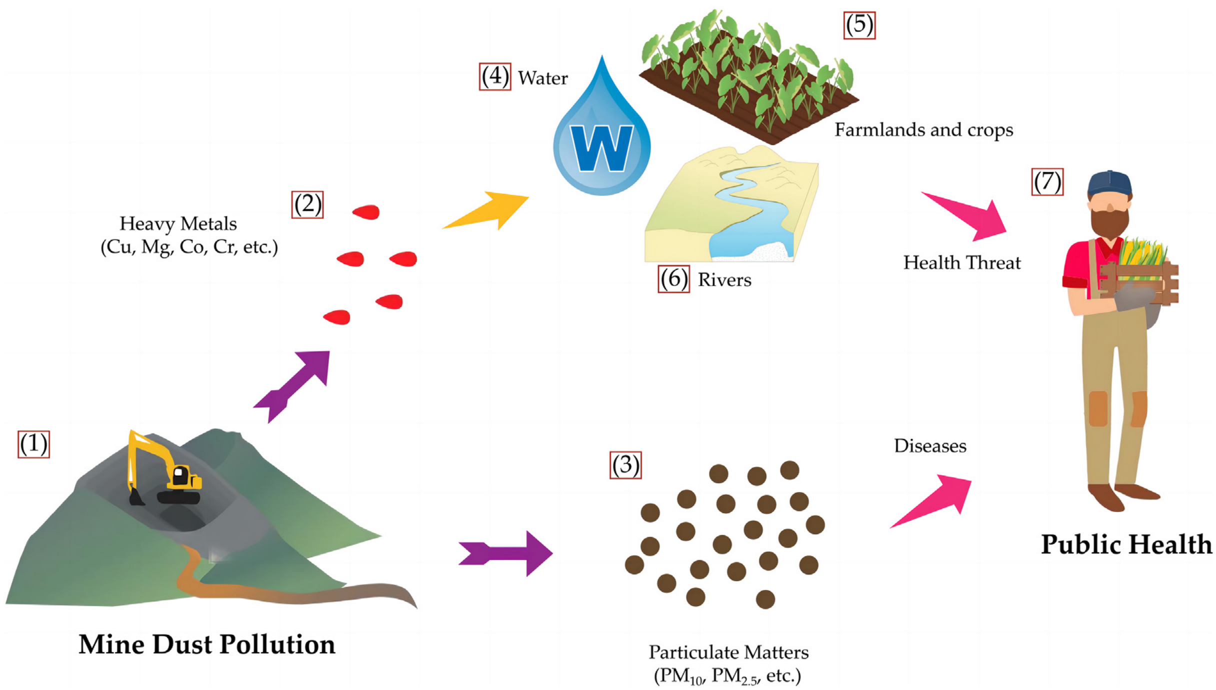



**Fig. 5.** The correspondence between mine dust pollution and public health (water pollution and food security threat).

where: $\rho_R$ is the surface reflectance of the red channel; $\rho_R$ is the surface reflectance of the blue channel; and $\rho^*_{2.1}$ is the apparent reflectance of the 2.1 μm channel.

In this study, we have also used the Dense Dark Vegetation Algorithm for the calculations of AOD changes within Dexing City from 2010 to 2021, for further details, please refer to http://dx.doi.org/10.13140/RG.2.2.32279.24485. The Eqs. (1) and (2) gave the surface reflectance of the dense dark vegetation in the red and blue channels, and then the 6S Radiative Transfer Model was used to calculate the AOD (Shi et al., 2016; Sun et al., 2010).

### 3.2. Results and discussion

The AOD distribution maps were charted through ArcGIS by classifying AOD into twelve classes: (<0.20), (0.20–0.25), (0.25–0.30), (0.30–0.35), (0.35–0.40), (0.40–0.45), (0.45–0.50), (0.50–0.55), (0.55–0.60),

