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The Need to Increase Indoor Air Quality Building, Well-Being and Improve the Quality of Life in the Mining Areas

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Abstract:- There are significant economic and environmental impacts associated with coal mining that the government must consider. Surface coal mining involves the removal of massive amounts of topsoil, resulting in faster soil erosion, air pollution, and a negative impact on the area's plants, quality of life, and human well-being. It can also lead to habitat loss, changes in water quality, and reduced quality of life and health in residential, urban, and public spaces. Air pollution from coal mining is dispersed more intensely in the environment and can cause breathing problems, harming human health and the environment. One possible solution for improving indoor air quality is to identify and reduce sources of outdoor pollution, which can help reduce health risks inside buildings. This paper analyzes the adverse effects that occurred during and after Hambach coal mine closure in Nordrhein-Westfalen, Germany. We present a causal loop diagram and recommend using outdoor air filtration in areas with elevated outdoor air pollution levels. We also examine governmental decisions' impact and new policies' influence on health and the environment. There is a positive relationship between ecosystem services and human well-being and health. These functions can significantly improve ecological conditions and reduce the pollution load. By integrating environmental processes such as ecosystem services, green space, and mechanical methods, we can achieve higher efficiency in controlling the environment and removing pollutants from the air, including gas pollution, fine dust, noise pollution, and unpleasant smells. This study focuses on air purification of indoor environments through mechanical equipment. The primary finding recommends using outdoor air filtration in areas with high outdoor air pollution levels. Overburden removal is recognized as one of the most critical parameters that affect other variables, given the changing groundwater elevation and human hazards.

Keywords*: Coal Mining, Conceptual Model, Indoor Air Quality, human well-being, and health.*

1. Introduction

The focus on well-being, environmental quality, social quality, sustainability, and distribution indicators are among the most critical policy in most countries [1]. The German government adopted a coal exit regulation in 2020. The government confirms a coal exit path through 2038, delivering considerable compensation for the coal companies. Using natural resources like coal positively affects economic and energy development. However, the effect of coal mining, its environmental issues, and consequences are visible [2].

Furthermore, coal mining activities also negatively influence the environment, resulting in environmental pollution in the soil and water, and it is the primary source of health-harming air pollution [3]. Burning fossil fuels (mostly Lignite, also called brown coal, is the most health-harming type of coal) plays a vital role in global electricity production, with 38% coming from hard coal. Since most Lignite mines are surface mines, they interact more with overburden removal and airborne particles. European countries (Germany on the top) are significant contributors to both consumption and production of Lignite coal despite governments' commitments to improving air quality and tackling climate change [4].

Environmental pollution caused by mining usually divides into two main groups, physical and chemical. Physical pollution is in the form of dust production, suspended solids in air and water, destruction and erosion of land, and soil dumps. Chemical pollutions are rare elements, such as nickel, mercury, and arsenic, released during combustion or drained water from mineral areas. The role of coal mines dust as the physical pollution in the etiology of these diseases needs to be seen concerning a broad view of possible determinants of disease: economic, individual, social, and environmental factors, which may interact as they affect people's health. The role and factors that cause air pollution problems in cities in the vicinity of coal mining activity areas cause the creation of an unstable urban spatial structure. These factors have caused health, comfort, freshness, and dynamism to disappear from the people and residents of the area inside the buildings. Since residents usually spend most of the day inside the work environment, indoor air pollutants become a significant risk factor. It is essential to avoid the consequences of breathing polluted air [5]. Therefore, to achieve pleasant and energizing air inside the buildings, solutions should be thought of to minimize the damage caused by the extraction of surface coal (Lignite) to nature and the health of the local people. These solutions and achievements are an approach that will positively impact the health and well-being of the residents in the homes in the short and long term. Determining engineering interventions requires correctly understanding how the disease is transmitted through polluted air [6].In this study, the Hambach lignite mine in NRW, Germany, is recognized as the primary source of airborne particles in the surrounding area of mines that can affect outdoor and indoor air quality. Although the chemical damage of coal mining, like the formation of acid mines, groundwater pollution, the effect of heavy metals (Hg, Cd, Pb, Cr, Cu, Zn, Ni), emission of suspended particles and gases including CH4, SO2, NOx, NOx, etc. cannot be ignored, this paper focuses on the essential variables that control pollution in the form of dust mining. Furthermore, the authors try to find the effect of coal dust and its dynamic interrelationship with outdoor and indoor air pollution in the villages near the Hambach Lignite mine. Finally, discuss some managerial decisions and engineering interventions to minimize disease by reducing exposure to indoor dust in areas near coal mines.

