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Reviewing the Influence of PM2.5 on Mental Health Among Workers in Various Industries: Examining Schizophrenia, Depression and Bipolar Disorder

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ABSTRACT

Mental health is a crucial factor of maintaining a healthy life and optimizing the productivity in workplace. A significant number of individuals and workers in urban areas are consistently exposed to $PM_{2.5}$, which comprises diverse properties and chemical compounds, its composition varying based on its source. These particulates can be inhaled or ingested reaching different organs within the human body through the respiratory system and blood stream. $PM_{2.5}$ has the potential to inflict harms on various body systems, including the respiratory, cardiovascular, reproductive and central nervous systems. High exposure to $PM_{2.5}$ was correlated with developing symptoms of many mental disorders which can be life threatening. Each disorder arises due to the impact of $PM_{2.5}$ on distinct regions of the brain, leading to alterations in its structure and affecting its functionality. A comprehensive review explores the influence of $PM_{2.5}$ on mental health, aiming to gain a deeper understanding of potential contributors to behavioural disorders among workers worldwide at their workplaces from 2018 to 2023. Despite extensive studies on job-related factors and fatigue contributing to workers' behavioural disorders, minimal research directly addresses the impact of $PM_{2.5}$ on the mental well-being of individuals across various industries. This oversight is significant, considering that these pollutants may contribute to severe human errors in the workplace.

1. Introduction

Mental health can be caused by varying factors that affect the life quality and productivity of individuals, especially the workers at different industries, as Health and Safety Executive (HSE) has indicated that construction sector suffers from significant proportion of diseases [39]. Some studies indicated high percentage of the employees suffer from different mental issues, mostly suffering from anxiety and stress, chiefly in workers with shift schedules [44]. Also, depression, cognition impairment and suicidal thoughts were among the mental disorders that threatens the life of the workers and employees [5]. These symptoms of mental health are believed to be correlated to

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pollutants like $PM_{2.5}$ they inhale and ingest at their working environment, especially individuals who work at closed indoor locations.

Recent studies have shown interest in studying the relationship between mental disorders and $PM_{2.5}$ exposure, as well many studies have shown higher $PM_{2.5}$ concentration indoor, especially homes, than outdoors, which makes this particulate a targeting threat to the human health everywhere. These particulates have the potential of causing numerous respiratory and cardiovascular diseases, however, little is known about their impact on the mental health, particularly for the individuals employed in indoor environments characterized by pollution stemming from their working conditions and requirements. Mental disorders can affect physical well-being as well, reflecting negatively on life quality and productivity of the workers, so it plays a key role in enhancing the productivity. Therefore, it is crucial to study how the working environment can lead to developing or relapsing mental symptoms for the workers. Many industries expose their workers to poor environmental conditions, where mostly $PM_{2.5}$ is vital component of the pollution. Numerous studies relate low productivity of the workers to fatigue and numerous human errors are associated with long tiring working hours, but there is a high possibility that these are caused by mental issues which are result of being exposed to pollutants such as $PM_{2.5}$.

2. Scenario of Mental Impact of $PM_{2.5}$

$PM_{2.5}$ is considered one of the most dangerous pollutants due to its small diameter that gives it inhalable and ingestion capabilities. The inhaled dose of $PM_{2.5}$ is linked to daily activities, posing a greater risk to those exposed to this pollutant in the workplace compared to residents [43]. In this short review, we will explore eight key aspects of the impact of $PM_{2.5}$ on mental health by examining the latest available literature. The focus will be on elucidating how these particulate matters reach and influence the brain, specifically identifying the brain regions affected by these mental health issues.

3. Sources of $PM_{2.5}$

In a study by Lu *et al.,* [31] in Tainan City of Taiwan, nine main industrial sources of $PM_{2.5}$ have been identified, where some of these industries emitted more $PM_{2.5}$ than the others, the highest emitter of this pollutant was diesel vehicle emissions and then the emissions from a power plant followed by the dust from construction and road projects. Lu *et al.,* [31] further suggested that the lowest emissions came from the open-air combustion. However, the study explores the phenomenon wherein pollutants have the capacity to traverse from other cities and countries, influencing the air quality of the region. Hence, the authors recommend the implementation of regulatory strategies to control the impact of these pollutants on air quality.