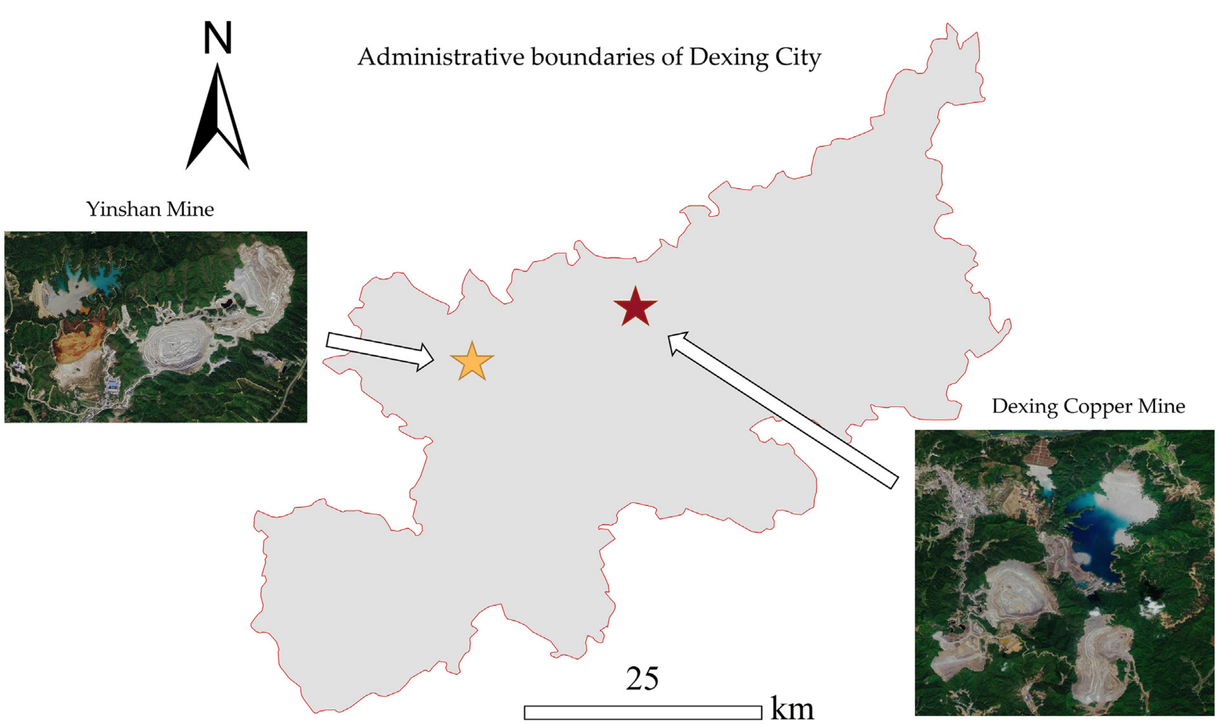



**Fig. 6.** The administrative boundaries of Dexing City and its main mines (satellite maps from tianditu.gov.cn).

**Table 1**
Statistics for the classes of AOD distribution in Dexing City.

| Class | Area percent 2010 | 2014 | 2018 | 2021 |
|---|---|---|---|---|
| <0.20 | 0.17 % | 0.08 % | 0.04 % | 0.63 % |
| 0.20–0.25 | 0.25 % | 0.04 % | 2.47 % | 14.67 % |
| 0.25–0.30 | 0.42 % | 0.13 % | 16.47 % | 74.29 % |
| 0.30–0.35 | 5.14 % | 0.42 % | 62.63 % | 9.24 % |
| High (<0.20) | 5.98 % | 0.67 % | 81.61 % | 98.83 % |
| 0.35–0.40 | 9.36 % | 3.93 % | 17.06 % | 0.59 % |
| 0.40–0.45 | 30.10 % | 9.11 % | 0.75 % | 0.13 % |
| 0.45–0.50 | 49.25 % | 17.81 % | 0.25 % | 0.13 % |
| 0.50–0.55 | 4.77 % | 58.86 % | 0.04 % | 0.08 % |
| Medium (0.35–0.55) | 93.48 % | 89.71 % | 18.10 % | 0.93 % |
| 0.55–0.60 | 0.25 % | 9.20 % | 0.08 % | 0.04 % |
| 0.60–0.65 | 0.17 % | 0.17 % | 0.13 % | 0.04 % |
| 0.65–0.70 | 0.08 % | 0.17 % | 0.04 % | 0.04 % |
| >0.7 | 0.04 % | 0.08 % | 0.04 % | 0.13 % |
| Low (>0.55) | 0.54 % | 9.62 % | 0.29 % | 0.25 % |

**Note:** Data, calculations, images, maps, etc., please refer to http://doi.org/10.13140/RG.2.2.32279.24485.
The AOD from the years 2010, 2014, 2018 and 2021 are charted by ArcGIS to obtain the distribution maps, which reflect the spatial characteristics of AOD changes in Dexing City from 2010 to 2021, as shown in Fig. 7.

(0.60–0.65), (0.65–0.70), (>0.70). The AOD distribution is further classified into three classes according to air quality: High (<0.35), Medium (0.35–0.55), Low (>0.55). According to the calculation results, the area and percentage statistics of each vegetation cover class (2010 to 2021) are shown in Table 1.

### 3.2.1. Analysis: 2010 to 2014

- According to the statistics (Table 1), the area percentage of High (<0.35) and Medium (0.35–0.55) in Dexing City showed a clear downward trend from 2010 to 2014; while the area percentage of Low (>0.55) showed a clear upward trend from 2010 to 2014; however by 2014, the area percentage of Low (>0.55) is even as high as 9.62 %, which revealed that the air quality of Dexing City has a significant decrease from 2010 to 2014.
- Combined statistics (as shown in Table 1 and Fig. 8) with the map analysis (Fig. 7), from 2010 and 2014, the air quality in the city of Dexing declined significantly, and it can be found that the areas of poor air quality are mainly located in the vicinity of the two mines in Dexing City, Dexing Copper Mine and Yinshan Mine (as shown in Fig. 6).

It can be surmised that from 2010 to 2014, Dexing City remained committed to the development of mineral resources, but it was clear that the air quality optimization and the treatment of mine dust pollution were not effective enough. In particular, there was a significant decline in air quality in the main mining areas of the two large mines from 2010 to 2014, probably due to the lack of attention and timely treatment of mine dust pollution caused by frequent mining activities.

### 3.2.2. Analysis: 2014 to 2021

- According to the statistics (as shown in Table 1), the area percentage of High (<0.35) showed a clear upward trend in Dexing City from 2014 to 2021; by 2021, the area percentage of High (<0.35) is even as high as 98.83 %; and the area percentage of Low (>0.55) showed a downward trend, and by 2021, only 0.25 % of the city area remained Low (>0.55), which indicated the efforts made by Dexing City and mines to combat air pollution (mine dust pollution) from 2014 to 2021.
- Combined statistics (as shown in Table 1 and Fig. 8) with the maps analysis (Figs. 7 and 9), it can be found that the air quality in Dexing City improved a lot after 2014, especially in the main mining area, reflecting the efforts made by the government and the mines on mine dust pollution treatment.

It can be speculated that from 2014 to 2021, Dexing City actively carried out the optimisation of air quality in mining areas and the treatment

