Evaluating the impact of stone quarrying on air and water environment in Mahendragarh district, Haryana

A thesis submitted in partial fulfillment of the requirements for the award of
degree of

Doctor of Philosophy
in
Environmental Engineering

by
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(2K15/PHDEN/02)

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DECLARATION

I hereby declare that the research work presented in this thesis entitled “Evaluating the impact of stone quarrying on air and water environment in Mahendragarh district, Haryana” is original and carried out by me under the supervision of Prof. Anil Kumar Haritash, Professor, Department of Environmental Engineering, DTU, Delhi, and being submitted for the award of Ph.D. degree to Delhi Technological University, Delhi, India. The content of this thesis has not been submitted either in part or whole in any other university or institute for the award of any degree or diploma.

(Saurav Kumar Ambastha)

CERTIFICATE

This to certify that the Ph.D. thesis entitled “Evaluating the impact of stone quarrying on air and water environment in Mahendragarh district, Haryana” being submitted by Mr. Saurav Kumar Ambastha for the award of degree of Doctor of Philosophy in Environmental Engineering, Delhi Technological University, Delhi, India, is a bonafide record of original research work carried out by him under my guidance and supervision. The results embodied in this thesis have not been submitted to any other university or institution for the award of any degree or diploma.

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ACKNOWLEDGEMENT

As I turn the past time old pages I realised this research work was initiated long back. During this tenure I came across many people without whose support this would not been possible. I would like to expresses my sense of gratitude and respect to all who helped me to achieve my goal easily. First of all, I express my deep sense of gratitude to my guide prof. A.K. Haritash, Head, Department of Environmental Engineering, Delhi Technological University for his immense support, guidance and expensive invaluable suggestion throughout the study and writing of this thesis. I would like to to thank him for encouraging my research and allowing me to grow as researcher. I am thankful to Vice chancellor, Delhi Technological University for regularly upgrading and providing optimum lab facilities and sophisticated instruments needed to carry out the in depth analysis. I sincerely express my gratitude for the kind support of prof. S.K.Singh and Dr. R.K.Mishra for their invaluable support. I accord my heartfelt thanks to Mr. Rajesh Sehravat, mine inspector Mahendragarh, Haryana, for helping me to carry out my research work in mining location.

I take my privilege thank to all faculty members of Environmental Engineering department, DTU. I am indeed to the cooperation and support of Lab technician Ms. Navita, who assisted me to carry out my experiments in lab smoothly. It would have not been possible without the help of Mr. Sahil and Mr. Keshav and students Ms. Mamta, Mr. Surinder and Mr.Ajay who assisted me on my sampling day. I am thankful to them. I have been greatly supported by my friends and colleagues Dr..Manisha, Dr. Sakshi, Dr. Shalendra, Mr. Harsh, Ms. Shivani, Mr. Kanakraj, Mr. Vignesh and Ms. Anshul throughout my research. I am grateful for them in helping me out, giving moral support in times of need and distress.

My acknowledge will be incomplete if I don’t mention the immense contribution of my family, My Sisters, My brother, in-laws and my wife Aashita, who never let their faith in me waiver. They stood by me like strong forces and gave me constant motivation during low times. My daughter Shivika has shown enormous patience during this process and has cheerfully sacrificed the time which was for her. My gratitude and love for everyone. In the end, I extend my profound and respected expression to God and my parents Mr. Kedar Nath Ambastha and Mrs. Rekha Ambastha who showered me with huge blessings always. Their prayers have given me strength and made me who I am today.

Saurav Kumar Ambastha

ABSTRACT

In recent years, the environment has become a major concern for the human survival across the countries. To comprehend the nature and scope of these potentially hazardous events, a systematic and interdisciplinary approach is required for mapping, monitoring, and managing the effects of mining activities**.** The need for building materials has significantly increased due to the construction industry's rapid expansion, which is necessary to satisfy the society's infrastructure and housing needs as well as the demands of today's growing population. Stone quarrying still plays a significant part in this process. However, the activity has severely damaged the ecosystem, and resulted in socio-economic conflicts in the study area. Several studies have identified significant environmental and socioeconomic issues associated with quarrying, including landscape modification that affects local biodiversity, creation of wastelands, air and noise pollution, illegal stone excavation, accidents, and in some places, a decline in groundwater table etc. Quarrying has a negative impact on the environment in a variety of ways including rock exploration and blasting, rock transport, and waste rock disposal. The present study was done to estimate seasonal variation of particulate matter ($PM_{2.5}$ and PM_{10}) emissions from various stone quarrying operations in Bakhrija mines, Mahendragarh, Haryana. According to the findings, the main factors contributing to dust production include drilling, blasting, crushing, and transport of mined material. While drilling, blasting, and loading were the causes of a larger proportion of PM_{10} emissions, vehicular movement caused roadside dust to be further crushed and re-suspended, which led to the formation of a substantially higher fraction of finer dust ($PM_{2.5}$). Quarrying/mining also degrade the quality of water around the mining region. Although water quality is acceptable for drinking but parameters such as TDS (total dissolved solids), TH (total hardness), Calcium, Magnesium, Fluoride etc, are recorded higher than the desirable limit at few places. Groundwater chemistry was observed to be influenced by silicate weathering and reverse Base Exchange. The shallow meteoric genesis groundwater was mostly Na-Cl type, while the deep meteoric genesis groundwater was mostly Na-HCO_3 type. The geochemical results indicate that dissolution of carbonate minerals may have resulted in fluoride solubilisation in groundwater via the ion-exchange mechanism. To manage the air quality it is suggested to restrict dispersion of dust during crushing. Dust dispersion may be controlled by developing green belt, and by regular sprinkling of water on unpaved roads. The resuspended dust can be minimised by covering the material during transportation.

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List of Abbreviations

AA	Ascorbic Acid
APHA	American Public Health Association
API	Anticipated Performance Index
APTI	Air pollution Tolerance Index
AQI	Air Quality Index
BIS	Bureau of Indian Standard
CEC	Cation Exchange Capacity
CGWB	Central Ground Water Board
COPD	Chronic Obstructive Pulmonary Disease
CPCB	Central Pollution Control Board
DW	Dry Weight
EC	Electrical Conductivity
EMP	Environment Management Plan
ERM	Enterprise Risk Management
FDI	Foreign Direct Investment
FICCI	The Federation of Indian Chambers of Commerce & Industry
FTIR	Fourier-Transform Infrared Spectroscopy
FW	Fresh Weight
GDAS	Global Data Assimilation
GDP	Gross Domestic Product
GEM	Global Eulerian Model
GIS	Geographic Information Systems
GIZ	Gesellschaft für Internationale Zusammenarbeit
GPS	Global Positioning System
GSI	Geological Survey of India
HSE	Health and Safety Executive
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory model
IDW	Inverse Distance Weighted
IEG	Independent Evaluation Group
IQR	Interquartile Range

IS	Indian Standard
ISID	Institute for Studies in Industrial Development
LDSA	Lung-deposited Surface Area
LULC	Land Use Land Cover
NAAQS	National Ambient Air Quality Standard
NEERI	National Environment Engineering Research Institute
NIOSH	National Institute of Occupational Safety and Health Hazard
NMP	National Mining Policy
NOAA	National Oceanic and Atmospheric Administration
OEHHA	Office of Environmental Health Hazard Assessment
PM	Particulate Matter
PNC	Particle Number Concentration
PND	Particle Number Distribution
PTFE	Polytetrafluoroethylene Polymer Filter
RWC	Relative Water Content
SPM	Suspended Particulate Matter
SPSS	Statistical Package for the Social Sciences
SMPS	Scanning Mobility Particle Sizer
SDWG	The Sustainable Development Working Group
TCh	Chlorophyll Concentration
TDS	Total Dissolved Solids
TISAB	Total Ionic Strength Adjustment Buffer
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TW	Turgid Weight
UFP	Ultra Fine Particles
UNEP	United Nations Environment Programme
USEPA	United States Environment Protection Agency
UV- Vis	Ultraviolet Visible
WHC	Water Holding Capacity
WHO	World Health Organisation

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CHAPTER 1

INTRODUCTION

Mining is one of the core industries which provide economic growth to the nation. Mining is the crucial process of extracting valuable minerals, ores, and other geological resources from the Earth's crust, serving as the backbone of modern industrialization and economic development. Utilizing various techniques like surface mining, underground mining, and placer mining, this multifaceted industry plays an indispensable role in supplying essential raw materials for construction, manufacturing, energy production, and technology, while also presenting significant challenges related to environmental impact and sustainability. Through advancements in technology and responsible practices, mining continues to evolve, striving to balance resource demands with environmental preservation for a sustainable future.

1.1 Mining and its History

One of the oldest professions in humankind is mining and quarrying. Extraction of ore from earth is done either on the surface or subsurface to take out non-mineral ore such as rocks and sand. An open cast mine, such as a quarry, is an exposed pit on the surface of the Earth. On the other hand, a subsurface mine consists of underground shafts or tunnels. These mines fulfill the demands of the construction sectors. Humankind is dependent on mining activities because it provides occupation to the people, and also severely influences the environment. For thousands of years, people are excavating earth's resources to meet up their needs and fulfill the market demand. Historical monuments are a great example and proof of massive limestone and granite stones that were manually excavated from quarries, to construct the Great Pyramids by the ancient Egyptians. Methods for mining sandstone and other minerals from the quarries evolved since the first quarries/mining were listed in Egypt's Aswan region. The quarrying activities were done using hammers, picks, and chisels made of stone or metals like bronze and iron. Later, in the Bronze and Iron ages, people were practicing mining for the extraction of copper, tin, and different iron ores. In the medieval age, western civilization started making big structures made up of stones, marble, and slate material. In the colonial era, the excavation of different ore from different parts of the world was done to fulfill the demand and fuel up the economies of the Western world.

