European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
http://eelet.org.uk

Air Pollution as a Risk for Mental Health Problems: An Exploratory Study of Direct and Indirect Pathways

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Abstract

Background: The World Health Organization defines mental health as a "state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively, and is able to make a contribution to his or her community". [1] It is well-known that high levels of air pollution can harm physical health in various ways, increasing the risk of morbidity and early death. However, the impact of air pollution on mental ability & well-being has been less explored. Other associated factors linking air pollution to mental health have been less commented on. Although, in recent years, it has been found that high levels of air pollution can damage children's cognitive abilities, increase risk of cognitive decline in adults and possibly contribute to anxiety & depression. [2]

Material and Method: The current study aimed to explore the possible links between mental health and air pollution and exploring the impact of air pollution on mental health (symptoms of anxiety, depression as well as cognitive processes), and well-being (physical, psychological, social functioning), in people residing in Delhi using a mixed method approach. A sample of 511 'healthy' individuals residing in various parts of the city, were first administered self-report questionnaires related to the variables of study. Of these, 20 persons were later also interviewed using a semi-structured schedule to generate narratives related to perceived impact of the air pollution. The qualitative data was carefully studied to understand the thoughts and beliefs that individuals had about the pollution of the region to draw possible reasons of depression, anxiety and compromised well-being.

Results: The results of the study indicated that there were numerous cognitive links that led individuals to feel depressed and anxious considering the air pollution. The cognitive appraisals of the pollution aspect of the state seem to have a direct impact on the affective state of the individuals. There was also preliminary quantitative evidence that suggested an increase in symptoms of anxiety and depression due to exposure to high levels of Air Quality Index. The data collected through semi-structured interviews suggested substantial impact on overall functioning as individuals expressed various concerns related to the impact of air pollution on their health and life.

Conclusion: The study sheds light on the possible links between pollution and mental health. The cognitive outlook of what could be making people have depressive and anxious symptoms has been explored in the current study. The results of the study support the importance of further investigation of mental health effects of air pollution. The cognitive aspect of individuals is a crucial step in understanding the possible mental health impacts that pollution could have on mental health. The study attempts to make some useful recommendations in this regard.

Keywords: Air-Pollution, anxiety, depression, cognitive processes, functioning, well-being, Delhi

Introduction

The air quality guidelines established by the World Health Organization usually serve as a reference for countries, regions, and cities by creating global targets for working towards achieving improved health for their citizens by combatting air pollution. Although clean air is considered as a fundamental right for all humans, air pollution continues to be a global significant threat to people and the biggest environmental hazard fuelling non-communicable diseases such as heart diseases and strokes. According to the WHO reports, approximately 7 million people globally die a premature death annually due to breathing toxic air while millions of others develop severe health concerns. More than fifty percent of these deaths are reported from developing nations. [3] One of the leading causes of air pollution in developing nations is the use of coal or biomass in different forms such as wood, cow dung and even crop residues for the purpose of producing domestic energy. These substances are burnt in conventional stoves with very little ignition resulting in more smoke. Therefore,

women and young children are subjected to high levels of exposure to the indoor pollution daily. [4] Reason most accountable for outdoor air pollution in developing countries is the shift towards industrialisation helping in reaching countries to middle income from being low income. [5]

Air pollution in Delhi National Capital Region

According to the Global Air report [6], New Delhi has been listed as the world's most polluted capital in the world as it enters the dangerous level of PM 2.5 exposure for people residing in the state. In the month of November 2022, the air quality Index (AQI) in most of the monitoring areas across New Delhi violated the "severe" and "hazardous" levels by measuring an AQI of over 450. While some areas of the city even recorded dangerous AQI levels of over 800 which practically makes it equivalent to breathing purely smoke. [7] The morning following Diwali 2021 around 3 am, the air quality index in the capital crossed the "hazardous" levels with PM 2.5 levels shooting as high as 774.69. [8] The significant rise in air pollution in the month of November post Diwali every year in the capital could be accounted to emissions from burning firecrackers on the account of the festival and farm fires. [9]