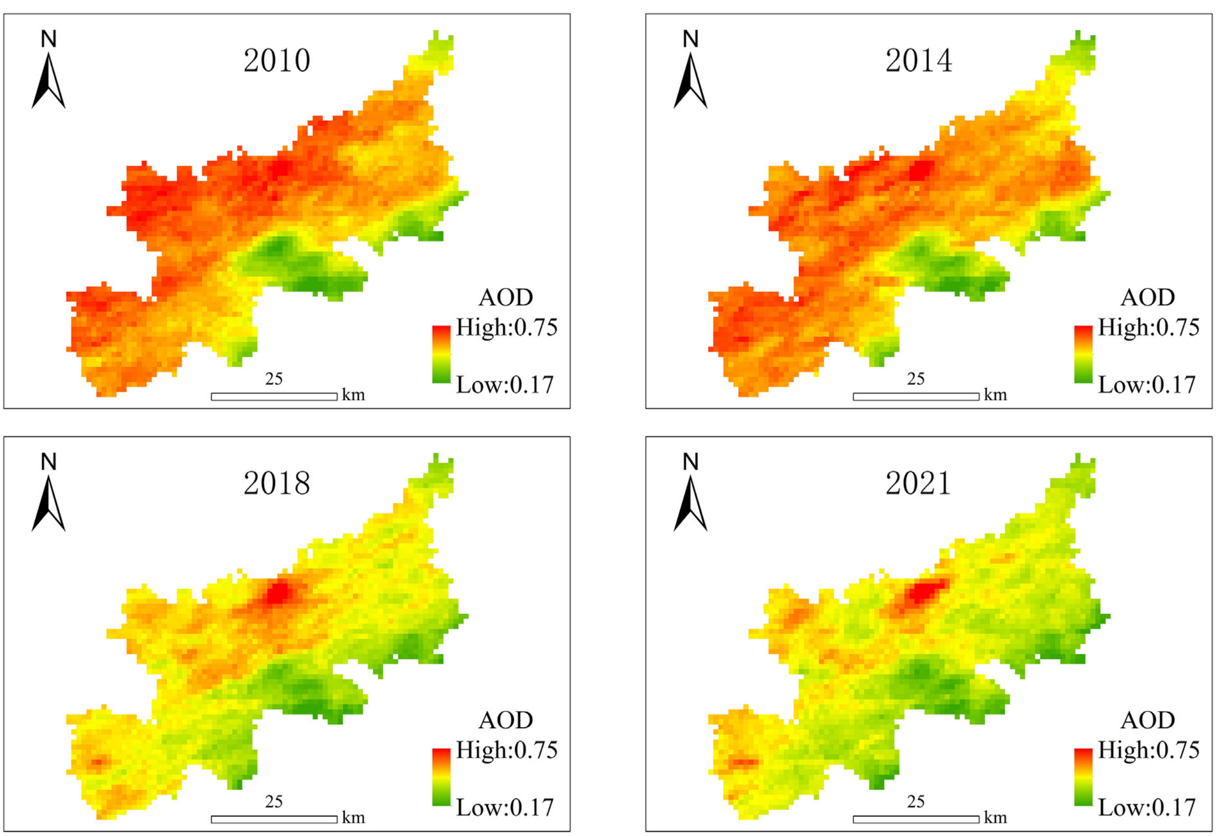



**Fig. 7.** The AOD distribution maps of Dexing City in 2010, 2014, 2018 and 2021.

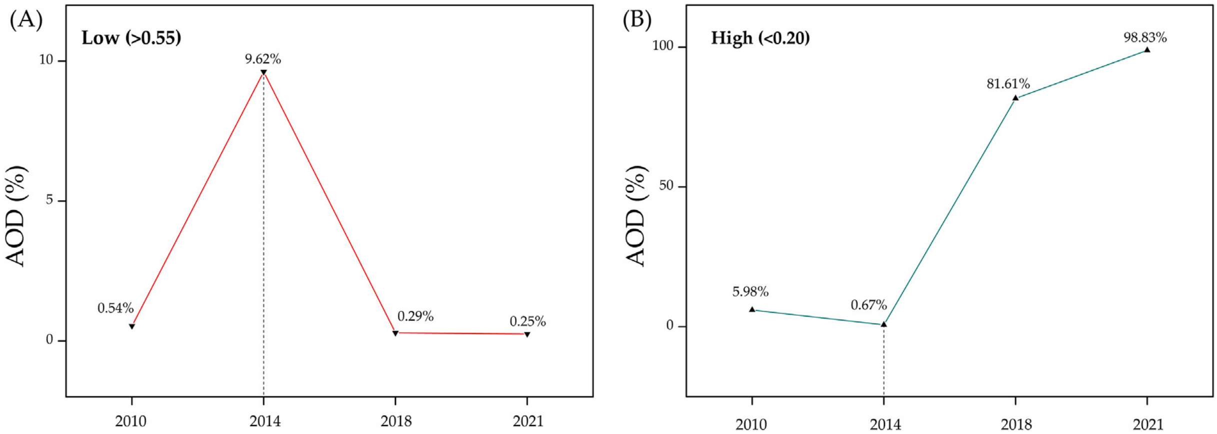



**Fig. 8.** The AOD changes in Dexing City from 2010 to 2014.

of mine dust while conducting mining activities, with significant results, especially in the main mining area of the Yinshan Mine. From 2014 to 2021, the air quality in the main mining areas of the two large mines was significantly improved, probably due to the government as well as the mining enterprises strengthening the prevention and control of mine dust pollution in Dexing City.

*3.2.3. Discussion: mine dust pollution prevention and control in Dexing City, China*

Around 2008, China put forward the proposal of "Green Mine Construction" (Li et al., 2022b; Huang et al., 2012), calling on mines to develop the mineral resources while keeping ecological disturbances in the mining areas and surrounding areas within a manageable range.

Clearly, Dexing City has done this: while Dexing City is vigorously developing its mineral resources, it also pays great attention to environmental protection, according to our study, the air quality in Dexing City has improved significantly from 2014 to 2021, all thanks to the efforts of the local government and mining companies in Dexing City.

In recent years, although the mining activities in Dexing City might have a serious impact on the ecological environment (e.g. rivers), agriculture and the health of the residents. At the same time, while extracting resources, Dexing City is also actively involved in pollution prevention and treatment, such as using fog cannons to spray ultra-micro water mist to adsorb mine dust. In addition, Dexing City is also actively engaged in vegetation restoration and land reclamation to treat mine pollution (Zhang et al., 2021b) and has made significant progress.

Mine dust management in Dexing City provides a good example for other mining cities, and in order to verify our inference about the mine dust pollution situation and mine dust management in Dexing City obtained by calculating the change in AOD from 2010 to 2021, we conducted a field survey combining local information and interviews with the managers of mining enterprises and nearby residents, and came to the following conclusions (as shown in Fig. 10):

- In parallel with the development of mineral resources, Dexing City has actively carried out environmental management of the mining areas, with particular emphasis on planting vegetation around the mine site, which has also effectively prevented the spread of mine dust.
- Since 2014, the Dexing Copper Mine has carried out comprehensive environmental management of its pits; while the Yinshan Mine has gradually shifted to underground mining to reduce the dust pollution caused by open-pit mining (Liu et al., 2014).