In India, the first mining activity was reported in the Indus Valley civilization where the quarries were visible as almost circular shapes filled with Aeolian sand of the Thar dunes and mounds of limestone blocks that were the historical proof of ancient mining operations. In the years 1985 and 1986, an archaeological excavation was conducted in Gujarat and Rajasthan, where Harappan-era quarries evidence were found (Biagi 2008).

The East India Company began mining in India for the first time in 1774 near the Damodar River in West Bengal's Raniganj Coal Field. A British industry began gold mining in the Kolar Gold Fields in Karnataka later in 1880. India's mining industry managed to be small-scale and low-tech in the years leading up to independence. However post-independence, the mining sector underwent modernization and expanded at a significantly higher rate as a result of the ambitious Five-Year Plans for mining sectors, the Indian government's economic reforms in 1991, and the introduction of the National Mining Policy (NMP) in 1993. The government's fiscal, industrial, and trade reforms were followed by the NMP, which "acknowledged the need to promote private investment, especially Foreign Direct Investment (FDI), and it also attract state-of-the-art new technologies in the quarrying/mining industry." Mining is a major economic activity and it accounts for 2.63 % share of the Gross domestic product (GDP) in India (ISID, 2012).

Meanwhile, along with economic growth, mining activities raised concerns about environmental conservation (UNEP, 1997). Non-metallic and minor minerals, in addition to the mining of fuel minerals and metallic minerals, are crucial in completing India's mineral potential. Nearly 60% of all mining/quarrying in India account for for non-metallic minor minerals. Apart from metallic minerals, the production of clay, chalk, mica, rock salt, and sandstone occupy a substantial amount of space and contributes significantly to GDP.

India is the world's third-largest producer of 88 different minerals which includes metallic, non-metallic, and fuel minerals. Large resources of iron ore, copper, aluminium, bauxite, manganese, chromite, and zinc are found in India. Odisha, Jharkhand, Chhattisgarh, Karnataka, Andhra Pradesh, Rajasthan, and Madhya Pradesh are most mining rich state of India. The majority of ore deposits, both mineral and non-mineral, are in Odisha, Jharkhand, Chhattisgarh, Maharashtra, Goa, and Karnataka. Copper deposits are found in Jharkhand, Madhya Pradesh, and Rajasthan. Majority of the world's zinc deposits are found in Rajasthan, Andhra Pradesh, Madhya Pradesh, Bihar, and Maharashtra. Haryana is the state holds the largest share of the tin (64%), quartz-silica sand (52%) and quartzite (49%) resources. In Haryana, most commonly found mineral is china clay which is present in the district of Gurgaon, Faridabad, and Rewari, whereas Mahendragarh, Bhiwani, Ambala, and Panchkula are famous for limestone, and Ambala, Bhiwani, Mahendragarh, and Panchkula is famous for quartz/silica sand. Quartzite is found in the districts of Faridabad and Gurgaon; and slate, barytes, calcite, felspar, and marble is also found in Mahendragarh. Copper is found in Bhiwani and Mahendragarh. In Bhiwani district, Tosham region contains reserve of granite, tin, and tungsten. Mahendragarh district has dominance of dolomite. (Indian bureau of mines, 2021)

In the case of non-mineral quarrying, the quarrying sandstone business is extensively distributed across all states of India. Building material product, includes different type and class of aggregate for road construction, building concrete aggregate, bituminous aggregate, and other defined and unnamed construction aggregates (UNEP, 1997). Similar to this, stone crushing is a significant industrial sector in India that produces crushed stone in a range of sizes according to demand, which serves as the raw material for several construction projects. According to estimates, there are more than 12,000 stone-crushing plants (CPCB, 2009). The stone crushing units are located in vicinity of all the major towns and cities as it requires a lot of manpower and electricity supply to operate. Majority of stone crushers are situated on the outskirts of cities or close to significant building sites because of ease in transportation of material. Haryana is one of the major suppliers of crushed building materials to fast-growing mega cities like Delhi-NCR.

1.2 Impacts of Quarrying on the environment

Mining/quarrying activities promote socio-economic development as it provides a source of local employment that doesn't require any specific skill set, simultaneously contributing to the local and regional economies. Since, the positive impact is limited to local employment, the environmental issues associated with the stone quarrying sector overshadow these positive impacts (Fig.1.1). Ground vibration, noise pollution, dust emissions, land disturbance, environmental degradation around the mining site, and social issues like displacement of population, marginalization of local communities, and economic disparities are major concerns in mining areas. Stone quarrying is a method used throughout the mining process to remove non-fuel and non-metal substances from rocks. In open-cast mining activities such as drilling of rocks, dynamite explosions to break the material into transportation size, and other technologies are employed. Quarrying/mining generates a significant amount of mining waste of no commercial value, which ultimately harms the environment. Therefore, mining waste has no economical use and has a strong potential as environment threat. As hundreds of tons of rock are excavated, moved, and crushed during mining operations, considerable amount of dust and other particles are released into the air. Further, mining operational dust, which contains varying size of particulate matter (PM), and have the potential to disperse and affect the atmospheric environment.

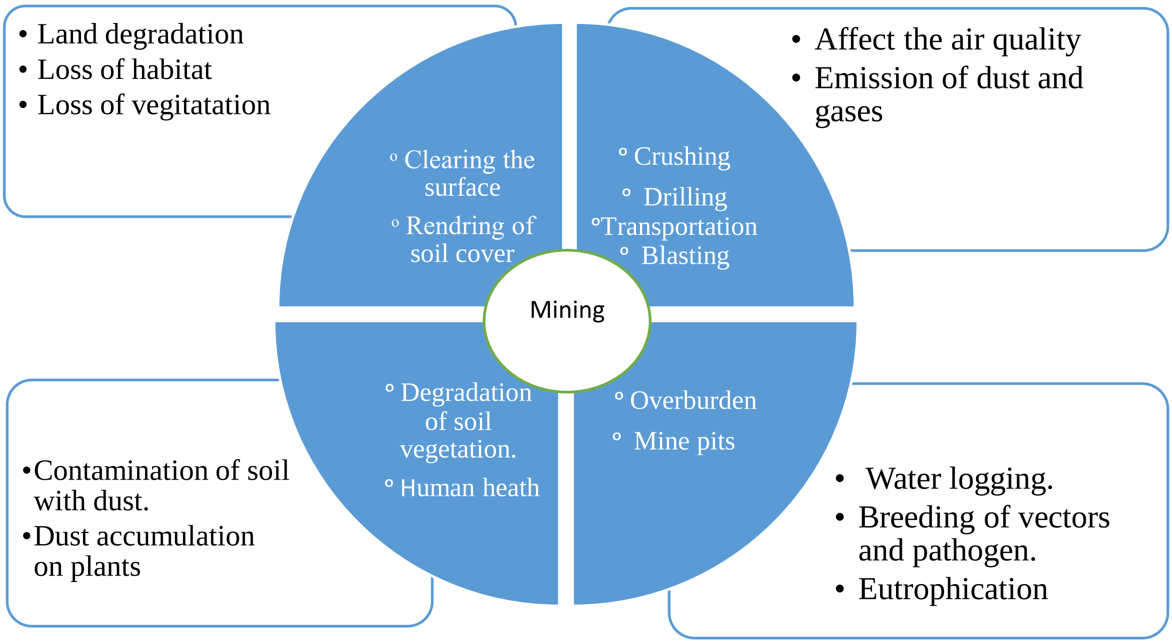

Fig. 1.1 Quarrying and its impact on the environment

The fine dust may contaminate the air and may pose serious immediate negative effects on human health. Quarrying operations may directly or indirectly contribute to air pollution. The most significant emissions occur through operational crushers which emit a large quantity of particulate matter (PM). Mining activities also contribute fugitive dust into the air various mining processes such as drilling big blocks for filling of explosives, blasting of material into transportation size, loading and unloading of raw material, resuspension dust from haul roads, wind dispersion of dust from stockyards, exposed overburden dumps, stock handling plants, emission of dust from operational and natural phenomenon from exposed pit faces, dispersion of dust from operation and exhausts of heavy earth moving vehicles and equipment, and crushing of stone to a smaller size for a different type of civil uses contribute to pollution around quarrying regions. Particulate matter deteriorate the air quality of surrounding mining region's which harms the human health, flora, and fauna. The locals and miners involved in the quarrying area developed respiratory, skin, and eye irritation due to stone dust (Emmanuel et al., 2018). The main health concern is of breathing in crystalline silica dust. These fine dust particles enter the human lungs and in prolonged exposure, different kinds of respiratory and pulmonary conditions such as silicosis, lung cancer, bronchitis, tuberculosis (Tb), etc can be diagnosed in workers and people living near mining areas. The dust in mining region contaminated areas, and increasing air pollution may potentially hinder plant development. Aerosols are released into the atmosphere by mining and crushing equipment. Depending upon the specific weights and higher concentrations of stone dust particles in the lower atmosphere, which may alter the microclimate and ecological balance of the area.

In an ecological context, the air pollutant also affects the local flora. Particulate matter present in the atmosphere undergoes dry deposition. The leaves of plants and trees have wide surface area, which helps in the deposition and accumulation of particulate matter, resulting in lowering the amount of particulate matter in the atmosphere. Gaseous pollutants exposure from the surrounding atmosphere affects the stomatal openings, which activate the intracellular responses that damage plant tissue. Plants that grow in plenty in mining areas are major recipients of air pollution. Often the changes at the stomatal level, disruption of membranes, modifications in catalytic reactions, biochemical interferences, and death of plants are reported around mining and crushing zones (Lee et al., 2022).