In addition to the previous study, Fakhri *et al.,* [11] stated that in Montreal of Canada, secondary organic aerosol and secondary inorganic aerosol are recorded as the major source of $PM_{2.5}$ as it is constituted of 39% of $PM_{2.5}$ mass. This study used a wide range of organic molecular markers to investigate the sources of this pollutant. The study delves into the anthropogenic sources of the pollutant, constituting 23% of the measured $PM_{2.5}$ mass. and it is emitted from traffic exhaust, road dust, industrial and cooking emissions. This makes daily human activities one of the main sources of $PM_{2.5}$, as an interesting fact from a study conducted in Korea, which demonstrated that children who participated in the study were exposed to a higher daily dose of $PM_{2.5}$ at home compared to the amount received at educational institutions and the dose was nearly double at home with 88 µg compared to 43.3 µg at the educational institutions [50]. Another study in Portugal stated that 75%

of indoor environmental pollution of participated homes exceeded daily limit level of $PM_{2.5}$ of 25 µg/m³ as a 24-hour mean $PM_{2.5}$ defined by WHO and the main source of pollution at homes are cooking, smoking and lit candles [33]. These findings are essential for assessing pollutant levels in environments deemed safest for human habitation, as homes are generally perceived to have cleaner air than the outdoor atmosphere. Moreover, there could be a significant relationship between prolonged periods spent at home and the development of certain mental and psychological issues which will be discussed later [27]. Additionally, Chu *et al.,* [8] found that the predominant source of indoor $PM_{2.5}$ was non-ambient in nature, stemming from activities like cooking and smoking [8,33]. Moreover, they observe an elevation in concentration during the colder seasons, particularly when using range hoods or other heating systems. They also noted, that the concentration of $PM_{2.5}$ increases in renting households due to greater air exchange between renters and higher building density [8].

The existing literature has a limited number of studies on the natural source of $PM_{2.5}$ worldwide, despite the fact that many natural disasters can serve as significant contributors to $PM_{2.5}$ which has the potential of travelling for long distances. Events like earthquake emits extreme amounts of dust to the air, in addition to naturally occurring fires. The air becomes a very important factor of taking these pollutants from the disaster source to the surrounding environment. Furthermore, warfare is another major source of $PM_{2.5}$ due to the use of various explosives and ammunition activities, causing massive dust to arise, burnings and the release of many hazardous particles. In a recent study by Meng *et al.,* [37], it was discovered that recent wars in Europe have led to intricate and substantial alterations in air pollutant concentrations. Since the commencement of the war, a sudden surge in $PM_{2.5}$ concentration has been observed in numerous European cities. Using a model, the researchers demonstrated that the pollution stemming from the onset of the war, particularly concerning $PM_{2.5}$, accounted for approximately 9.78%. A similar pattern is anticipated in the Middle East and other parts of the world as wars persist. The unexpected elevation of pollutant levels, especially $PM_{2.5}$, could have significant implications for both the environment and human health.

4. Chemical Properties of $PM_{2.5}$

Determining the chemical properties of $PM_{2.5}$ is a highly intricate task, yet it is believed that there are different components in this pollutant. This variability is evident in its impact rates, which has been observed to differ across various seasons [52]. Although the study has focused only on two $PM_{2.5}$ samples from different seasons (winter and summer), it underscored the need for further exploration and research to gain a comprehensive understanding of the characteristics of this pollutant. The study has identified that $PM_{2.5}$ can contain heavy metals; such as aluminium (Al) and zinc (Zn) consisting he major elements throughout all seasons. Goudarzi *et al.,* [15] indicated major presence of Al and F in $PM_{2.5}$. However, the authors argued that the presence of these elements might be attributed to their natural presence in Earth's crust, suggesting that dust logically contains the same elements. Additionally, $PM_{2.5}$ that comes into contact with humans is recognized to contain water-soluble ions (WSIs) such as sulphate (SO42-), ammonium (NH4+), nitrate (NO3-), chloride (Cl-), magnesium (Mg2+), potassium (K+), sodium (Na+), calcium (Ca2+), Fluoride (F-) organic carbon and elemental carbon are . The concentration of these water-soluble ions is found to vary between summer and winter seasons [52]. Quijano *et al.,* [41] add that $PM_{2.5}$ composition is dependent on their emission sources. Their study in Rio de Janeiro, Brazil indicated that $PM_{2.5}$ sampled from urban sites indicated presence of $NO3^-$, SO42- vanadium (V), lead (Pb) and tin (Sn) elements, while the rural and industrial sites showed predominately presence of sodium (Na+), and SO42- ions along with Na, Zn and barium (Ba) elements. Carbon (C), oxygen (O) and silicon (Si) were of high concentration in all

sites. Moreover, the study showed that the $PM_{2.5}$ particles are more diverse in urban sites than the rural and industrial sites. Thus, when considering the impact of this pollutant based on their chemical properties, it is imperative to consider all the mentioned ions and particles. Nevertheless, when analysing a specific area and community, emphasis must be placed on specific elements and ions more than others, depending on their concentration relative to their source of emission.