In the last few decades, burning field crop residue i.e., biomass burning has become a widely popular and common agricultural practice among farmers in Asian countries such as India, China, Thailand, and Indonesia [10] and a serious factor towards increasing air pollution. [11] Crop burning in North-western Indian states is a significant pressing concern for New Delhi and its surrounding areas (Delhi-NCR) particularly in winter months (October and November) as the residue remains of rice crop are being burnt massively. [12,13,14]

India, being among one of the largest agro-based economies globally, yields the highest wheat and rice production. Crop cultivation and harvesting are ongoing processes carried out all over the year. The high production of agro based products leads to increased amounts of waste generation and leads to more environmental pollution. [15] An ever-increasing demand of yield production puts a high supply burden on farmers forcing them to burn agro waste postproduction. India is the second largest contributor to burning crop residue in the world. [16] The rice and wheat are sown in the months of June-July and November-December respectively while the harvesting of each is done between October-November and April-May respectively. [17] Practically, it leaves farmers only with 3-4 weeks in hand before switching to the next harvest season. A lack of alternate economical technologies to collect agro waste limits the choices of farmers and they prefer in-situ burning of crop residue as its time efficient, economical, and quickly equips the field for the next harvest. [18] In the year 2016, an episode of seasonal crop residue burning coincided with the firecracker burning that happens during the Diwali festival leading to overall deterioration of the air quality in the National Capital and surrounding regions. [19] The study also suggested that Delhi and surrounding regions were covered with haze and thick layer of smog through most of the days of October.

A study conducted by Central Pollution Control Board [20] to understand reasons for air pollution in New Delhi and the National capital region (NCR) suggested that are several other reasons responsible for the pollution such as vehicular emissions, domestic or indoor pollution, industrial emissions, dust on the streets and burning waste. These sources add up to a considerable amount of air pollution in Delhi-NCR. Additionally, construction sites of high-rise buildings are a potential source of air pollution in Delhi-NCR.

Role of Cognitive Appraisals

Stress can be defined as the adaptive response of an individual which could differ according to their personal characteristics or cognitive appraisals of any external situation that impose psychological challenges upon them. [21] Cognitive theorists tend to pay careful attention over how experiences can reshape an individual's cognitive processes and its direct relationship with stress. [22] As a result, variables of individual differences have been emphasised upon as acting as mediators or moderators resulting in stress as affect and response.

According to the Cognitive Appraisal Theory [23], cognitive processes tend to mediate the relationship between external stimuli and the individual, resulting in affective and behavioural responses. It views the cognitive appraisal of a stimuli as stressful by individuals. Cognition and affect have been viewed as co-dependent components for mediating process of stress by this theory. [24] The central theme of the theory is that affect (stress), and behavioural responses are followed by the cognitive appraisals of a situation by an individual which could be complimenting or threatening their well-being. The

cognitive model [25] as well infers that an individual's emotions and behavioural responses are influenced with how an external event is perceived by the individual and the meaning they attach to it.

Through semi-structured interviews, the current study has attempted to study the cognitive appraisals of individuals towards the high AQI levels of their city. The cognitive appraisals would help in understanding the possible pathways leading to compromised mental health during high levels of pollution.

Connection between Air Pollution and Mental Health

In a recent systematic review of over 100 studies, Zundel and colleagues [26] found that humans and animals exposed to polluted air which exceeds the average levels of air pollution present more mental health and behavioural concerns. The primary author of the review, Clara G. Zundel stated in a World Economic Forum Report [27] that humans exposed to polluted air tend to experience changes in the brain regions that govern emotions such as amygdala, hippocampus, and the prefrontal cortex. These individuals are more likely to develop anxious and depressive symptoms in comparison to the individuals who inhale less polluted and cleaner air.

Exposure to significant high levels of air pollution could prove dangerous for children and adolescents as they are in a sensitive period of brain development. According to research, [28] children and adolescents breathing polluted air could display depressive symptoms and be at a high risk for suicidal behaviours. The same research also observed structural and functional changes in the brain region through neuroimaging techniques.