## 4. Conclusions

In this paper, the second section combined literature studies, statistical studies and meta analysis to introduce the public to the severity of current worldwide mine dust pollution and its hazards to the environment, miners (occupational health) and public health; and taking Dexing City of China as an example, the third section calculated the changes in aerosol optical depth (AOD) over the years (2010, 2014, 2018 and 2021), charted AOD distribution maps, and analysed the trend of AOD changes, to infer the severity of mine dust pollution, the progress of pollution treatment and the efforts made by the local government and the mines for mine pollution treatment. As a result, we made the following conclusions and suggestions:

- Mine dust pollution and its environmental & health risks: mine dust causes damage to the eco-system through particulate matter (e.g. $PM_{10}$, $PM_5$, $PM_{2.5}$, etc.) and heavy metals (e.g. Cu, Mg, Co, Cr, etc.), leading to environmental damage such as vegetation reduction and landscape destruction, an increase in the incidence of occupational diseases (e.g. pneumoconiosis, silicosis, etc.) and lung cancer, crop contamination and food crises. The environmental hazards caused by mining dust are so serious

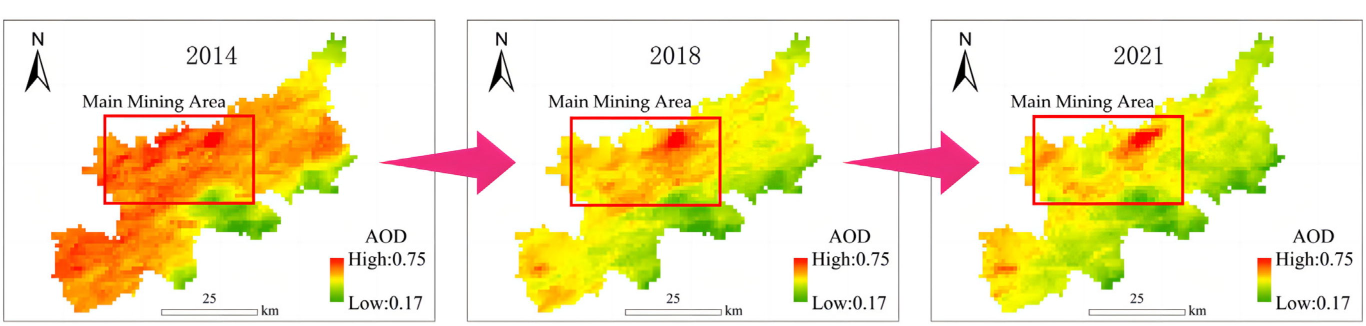



**Fig. 9.** The AOD changes in Dexing City from 2014 to 2021.

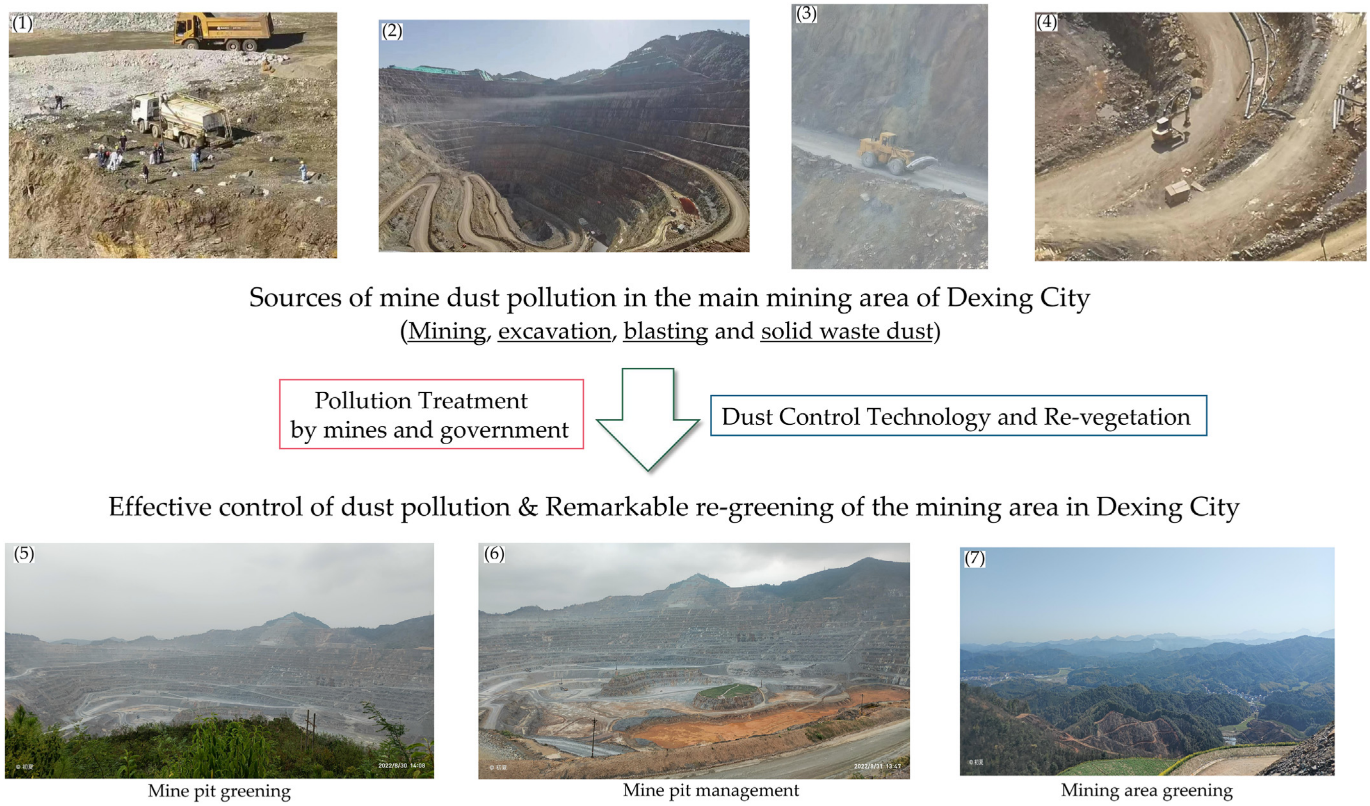



**Fig. 10.** Sources of mine dust pollution in the main mining area of Dexing City, and the dust pollution management of the main mining areas in Dexing City.

that it is essential to monitor, control and prevent it; residents, workers and researchers who are exposed to mine dust for long periods of time also need to protect themselves, for example by wearing dust masks.

- Mine dust pollution and its monitoring: Calculating the change of aerosol optical depth (AOD) to infer the mine dust pollution and the progress of mine dust management is a very intuitive and effective method to monitor mine dust pollution on a regional scale. In this paper, the changes in AOD over the years (2010, 2014, 2018 and 2021) were calculated and mapped, the trends of AOD changes were analysed to infer the severity of mine dust pollution, the progress of pollution control and the efforts made by the local government and mine authorities to control mine dust pollution. Based on the changes in AOD, it is inferred that mine dust pollution was more serious in Dexing from 2010 to 2014, while mine dust pollution was effectively managed after 2014, which is basically consistent with the results obtained from the field survey.