Depending on the specific combination of deposited particles and exposure to a given mass concentration of airborne particulate matter, different phytotoxic reactions were observed. Rather than a single pollutant, the word "particulate matter" refers to a heterogeneous mixture of particles of different sizes, sources, and chemical compositions (Federico et al., 2015). Fine particulate matter is secondary and typically more diverse than coarse particulate matter. It condenses from the vapour phase and is formed by chemical reactions from gaseous constituents through nucleation, condensation, and coagulation, or is left over after water from contaminated fog and cloud droplets have evaporated. These substances are found there either as liquid or solid aerosols or dissolved in fog water.

Mining activities affect the soil by disrupting the geology and landscape and severely degrading the soil-plant stability circuits. It also increases intermixing of pollutants through other sources like runoff from the stockpiles and over the dump. It may cause depletion of the soil organic pool around the mining area. Studying the effects of mining on soil quality is crucial since soil serves as the final sink for all the contaminants produced during mining. Altering of landscape and cutting down trees degrading the soil quality lowers the organic matter and critical nutrients, biological activity along with the overall productivity of soil, especially in places where agriculture is the dominant activity is majorly affected (Wantzen et al., 2013). Development of soil take place by weathering of chemical components from the parent rock and the in absence of additional constituents. Due to mineralogy of residual soil and parent rock considerable amount of metal elements were present due to weathering in the soil. Changes in the physicochemical quality of soil results in infertile or barren soil, which does not support plant development and has a negative impact on agricultural productivity. Mining, and slate quarrying activities are responsible for the growth of wasteland areas and altering the soil physical composition, which in turn affects the agricultural production yield in and around the mining region.

Water shortages and excessive groundwater extraction are prominent at mining locations. Radioactivity, hazardous anions from mine tailing, heavy metals traces, and biological contaminants have been detected around mining area (Birabwa., 2009). In other words, it depletes the water resources and quality in the area. Sandstone quarrying affects water resources less than mining for coal, metals, radioactive material, etc (Liu et al., 2021). Quarrying activities have a diverse effect on the ecosystem, destroying the existing vegetation and also degrading the quality of the surface and ground waters in the mining province. Water quality gets degraded and gets contaminated by mining wastes such as dust, oil used in heavy machinery, and other minerals such as tailing that include trace of heavy metal. The runoff gets collected in depressions and in the trenches, where the water turns murky and contaminates the groundwater. The degraded and contaminated water near the quarrying area imposes ill health effects on humans, animals, and plants.

It is well acknowledged that noise in the stone quarrying sector is a huge inconvenience, may affect hearing, and may even have negative physiological and psychological effects. Significant implications include an increase in accidents, general ill health, occupational health risks in the workplace, and a decline in productivity. It can hinder communication, disrupt sleep, and cause a lack of focus, irritation, and decreased effectiveness. prolonged exposure to loud noises is thought to induce headaches, increase blood pressure, aids in psychological breakdowns, and eventually hearing loss and deafness (Manwar et al., 2016)

Several concerns have been raised over whether mining operations should be continued in consideration of the extensive environmental damage caused by such operations. Inappropriate and inefficient operating techniques and restoration efforts are the primary causes of environmental degradation by mining activities. Since these are the limited studies to establish environmental effects of stone quarrying is limited and the measures for environmental management are sanity, the present study was undertaken to cover the research gaps in respect of stone quarries in the state of Haryana, India with the objective given below:

1.3. Objectives of the study

There are multiple environmental concerns but this study will be focused on:

1. To study the effect of stone quarrying on the air and water environment in Mahendragarh district, Haryana.
2. To study the seasonal variations of water quality, and particulate matter ($PM_{2.5}$/PM_{10}) around the quarrying region.
3. To ascertain the season-specific sources (within the quarrying region) responsible for air and water pollution.
4. To suggest a suitable environment management plan (EMP) for stone quarrying and crushing.

1.4. Scope of the study

The present study contributes to determine the extent of these impacts, understanding the ecological changes caused by quarrying activities, and identifying measures to reduce or mitigate them. Addressing these research gaps will give a better understanding of the environmental consequences of quarrying activities. It can help to shape evidence-based policies, management practices, and technological advancements that promote sustainable resource extraction while minimizing negative impacts on ecosystems and communities. Overall, data collection, analysis, and monitoring in each study area is done for a thorough investigation to analyse the effects of quarrying on air, water, soil, and vegetation.

CHAPTER 2

REVIEW OF LITERATURE

Since the dawn of human society, practicing quarrying and mining activities are part of civilization. From the stone age, mining has aided in the advancement of human civilisation. By enhancing infrastructure, providing employment, fostering rural community development, and opening up new ventures and downstream industries. The mining sector has a direct influence on the macro economy. Vast deposits of essential minerals and their small- to large-scale mining have helped the Indian economy to thrive. In 2010, the mining industry in India made up around 3% of the country's Gross Domestic Product (GDP), down from a 2.3% contribution in 2000 (FICCI, 2013). With a population of more than 1.35 billion (UN, 2015) and one of the fastest-growing economies in the world (World Bank, 2017), India is likely to be a major player in the mineral sector. The need for rock aggregates in India is estimated to be between 2 - 10.3 billion tonnes by the end of the next decade (GIZ, 2016). Annual average rock usage in India exceeds 1.3 billion tonnes (GIZ, 2015, 2016).

Historical evidence shows mining operations were done only for personal financial gain with the help of the local population whereas their progress and environmental impact were least concerning (ISID, 2012). However, even outside the actual limits of individual mining leases, the extraction of coal and other minerals resulted in multi-dimensional social footprints because of environmental deterioration, effects on human health, and social displacement. Additionally, the long-distance transportation of minerals and in-situ operations, increased the mining footprint over a wide geographic region. This implies that mining can’t be completely free of all negative environmental effects, and hence, there is an urgent need of reformation and improvement in the mining industry overall performance with reference to the concerens of environment and public health (ERM, 2011).

Agriculture, quarrying, and mineral extraction are important in improving rural livelihoods and alleviating rural poverty. Even though agriculture remains the principal alternative for alleviating rural poverty, access to agricultural land to earn and progress remains a significant obstacle for people living below the poverty line. It is estimated that over 45 percent of the world's population lacks access to land (Fellmann et al., 2005). Over 500 million people in developing nations are, forced to work in small-scale surface mining and quarrying to survive (Wang et al., 2010). Third-world nations of from Africa, East Asia, Southeast Asia, and Latin America rely heavily on access to natural resources to get a livelihood. As the formal sectors in underdeveloped nations have extremely limited, this is the case because the informal sector has emerged as a substitute for meeting necessities for subsistence potential for employment development (Ibrahim, 2007). Population expansion has put a tremendous amount of strain on natural resources, seriously jeopardizing their sustainability. Overuse and over exploitation has made the majority of resources exhausted while the majority of fertile land has been irreparably damaged (IEG, 2008). The health and employment issues of the impoverished majority are looking for alternative support in rural regions which are likely to be exacerbated by this trend. According to a study by the World Bank (2001) about 40% of the world's population is living in poverty, while about 75% of rural dwellers in the emerging nations live in absolute poverty. These are seen as landless, helpless, defenceless, and disadvantaged individuals. Due to their restricted access to society, and the socioeconomic advantages enjoyed by urban residents, impoverished rural residents typically look for employment prospects in the primary and unorganized sectors of the economy, particularly in subsistence agriculture, small-scale mining, and quarrying (Birabwa, 2006).

In India, one of the key economic activities of mining/quarrying operations are established in locations with abundant mineral and energy resources. These places have seen tremendous economic growth as a result of the increased per capita income and consequent increase in regional and national revenue. Since, mining and quarrying account in respectable share of GDP. Meanwhile, mining activities has raised concerns about how to promote economic growth simultaneously protecting the environment. (UNEP, 1997). According to an estimates there are more than 12,000 stone-crushing facilities, (CPCB, 2009).

2.1 Mining and its effect on environment

Environmental effects might be acute and brief (during operating conditions), transient (typically acute and related to accidental spills or explosions), or chronic (long-term, resulting from mineral extraction and waste disposal). Activities like quarrying have a significant impact on the environmental ecology (Table 2.1). (Xue et al., 2010). To understand the quarrying stages and the waste a flow diagram (Fig.2.1) is drawn which defines the steps of mining and their waste.

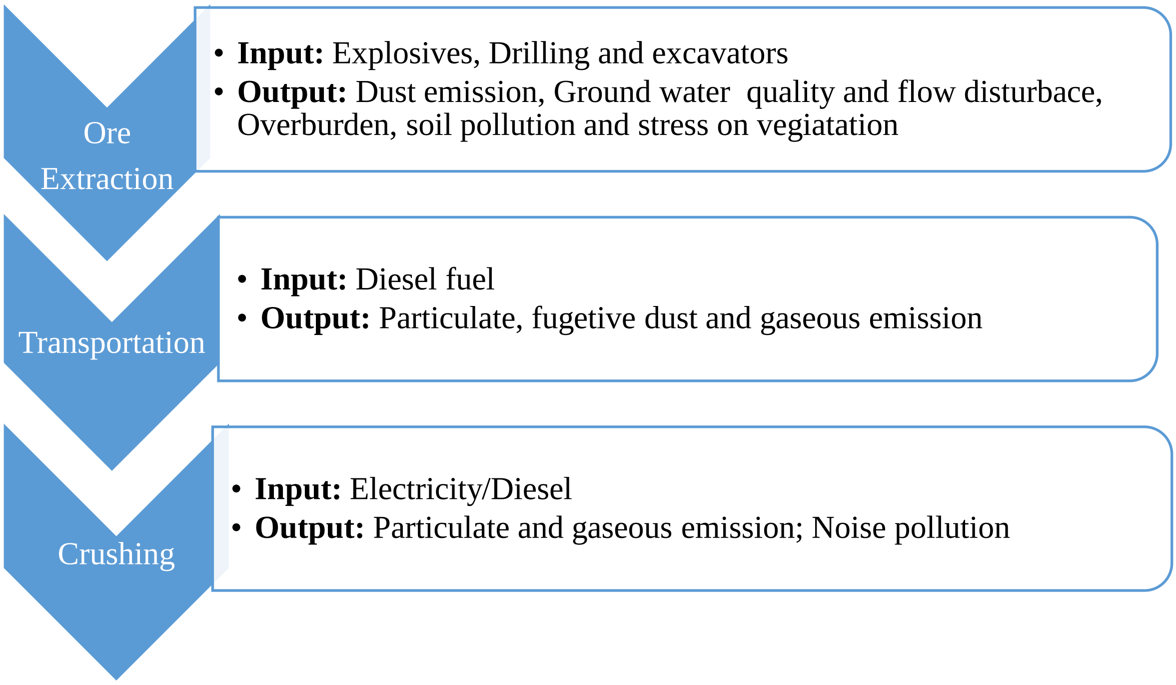

Fig. 2.1 Flow diagram and system boundaries of limestone quarrying operation.