Data reported from China stated that standard deviation by 1 for increase in the particulate matter according to the accepted level of PM2.5 concentration in the air tends to increase the chances of developing psychiatric illness (comprising depression) by 6.67% in individuals which is equivalent to a medical expense of approximately 22.88 billion dollars. [29] This data holds important implications as majority of the global population resides in regions which have PM2.5 concentration levels much higher than permissible limits defined by the WHO guidelines. [30]

Rationale of the study

The study was carried out recognizing the need to study the possible links between mental health (Depression, anxiety, and well-being) and air pollution of individuals residing in the capital given the high levels of Air Quality Index in Delhi-NCR. The study was initiated to understand the possible psychological concerns faced by individuals who breathe polluted air with a much higher PM 2.5 level than permissible by the WHO Guidelines. Literature shows a strong correlation between breathing polluted air and deterioration of physical health. There is a need of research to understand the possible psychological pathways leading to compromised mental health (if any) due to the alarming levels of air pollution.

Materials and Method

Aim of the study

The study aimed at exploring the possible links between mental health (depression, anxiety, and well-being) and high levels of air pollution for individuals residing in Delhi-NCR.

Objectives

- To understand whether individuals who reside in regions with high Air Quality Index (AQI) levels tend to experience depression, anxiety, and compromised wellbeing.
- To explore the cognitive appraisals of individuals residing in Delhi-NCR about the state of air pollution and study the possible links between their cognitions, emotional states, and mental health challenges (if any) through semi-structured interviews.

Inclusion Criteria

- Individuals must be residents of Delhi-NCR.
- The individual must be above 18 years of age.
- The individual should have English proficiency.

- Individuals must be healthy and shall not be dealing with any acute physical ailment.
- The individual must not have been formally diagnosed with any psychiatric disorder or receiving any psychiatric medication.

Study Design

The current study is an exploratory sequential mixed method research which was carried out on 511 individuals, above the age of 18 years, residing in different regions of Delhi-NCR. The study was conducted in two phases sequentially. In the first phase (Quantitative), three questionnaires namely, Generalized Anxiety Inventory, Patient health questionnaire and WHO Wellbeing Index were circulated as google forms to individuals. During phase two (Qualitative) semi-structured interviews were conducted with twenty individuals who were selected randomly from the complete sample. The data for the current study was collected through a convenience and snowball sampling technique.

Data Analysis

Post the data collection of both phases 1 and 2, the respondent's quantitative data were divided into two groups based on the AQI levels of their region i.e., very unhealthy, and hazardous category of AQI. The data was then manually entered into excel and the data analysis was carried out with the help of SPSS.

The basic analysis was done using descriptive statistics for finding frequencies and percentages, mean values, and standard deviation. An independent-samples *t*-test was conducted to compare the participants' well-being, depression, and anxiety between very unhealthy and hazardous category of AQI regions in Delhi-NCR. Additionally, Pearson correlation test was used to understand whether there is any relationship between the variables such as anxiety, depression, well-being and AQI levels (very unhealthy and hazardous). The qualitative data collected through semi-structured interviews was analyzed using thematic analysis.

Ethical Considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely ob-served by the authors.

Results and Discussion

The data for the study was collected during the month of November 2022 as the AQI levels ranged from very poor to severe category in the capital due to crop residue burning as well as the firecracker burning on account of Diwali, the Hindu festival. A rigorous attempt was made to collect the data from various regions of Delhi-NCR to satisfy the aim and objectives of the study.

The data comprised of 205 males and 306 females who were older than 18 years of age. The participants were divided into two groups i.e., "very unhealthy category AQI" and "hazardous category AQI". According to the guidelines of the United States Environmental protection agency (2022), AQI levels ranging from 201-300 are considered "very unhealthy" and from 301-500 are considered "hazardous" for human beings.

When the AQI levels of the regions of the respondents were extracted for the month of November 2022, it was found that 345 respondents belonged to regions reporting hazardous levels of AQI and 163 respondents belonged to regions reporting very unhealthy levels of AQI. Two respondents belonged to the Unhealthy category of AQI (151-200 AQI) which resulted in the exclusion of their data from the final analysis.