2. Literature

Based on "Reference [4]", 40% of coal power plants in the European region run on Lignite (110 power plants out of 293), and Germany is on top of them (**Fig. 1**). Lignite is comparatively cheaper than hard coal. However, its environmental and social effects include topsoil removal, rehabilitation of open mines, or forced resettlement of the population living around the mining area are much more. Since it has more water content (40% to 60%), it is considered "lower quality coal rather than hard coal and has a smaller energetic value per mass unit [7].

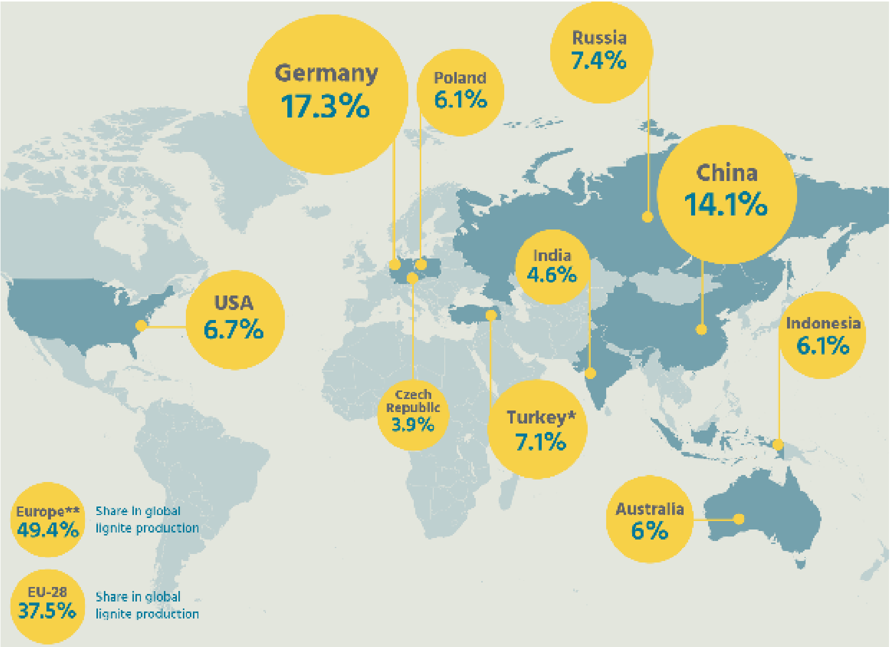

Fig. 1: 10 largest lignite mining countries with their share in global lignite production [4]

"Reference [7]" studied the states of coal mining in the USA (between 2007 and 2019, coal consumption in the USA dropped to almost 50%) and its future environmental and health impacts. They believed that any interaction with coal, like extraction, transportation, storage, and utilization of coal, produces dust that causes a noticeable risk to animals, human health, and the environment. Generated dust during extraction causes pulmonary diseases such as mine workers' pneumoconiosis (black lung disease); long-term, nearby cities will also be affected. Setiawan et al. studied the chemical pollution due to coal mining activity and its impact on soil, air, and water. They believed that coal mining activities on any stage of clearing land (impact on forest ecosystems), taking exploitation (effect on air pollution by coal dust particles), transporting (impact on erosion), stockpile (pollution in the air, soil, and water) and when the coal is burned (emission hazardous materials into the air like Hg, As, Se and CO2 gas, NOx, SO2) ultimately affect human health [3]. In 2022 the significance of mechanical ventilation systems and air purifiers equipped with in-line filters in withdrawing indoor airborne particles from indoor and outdoor sources in public areas was studied. This study suggested a significant insight for public health officials to implement air pollution control systems and improve indoor air quality [8]. "Reference [9]" discussed the effects of MERV 16 filters in an underground limestone mine in closed cabins. They considered the importance of keeping doors and windows closed and showed that filters could clean the cabin air with very high efficiency. Conversely, if the cabin door is open, it reduces the efficiency from 90% to below 50%. "Reference [10]" studied the requirements for expanding standards in building design to create health and well-being for professionals and users. They considered some strategies to improve indoor air quality and illustrated that the results would be positive if the standards are formulated clearly and repeatable. "Reference [11]" investigated the efficacy of HEPA air cleaners in improving indoor particulate matter 2.5 concentration. They concluded from their studies that portable air purifiers equipped with HEPA filters used for indoor air purification are powerful and high-efficiency air purifiers and significantly reduce indoor PM 2.5 to less than ten micrograms per cubic meter. "Reference [12]" considered the risk and operating costs associated with HVAC filters and outdoor air conditioning. The results show that MERV 13-16, compared with MERV 7-11 filters, are more efficient for HVAC systems and are the most suitable for achieving lower-cost HVAC risk reduction. Based on the literature, the coal dust surrounding the coal mine is the primary source of outdoor air pollution, which many countries, such as the USA and Germany, are trying to reduce. However, besides stopping coal extraction, different filtration systems are suggested to reduce the side effect of airborne coal. This study first illustrates a dynamic interrelationship model of the influential variable that creates and controls these airborne and the optimum border of the system to decrease the sources of the primary pollutants. Then provides an overview of the most effective filtration systems.