In a nutshell, we claim that this paper serves as a guide to starting a conversation, it also has limitations, which are mainly reflected in the following:

- While the paper reviewed the environmental and health threats posed by mine dust, and also explored and discussed the correlation between mine dust exposure and lung cancer through meta-analysis, the correlation between mine dust exposure and diseases such as cardiovascular disease, cerebrovascular disease and diabetes remains unexplored and unknown;
- While the paper advocated remote sensing technologies (e.g. calculating changes in AOD) to infer mine dust pollution situation and mine dust management progress, the inferences also need to be verified through field surveys, otherwise the results will be inaccurate.

Finally, we hope more experts, researchers and scholars will be interested and engage in research in this field of mine pollution assessment and treatment.

## Image sources

Some of the material images are from the following websites, and authors really appreciate it and declare that the images in the text are not infringing (License CC BY-SA 4.0 http://creativecommons.org/licenses/by-sa/4.0).

Fig. 1: (1)-ian.umces.edu/media-library/mine-drainage/; (2)-ian.umces.edu/media-library/sediment/.

(3)-ian.umces.edu/media-library/acid-rain/; (4)-ian.umces.edu/media-library/air-quality-medium/.

(5)-ian.umces.edu/media-library/quercus-palustris-swamp-spanish-oak/.

Fig. 4: (1)-ian.umces.edu/media-library/mine-drainage/; (2)-ian.umces.edu/media-library/petroleum-industry-mining-truck/.

(3)-ian.umces.edu/media-library/forestry-worker/.

Fig. 5: (1)-ian.umces.edu/media-library/mine-drainage/; (2)-ian.umces.edu/media-library/acid-rain/.

(3)-ian.umces.edu/media-library/sediment/; (4)-ian.umces.edu/media-library/drinking-water/.

(5)-ian.umces.edu/media-library/taro-plantation/; (6)-ian.umces.edu/media-library/river-3d-foothills-and-sandy-riverbed/.

(7)-ian.umces.edu/media-library/farmer-with-corn/.

## CRediT authorship contribution statement

Conceptualisation, H.Y. and I.Z.; methodology, H.Y.; validation, I.Z.; formal analysis, H.Y.; resources, H.Y.; data curation, H.Y.; writing - original draft preparation, H.Y.; writing - review and editing, I.Z.; visualisation, H.Y.; supervision, I.Z.; project administration, I.Z. Both authors have read and agreed to the published version of the manuscript.

## Data availability

Data will be made available on request.

## Declaration of competing interest

Both authors declare no conflict of interest.


## Acknowledgments

Firstly, the authors thank the Graduate Research Excellence Scholarship (GRES) from Monash University; secondly, the authors express their gratitude to the experts in the research field of mine pollution and public health for their effort; finally, the authors would like to thank the sources of the material in the graphic abstract (CC BY-SA 4.0 License: creativecommons.org/licenses/by-sa/4.0): Remote Sensing (author: @macrovector, from freepik.com), Environmental Protection (author: @rawpixel.com, from freepik.com), Mine Dust Pollution (author: @macrovector, from freepik.com).


## References


Asati, A., Pichhode, M., Nikhil, K., 2016. Effect of heavy metals on plants: an overview. Int. J. Appl. Innov. Eng. Manag. 5 (3), 56–66.

Baghaie, A.H., Aghili, F., 2019. Investigation of heavy metals concentration in soil around a PbZn mine and ecological risk assessment. Environ, Health Eng. Manag. J. 6 (3), 151–156.

Bai, R., Xue, Y., Jiang, X., Jin, C., Sun, Y., 2022. Retrieval of high-resolution aerosol optical depth for urban air pollution monitoring. Atmosphere 13 (5), 756.

Bakhtavar, E., Hosseini, S., Hewage, K., Sadiq, R., 2021. Air pollution risk assessment using a hybrid fuzzy intelligent probability-based approach: mine blasting dust impacts. Nat. Resour. Res. 30 (3), 2607–2627.

Baluchová, B.M., Bačík, P., Mamová, A., 2019. The health impact of mineral dust air pollution on the global and local scale (on the example from Slovakia). Neuroendocrinol. Lett. 40, 1.

Battogtokh, B., Lee, J.M., Woo, N., 2014. Contamination of water and soil by the Erdenet copper–molybdenum mine in Mongolia. Environ. Earth Sci. 71 (8), 3363–3374.

Bhuiyan, M.A., Islam, M.A., Dampare, S.B., Parvez, L., Suzuki, S., 2010. Evaluation of hazardous metal pollution in irrigation and drinking water systems in the vicinity of a coal mine area of northwestern Bangladesh. J. Hazard. Mater. 179 (1–3), 1065–1077.

Blondet, I., Schreck, E., Viers, J., Casas, S., Jubany, I., Bahí, N., Darrozes, J., 2019. Atmospheric dust characterisation in the mining district of Cartagena-La Unión, Spain: air quality and health risks assessment. Sci. Total Environ. 693, 133496.

Brüske-Hohlfeld, I., Mühner, M., Pohlabeln, H., Ahrens, W., Bolm-Audorff, U., Kreienbrock, L., Jückel, K.H., 2000. Occupational lung cancer risk for men in Germany: results from a pooled case-control study. Am. J. Epidemiol. 151 (4), 384–395.

Cao, Y., Gao, H., 2012. Prevalence and causes of air pollution and lung cancer in Xuanwei City and Fuyuan County, Yunnan Province ,China. Front. Med. 6 (2), 217.

Cassidy, A., Mannetje, A.T., van Tongeren, M., Field, J.K., Zaridze, D., Szeszenia-Dabrowska, N., Boffetta, P., 2007. Occupational exposure to crystalline silica and risk of lung cancer: a multicenter case-control study in Europe. Epidemiology 36–43.

Cavusoglu, I., Yilmaz, E., Yilmaz, A.O., 2021. Sodium silicate effect on setting properties, strength behavior and microstructure of cemented coal fly ash backfill. Powder Technol. 384, 17–28.

Chen, R., Lee, I., Zhang, L., 2015. Biopolymer sstabilisation of mine tailings for dust control. J. Geotech. Geoenviron. 141 (2), 04014100.

Chen, X., Guo, C., Song, J., Wang, X., Cheng, J., 2019. Occupational health risk assessment based on actual dust exposure in a tunnel construction adopting roadheader in Chongqing, China. Build. Environ. 165, 106415.