An independent-samples *t*-test was conducted to compare the participants scores on well-being, depression, and anxiety between the two groups they were divided into (very unhealthy and hazardous levels of AQI). The results of the *t*-test found statistically significant differences in scores of wellbeing (t=3.357, p=0.001, d=0.31), depression (t = -2.663, p = 0.001, d = 0.25) and anxiety (t= -2.408, p =0.01, d = 0.22) between the two groups. The participants belonging to the regions with hazardous levels of AQI displayed significantly higher levels of depression and anxiety (p =0.01) and significantly lower levels of well-being (p =0.01).

The mean scores of Well-being were higher for respondents belonging to very unhealthy AQI level areas whereas the mean scores of depression and anxiety were higher for respondents belonging to hazardous AQI level areas. Detailed results are given in Table 1.

Table 1. Mean difference, *t*-test values, and Cohen's D for two groups of respondents (Unhealthy and Hazardous levels of AQI).

Variables	AQI Category Very Unhealthy (201-300) Hazardous (301-500)	N	Mean ± SD	t	p	Effect Size (Cohen's D)
Well-Being Index	Unhealthy	163	11.41±5.76	3.357	**0.001****	0.31
	Hazardous	345	9.66±5.37			
Depression	Unhealthy	163	7.74±5.02	-2.663	**0.001****	0.25
	Hazardous	345	9.03±5.16			
Anxiety	Unhealthy	163	6.37±4.89	-2.408	**0.01****	0.22
	Hazardous	345	7.43±4.52			

Additionally, Pearson coefficient correlation test was used to check the relationship between AQI levels and scores of well-being, depression, and anxiety. The results of the test revealed that AQI levels had a significantly negative correlation (r_s=-.348, $p<0.01$) with well-being scores and had a significantly positive correlation with depression (r_s=-.110, $p<0.05$) and anxiety (r_s=-.098, $p<0.05$) scores respectively. Detailed results are given in Table 2.

Table 2. Pearson correlation between AQI levels and scores of well-being, depression and anxiety.

		Well-being Index	Depression	Anxiety
AQI	Pearson Correlation	-.140**	.110*	.098*
	Sig. (2-tailed)	.002	.013	.027
	N	509	509	509

Qualitative Analysis

A semi-structured interview was conducted with 20 participants to understand their cognitive appraisals regarding the situation of the pollution and the concerns faced followed by an in-depth thematic analysis of the manuscripts.

Theme 1: Uncertainty of the future. A majority of the participants expressed feelings of uncertainty about the future of their future generations as well as themselves (n = 14, 70%). Their concerns and issues varied in nature, and it is quite evident through their verbatim below.

"What is the future of my children breathing such toxic air."

"I have started having panic attacks when I imagine what we are walking towards."

"Would we ever get to see a Delhi like we did in our childhood or always be in a state of lockdown?"

Theme 2: Catastrophising. The participants expressed that they could not seem to find any ray of hope to feel better and just felt that everything would only become worse moving forward. Majority of them felt that they had nothing to look forward and everything bad was going to happen with their physical as well as mental health (n= 17, 85%). Few of them felt that despite making conscious efforts, they could only imagine the worst.

"We will eventually all end up suffering with major diseases like cancer."

"Aren't we all just stuck in a city full of smoke."

"We anyway live in a time where our food is adulterated, now we also breathe smoke and kill any scope for our good health."

Theme 3: Regret, Guilt and Self Blame. When asked about the emotions that the participants felt due to the situation, one of the most prevalent emotions experienced by the participants was Regret (n=18, 90%). The participants felt guilty as they were to be blamed for what they were experiencing now and what their future generations must suffer. They felt responsible for their situation and all others (n=16, 80%).

"Just few days back during Diwali, my husband bought firecrackers for the children and today we get to breathe smoke. Who's fault is it?"

"What is the use of our education when we couldn't take care of our own homes (city) and acted illiterate. The most basic thing we all need to live (air), we couldn't keep that clean. Aren't we all stupid?"