In summary, when studying the impact of chemical properties of $PM_{2.5}$ on the human health, numerous complex challenges arise, leading to limitations in reaching a comprehensive conclusion about the physiopathology mechanism of these chemical both individually and as interacting compound [26]. The chemical properties of the components within $PM_{2.5}$ may confer upon it the potent and impactful properties to affect the cells of various organs collectively. Simultaneously, it is plausible that the toxic effect on a specific organ could be attributed to a single component within $PM_{2.5}$. However, in some instances, the effects might be attributed to chemical reactions among specific elements, independent of the other components of $PM_{2.5}$. Conducting such studies to unravel the relationship between $PM_{2.5}$ and specific health issues can be exceedingly intricate and time-consuming.

5. Impact of $PM_{2.5}$ on Human Health

In the investigation conducted by Malakootian *et al.,* [34] on the health impact of $PM_{2.5}$ exposure in Kerman, Iran, the findings indicated a relationship between mortality in individuals aged 30 and above and exposure to $PM_{2.5,}$ particularly in terms of NO_2 and O_3. Notably, deaths from stroke in individuals aged 25 and above due to O_3 exposure had the highest contribution proportion, accounting for 2.48%. There was a slight decrease of 0.09% the following year. Additionally, records of natural death caused by $PM_{2.5}$ exposure reached 15.24% with a marginal decrease of 0.09% in the subsequent year. The marginal improvements observed can be attributed to poor governing system and lack of air quality improvement projects within the country. Therefore, it is vital to focus on regulatory strategies to improve air quality, particularly regions situated at critical geographical locations [31].

Many studies have shown diverse degrees of damage to organs and systems caused by exposure to $PM_{2.5}$. The respiratory system, cardiovascular system, nervous system and different organs exhibited responsiveness causing many critical problems [20,32,46,51]. The collective findings of these researchers point to several complications targeting different systems and organs within the human body upon exposure to $PM_{2.5}$.

5.1 Impacts on Respiratory System

According to Zhang *et al.,* [51] in response to $PM_{2.5}$ exposure containing WSIs (NO_3^-, SO_4^{2-} and NH_4^+) major components; the young mice's respiratory system was more vulnerable to this exposure causing significant decline of their respiratory system which was attributed to NO_3^- exposure. This decline was mainly caused by airflow obstruction, affecting adult mice as well. Exposure to 22 $\mu g/m^3$ of NO_3^- caused an 11.3% decline of Forced expiratory volume in 0.5 s ($FEV_{0.5}$), accompanied by increased pulmonary neutrophil infiltration of 7.9% besides and elevated macrophages levels, similar results were demonstrated by Jeong *et al.,* [20] in another study, thereby suggesting these as an underlying mechanism for $PM_{2.5}$ toxicity. The other components showed more than three times weaker effect than NO_3^-, with NH_4^+ exposure showed almost no effect on the respiratory system. Additionally, Lu *et al.,* [32] highlighted an association between $PM_{2.5}$ exposure and increase in airway hyperresponsiveness (AHR), a key characteristic of asthma. AHR is a condition of airway resistance

that is caused by excessive bronchoconstriction in response to unspecified stimuli, underscores the respiratory impact of $PM_{2.5}$ exposure.

There is substantial evidence indicating direct association between $PM_{2.5}$ and lung cancer mortality, where higher exposure correlating to a higher risk of lung cancer due to inhalation of these microscopic particulates [48,54]. In a study conducted by Jeong *et al.,* [20] and focused on analysing the response of immune cells in the lungs to $PM_{2.5}$. This study contributes to possible treatment of $PM_{2.5}$ exposure by elucidating that $PM_{2.5}$ exposure induces some changes to mRNA expression associated with the interleukin 17, which consists of cystine knot cytokines with pro-inflammatory properties. Signalling the pathway in the lungs. The study suggests that, treatments should be tailored according to the symptoms, indicating the specific component responsible for the damage.