Dang, X., Shan, Z., 2018. Dust pollution and control with leather waste. Environ. Chem. Lett. 16 (2), 427–437.

Entwistle, J.A., Hursthouse, A.S., Marinho Reis, P.A., Stewart, A.G., 2019. Metalliferous mine dust: human health impacts and the potential determinants of disease in mining communities. Current Pollution Reports 5 (3), 67–83.

Esmaeili, A., Moore, F., Keshavarzi, B., Jaafarzadeh, N., Kermani, M., 2014. A geochemical survey of heavy metals in agricultural and background soils of the Isfahan industrial zone, Iran. Catena 121, 88–98.

Farmer, A.M., 1993. The effects of dust on vegetation—a review. Environ. Pollut. 79 (1), 63–75.

Frank, D., 2008. One world, one health, one medicine. Can. Vet. J. 49 (11), 1063 (access on November 2008) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2572090/.

Ganesan, S., Sangeetha, R., Arivazhagan, R., Swaminathan, S., 2019. Exposure to coal mine dust predisposes mine workers to oxidative stress and diabetes mellitus. Age (years) 60 (60), 60.

Gautam, S., Patra, A.K., Sahu, S.P., Hitch, M., 2018. Particulate matter pollution in opencast coal mining areas: a threat to human health and environment. Int. J. Min. Reclam. Environ. 32 (2), 75–92.

Ghose, M.K., Majee, S.R., 2001. Air pollution caused by opencast mining and its abatement measures in India. J. Environ. Manag. 63 (2), 193–202.

Gil-Loaiza, J., Field, J.P., White, S.A., Csavina, J., Felix, O., Betterton, E.A., Sáez, A.E., Maier, R.M., 2018. Phytoremediation reduces dust emissions from metametal (loid)-contaminated mine tailings. Environ. Sci. Technol. 52 (10), 5851–5858.

Gui, C., Geng, F., Tang, J., Niu, H., Zhou, F., Liu, C., Teng, H., 2020. Gas–solid two-phase flow in an underground mine with an optimized air-curtain system: a numerical study. Process Saf. Environ. Prot. 140, 137–150.

Gumenik, I., Lozhnikov, O., 2015. Current condition of damaged lands by surface mining in Ukraine and its influence on environment. New Developments in Mining Engineering/ Theoretical and Practical Solution of Mineral Resources Mining. 139, p. 145.

Guo, X., Sun, Q., Zhao, Y., Cai, H., 2019. Identification and characterisation of heavy metals in farmland soil of Hunchun basin. Environ. Earth Sci. 78 (10), 1–11.

Han, L., Han, R., Ji, X., Wang, T., Yang, J., Yuan, J., Ni, C., 2015. Prevalence characteristics of coal workers' pneumoconiosis (CWP) in a state-owned mine in Eastern China. Int. J. Environ. Res. Public Health 12 (7), 7856–7867.

Han, L., Yao, W., Bian, Z., Zhao, Y., Zhang, H., Ding, B., Ni, C., 2019. Characteristics and trends of pneumoconiosis in the Jiangsu Province, China, 2006–2017. Int. J. Environ. Res. Public Health 16 (3), 437.

Hendryx, M., 2009. Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia. Int. Arch. Occup. Environ. Health 82 (2), 243–249.

Hendryx, M., O'Donnell, K., Horn, K., 2008. Lung cancer mortality is elevated in coal-mining areas of Appalachia. Lung Cancer 62 (1), 1–7.

Hendryx, M., Higginbotham, N., Ewald, B., Connor, L.H., 2019. Air quality in association with rural coal mining and combustion in New South Wales Australia. J. Rural. Health 35 (4), 518–527.

Hendryx, M., Islam, M.S., Dong, G.H., Paul, G., 2020. Air pollution emissions 2008–2018 from Australian coal mining: implications for public and occupational health. Int. J. Environ. Res. Public Health 17 (5), 1570.

Hendryx, M., Islam, M.S., Dong, G.H., Paul, G., 2020. Air pollution emissions 2008–2018 from australian coal mining: Implications for public and occupational health. Int. J. Environ. Res. Public Health 17 (5), 1570.

Hnizdo, E., Vallyathan, V., 2003. Chronic obstructive pulmonary disease due to occupational exposure to silica dust: a review of epidemiological and pathological evidence. Occup. Environ. Med. 60 (4), 237–243.

Hua, F., Xueqi, G., Xipeng, J., Shunzhang, Y., Kaiguo, W., Guidotti, T.L., 1994. Lung cancer among tin miners in southeast China: silica exposure, silicosis, and cigarette smoking. Am. J. Ind. Med. 26 (3), 373–381.

Huang, X., Li, X., Hu, K., Liu, Y., Liu, D., 2012. Status and Achievement of the Green Mine in China. International Proceedings of Chemical Biological & Environmental Science and Development (ICESD. http://ipcbee.com/vol36/005-ICGES2012-S014.pdf.

Izydorczyk, G., Mikula, K., Skrzypczak, D., Moustakas, K., Witek-Krowiak, A., Chojnacka, K., 2021. Potential environmental pollution from copper metallurgy and methods of management. Environ. Res. 197, 111050.

Jorgenson, M., Sandlos, J., 2021. Dust versus dust: aluminum therapy and silicosis in the Canadian and global mining industries. Canadian Historical Review 102 (1), 1–26.

Kachuri, L., Villeneuve, P.J., Parent, M.É., Johnson, K.C., Harris, S.A., Canadian Cancer Registries Epidemiology Group, 2014. Occupational exposure to crystalline silica and the risk of lung cancer in Canadian men. Int. J. Cancer 135 (1), 138–148. https://doi.org/10.1002/ijc.28629 Epub 2013 Dec 7. PMID: 24272527.

Kasap, T., Yilmaz, E., Guner, N.U., Sari, M., 2022. Recycling dam tailings as cemented mine backfill: mechanical and geotechnical properties. Adv. Mater. Sci. Eng. 2022, 6993068.

Kasap, T., Yilmaz, E., Sari, M., 2022. Physico-chemical and micro-structural behavior of cemented mine backfill: effect of pH in dam tailings. J. Environ. Manag. 314, 115034.

Kaufman, Y.J., Sendra, C., 1988. Algorithm for automatic atmospheric corrections to visible and near-IR satellite imagery. Int. J. Remote Sens. 9 (8), 1357–1381.