"The guilt seems to be eating me every day. Haven't we all been blinded by our own convenience and today my own child has asthma and I see him gasping for breath. I deeply regret my ignorance. Why didn't we all do our part when time was right?"

Theme 4: Restricted Living. The participants were asked about how the air pollution impacted their regular lives and most of them mentioned they had to live a restricted lifestyle and found themselves in a lockdown situation yet again (n= 17, 85%).

"My children can't even play outside, what kind of a childhood am I giving them? We have to allow them screen time."

"What nonsense is this, it got us all feeling so stuck and restricted. We can't even go out and meet people, it's a lot like COVID-19."

"I have been feeling very disheartened because of being trapped and limited. I used to enjoy outdoor exercises but now we have come to a situation where something as fundamental as clean air has become a luxury for all of us to afford."

Theme 5: Mental and physical health concerns The participants expressed that they were experiencing difficulties in regulating their mental health such as having episodes of unexplained anger (n=15, 75%), overwhelming thoughts (n=14, 70%), confused state of mind (n=18, 90%), anxiety (n=18, 90%) and difficulty concentrating (n=17, 85%). Some participants (n=12, 60%) expressed how their physical health deteriorated during that time as they had been previously suffering with some health concerns that led them to simultaneously experience added stress.

"I stay at a high alert state all the time and find myself obsessively checking the AQI levels of my region."

"I find myself getting irritated at everything for no actual reason. I have started yelling so much and always worrying about everyone's health."

"I keep procrastinating my work as I just can't keep my head focused at one thing."

"The constant what if, what if questions trouble me so much. I fail to remain at ease in my head."

Theme 6: Added stress on parents. The most common concern faced by parents (n= 11, 55%) during the high level of smog was the added burden and responsibility of keeping the children occupied with different activities and managing between household chores, work and finding time for their children. The smog made parents restrict outdoor activities for their children. The statements were of different natures such as frustration, burden, helplessness, and exhaustion.

"Our maid has been on leave and I have to keep the kids entertained alongside my job and kitchen work."

"Kids feel very energetic in the morning hours, and it becomes so hard to manage their online classes and household work."

"I can't send the kids to play and keeping them busy for long hours is hard."

Theme 7: Role of Media. The participants (n=17, 85%) reported experiencing heightened anxiety due to the media reporting a state of distress through images and statements which led them to have disturbing thoughts.

"Every time I switch on the news, the media only has one business to blow the situation out of proportion."

"Rather than showing how bad the situation is, they should motivate people to take initiatives to do better."

Conclusion

Pertaining to dangerous levels of air pollution in Delhi-NCR, it has been listed as the world's most polluted capital according to the Global Air Report. [6] Several factors could be contributing to the deteriorated air quality of the capital such as Crop residue burning, vehicular emissions, domestic or indoor pollution, industrial emissions, dust on the streets and burning waste. The air quality sees a sharp dip around the months of November-December every year in the capital due to firecracker burning on the account of the Hindu festival, Diwali as well as crop residue burning. Some regions of the capital witness hazardous levels of Air quality Index (AQI) during these months causing individuals to experience physical and psychological discomfort.

Literature suggests that there is a relationship between people being exposed to polluted air and presenting more psychological health concerns. These individuals are more likely to present anxious and depressive symptoms in comparison to the individuals who inhale less polluted and cleaner air. Changes have been observed in brain regions governing emotions such as amygdala and hippocampus of individuals who are exposed to higher-than-normal levels of air pollution. [26]

The current study was structured and carried out to explore the possible link between pollution and mental health (depression, anxiety, and well-being) for individuals residing in Delhi-NCR.

Our study reported that there was a statistically significant difference in scores of well-being ($t=3.357$, $p=0.001$, $d=0.31$), depression ($t=-2.663$, $p=0.001$, $d=0.25$) and anxiety ($t=-2.408$, $p=0.01$, $d=0.22$) between the two groups. The participants belonging to the regions with hazardous levels of AQI displayed significantly higher levels of depression and anxiety ($p=0.01$) and significantly lower levels of well-being ($p=0.01$). The results are consistent with a study [31] which observed a positive correlation between increasing levels of particulate matter in the air and levels of depression and anxiety among individuals residing in Barcelona, Spain. The study also reported an increased use of antidepressants and benzodiazepines among individuals having exposure to polluted air. Alongside, a meta-analysis [32] inclusive of 30 studies concluded similar results to our study. According to the meta-analysis, an increased exposure to higher PM 2.5 and PM 10 particulate matter in the air leads to a significantly higher risk of depression and suicide among individuals.