5.2 Impacts on Cardiovascular System

In the research conducted by Zhang *et al.,* [53] epidemiologic evidence of a relationship between exposure to $PM_{2.5}$ and cardiovascular diseases such as mortality, ischemic heart disease and stroke has been established. Guo *et al.,* [16] delved into exploring the correlation between different heavy metals constituents of $PM_{2.5}$ contribution and their relation to cardiovascular disease, heart disease and cerebrovascular disease. The result of this research highlighted the association between $PM_{2.5}$ and all three conditions mentioned above, as they find their way to these organs after being inhaled and travelled through the blood and cells of different organs and systems. Moreover, Jalali *et al.,* [19] stated in another study conducted in Isfahan, Iran that elderly, smokers and patients with high blood pressure are more vulnerable to cardiovascular diseases due to $PM_{2.5}$ exposure and high exposure for long term places individuals at risk of ischemic heart disease, which can lead to stroke. However, the study has shown no evidence of mortality directly caused by this exposure.

Despite the widespread belief that $PM_{2.5}$ exposure is directly related to cardiovascular diseases, yet rare and little studies focusing on the effect and the detailed mechanisms through which PM2.5 affects the function of different organs and cardiovascular system, leading to mortality and stroke in numerous cases. In addition, a thorough examination of different $PM_{2.5}$ components must be considered when studying different symptoms associated with cardiovascular diseases resulting from exposure to these particulates.

5.3 Impacts on Reproductive System

Many studies have pointed to the association between $PM_{2.5}$ exposure and reproduction system proficiency. As demonstrated by Zhang *et al.,* [22] their study involving mice shows that prolonged exposure to $PM_{2.5}$, especially at high concentrations adversely target the semen quality in males. When exposing mice to PM2.5 for a period of 30 days, an increase in sperm malformation was detected, while sperm motility rates decreased extremely because of a drop in ATP levels resulting from impairment of mitochondria structure by $PM_{2.5}$. These impacts affect the sperm quantity, besides preventing the sperm from reaching the egg properly, also decrease their quality and capability of fertilizing the egg. Likewise, in a study about the impact of $PM_{2.5}$ on female reproductive functions; although so little is known; showed that female mice after being exposed to $PM_{2.5}$, they experienced an increase in apoptotic granulosa cells and oocytes which prevents normal development of embryo [29]. Numerous studies examining the relationship between reproductive system and fertility in both males and females consistently show a direct relationship between infertility and exposure to $PM_{2.5}$. This exposure directly impacts the quality of reproductive organs.

6. Mental Disorders Due to $PM_{2.5}$ Exposure Mechanism

WHO describes mental health to be an issue and unwellness that threatens one's intellectual capabilities, so it is linked to individual's social and physical functioning and health outcomes [39]. Despite being a complex facet of scientific inquiry, numerous studies have shown a relationship between exposure to $PM_{2.5}$ ad mental diseases, leading to psychological issues. Typically, these issues are a result of an impact from these particulates on a specific region of brain or mutations occurring in specific genetic sequence [30].

6.1 Schizophrenia (SZ)

SZ is a mental disorder that can destroy individuals' life if not treated at early stages. There are numerous symptoms associated with this disease that aid in the diagnosis of the condition. The adverse symptoms of SZ are summarized in five key constructs which provide insights into patients' social behaviour, where the patient suffer from blunted effect, alogia, avolition, sociality and anhedonia [9]. According to Correll *et al.,* [9] this disorder is commonly believed to be because of genetic factors since birth, even though in many cases the symptoms appear in middle-age and young adult stages. Nonetheless, Marder [35] found that other factors like environment can contribute to vulnerability to this disorder. As well, there are strong evidence that highlight the direct association between air pollutants and increased risk of SZ [3]. $PM_{2.5}$ was found to play a key role in these studies. SZ also changes the structure of the brain; affecting its function and making some of these changes of structure more dangerous in some areas of the brain compared to other areas. Most commonly the front lobe of the brain that is responsible for memory, judgment, motor tasks and social appropriateness gets affected by this disorder [23].

According to the research conducted by Duan *et al.,* [10] and Bai *et al.,* [3], an increase in $PM_{2.5}$ has led to more hospitalized cases due to SZ. Additionally, Ji *et al.,* [21] indicated that more male patients have shown vulnerability being readmitted to hospitals because of schizophrenia relapse in China, which is believed to be due to $PM_{2.5}$ exposure [13]. Moreover, a case report of 1193 patients with SZ disorder showed clear evidence of $PM_{2.5}$ concentration association with worsening the SZ condition for the patients. Though, in research studies conducted by Antonsen *et al.,* [2] and Li *et al.,* [28], the findings indicated less steady association between SZ and exposure to $PM_{2.5}$. In any case, most of the studies have proved that there is a correlation between SZ and $PM_{2.5}$ exposure, this association is caused by cytokine IL-17 abnormality as outlined in Table 1 [13].