3. Methods

This study initially recognized the main variables related to lignite coal mining pollution and outdoor/indoor air quality in the villages around the Hambach coal mine. Then, the interrelation of these variables is illustrated using a Casual-Loop-Diagram (CLD), which is the qualitative feature of the system dynamics (SD) approach. After all, the most critical loop related to the air quality in the mining area and the surrounding cities is recognized, and the possible solutions are discussed. Furthermore, some high-tech filters with their application to decrease the hazards are compared.

4. Case study

Hambach Lignite coal mine is selected as a case study; it is owned by RWE and located in NRW, Germany. It is the largest open-cast mine in Western Europe, with a 40 mt/year capacity. In 2029, coal extraction in the Hambach lignite mine will end. Several leading regional planning, water management, and mining law approval procedures are underway. They will decide what the landscape will look like with a new forest and a large artificial lake [13]. The effect of coal dust (airborne) from the Hambach mine and the three villages surrounding it (Echweiler, Manheim, and Morschenich) is considered. Most of the surrounding land is used for the mining industry's logistics, energy supply, and refinement. The surrounding villages were forced to move to Elsdor in 2001 because of the mining effects. The current situation in the Hambach mine area is that around 40% of forests were lost because of the open lignite mining, which caused to increase in dust production rate (Fig. 1 and Fig. 2).

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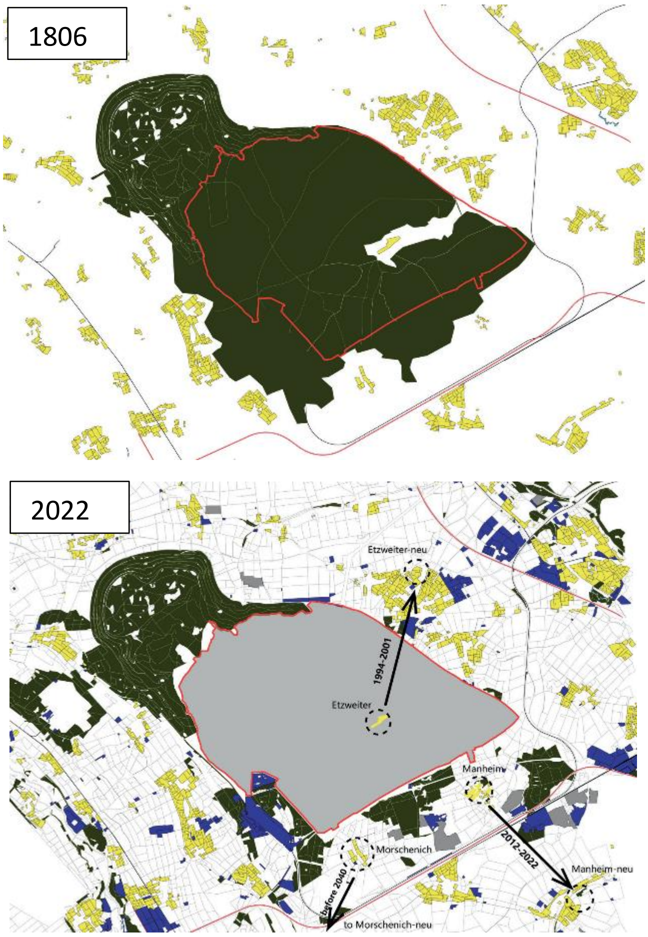

Fig. 1: Deforesting of Hambach mine between 1806-2022 [13]

In addition, wind speed and direction are critical in controlling airborne dust replacement. Fig. 4 illustrates the overall wind direction surrounding the Hambach mine (the wind direction might differ in different seasons, but it is mostly from east to west and southwest, and from south to northwest, based on satellite photo analysis). As can be seen, the Hambach pollution and the pollutants that come with wind from other areas (Fig. 5) can change the air quality of mine surrounding villages or the upstream villages. It might be correct that wind direction in the study area decreases the pollutant index (the wind direction varies on different days). Still, since the NRW has a high coal-mining capacity, the wind might bring the CH_4 (the most dangerous gas in coal mines) from other areas into the Hambach area.