Quarries affect the different dimensions of the environment, which include the formation of irregular and depressions, resettlement of human population, conversion of leftover pit into artificial ponds, the partial or complete destruction of surface water bodies, erosion through wind and runoff also cause instability for quarry dump, the depression of piezometric surfaces which disturb the subsurface water, the alteration of groundwater flow, the formation of periodically flooded areas, the permanent removal of farming-related activities from certain areas, the modification of farming techniques, and changes to the characteristics of the soil. The socio-economic development and urban modernization processes have been plagued by many serious environmental-geological issues, including increased environmental pollution, soil erosion, destruction of the aesthetics, patterns, and integrity of the landscape, groundwater seepage fluctuations, and ensuing natural habitat-induced geological disasters (Khater et al., 2003). Quarrying, have substantial and permanent impacts on the climate in the long run including species extinction, habitat degradation (Shaban et al., 2007; Aryafar et al., 2012), emissions of dust/particulate matter (Zobrist and Giger, 2013) and possible mining-related environmental risks (Mölders, 1998). Drilling, unpaved road haulage, loading, primary crushing and stockpile, excavation, and processing of minerals from surface mines and quarries are just a few of the site operations that can produce significant pollution.

Table 2.1 Effect of quarrying/mining on environment

Type of the mining	Issues	Country	References
Stone Quarrying	Growth of the tree, and tolerance compromised in mining area	India	Haritash et al., 2020
	Mining water degrade air quality of surrounding area	Turkey	Ozcan et al., 2012
	Mining activity alter plant biodiversity	India	Pawan, 2013
	Noise pollution	India	Paramesha et al., 2007
	Quarry waste deposited form cementus composites on plants and nearby location	S.Arabia	Altheeb, 2022
	Dust emission from mining process	Sweden	Bhadani et al., 2020
	Hydro-geochemistry of ground water degradation in mining region	India	Chitrakshi and Haristash, 2018
Coal Mining	Mining waste, overburden, deforestation, and site specific mining activities affects the environment of the area	India	Dhar, 1993
	Air quality degradation due to mining	India	Ghose and Majee, 2002
	Mine pond act as recharge source of ground water and changes the quality of water	USA	Bennett et al., 1988
	Acid mine drainage due to mining	Turkey	Akcil and Koldas., 2006
	Soil Contamination due to mining	India	Chaulya et. al., 2002
	Land degradation due to mining	India	Singh et.al., 2016
Other mining	Deforestation and wildlife disturbance due to mining	India	Singh et.al., 2012
	Agriculture land shrinkage due to mining	China	Adator et al., 2023
	Activities of blasting can affect historical monuments due to mining	India	Joshi et al., 2022
	Ground water contamination due to mining	Belgium	Bzowski & Dawidowski, 2002
	Emission of Fugitive dust due to mining	Egypt	Sadek et al., 2016

The major environmental effects (Table 2.2) of mining are as follows:

- Air quality

  Quarrying associated activities can have a significant impact on air quality due to the release of particulate matter and gaseous into the atmosphere. One of the primary concerns is particulate matter, which is generated during the quarrying processes of blasting, drilling, and crushing. Emitted fine particles smaller than 2.5µm remain suspended in the air for longer time and be carried by wind over long distances, posing risks to nearby communities and ecosystems. Also, quarrying operations frequently involve the use of heavy machinery and vehicles that emit gases such as, nitrogen oxides, and sulphur dioxide, contributing to air pollution. These pollutants can harm human health by causing respiratory issues, as well as affecting vegetation and wildlife.

- Water quality

  Mining operations severely damage the surface and subsurface water sources. The extraction process has the potential to disrupt the natural hydrological balance, resulting in changes in water drainage patterns and groundwater levels. The dust pollution settling from the air can increase the dissolved solids level in the surface water near the crushing area. In some cases, open pit is used as solid waste dumping ground which may impact the groundwater quality due to leaching. Runoff coming from overburden laden with different type of solid waste and dissolve solids also impact surface water and subsurface water quality.

- Land degradation

  Quarrying involves removing large amounts of topsoil, rocks, and vegetation, which destroys natural habitats and ecosystems. This disruption causes soil erosion, biodiversity loss, and wildlife habitat fragmentation, affecting the local flora and fauna populations. These changes can have far-reaching consequences, such as reduced water availability and increased risk of flooding in nearby areas.

- Waste generation

  Quarrying operations generate a substantial amount of waste, which can have negative environmental consequences if not properly managed. Raw material extraction and processing generate a variety of waste products, including overburden, tailings, and unused or discarded materials. These waste materials occupy big area of land, causing land degradation and the depletion of natural resources. Quarrying waste improperly disposed off can also contaminate soil and water sources, potentially affecting local ecosystems and human health as well.

- Biodiversity loss

  Quarrying activities can have serious consequences an biodiversity, resulting in habitat loss and degradation, as well as purporting threat to extinction of plant and animal species. Mineral extraction frequently involves the removal of topsoil and vegetation, disrupting the ecological balance and the intricate relationships between species. Quarrying has the potential to fragment habitats, resulting in formation of isolated patches of land, unable to support diverse ecosystems. This fragmentation may hamper species movement and migration, resulting in population decline and reduced genetic diversity.

Table. 2.2. Major impacts factors of mining/quarrying

Impacts on	**Factor**
Land	• Removal of top soil • Biodiversity loss • Loss of local species of flora and fauna. • Change in landscape
Water	• Sensitivity to contamination, leaching, and erosion. • Contamination of surface and ground water.
Air	• Ambient air quality degrades. • Dispersion of dust with wind.
Geology	• Dimensions of the overburden • overburden's composition leads to water pollution
Community	• The urbanization of rural places • Job opportunity involving the community • Affected by pollution
Biodiversity	• Loss of native plants and animals • Loss of habitat and ecosystem

(Source: GIZ 2016)

Mining industries are established worldwide, but it can be differentiated by the type of mining with the country's economic status and their policies to curb the pollution level. In mining, handling waste is a huge task. Every year about 23 billion tons (EOHS, 2011) of minerals are produced however quantity of waste is much higher than the quantity of final product. For instance, in the case of copper mining, one tonne of pure copper is produced from thirty tonnes of ore (EOHS 2011), and this implies for all metals in all minerals mining. In the case of non-mineral mines, the requirement of materials in bulk, hense the amount of waste materials is minimal and can be tolerated. Globally, about 50 billion tonnes of ore is excavated annually which is equivalent to digging 1.5 meter deep hole size of Switzerland each year (EOHS, 2011).

2.2 Impact of quarrying on air quality

Air pollution is caused by the extraction of non-minerals and minerals, leads to the generation of solid waste, and the processing and refining of ore. Each stage of the mining process contributes towards the release of of airborne pollutants and particulate matter (PM) from drilling, blasting, crushing, hauling, collecting, and transportation. Quarrying have detrimental overall effect on the environment and public health.

The term "dust" refers to aerodynamically dispersed particles of size less than 75 µm in diameter. These particles remain suspended in the atmosphere until they descend by gravity. Similar to other anthropogenic sources of dust emission, the mining and quarrying industries are a source generation of coarse as well as fine particulate matter (Hinds, 1999). Dust emitted from natural activity (from wind erosion, dust or sand storm, and natural resuspension) and anthropogenic activities dust (from mining industries) are the major contributors to $PM_{2.5}$ and PM_{10} (Jain and Khare, 2010), which is responsible for more than 50% of the accumulation of dust particle in the mining areas. The emitted dust dispersion along with prevailing wind can be responsible for dust-related allergies and respiratory diseases the vulnerable population along the direction of wind (Jain and Khare, 2008). Environmental effects of mining of coal, minerals, and radioactive materials have been well documented, but the availability of literature on stone quarrying and its effect on the environment is very limited, particularly in the Indian context (Amitshreeya and Panda, 2012).

Prevailing wind condition with local disturbances exhibit an important role in quantifying and analysing the dilution and dispersion of particulate emissions in the atmosphere around the mining region. To forecast regional wind patterns the relationship between regional air quality and the complex terrain should be evaluated for the forecasting of pollution dispersion in the atmosphere, with information and data of local wind direction and speed prediction over complicated terrain, such as hills, valleys, and urban canyons (Shi et al., 2000).