Various mechanisms that induce SZ, particularly those associated with $PM_{2.5}$ high concentration or long exposure. Oxidative stress is considered one of the key causes of SZ [42] as indicated in Table 1. As Pedone *et al.,* [40] stated, Total Antioxidant Capacity (TAS) representing the total antioxidant level, including many antioxidant substances and enzymes, demonstrates a negative correlation with SZ patients' symptoms severity [30]. According to Zhang *et al.,* [55], individuals who are exposed to high $PM_{2.5}$ concentration have recorded a 1.85-fold decrease in their TAS compared to individuals exposed to lower concentration of the pollutant. This reduction in TAS is faced with body's antioxidant capacity reduction, increasing the risk of SZ relapse and compromise the efficiency of body's antioxidant system.

In a study conducted by Hasegawa *et al.,* [17] using an animal model, $PM_{2.5}$ exposure was found to be directly correlated with inflammatory cytokine levels which leads to neuroinflammation due to influencing TNF-α and IL-1β and activation of microglia. Additionally, they demonstrated that $PM_{2.5}$ could travel to the central nervous system by the olfactory neuron pathway and cause inflammation in the olfactory neuroepithelium affecting specific areas of the causing brain [47]. The affected part

of the brain is directly associated with cognitive abnormalities and inducing negative symptoms in SZ patients [18]. While another animal study has revealed that $PM_{2.5}$ inhalation causes local nasal cavity inflammation which affects the neurobehavioral function causing SZ. There are still lack of direct studies to test the direct association between $PM_{2.5}$ and SZ. This scarcity could be attributed to the rarity of disorder and its limited availability for study under controlled conditions.

6.2 Depression

As a common comorbidity of chronic medical diseases such as cancer and cardiovascular, metabolic, inflammatory and neurological disorder [14]. Depression is considered a dangerous psychological condition that threatens the life of many individuals, as it is associating with restlessness, loss of interesting and many other factors that affects the quality of personal and professional life [39]. According to Gold *et al.,* [14], the factors that prompts the occurrence of depression in patients are genetic and social factors, converging biological pathways, health behaviour and other psychological factors. Additionally, the findings of a study conducted in Northern California indicating a positive correlation between $PM_{2.5}$ exposure and an increase in symptoms of depression and anxiety. This exposure has been associated with enhancement in reactions to social stress [38]. Liu *et al.,* [30] indicated that long-term exposure to $PM_{2.5}$ increased the potential risk of adults getting major depressive disorder (MDD) and this exposure was estimated to be 26.7 $\mu g/m^3$ in average, while no significant correlation was found between short-term exposure to $PM_{2.5}$ and depression [12]. In another study, Tsai *et al.,* [45] found that, the risk of MDD increases 2.26 times with only 10 $\mu g/m^3$ concentration increase of $PM_{2.5}$. Even though many studies up to date have clearly proved the association between $PM_{2.5}$ exposure and adolescents depression risks, there are lack of studies explaining the impact of this pollutant on children's psychology wellbeing and mental health.

Possibilities indicate a crucial relationship between Nrf/NLRP3 signalling pathway (Table 1); which plays an important role in regulating inflammation and depression induced by $PM_{2.5}$ [7]. Being exposed to $PM_{2.5}$ at high concentrations can impact Nrf2 by activating it, causing resistance to oxidative stress. Nrf2 is a key factor that regulates intracellular defence against this stress, as the exposure to $PM_{2.5}$ can promote inflammation due to Nrf2 deficiency, subsequently up-regulates astrocyte activation and causing nerve damages [30]. NLRP3 serves as central mediator of depression by targeting cellular injuries. It plays a critical mediated role as pro-inflammatory in case of oxidative stress and inflammation. This involvement is essential for maintaining damaged cells by its vesicle activation properties [24]. According to a study by Kouba *et al.*, [25], NLRP3 is believed to be the central mediator of depression in human body. $PM_{2.5}$ causes inflammatory response through NLRP3 inflammasome pathway activation leading to depression.