Fig. 2: Current state of topsoil and coal removal in Hambach mine (self-took photo, Sep. 2022)

Based on the site visit and interview with residents, Manheim and Morschenich are currently almost free of population, and less than 10% of their residents live there. Another parameter that can control the coal dust in this area is rainfall. Based on Fig. 3, the average annual precipitation between 1980-2011 was lower than in the other place around the Hambach. Furthermore, the high rate of groundwater evacuation (557×10^6 m^3/year) in Hambach caused dryer land and increased coal/soil dust in the air [14].

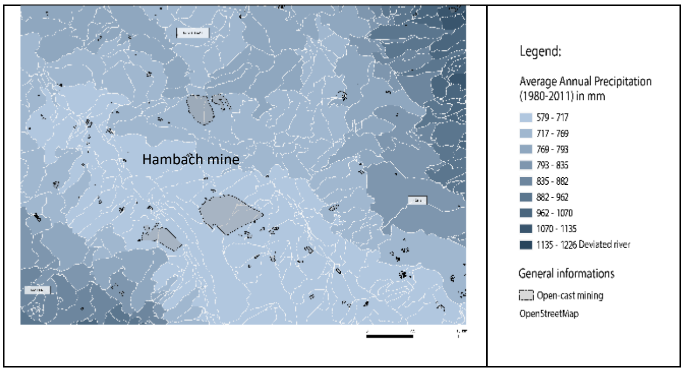

Fig. 3: Average annual precipitation 1980- 2011

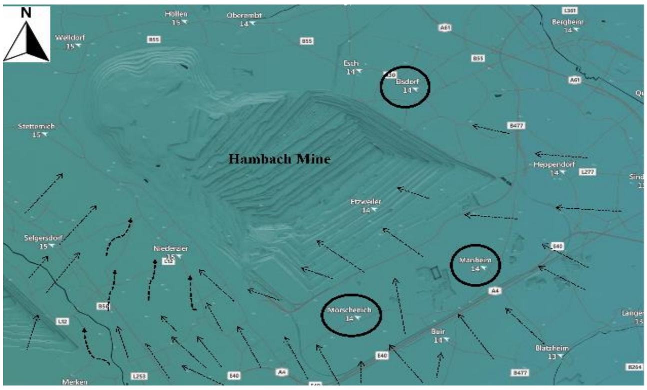

Fig. 4: Wind direction in the surrounding Hambach mine [15]

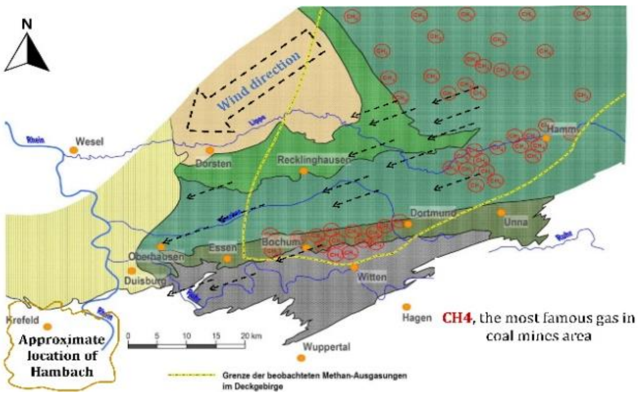

Fig. 5: Effect of wind direction to bring the pollutant from other areas- modified [16]

5. Results

In this study, we used SD to provide insight into the dynamic interrelationship between variables that impact indoor/outdoor air quality. Fig. *6* illustrates the border of study that includes a CLD of the most influential variables that affect the human health system and its interaction with lignite mining. CLD identifies the nature and extent of cause-and-effect dynamic relationships between two or more parameters (using signs on the ± arrows) and helps recognize the consequences of changing methods and procedures. Furthermore, it is suitable to show the future trend (none linear) between different variables (ascending, descending, or balancing) [24], [18].