However, the environment of surface mines and quarries behaves differently because of some ground factors, which are over 100 meters deep and barely a few kilometers broad. Mining pit or open-cast mine projects are typically different from each other. Open-cast mines are different in appearance and terrain and are not naturally formed. The landscape of the open-pit mine may create the internal circulation of air movements inside the opening of open-cast projects. Frequent generation of significant amounts of fugitive dust is generated due to extraction, processing, and transportation of raw materials. Recirculation and turbulence fluxes are also produced inside mine trenches. Mine may lead to a decline in the visibility and air quality throughout the operations and may have an impact on the emission. (Baklanov, 1984, 1986, 1995; Baklanov and Rigina, 1995; Peng and Lu, 1995). The influence of internal pit results in the flows which leads the retention of released dust within the quarry pit (Cole and Fabrick's,1984) . Opencast mine utilise of high-capacity equipment that cannot be employed in underground mines, and contributes more pollution load than subterranean mines (Kan et al., 2012). Massive amounts of particulate matter (PM) are produced by large-scale operations the use of powerful heavy machinery raises pollution levels in and near opencast mines (Kurth et al., 2014; Marrugo-Negrete et al., 2014; Pandey et al., 2014). Primary source of particulate matter includes different mining processes, such as crushing, drilling, and blasting whereas process such as loading, unloading, and transporting material are considered as secondary sources of PM generation. Depending on the location and affiliation of a certain mining operation, workers are exposed to varying quantities of PM at different locations (Naidoo et al., 2006).

Several investigations has been conducted and reported on modelling the transport and effects of air pollution in respect of major cities (Jain and Khare, 2010), but the studies on modelling the emission and transport of dust from non-mineral quarries are very limited. Uncontrolled emissions of fugitive dust cause significant environmental, health, safety, and security concerns to both site staff and the local community exposed to it. (Ambastha and Haritash, 2022). Natural sources of dust emission are one side of the coin, but mining and quarrying industries are one of the major anthropogenic sources of coarse as well as fine particulate matter emission. (Hinds et al., 1999). Quarrying's most noticeable, intrusive, and possibly annoying effect is dust, and because of this impact appearance, people frequently have worries that are not proportionate to how harmful it is to their health and the environment

(Moshammer et al., 2014). Dust emission might occur from different point sources, such as drilling, crushing, and transporting, or it can come from fugitive sources like excavation, haul roads, and blasting (Tian et al., 2015). Site factors affecting the quantity of dust is produced during the extraction of aggregate and dimension stone, includes characteristics of the rock, ambient moisture, ambient air quality, prevailing winds, as well as the size of the operation and its proximity to populated areas. However, at distant locations, dust concentrations, deposition rates, and possible effects tend to diminish quickly (Howard and Cameron, 1998).

Particulate matter undergoes dry deposition in the mining region. Trees and plant leaves of that region facilitates the deposition, concentration, and incorporation of the pollutants over canopy surface thereby bringing down the level of pollutants in the atmosphere (Rawat and Banerjee, 1996; Escobedo *et al.,* 2008). For the gaseous pollutants, gas transfers from the atmosphere before ending up in the stomatal pores stimulating intracellular reactions resulting in damage to the plant tissue (Currie and Bass, 2008; Jim and Chen, 2009). Plants which are abundantly found in polluted mining area are observed to be prime receptors of air pollutants. Due exposure of pollutants, alterations at the stomatal level, membrane rupture, changes in catalytic processes, biochemical interferences, and mortality of plant occurs (Liu et al., 2008). It is essential to recognize and then classify plant species according to how well they can withstand air pollution.

As quarries and open-pit mines get deeper and larger, the production of raw materials leads to emission of more pollutants (Table 2.3). Heavy operation enhances the emission of dust. It is essential to create effective mitigation for dust emissions procedures to decrease fugitive dust emissions and boost the ventilation of the pit entry to minimise, and disseminate the dust. Improve and maintained strategic approach helps the health and safety of in-pit operations and decreasing off-site effects. In mining industries specially in opencast project utilization the topography and the geometry of the excavation is important to utilize the natural wind systems which helps air penetration to sustain the mine openings and air exchange. The airflow within a deep quarry is formed by a combination of mechanical shearing of the atmospheric boundary layer over the surface aperture and thermal buoyancy forces brought about by the differential heating of the quarry surface by the sun's movement over the day. Additionally, the occurrence of thermal temperature inversions at night may also help to retain the dust inside the quarry. (Cole and Fabrick, 1984). The particulate matter mixing height and wind speed is influenced by the stability of atmosphere and these factor is also affect on emitted dust inside the quarrying region (Reddy and Ruj, 2003).

Mining operations associated works emit fugitive dust into the environment and degrade the surrounding quality of air. In order to determine the concentration of fugitive dust emission factors, it is necessary to use them to estimate dust emissions from mining activities. (USEPA, 1972, 1973; Dupery, 1968). The mining activities caused the emission of both PM and settable fractions. During winter, the air quality in the quarrying region experienced significant changes due to meteorological condition. To represent the area's predominant wind directions, to analyse the concentration of ambient air quality in monitoring sites were chosen according to the metrological parameters (Ghose and Banerjee, 1995).

At the quarrying and crushing site, concentration of particulate matter was analysed by limits prescribed by the Central Pollution Control Board (CPCB), Government of India (CPCB, 2012). Coarse mining and its dump are also responsible for the increased concentration of particulate matter in mining areas. Natural dispersion with wind speed re-suspends a good amount of dust in semi-arid areas. Fine dust is formed through natural process either from aggregate waste or due to crushing to pollutant dispersion processes is prefunded by, the topography of the site and the weather, significantly impacting on particle concentrations (Charron and Harrison, 2005). In the winter season due to lower temperatures and high humidity, the concentration of particulate matter is high because the inversion condition restrict the dispersion. In contrast, particulate matter concentrations in summer season were found lower because of enhanced dispersion and high wind speed. Low mixing height and poor dispersion conditions are induced by high wind speed. Fine particles ($PM_{2.5}$) and ultrafine particles ($PM_{1.0}$) are formed by chemical reactions such as the nucleation, condensation, coagulation, and evaporation of fog and cloud droplets, in which gases also dissolve and react (Wilson and Suh, 1997). According to studies, quarry mining dust can serve as both a source of coarse particles ($PM_{2.5}$) and a source of fine particulates ($PM_{2.5}$) (Bluvshtein et al., 2011). The quarry mining dust is well acknowledged to have the potential to be dangerous like $PM_{2.5}$ and PM_{10}. The issue of quarrying dust minimization is a serious problem in the mining area as their exposure causes harmful effect on human health and pose threat to air, water, and soil environment. The re-suspension of settled dust occurs from the haul road by the action of natural factors, anthropogenic activities and vehicular movement, which is responsible for increasing concentration of PM in the air. Due to the moving source, it's very hard to control such dust remitting. Enough research is not available on the formation and dispersion of these fugitive dust from quarrying regions. To prevent pollution at the source, it is necessary to identify primary and secondary sources in these cases. To determine the environmental impact of fugitive dust, it is important to examine how dust affects with distance.

Table 2.3. Effect of quarrying on air quality in different region of world

Source	Issue	Country	Reference
Stone Quarrying	Stone processing contribute huge amount of dust into the atmosphere	United States	USEPA, AP42, Fifth Edition
	PM_{10} and $PM_{2.5}$ Concentration is higher in mining region	Brazil	Almeida et al., 2002
	Due to mining higher concentrations of TSP and PM_{10} are found in a mining area	India	Chaulya et al., 2001
	Local air quality issue and its Management	India	Ramana, 2011
	Size distribution of the particulate matter	India	Sivacoumar et al., 2006
	Opencast mining emit particulate matter from various opencast mining	India	Chakraborty et al., 2002
	Reemission of dust occurs in mining area through unpaved roads.	United States	Organiscak and Reed, 2004
	Due vehicular movement resuspension of dust occur in limestone quarry	Jordan	Abu-Allaban et al., 2006
	Modelling for predicting ambient concentrations of particulate matter	Isreal	Tartakovsky et al., 2013
	Monitoring air-born dust in basalt quarry	Italy	Degan et al., 2013

	The defining characteristic-source dust deposition from mining and diffuse-source dust.	Australia	Cattle et al., 2012
Stone Quarrying	Fugitive dust emission source profiles and assessment	Taiwan	Chang et al., 2010
	Dust emission calculations in open pit storage dumps	Spain	Toraño et al., 2009
	Rocks laden with different chemicals can cause health issues	USA	Knuckles et al., 2013
	Modelling of air pollution to analyse dispersion in limestone quarry	India	Chaulya et al., 2001
	Quality of air detoriate in the vicinity of mining site	Nigeria	Bada et al., 2013
	Concentration of Particulate matter analysis during granite quarrying and its impact	Nigeria	Olusegun et al., 2009
Coal Mining	PM concentrations drops with distance	United Kingdom	Jones et al., 2002
	Mining activities contribute to air pollution	India	CMRI, 1998
	Impact of dust pollution on workers	USA	Kurth et al., 2015
	vehicular emission and resuspension of dust degrade quality of air	USA	Hendryx and Luo, 2014

	Loading and unloading of raw material , road transport re-emission and exposed overburden dumps	India	CMRI, 1998
	Resuspension of dust is higher in summer season	Australia	Islam et al., 2019
Coal Mining	vehicular emissions, lead and gaseous pollutants	India	Pandey et al., 2014
	Mining machinery contribute in gaseous pollutants	China	Li et al., 2021
	Raw material transportation in mining area emit particulate matter.	India	Sinha and Banerjee, 1994; Sinha, 1995; Soni and Agarwal, 1997; Ghose and Majee, 2000
	Particulate matter concentration in winter season is higher	India	Ghose et al., 2002
	Particulate matters dispersion is higher in summer season	Australia	Crabbe et al., 2000
	Seasonal variations and meteorological parameters affect the dispersion of particulate matter	United Kingdom	Wheeler at al., 2000
	Concentration of particulate varies with the season	United Kingdom	Baldauf et al., 2001