The current study also reports a significantly negative correlation between AQI levels ($r_s=-.348$, $p<0.01$) with well-being scores and a significantly positive correlation with depression ($r_s=-.110$, $p<0.05$) and anxiety ($r_s=-.098$, $p<0.05$) scores respectively. A study [33] conducted on older adults reported a positive association between depressive and anxious symptoms with increase in PM 2.5 levels in the air. Additionally, the study also found the strongest depressive and anxious symptoms in individuals belonging to the low socio-economic status. Another study [34] found that increased exposure to high levels of PM 2.5 has a positive association with depressive symptoms whilst reducing hedonic happiness. The study shows contrasting results to our study as it could not find any relationship between high levels of PM 2.5 and subjective well-being and life satisfaction.

Twenty participants were then interviewed to understand the possible pathways between pollution and mental health with the help of understanding their cognitive appraisals about the situation. Majority of them reported having overwhelming thoughts and constant state of worry due to the air pollution in the city. In an attempt to study the relationship between the air quality and different aspects of well-being, Dolan & Laffan [35], through interviews found that individuals living in areas with high levels of air pollution report having lower satisfaction with life and feeling unhappy.

Other interesting themes that emerged during interviews in our study were a state of feeling uncertain about the future, catastrophizing, experiencing emotions such as guilt, self-blame, regret and unexplained anger, restrictive living, confusion. Few of the participants reported experiencing heightened anxiety due to the role of the media in reporting the entire situation.

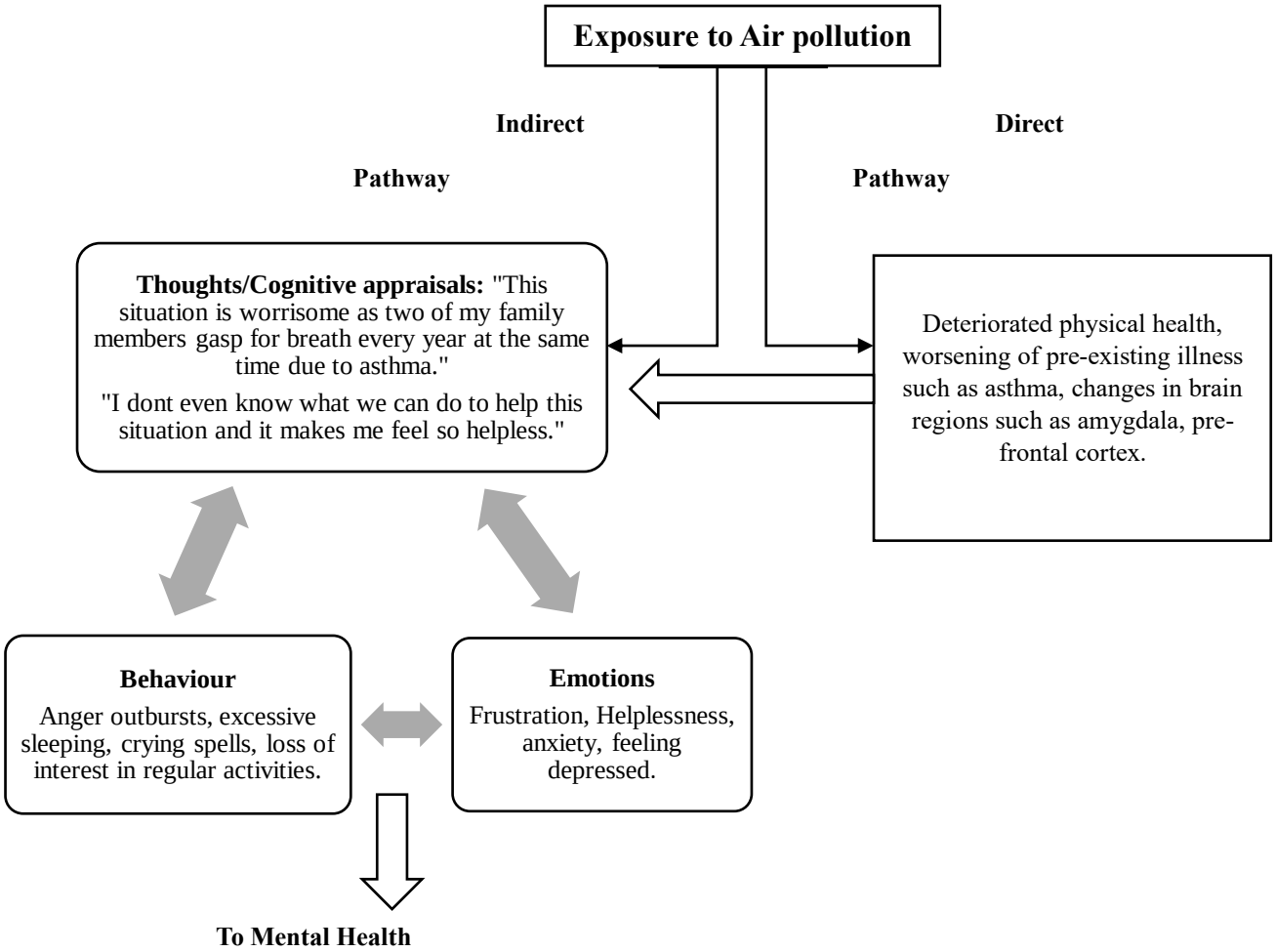
European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
http://eelet.org.uk