However, due to the lack of quantitative measurements, we illustrated the system's interaction graphically and did not run a simulation. Furthermore, in the proposed CLD model, chemical pollution is not considered and mainly focuses on physical pollutants such as coal dust and airborne.

In Fig. *6*, if we start with mining, like any industry, it has its share of unfavorable effects on the environment and humans. The role of lignite mine dust in the etiology of these diseases needs to be considered in a broad view of possible determinants of disease: social (emigration), economic (new policy and investment), and environmental factors (deforestation and airborne dust), which interact as they impact people's health.

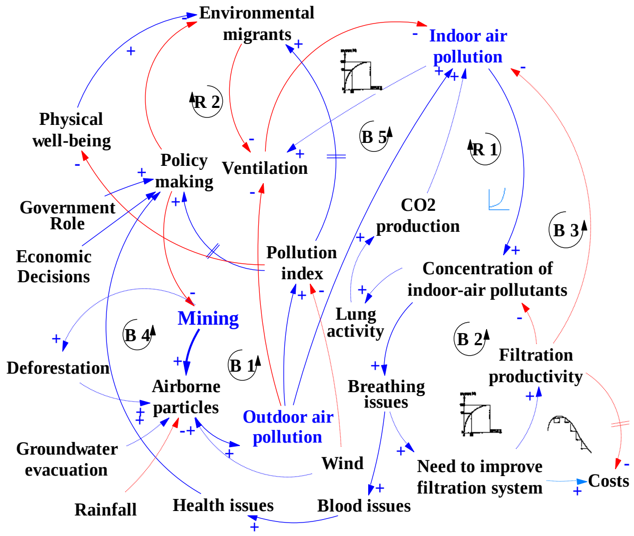

Fig. 6: Casual-loops diagram of Lignite coal mining effect and the out/indoor air quality

There is a direct relationship between mining & airborne particles and also a direct connection between airborne particles & outdoor air pollution (illustrated with a blue arrow and a (+) sign at its end). This direct interaction means that if mining increases, the airborne will also increase and vice versa. At the same time, there is a direct interaction between outdoor air pollution & pollution index, a direct interaction between outdoor air pollution & indoor pollution, and an indirect interaction between outdoor air pollution & ventilation. It means that when the outdoor air is more polluted, the outdoor ventilation into the houses will decrease because nobody wants to ventilate the contaminated air into his home; this interaction is illustrated with a red arrow and a (–) sign at its end.

In continuation, there is a direct interaction between the pollution index & policy-making, a direct interaction between the pollution index & environmental migrants, and an indirect interaction between the pollution index & physical well-being (the two-parallel line on the arrow means a delay). The indirect interaction between policy making & environmental migrants and the indirect interaction between policy-making & mining illustrates the results of new positive decisions to decrease the pollution index. In this case, the Hambach mine was temporarily stopped in Oct. 2018 by the supreme administrative court of NRW. Finally, it decided to stop mining activities and close Hambach in 2029, sooner than its long-term plan.

After increasing the environmental migration, the population in the villages decreased, and the need for ventilation descended. However, ventilation of polluted outdoor air causes increased indoor air pollution. Consequently, the desire for ventilation decreased, and residents used ventilation temporarily (if the outdoor air quality was high enough). This decision to use or not use ventilation during the day creates negative loops called balancing loops (illustrated with B5). In the SD approach, with a balancing loop, the system's behavior tries to reach a stable point by passing the time.

Furthermore, the concentrations of indoor air pollutants sometimes decrease with ventilation. However, increasing the concentrations of indoor air pollutants causes more lung activity, increases CO2 production, and finally increases indoor air pollution. This procedure creates a reinforcing loop that causes an exponential behavior in the

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long term (illustrated with R1). There are many balancing and reinforcing loops in the proposed model (Fig. *6*). Finding these loops (also called feedback loops) can help managers and engineers to focus on essential loops and variables, which are a practical key to improving the system into the desired trend.