	Composition of PM changes with season	India	Rawat, 1982
Bauxite Mining	Mining activities contribute to particulate matter air pollution	India	Kumar et al., 1994
Iron ore mine	Emission and estimation of air pollutants in opencast mining are total suspended particulate (TSP) matter and respirable particulate(PM_{10}) matter	India	Sinha and Banerjee, 1997
Other type of mineral mining	Particulate matters concentration vary with the meteorological parameters	USA	Gill et al., 1999
	Meteorological parameters helps in bonding of TSP and PM_{10}	Greece	Triantafyllou and Kassomenos, 2002
	Analysis of pattern of dust emission	Switzerland	Segura-Salazar and Tavares, 2018
	Concentration of particulate matter analysis during compression crushing	Sweden	Leon et al., 2020
	Due to prevailing wind particulate matter dispersion takes place	Italy	Corti and Senatore, 2000
	Higher concentration of $PM_{2.5}$ invite trouble.	Hong Kong	Qui et al., 2013
	Seasonal trends of air quality index	Swedon	Bengtsson and Evertsson, 2006

	Emission of Particulate matter from under atmospheric condition degrade the air quality	United Kingdom	Silvester et al., 2009
	Modelling to predict fugitive dust dispersion and deposition around mining area	United States	Lowndes et al., 2008
	Characterization and source apportionment of $PM_{2.5}$	USA	MSHA, 2013
Other type of mineral mining	Characterization and source apportionment of PM_{10}	USA	MSHA, 2013
	Chemical composition and source identification of PM	USA	Dudka and Andriano, 1997
	Local and transboundary movement sources of $PM_{2.5}$ and PM coarse	Spain	Navarro et al., 2008
	Regular interval of vehicle movement increase the concentration of particulate by resuspension	Germany	Czaplicka-Kolarz et al., 2015
	$PM_{2.5}$ and PM_{10} emission source and its effect	India	Sarkar, 2022
	Air quality modelling to analyse the dust dispersion	China	Bai et al., 2018

2.2.1 Air Quality and particle number concentration

Particles are classified as coarse, fine, or ultrafine based on their aerodynamic diameter, which ranges from nanometres (nm) to microns (m), PM_{10} particles have aerodynamic diameter between 2500 nm and 10000 nm, $PM_{2.5}$ particles have an aerodynamic diameter between 100 nm and 2500 nm, and $PM_{0.1}$ particles having an aerodynamic diameter less than 100 nm (WHO, 2006). This fine particle has a negative effect on human health. The concentration of these fine particles was observed across the globe (Table 2.4). Particles less than 300 nm are classified as atmospheric nanoparticles/ ultrafine particles (Kumar et al., 2016), while even finer particle sizes (less than 100 nm), i.e. $PM_{0.1}$, are classified as ultrafine particle (UFP) (De Jesus et al., 2019). UFP concentrations are preferentially stated in terms of particle number concentration (PNC). These UFPs have the potential to enter the lungs more deeply and, thus, get deposited and reach the different organs of the body. In suspended form, these fine and ultrafine particles stay in the atmosphere for days or even weeks, enabling long-distance transboundary air transport. These particles are everywhere in the air around us, yet they are so minute that they are invisible to the naked eye. Their contrast with the normal diameter of human hair (~70 µm), which is about 70,000 times larger in diameter than a 1 nm size particle, is a real-world example (Kumar et al., 2016). Nanoparticles are commonly quantified and represented in terms of particle concentrations per unit volume of air (Morawska et al., 2008). Because of the effect of transformation processes including coagulation and condensation, as well as turbulence, which causes mixing and dilution, the number concentration, and size distribution of these particles in the atmosphere may vary (Kumar et al., 2011).

Meteorological and environmental factors like wind speed, temperature, relative humidity, mixing height, local-scale roadside structures, interactions of multiple streets, and topography may also have a significant impact on the spatial and temporal variability of particle number size distributions (Hussein et al., 2005; Paatero et al., 2005; Bowker et al., 2007; Ogulei et al., 2007). Particles are also created in the environment by natural processes. and are found in the atmosphere by the condensation of semi-volatile organic aerosols, photochemically driven nucleation, and/or gas-to-particle conversion (Holmes, 2007; (Morawska et al., 2008; Kumar et al., 2009).

Table 2.4 Concentration of UFPs in different region of the world

Source	Issue	Location	Reference
Industrial	Higher concentration of UFPs in three monitoring location	USA	Patton et al., 2014
	One year of regular monitoring of UFPs in one location	Rome	Marconi et al., 2007
	Six month of regular monitoring of UFPs	Helsinki, FI	Dos Santos-Juusela et al., 2013
	variation of UFPs concentration for eight month	Erfurt, DE	Tuch et al., 1997
	One month of regular monitoring of UFPs at industrial area	Basel, CH	Eeftens et al., 2015
	One year of regular monitoring of UFPs at five industrial location	Tehran, IR	Halek et al., 2010
	One year of regular monitoring of UFPs at six industrial location	Australia	Keywood et al., 1999
	variation of UFPs concentration for three years in industrial area	Erfurt, DE	Cyrys et al., 2003
	One year of regular monitoring of UFPs at twenty industrial location	Europe Augsburg, DE	Wolf et al., 2017

Industrial	hourly mean of UFPs concentration for one years	Rochester, US	Jeong et al., 2006
Urban and Industrial	Seasonal variation of UFPs concentration	London, UK	Rodrıguez et al., 2007
	Six month of regular monitoring of UFPs	Copenhagen, DK	Wang et al., 2010
	One day of regular monitoring of UFPs	Asia Guangzhou, CN	Han et al., 2015
	Seasonal variation of UFPs concentration	Toronto, CA	Jeong et al., 2006
Urban area roadside	One day concentration of UFPs at roadside	New York, US	Wang and Gao, 2011
Urban	variation of UFPs concentration for one year	Barcelona, ES	Rodrıguez et al., 2007
	Bi annual variation of UFPs concentration for one years	Geneva, CH	Eeftens et al., 2015
	One month fluctuation of UFPs	London, UK	Kaur et al., 2005
	Bi annual variation, and hourly mean of UFPs concentration for one years	Milan, IT	Rodrıguez et al., 2007

2.3 Impact of quarrying on water sources

For the sustainable growth of society, water supplies are crucial. Even in the forest, wildlife, and aquatic life all depend on water. Everyone needs access to clean and fresh water. The amount and quality of water are being progressively worsened by mining activity. Therefore, maintaining water quality is an essential objective at mining and raw material processing facilities. In mining operations, water contamination (Fig.2.2) is a big problem (Sumi et al., 2001; Hudson, 2012; Dasgupta, 2012). There have been numerous studies on determining the quality of surface water (Razak et al., 2015; Haritash et al. 2016; Kambhoj and Khabhoj 2019), groundwater (Haritash et al. 2008; Adimalla et al., 2020; Singh et al., 2020), and water in coastal regions (Haritash et al. 2017; Li and Wu., 2019; Selvam et al., 2020), but there have only been a small number of studies on the environmental effects of mining and quarrying (Haritash et al. 2007; Amitshreeya and Panda., 2012; Bayram and Onsoy., 2015). One of the major effects of mining operations is the contamination of surface and groundwater (Hudson, 2012). Deterioration of water quality is caused by hazardous chemical spills or leaks, mine waste leachate discharges, and surface runoff from overburden dumps (Hudson, 2012; Karmakar et al., 2012). Mining excavation is responsible for the loss of the natural drainage channel system (Sumi et al., 2001; Dasgupta, 2012; Mondal et al., 2014).. Although some mines recycle their water input, the mining industry consumes a significant amount of water (Sumi et al., 2001). Sulphide-containing minerals are released during mining, and when they are exposed to air and water, they oxidize and produce sulfuric acid (Sumi et al., 2001; Mehta, 2002; Hudson, 2012). The formed acid along with different trace elements, has an influence on groundwater from both surface- and underground mining (Hudson, 2012). The frequency that such chemical compounds will pollute ground and surface water is increased by the large amounts of leachate formed by mine drainage and other mining activities (Dasgupta, 2012)

As a result, some chemicals may be present at very high concentrations over a wide area of surface or groundwater (Kamakar et al., 2012). Due to the numerous chemicals employed in the mining process as well as the potentially harmful substance and the metal recovered from the ore, there is a risk of significant pollution of the region around mines (Hudson, 2012). The mining process has detrimental effects on the environment (Sumi et al., 2001; Dasgupta, 2012). Surface water pollution can result from mining water discharge, waste material erosion, unintended chemical spills, and more. This pollution can affect rivers, lakes, and occasionally even the ocean. Chemicals and explosives used in mines cause issues, wherever they are used, accidental discharges of dangerous chemicals from storage or processing facilities pose a risk to nearby waterbody. Surface water quality may be impacted by waste material erosion, particularly by waste rock and tailing (Sumi et al., 2001; Hudson, 2012). In Jharkhand and West Bengal stone quarries, blasting and transportation are the main causes of pollution and its effects on water quality (Pal and Mandal, 2017).