According to the Stoic philosopher Epictetus, humans are not disturbed by things themselves but what they choose to perceive out of the situation or simply the thought they attach to it. [36] In the current study too, it's important to understand the cognitive pathways leading to depressive and anxious emotional and behaviour patterns. The theoretical foundation of Cognitive Behaviour Therapy suggests that humans interpret situations in their life according to their set of beliefs, values, and learnings from past experiences. The thoughts of an individual cause them to experience an emotion which then governs their behaviour towards any situation. When an individual is faced with a stressful situation, their interpretation of the situation becomes faulty and skewed which results in negative emotions and unhealthy reactions. [37] To better understand how exposure to high levels of air pollution impacts the mental health of individuals, it's important to understand the interpretations made by individuals of the situation.

The direct pathways of impact of air pollution on an individual's physical health and wellbeing has been well established by the literature. The semi-structured interviews in our study revealed that individuals had attached negative meaning to the situation of high pollution level which played the role of an indirect pathway contributing to depressive and anxious states.

Some of the most associated thoughts with high levels of pollution were about being restricted to indoor activities, change of plans to meet friends and family, worried thoughts about the environmental concerns, worrisome thoughts about the health of children and family members with comorbidities, thoughts regarding feeling powerless about the situation, helpless and frustrated thoughts like "what do we even do now to make it better?". These negative thoughts then result in negative emotions such as anxiety, depressed, helplessness and frustration. A detailed formulation of air pollution's direct and indirect pathways to mental health of an individual has been depicted in Image 1.