During extreme air pollution events like high wind speed and surface mining activities in dry seasons, ventilation cannot bring fresh outdoor air to dilute indoor pollutants. It can get even more contaminants from the polluted outdoor air into indoor air. However, rainfall might improve the situation and result in less airborne dust. Concentrations of outdoor pollutants can also constantly change (fall and rise) because of temperature changes in cold seasons. For instance, outdoor pollutants may stay in the lower atmosphere because of temperature inversions. It takes place during periods of low temperature when warm air enters the upper atmosphere and traps cold air beneath it, resulting in pollutants building up at low altitudes. This phenomenon can be even worse with the slow wind speed and wind direction. Wind plays a significant role in airborne particles; on one side, it increases airborne particles, and on the other, it helps to decrease pollutants (moving to somewhere else). Mostly, the wind direction around the Hambach mine is from south or southeast toward the mine, this direction might not push the dust toward villages like Manheim and Morschenich, but it negatively affects the outdoor air quality in Elsdorf; the city that already has been chosen as the second place to settle the residence of Manheim and Morschenich (Fig. 4).

Furthermore, airborne particles and air pollutants can penetrate inside the building through the door, window, or open cracks, pores, and capillary cracks in walls (Figure 8), which also causes to increase in the concentration of indoor-air pollution [17] and consequently, it increases the breathing issues. Polluted and breathable air, including suspended particles (PM10 and PM2.5), can enter the blood system through the lungs [11]. The respiratory system is the first part of the human body that comes into direct contact with dust pollution in the air [18]. Therefore, if the concentration of air pollutants and suspended particles is higher than the filtering capacity of the human lung, particulate matter enters the bloodstream through the lungs [19]. Regarding this, with more indoor air pollution concentrations and pollution particles in the air, the work and activity of the lungs become problematic because they must absorb more oxygen and expel more carbon dioxide. If residents are exposed to indoor air pollution and pollutants, they have health issues that threaten their health [23]. For this reason, contamination inside the building is an issue that should be seriously investigated. One solution to decrease the concentration of indoor-air pollution is to improve the filtration system and select the appropriate filters based on their application. Furthermore, increasing filtration productivity cause to decrease the energy consumption in the long term. And finally, it can reduce the concentration of pollution in the air inside the buildings.

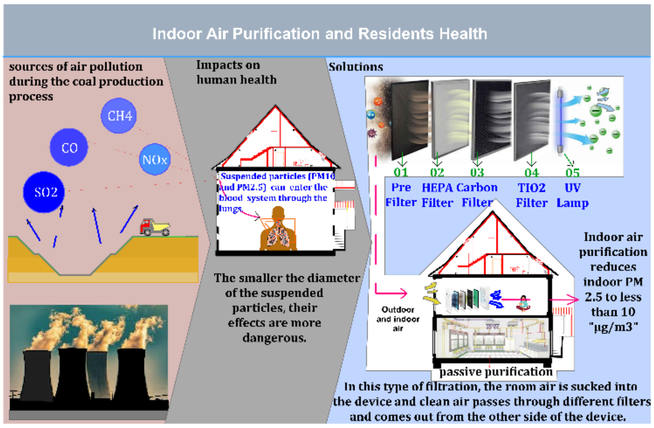

Fig. 8: Indoor air purification and resident's health (self-designed)

Table 1 illustrates the different MERV (Minimum Efficiency Reporting Value) filters and their application in different palaces to minimize contaminants. MERV is commonly known as a practical scale for air filters. It is a measurement scale developed in 1987 [20]. The MERV 1 to 12 cannot absorb the coal dust in the study area. The most efficient and effective filters in MERV 13 to 20 can absorb coal and carbon dust [21]. HEPA filter (Figure

8), which has MERV with a rating of 17 and above, has a better ability to absorb tiny particles such as viruses and bacteria and traps air particles with a size of 0.3 to 1.0 microns [22].

Table 1: MERV filters and their usages, modified [23], [24]

MERV	Range	application	Contaminants
MERV 13 MERV 14 MERV 15 MERV 16	0.30-1.0 microns	- Final filters - General surgery - Superior commercial buildings - Hospital inpatient care - Smoking lounges	- Pollen - Dust mites - Dust lint - Cement dust - Lead dust - Humidifier dust - Coal dust - Nebulizer dust - Auto fumes - Insecticide dust
MERV 17 MERV 18 MERV 19 MERV 20 (also called HEPA)	Filters down to 0.3–1.0 microns	- Final filter - Clean rooms - Radioactive materials - Pharmaceutical manufacturing facilities - Carcinogenic materials - Orthopedic surgery room	- Pollen - Dust mites - Dust lint - Cement dust - Legionella - Lead dust - Humidifier dust - Coal dust - Nebulizer dust - Insecticide dust - Carbon dust - Combustion smoke - Radon progeny - Microscopic allergens

By controlling the sources of pollution and reducing the concentration of pollutants through mechanical and technological methods, a step can be taken to improve environmental protection and the air quality inside the buildings and help the health and satisfaction of the residents. Neglecting the beneficial role of purifiers and not using them to maximize air conditioning causes it to endanger environmental safety (inside buildings close to areas close to mining activity) and the health of the residents in terms of physical and mental aspects of the residents. These damages and the threat of danger lead to "climate migrants" and "environmental migrants" [5].