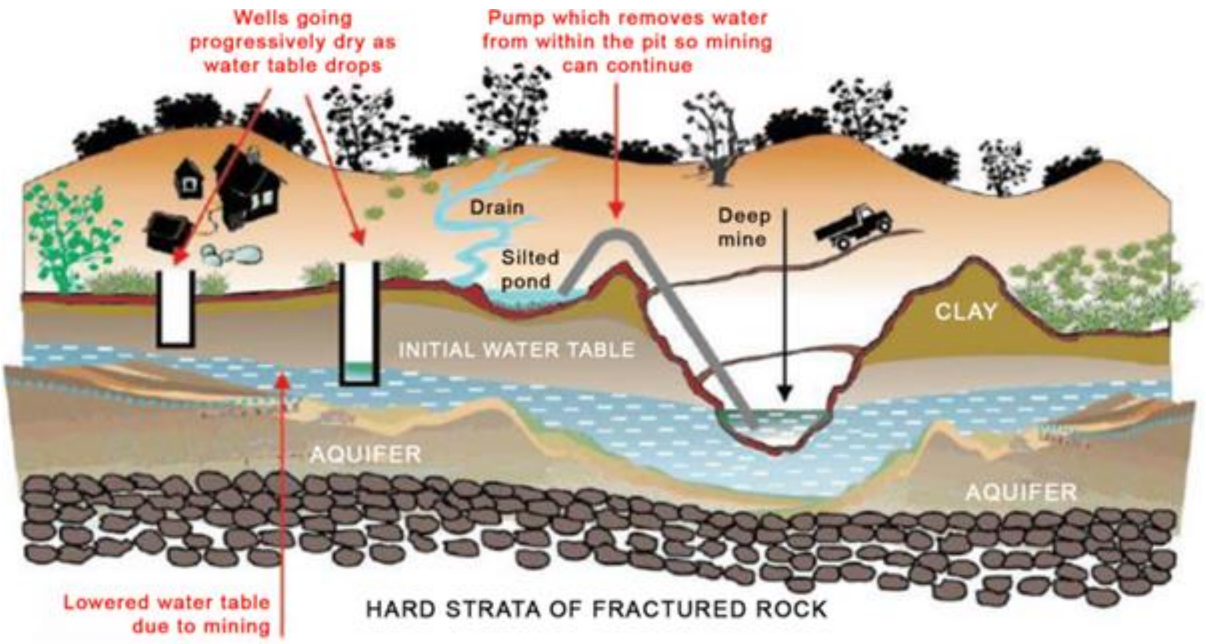

Fig 2.2. Representation of impact of mining on water bodies (adapted from Sarupria et al., 2019)

Due to the presence of heavy metals and suspended solid particles, the polluted water in the aggregate quarrying and crushing operating sites has major impact on the nearby water bodies, ground water, agricultural fields, and on living organisms (Monjezi et. al., 2009). Mining pit areas, and the overburden of mine is responsible for leaching and ground water pollution. Waste rock, overburden piles. Haul roads and ore stockpiles, vehicle maintenance areas, and equipment maintenance areas are also responsible for groundwater pollution. Exploration and reclamation areas can cause significant erosion during mining operations leads to pollution in ground water (Sills et al., 2006). Mining activities also affect groundwater quality and quantity through several factors, including surface hydrology, soil texture, and terrestrial vegetation (MINEO consortium, 2000). The water table may be lowered by the amount of water being collected, pumped out, or lost via evaporation (Hudson, 2012). The degradation in the quality of the groundwater may occur in case when sewage or mine tailings seep into groundwater from surface waters or when there is a hydraulic link between groundwater and surface waters. According to a study (NEERI, 2002), during the monsoon season in the Bellary Hospet region, the fine debris from the dump site were transported down the hill slopes along with surface run-off and into the neighbouring water bodies.

The extraction of groundwater for mine operations lowers the water table and alters the way groundwater migrates in the subsurface during the mining process, which also disturbs the surface contour and drainage system (Jhariya and Chourasia, 2010; Hudson, 2012; Karmakar et al., 2012). Excavation of sandstone in the Bijolia mine, resulted in production of silica dust (Chauhan, 2010). Due to its weight and insoluble nature, silica gets deposited in the substratum of water bodies e.g. ponds and wells, inhibiting the percolation of groundwater into the aquifers. The presence of harmful anions, heavy metals, radioactivity, and other organic and biological pollutants has been documented in mine water released in addition to the water shortage in mining locations (Singh et al. 2012; Wu et al. 2011; Abiye and Shaduka 2017). In other words, it depletes and contaminates the local water supplies. Sandstone quarrying has limited or substantially less influence on water resources than mining for coal, metals, radioactive material, etc. Although the impact of stone mining and crushing on the quality of the air, soil, vegetation, and surface water has been investigated in some studies (Amitshreeya and Panda., 2012; Haritash et al. 2007; Saha and Padhy, 2011; Bayram and Onsoy, 2015), Studying the impact on groundwater quality in a semi-arid region where scarcity of ground water is reported (CGWB 2018) in these areas, especially during non-monsoon season. According to the report, the district of Mahendragarh in particular has a negative net groundwater draft available for the future (CGWB 2013a, b).

Open-pit mine water quality assessment reported high TSS, TDS, traces of heavy metals, carbonate and bicarbonate hardness, sulphate, oil, and grease from mining equipment and nitrate from explosives. Gradual release of these pollutants into the environment without any proper treatment. Later disrupt the water system. Heavy metals also affect the health of aquatic animals and restrict their growth and reproductive health. They have the tendency to accumulate in fish tissue (Emenike et al., 2022) and enter the food chain, leading to bio-accumulation and bio-magnification. Due to exposure that often lasts more than a year, toxicity can be either acute or chronic imparts in freshwater. (Tiwary *et al*., 1994). Water quality may be impacted negatively by the high levels of total dissolved solids that are frequently present in mining areas. When stones are blasted in quarrying sites using explosives, nitrate ions are formed. Further nitrates ions also come through fertilizer used in agricultural areas. Nitrate contributes to around 85% of the total nitrogen released by fertilizer, whereas ammonia makes for the remaining 15% of the nitrogen ion components for explosives (Sobolewski, 1998). Ore extraction results in discharge of acid mine drainage, which is a type of mine wastewater, of. It has a high concentration of heavy minerals and a low pH content (Regmi et al., 2009). High amounts of total dissolved solids (TDS), sulphates, and heavy metals, including iron, manganese, nickel, and cobalt, has been reported in acid mine drainage (Mulopo 2015).

Around the mining vicinity, water bodies shows excessive hardness and the presence of sulphate and chlorides, for all source of water, indicating the water unfit for drinking and other domestic use. Pressure of suspended particles in surface water may hinder the self-purification of water bodies by reducing light penetration and consequently photosynthetic process. In severe circumstances, silt deposition can cause floods and obstruct other biological processes. Surface water colour changes in the mining area, lowers the aesthetic value of receiving water bodies and contains high concentration of finely mined materials. Water resource quality is significantly influenced by mining waste, particularly in the vicinity of active and abandoned mine sites. (Zyl et al., 2001; Eyankware, et al., 2021). Furthermore, Groundwater quality is expected to deteriorate unless steps are made to reduce runoff and sedimentation. Quarrying has the potential to significantly alter recharge flow patterns and impact water quality (Gunn and Hobbs, 1999) (Table 2.5). The soil on top of the rock often serves as a zone of filtration and water purification (Gunn and Hobbs, 1999). In the mining region, if the limestone is unsaturated, it may also serve as a cover for the underlying aquifer. Surface water may be interconnected to the ground-water system via the mining pit if the protective soil cover or unsaturated rock is removed. According to a study, if the surface water is contaminated, the groundwater can be contaminated very fast (Hobbs and Gunn, 1998; and Ekmekçi, 1993). In the quarrying region the leftover pit can be used to store surface water, but according to a study done in Southern Belgium, about thirty open cast was going on alongside the river Escaut and, due to mine tailing the river water got polluted, and as a result groundwater got polluted too. Although inflow water eventually participates in regional water circulation, its impact on the quantity of water resources available appears to be minimal. Waste water and groundwater acidification are becoming a new source of pollution in the mining area's underground water resources.

Groundwater can carry dust via conduits and smaller apertures (Gunn and Hobbs, 1999). Runoff events can cause the fine debris generated from sandstone cutting to seep into the groundwater system (Drysdale et al., 2001). In quarrying blasting may block off already-existing ground-water tunnels or create brand-new ones, changing the direction in which the water flows (Ekmekçi, 1993) In blasting operations' shock waves dislodge clay particles, causing the groundwater to become "muddy." (Spigner, 1978) Changes in the direction of groundwater flow increase the possibility of ground-water contamination. For instance, addition of new recharge source locations, could serve as new source of pollution. This problem may result from groundwater pumping (Adamczyk et al., 1988; Sedam et al., 1988), or it might happen if existing blocked passageways are cleaned and opened again. In arid and semiarid areas, the scarcity of water resources and natural climatic conditions are the primary causes of water resources and the ecological crisis. The degradation of the ecological environment semi-arid areas is accelerated by the excessive exploitation and utilization of water resources. The mining stage caused a series of environmental geological problems due to the over-exploitation of water resources. Through the above calculation of water resources in mining area, can be seen that the main reason for mining-induced reduction of water resources. The hydrogeological conditions of the mining area are altered by drainage, leading to a change in the transformation relationship between surface water, groundwater, and mine water (Hu et.al 2018).

The majority of the quarrying area overlaps with a phreatic conduit, in the saturated zone, negatively affecting the conduit's ability to transfer water. Quarry dewatering can damage the conduit's performance even in the absence of intersecting conduits by causing leakage into dispersed flow zones (Edwards et al., 1991; Sedam et al., 1988). Dewatering process also disturb the hydraulic gradient of the area, gradient depends on types of rock, their porosity and occurrence of cracks and faults. To safeguard the people, workers, and equipment, it may be required to drain or pump the water from the pit. Reducing the hydraulic head in a quarry will cause water levels in the rock which is draining into the quarry to decrease as a result of pumping from the quarry. Cone of depression refers to the simplest scenario in which the area of the water table affected by quarry. Dewatering would resemble a downward-pointing cone that has been lowered into the water table and may be because of it soil may loose moisture content. For human existence to grow sustainably, water is necessary, including aquatic life and wildlife. Everyone needs access to clean, fresh water. Every day, mining operations decrease the quality and amount of water. Therefore, maintaining water quality is a top environmental concern in mining and mineral processing locations.