Koohestani, N., Darban, A.K., Mokhtari, P., Darezereshki, E., Yilmaz, E., 2021. Geopolymerization of soil by sodium silicate as an approach to control wind erosion. Int. J. Environ. Sci. Technol. 18 (7), 1837–1848.

Kumar, N., 2015. Effect of different mining dust on the vegetation of district Balaghat, MP-a critical review. Int. J. Sci. Res. 4 (8), 603–607.

Kumar, N., 2015. Effect of different mining dust on the vegetation of district Balaghat, MP-a critical review. Int. J. Sci. Res. 4 (8), 603–607.

Kumar, N., Chu, A., Foster, A., 2007. An empirical relationship between PM2. 5 and aerosol optical depth in Delhi metropolitan. Atmos. Environ. 41 (21), 4492–4503.

Landen, D.D., Wassell, J.T., McWilliams, L., Patel, A., 2011. Coal dust exposure and mortality from ischemic heart disease among a cohort of US coal miners. Am. J. Ind. Med. 54 (10), 727–733.

Laney, A.S., Weissman, D.N., 2012. The classic pneumoconioses: new epidemiological and laboratory observations. Clin. Chest Med. 33 (4), 745–758.

Laney, A.S., Weissman, D.N., 2014. Respiratory diseases caused by coal mine dust. J Occup. Environ. Med. 56 (0 10), S18.

Leonard, R., Zulfikar, R., Stansbury, R., 2020. Coal mining and lung disease in the 21st century. Curr. Opin. Pulm. Med. 26 (2), 135–141.

Leonard, R., Zulfikar, R., Stansbury, R., 2020. Coal mining and lung disease in the 21st century. Curr. Opin. Pulm. Med. 26 (2), 135–141.

Li, K., Liang, T., Wang, L., Yang, Z., 2015. Contamination and health risk assessment of heavy metals in road dust in Bayan Obo Mining Region in Inner Mongolia, North China. J. Geogr. Sci. 25 (12), 1439–1451.

Li, J.J., Yilmaz, E., Cao, S., 2020. Influence of solid content, cement/tailings ratio and curing time on rheology and strength of cemented tailings backfill. Minerals 10 (10), 922.

Li, L., Zhang, R., Sun, J., He, Q., Kong, L., Liu, X., 2021. Monitoring and prediction of dust concentration in an open-pit mine using a deep-learning algorithm. J. Environ. Health Sci. Eng. 19 (1), 401–414.

Li, S., Yu, L., Jiang, W., Yu, H., Wang, X., 2022. The recent progress china has made in green mine construction, Part I: mining groundwater pollution and sustainable mining. Int. J. Environ. Res. Public Health 19, 5673. https://doi.org/10.3390/ijerph19095673.

Li, S., Yu, L., Jiang, W., Yu, H., Wang, X., 2022. The recent progress china has made in green mine construction, part I: mining groundwater pollution and sustainable mining. Int. J. Environ. Res. Public Health 19 (9), 5673.

Liao, Q., Feng, G., Fan, Y., Hu, S., Shao, H., Huang, Y., 2018. Experimental investigations and field applications of chemical suppressants for dust control in coal mines. Advances in Materials Science and Engineering 2018.