In such conditions, if the government does not make the appropriate decisions to decrease the airborne lignite dust and suggest some subsidies to provide new facilities that improve the filtration system and cheap electricity consumption, it impacts the general health state of residents. If people stay for a long time in such situations, it causes blood heals problems and causes new health issues. New practical policies and subsidies for surrounding cities, such as cheaper energy costs, free indoor filtration systems, redesigning the building to minimize dust penetration, etc., might decrease the migration rate in the surrounding villages and increase the health index.

6. Discussion

One of the limitations in the current study is the need for quantity measurement for analyzing the chemical effect of lignite mining in the Hambach area and the downstream cities where wind direction pushes the pollutant into them. The measure of each emission-gas due to the mining needs its instrument and requires an extended period (at least a-four different seasons). Because of this, this study tried to consider mainly the airborne dust effect in the surrounding cities. The wind direction is also illustrated overall, which may vary on different days; therefore, it is also possible that wind not only brings pollution from other areas but also move the Hambach pollution into other are. However, the authors did not investigate the exact wind direction in this study. Furthermore, air filtration systems with MERV-rated and their ability to absorb particles are reviewed. This review is intended to be a general guide to filter use and does not address specific applications or individual filter performance in a given application.

Suppose the governing bodies provided methods to gain public trust regarding their performance in reducing outdoor dust and preventing disease occurrence in these mining areas; it may stop or decrease the environmental migration rate in the villages near the Hambach mine. Late policies and instructions and neglecting their efforts to control and eliminate these diseases around mines will be irreparable. It may lead to dangerous and fatal losses. Therefore, it is evident that if there is no policy to control the crisis and not prevent its destructive effects on society, it will cause appear more serious social issues, such as decreasing the population in one area and increasing the population density in other locations. It will bring problems such as social anomalies, stress, depression, lack of identity with the place, and dissatisfaction with the neighborhood and neighbors for unwanted immigrants. The use of filtration systems in air purifiers is a unique method that has been proposed to control, deal with, and manage in reducing the effects of adverse effects on the health of the indoor environment for residents.

7. Conclusion

Surface coal mining operations and specialty in lignite coal mines, there will be severe environmental problems for the cities near the mines (caused by suspended particles of coal dust and the passage of mining machines), which cannot be ignored. Measures should be taken to minimize damage caused by surface coal mining to nature and the local population's health. Closing mines is not always the best way to solve the pollution issues because, in some cases, such as energy crises, it might need to continue coal mining. In such cases, appropriate policies and subsidies can help to survive the system.

The high volume of dust and polluted air causes psychological stress to residents and the local population and gives them the feeling of disease. For this reason, it must be clear and proven to the residents that urban development services for urban infrastructures are constantly providing development and progress with purposeful, principled measures and innovative engineering solutions to achieve and balance the health development of people living in the region and prevent exposure to indoor air pollution. The government's performance shows care and helps the city's future in the housing sector, fully guarantee people's and residents' health. This action gives the residents, in addition to having better indoor air quality, to achieve physical, mental, social, and environmental health a suitable platform is created to gain a sense of security within them. Undoubtedly, these factors have caused a lack of complete physical and mental well-being and created social tensions and conflicts, and the area's residents are forced to leave the city. Unwanted migration causes wandering and displacement in the surrounding regions and villages. As a result, it will bear the consequences and problems in social security and social health for the residents of the villages around Hambach. This study developed a conceptual framework of the most critical variables related to outdoor and indoor air quality, which outdoor air conditioners significantly link to indoor air quality control. This study's findings show that using a high-tech filtration system (with low energy costs in the long term) is vital in controlling indoor air quality, reducing the effects on respiratory health, and preventing diseases. Implementing effective air filtration systems and ensuring proper sealing of building envelopes can help minimize the infiltration of dust particles and improve indoor air quality.

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