Zheng *et al.,* [56] elucidated that $PM_{2.5}$ exposure influence many molecules and cells of the central nervous system, affecting the estrogenic level leading to depressed behaviours. In these cases, the exposure to $PM_{2.5}$; as represented in Table 1; targets the hippocampal inflammation mechanism, involving up-regulation of cytokines such as IL-1β, IL-6, TNF-α and chemokines [56]. High $PM_{2.5}$ exposure concentration has shown direct impact on the mental cellular parts of the brain causing changes to the function and structure of these parts, such as shrinking by losing grey matter volume (GMV) in hippocampus and prefrontal cortex [49]. There are limited recent studies about the exposure mechanism of $PM_{2.5}$-induced depression, more intense studies are needed to better understand the impact of $PM_{2.5}$ on the nervous system causing depression disorders in all ages.

6.3 Bipolar Disorder (BD)

Bipolar is one of the most complicated mental disorders to be addressed and treated, it is characterized by sudden significant mood shifts which can lead to suicidal thoughts, sleep disorders and dysfunction of psychological traits where the patient can go through mania or hypomania episodes often daily [36], therefore it leads to depression and abnormal living conditions.

Even though there are limited number of studies done to test the association between BD and $PM_{2.5}$, a cross-sectional study in Milan, Italy showed an association between severity of manic episode in the patients and exposure to air pollution [6]. Another meta-analysing study shows a significant relationship between BD and $PM_{2.5}$ exposure [4], however, this study did not aim to investigate this correlation specifically, as it focused on several mental disorders (including BD) caused by particulate matter under study.

As listed in Table 1, BD affects the structure of four brain regions, including: prefrontal cortex, temporal cortex, cingulate gyrus and subcortical regions [1]. However, there are lack of studies about the exposure mechanism and how $PM_{2.5}$ affects different channels and molecules in the human brain to cause changes in the affected brain regions or lead to structural deficiencies as proved in previous discussed disorders. The lack of studies and scientific proofs affect taking the correct treatment procedures in dealing with BD patients who are hospitalized due to $PM_{2.5}$ exposure on their condition.

Table 1
Exposure mechanism, affected brain parts and molecules from mental disorder: SZ, depression and BD

Mental Disorder	Exposure Mechanism	Affected Brain regions	Affected molecules
Schizophrenia	• Oxidative Stress • Neuroinflammation • Nasal inflammation	Mostly front lobe	• Cytokine IL-17 • TAS • TNF-α • IL-1β • microglia
Depression	• Dysregulation of the Nrf2/NLRP3 • Hippocampal inflammation	• Hippocampus • Prefrontal cortex	• Cytokine: IL-1β, IL-6 and TNF-α • Chemokines • GVM
Bipolar Disorder		• Prefrontal cortex • Temporal cortex • Cingulate gyrus • Subcortical regions	

Table 1 represents the summary of several study findings on the exposure mechanism of SZ, depression and BD, the affected brain regions and affected molecules as channels in the nervous system.

7. Conclusion

$PM_{2.5}$ can lead to several diseases by affecting multiple systems in the human body, particularly the respiratory and cardiovascular systems. This occurs as the particulate reaches the organs of these systems through inhalation and ingestion while being exposed. Recent studies have focused on studying and proving the association between air pollutants and different severe mental health disorders such as schizophrenia, depression and bipolar disorder. These mental disorders coexist as

comorbidities, with depression mostly associated with the other two disorders. The reason why studies are focusing on mental disorders caused by $PM_{2.5}$ is due to the extreme effect on relapsing symptoms of these disorders leading to hospitalization of many individuals. Different mental issues affect different brain parts; often leading to changes in the structure and functioning abilities of these regions. This, in turn, gives rise to extreme behavioural and mental disabilities.

Most of the studies provided through and full insight to the concept of the study, elucidating how the pollutant reaches various parts of the body and identifying the molecules it targets. Yet the ways of reaching to the brain were ignored due to farthest limitation of different information, as only inhalation and blood circulation are believed to be the mechanisms used by $PM_{2.5}$ to reach its targeted cells throughout the brain. Moreover, there are extremely little studies about the impact of $PM_{2.5}$ exposure on the workers of different industries, as the studies are done on citizens of different big communities and industrial cities. However, the results of these studies can be used directly to estimate the impact of $PM_{2.5}$ on workers according to their average exposure rate to these particulates. Furthermore, there are limited number of studies estimating the correlation between suicidal thoughts of individuals and the exposure to $PM_{2.5}$, for almost all the untreated mental disorders could lead to suicide. The findings of the studies shed the light into the reasons why workers develop some behavioural disorders after working at a specific place for a long time, emphasizing the importance of government interventions such as vacations and restrictions on working hours.

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