Liu, T., Liu, S., 2020. The impacts of coal dust on miners' health: a review. Environ. Res. 190, 109849.
Liu, Xuan, et al., 2014. Cooling and exhumation of the mid-Jurassic porphyry copper systems in Dexing City, SE China: insights from geo-and thermochronology. Mineral. Deposita 49 (7), 809–819.
Liu, G., Xu, Q., Zhao, J., Nie, W., Guo, Q., Ma, G., 2021. Research status of pathogenesis of pneumoconiosis and dust control technology in mine—a review. Appl. Sci. 11 (21), 10313.
Liu, Y., Wang, P., Gojenko, B., Yu, J., Wei, L., Luo, D., Xiao, T., 2021. A review of water pollution arising from agriculture and mining activities in Central Asia: Facts, causes and effects. Environ. Pollut. 291, 118209.
Liu, W., Liang, R., Zhang, R., Wang, B., Cao, S., Wang, X., Chen, W., 2022. Prevalence of coal worker's pneumoconiosis: a systematic review and meta-analysis. Environ. Sci. Pollut. Res. 1–9.
Lozano, Rafael, et al., 2012. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 380 (9859), 2095–2128.
Lyapustin, A., Wang, Y., Korkin, S., Huang, D., 2018. MODIS collection 6 MAIAC algorithm. Atmos. Meas. Techn. 11 (10), 5741–5765.
Maqbool, A., Bian, Z., Akram, M.W., 2019. Bioassessment of heavy metals in wheat crop from soil and dust in a coal mining area. Pollution 5 (2), 323–337.
McBean, R., Tatkovic, A., Edwards, R., Newbigin, K., 2020. What does coal mine dust lung disease look like? A radiological review following re-identification in Queensland. J. Med. Imaging Radiat. Oncol. 64 (2), 229–235.
Miler, M., Gosar, M., 2019. Assessment of contribution of metal pollution sources to attic and household dust in Pb-polluted area. Indoor Air 29 (3), 487–498.
Minowa, M., Stone, B.J., Blot, W.J., 1988. Geographic pattern of lung cancer in Japan and its environmental correlations. Jpn. J. Cancer Res. 79 (9), 1017–1023.
Murgia, N., Torén, K., Blanc, P.D., Tarlo, S.M., 2021. Chronic obstructive airway disease due to occupational exposure. Asthma in the Workplace. CRC Press, pp. 311–320.
Mwaanga, P., Silondwa, M., Kasali, G., Banda, P.M., 2019. Preliminary review of mine air pollution in Zambia. Heliyon 5 (9), e02485.
Mzileni, O., Sitas, F., Steyn, K., Carrara, H., Bekker, P., 1999. Lung cancer, tobacco, and environmental factors in the African population of the Northern Province,South Africa. Tobacco Control 8 (4), 398–401.
Nagajyoti, P.C., Lee, K.D., Sreekanth, T.V.M., 2010. Heavy metals, occurrence and toxicity for plants: a review. Environ. Chem. Lett. 8 (3), 199–216.
Nelson, Gill, 2013. Occupational respiratory diseases in the South African mining industry. Glob. Health Action 6 (1), 19520.
Oxman, A.D., Muir, D.C., Shannon, H.S., Stock, S.R., Hnizdo, E., Lange, H.J., 2012. Occupational dust exposure and chronic obstructive pulmonary disease: a systematic overview of the evidence. Am. Rev. Respir. Dis. 148 (1), 38–48. https://doi.org/10.1164/ajrccm/148.1.38.
Pal, S., Mandal, I., 2017. Impacts of stone mining and crushing on stream characters and vegetation health of dwarka river basin of Jharkhand and West Bengal, Eastern India. J. Environ. Geogr. 10 (1–2), 11–21.
Phillips, J., 2016. Climate change and surface mining: a review of environment-human interactions & their spatial dynamics. Appl. Geogr. 74, 95–108.
Qin, G., Niu, Z., Yu, J., Li, Z., Ma, J., Xiang, P., 2021. Soil heavy metal pollution and food safety in China: effects, sources and removing technology. Chemosphere 267, 129205.
Rodríguez, V., Tardón, A., Kogevinas, M., Prieto, C.S., Cueto, A., García, M., Zaplana, J., 2000. Lung cancer risk in iron and steel foundry workers: a nested case control study in Asturias, Spain. Am. J. Ind. Med. 38 (6), 644–650.
Sairanen, M., Pursio, S., 2020. Near field modelling of dust emissions caused by drilling and crushing. SN Appl. Sci. 2 (7), 1–15.
Samet, J.M., Pathak, D.R., Morgan, M.V., Coultas, D.B., James, D.S., Hunt, W.C., 1994. Silicosis and lung cancer risk in underground uranium miners. Health Phys. 66 (4), 450–453.
Sedibe, M., Achilonu, M.C., Tikilili, P., Shale, K., Ebenebe, P.C., 2017. South African Mine Effluents: Heavy Metal Pollution and Impact on the Ecosystem.
Shi, H., Xiao, Z., Liang, S., Zhang, X., 2016. Consistent estimation of multiple parameters from MODIS top of atmosphere reflectance data using a coupled soil-canopy-atmosphere radiative transfer model. Remote Sens. Environ. 184, 40–57.
Shi, G., Qi, J., Wang, Y., Liu, S., 2021. Experimental study on the prevention of coal mine dust with biological dust suppressant. Powder Technol. 391, 162–172.
Shukla, S., Sharma, R.B., Sahu, M., 2019. Research article dust pollution affect morphophysiological traits of plant Mangifera indica Linn. Int. J. Bot. 15, 1–4.
Silver, S.R., Alarcon, W.A., Li, J., 2021. Incident chronic obstructive pulmonary disease associated with occupation, industry, and workplace exposures in the health and retirement study. Am. J. Ind. Med. 64 (1), 26–38.
Stayner, L.T., Graber, J.M., 2011. Does exposure to coal dust prevent or cause lung cancer? Occup. Environ. Med. 68 (3), 167–168.
Sun, L., Sun, C., Liu, Q., Zhong, B., 2010. Aerosol optical depth retrieval by HJ-1/CCD supported by MODIS surface reflectance data. Sci. China Earth Sci. 53 (1), 74–80.
Tang, Z., Chai, M., Cheng, J., Jin, J., Yang, Y., Nie, Z., Li, Y., 2017. Contamination and health risks of heavy metametals in street dust from a coal-mining city in eastern China. Ecotoxicol. Environ. Saf. 138, 83–91.
Tong, R., Cheng, M., Yang, X., Yang, Y., Shi, M., 2019. Exposure levels and health damage assessment of dust in a coal mine of Shanxi Province, China. Process Saf. Environ. Prot. 128, 184–192.
Toufigh, V., Ghassemi, P., 2020. Control and sstabilisation of fugitive dust: using eco-friendly and sustainable materials. Int. J. Geomech. 20 (9), 04020140.
Tse, L.A., Yu, I.T.S., Qiu, H., Au, J.S.K., Wang, X.R., 2012. Occupational risks and lung cancer burden for Chinese men: a population-based case–referent study. Cancer Causes Control 23 (1), 121–131.
Ulm, K., Waschulzik, B., Ehnes, H., Guldner, K., Thomasson, B., Schwebig, A., Nuβ, H., 1999. Silica dust and lung cancer in the German stone, quarrying, and ceramics industries: results of a case-control study. Thorax 54 (4), 347–351.
Vida, S., Pintos, J., Parent, M.É., Lavoué, J., Siemiatycki, J., 2010. Occupational exposure to silica and lung cancer: pooled analysis of two case-control studies in Montreal, CanadaOccupational exposure to silica and lung cancer. Cancer Epidemiol. Biomark. Prev. 19 (6), 1602–1611.
Wang, Yapeng, Jiang, Zhongan, 2021. Research on mine cleaner production based on high wettability spray control dust pollution. Case Stud. Therm. Eng. 25, 100896.
Wang, Z., Zhou, W., Jiskani, I.M., Ding, X., Luo, H., 2022. Dust pollution in cold region surface mines and its prevention and control. Environ. Pollut. 292, 118293.
Wang, H., Maqbool, A., Xiao, X., Yang, H., Bi, W., Bian, Z., 2022. Seasonal pollution and risk assessment of heavy metals in atmospheric dust from coal mining area. Int. J. Environ. Sci. Technol. 1–10.
Wei, X., Chang, N.B., Bai, K., Gao, W., 2020. Satellite remote sensing of aerosol optical depth: advances, challenges, and perspectives. Crit. Rev. Environ. Sci. Technol. 50 (16), 1640–1725.
Witschi, H., 2001. A short history of lung cancer. Toxicol. Sci. 64 (1), 4–6.
Xiu, Z., Nie, W., Yan, J., Chen, D., Cai, P., Liu, Q., Yang, B., 2020. Numerical simulation study on dust pollution characteristics and optimal dust control air flow rates during coal mine production. J. Clean. Prod. 248, 119197.
Xiu, Z., Nie, W., Yan, J., Chen, D., Cai, P., Liu, Q., Yang, B., 2020. Numerical simulation study on dust pollution characteristics and optimal dust control air flow rates during coal mine production. J. Clean. Prod. 248, 119197.
Zhang, H., Han, W., Xu, Y., Wang, Z., 2021. Analysis on the development status of coal mine dust disaster prevention technology in China. Journal of Healthcare Engineering 2021.
Zhang, M., He, T., Li, G., Xiao, W., Song, H., Lu, D., Wu, C., 2021. Continuous detection of surface-mining footprint in copper mine using Google Earth Engine. Remote Sens. 13 (21), 4273.