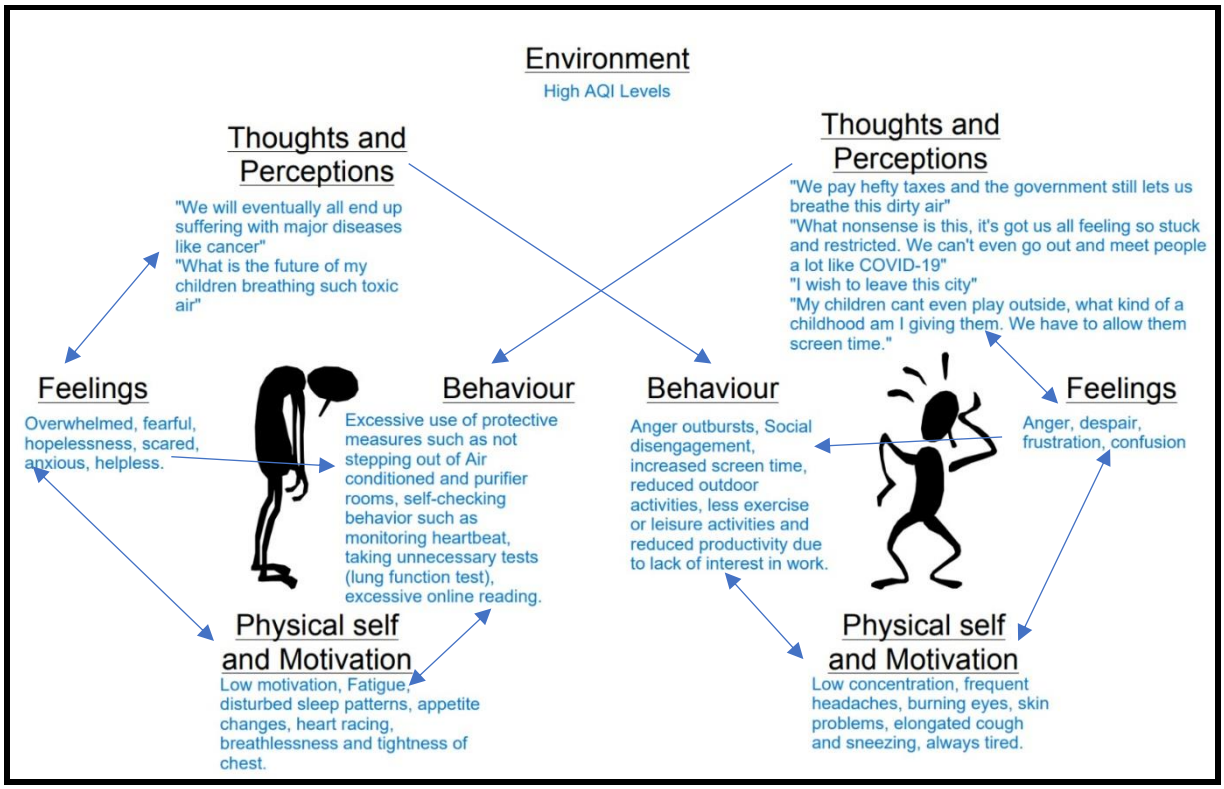
Image 1: Detailed formulation of Direct and Indirect Pathways to Mental Health



European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
http://eelet.org.uk

To better understand the difficulties of the participants, an attempt was made to conceptualise and formulate the thoughts and emotions of the participants into a framework of the Padesky and Mooney 5 systems Model. [38] Due to the high levels of pollution participants expressed having negative thoughts which led to feel negative emotions and physiological reactions. The behaviours followed by these emotions were becoming a difficulty for individuals to manage such as excessive self-checking behaviours. The conceptualisation helps in better understanding the cognitive and emotional state of these individuals. Detailed formulation in Image 2.

Image 2: Formulation and conceptualisation of challenges encountered by individuals.



The current study is a preliminary trend in supporting that individuals residing in regions with high AQI levels such as Delhi-NCR tend to experience compromised mental health possibly due to the cognitive appraisals attached to the situation. Moreover, the overwhelming thoughts interfere with their physical wellness along with disturbed mental health state. The results of the study could serve as a reminder to the government officials of the capital to investigate the alarming levels of air pollution and its impact on the physical as well as mental health of individuals. The levels of air pollution experienced by the capital are a silent threat to the mental and physical wellness of its residents and require feasible mitigations to be made. The study would also serve its purpose for clinicians and mental health practitioners practicing in the capital to consider pollution as a predisposing factor while observing depressive or anxious symptoms in an individual during a diagnosis.

Financial Supports

The authors of the study have received no financial support from any organization and the research is funded independently by the authors.

Competing interests

The authors have no conflicts of interest to declare.

Acknowledgements

The authors would like to thank the participants for their active participation for the current study and granting the permission for public representation of their data for academic and research purposes.

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