Table 2.5. Effect of quarrying on water quality in different region of world

Source	Issue	Country	Reference
Coal mining	Effects of mine drainage on groundwater quality (pH, TSS,TDS, Chloride, Sulphates)	Turkey	Yesilnacar and Kadiragagil, 2013
	Maine tailing impacts water quality increases contamination (Sulphates and heavy metals)	Australia	Barrett et al., 2013
	Acid Mine Drainage impacts water bodies and changes the properties of water	Chile	Dold, 2014
	Mining impact on water (pH, TDS, EC, TSS and Chlorides)	Mongolia	McIntyre et al., 2016
	impact on water quality (Sulphates, Hardness, TDS)	India	Tiwary, 2001
	Acidification of water source by acid mine drainage and making it laden with heavy metals (TSS, Sulphates)	China	Zhang et al., 2013
	Change in geochemistry and quality water (Sulphates, nitrate, phosphates)	India	Singh et al.,2012
	Influences of mining on surface water bodies (Sulphates , hardness , Chloride & Heavy metals)	China	Wu et al., 2011
	Degradation of water quality (nitrate, phosphates, Sulphates , hardness)	India	Tiwary et al., 1997
	Coalmine drainage increases acidity of the soil	United States	Rose and Cravotta, 1998
	Sulphate increases in water due to handling of raw materials in mining area	Iran	Ghaedrahmati and Ardejani, 2012
	Toxicity of water due to mining	India	Das and Chakrapani, 2010

Stone quarrying	Surface water and groundwater degradation (Carbonate, sulphate , Chloride and magnesium)	China	Fang et al., 2009
	Heavy metal pollution index for surface and spring water near a limestone mining area	India	Prasad and Bose, 2001
	Leachate from non-engineered sites and its effect on groundwater quality	India	Rana et al., 2018
	Hydro-geochemical assessment of groundwater quality in quarrying area	India	Mallick et al., 2018
	Physical parameters degradation due to mining	United States	Langer, 2001
	Change in chemical characteristics of water due to mining (Physical parameters)	India	Saviour, 2012
	Impact of on water bodies TSS , pH, TH	United Kingdom	Langer, 2001
	TDS increase in water due to mining due to quarrying	Negeria	Chaanda et al., 2010
	Increase in TSS in water due to quarrying	Lebanon	Darwish et al., 2010
	Water quality -sulphate, sodium, magnesium higher than standard at mining area (WHO 2017)	Nigeria	Kalu and Ogbonna, 2019
Sand Mining	The quality of water changes the properties of the water (nitrate, phosphates, Sulphates , hardness)	China	De Leeuw et al., 2010
	Mining impact on the surface water quality and its properties (TDS, Na$^+$, Cl$^-$, pH)	Turkey	Bayram and Onsoy, 2015
Mineral mining	fresh water quality alteration, (TDS, Na$^+$, Carbonate and bicarbonate)	United kingdom	Younger and Wolkersdorfer 2004

Other Mineral/non-mineral mining	water sources and degradation in properties of water (Carbonate and bicarbonate, Cl^-, Nitrates)	Australia	Lechner, et al., 2017
	Effects of mining activities on hydrological properties and aquifer	Czech Republic	Richter and Pecharova., 2013
	water pollution and its contamination (Heavy metals)	United kingdom	Young et al., 1997
	Mining impacts on the fresh water environment	United States	Younger and Wolkersdorfer, 2004
	Ground & Surface water (Carbonate and bicarbonate, Cl^-, Nitrates)	India	Karmakar and Das, 2012
	Water quality(Heavy metals, arsenic)	Tibet, China	Huang et al., 2010
	Mining dump degrade quality of water degrade the physical properties of water (TDS , TSS , Heavy metals)	Morocco	Iavazzo et al.,2012
	In mining region pit act as water recharge pit (Contains heavy metals)	United States	Brown, 1998
	Contamination of groundwater index and mining (Heavy metals)	Finland	Backman et al., 1997
	Heavy metals laden ground water degrade the soil quality	Italy	Cabboi et al., 1999
	Heavy metal contamination in water due to over dump	Iran	Askari et al., 2020
	Intermixing of Over dump and runoff water increases heavy metal contamination in water resources	China	Wang et al., 2017
	Heavy metals contamination due to mining in water sources (Chloride, Sulphates, calcium and magnesium)	Nigeria	Ezeh, 2010

Other Mineral/non-mineral mining	Change is PH and physical parameters of water due to mining activities	Negeria	Omosanya and Ajibade, 2011
	Geological defects in aquifer leads to contamination of ground water	Africa	Bewiadzi et al., 2018
Marble quarries	Environmental pollution and its effect on water sources from marble quarries	Turkey	Ozcelik, 2016
Gold mining	Higher concentration of heavy metals TDS, Cl^-, Carbonate and bicarbonate found in water	California , South America	Olivero and Solano.,1998
Gravel Mining	Effect of mining on natural channels disturbance of natural channel	United States	Kondolf, 1994
	Mining effect leaching and degradation of ground water (total iron , potassium, fluoride)	South Africa	Kori and Mathada., 2012
Copper mine	Water quality degradation due over-dump and leaching (Heavy metals)	Romania	Levei et al., 2011
Barite mining	Heavy metal concentration in water at mining site	Nigeria	Adamu et al., 2015
Mercury mine	AMD degrade in water quality leads to acidify (Toxic matter and heavy metals)	Turkey	Gemici, 2008
Bauxite mining	Water acidification due to mining	India	Lad and Samant, 2011
Mining with agriculture	Increase in nitrate concentration in water due to agricultural activities	India	India Ministry of Agriculture and Co-operation (1972)
	Agricultural activities increase the nitrate in ground water	Malawi	Dafter et al., 2019
	Groundwater quality contamination due to quarrying in a semi-arid area- heavy metals	Africa	Maskooni et al., 2020

2.3.1 Weathering profile and geochemical classification of ground water in Quarrying area

The geological fold and faults and cracks are responsible for the dissolution of different chemical interacting rocks present in aquifer through percolation the concentration of such chemicals in groundwater may be used to infer indirectly the kind of weathering process, which could significantly influence the chemistry of groundwater. The principal methods of introduction of various anions and cations is water include atmospheric deposition, contact with rocks, and anthropogenic activity (Subramanian, 1987). In semi-arid regions, groundwater chemistry is regulated primarily by silicate weathering (Ca/Na ratio is 0.35-0.15, Mg/Na is 0.24-0.12, and HCO^{-3}/Na is 1 (Gaillardet et al., 1999)). The correlation between calcium and magnesium also shows that silicate weathering dominates groundwater chemical regulation. As per the studies, it’s known the silicate weathering as predominant process then followed by carbonate weathering, if the values of (Ca + Mg)/(Na + K) are near to 1.0. The weathering of silicate rocks may be expressed as (Zaczek and Porowski, 2017):

$$2NaAlSi_3O_8 + 2CO_2 + 6H_2O \rightarrow Al_2Si_4O_{10}(OH)_2 + 2Na^+ + HCO^{-3} + 2\,H_4SiO_4 \quad (1)$$

$$2NaAlSi_3O_8 + 2CO_2 + H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 2Na^+ + 2HCO^{-3} + 4\,H_4SiO_4 \quad (2)$$

Halite dissolution can be detected when the Na/Cl ratio is near 1.0. If any negative ratio appears it means evidence that Na ions are added as a result of reverse ion exchange (Meybeck, 1987). Direct base ion exchange might be the cause of the excess Ca and Mg ions (Jankowski and Acworth, 1997).

$$\tfrac{1}{2}\,\text{Ca-clay} + Na^+ \rightarrow 1/2\,Ca^{2+} + \text{Na-clay} \quad (3)$$

Also, larger concentrations of (Ca + Mg) against (HCO^{-3} + SO_4) is responsible for primary process in the Base Exchange governs cations present in groundwater (Meybeck, 1987). Additionally, if carbonate or silicate weathering is the primary source of calcium and magnesium in groundwater, then the ratio of (Ca + Mg)/HCO^{-3} is near 0.5. (Sami, 1992). Dolomite rocks dissolve when the Ca/Mg ratio is equal to one; calcite rocks dissolve when the ratio is higher than one; silicate minerals dissolve when the ratio is more than two (Katz et al., 1997); and dolomite rocks dissolve when the ratio is greater than two (Mayo and Loucks, 1995).

Mining operation impacts the water regime immensely and due to the excavation process the groundwater level gets depleted and the quality is degraded. Mining operations may change delicate ecosystem components on-site or close by, having a ripple effect on the environment. Activities like removal of rock blocks also have an ill effect on the environment. Disturbance to the natural system and water flow channels, imparts negative effect on the water system and its quality.

2.3.2 Quarrying and fluoride in Groundwater

The salinity of groundwater and the high concentration of fluoride are serious quality issues on a global scale they are influenced the local or regional geological characteristics and climatic circumstances directly or indirectly. Additionally, anthropogenic activities (Quarrying/mining) and activities like irrigation have an impact on it. According to a study in reactivity fluoride is the second most common chemical among the halogens after chlorine (Rankama and Sahama, 1950),. It has been investigated (WHO, 1970, 1984a), that fluoride-related health and environmental issues have grown alarmingly worldwide. F^- in the drinking water is a major concern in more than 23 nations, including India (Table 2.6). illustrate the different states (Susheela et al., 1993). Fluorosis is a condition that has long been recognized in India sometimes known as "mottled enamel." First note on dental fluorosis on humans was reported before independence of India (Viswanathan, 1935), observed similar type of illnesses in cattle is observed in several areas of the former Hyderabad state (Mahajan, 1934).

Since fluoride-rich minerals are more widely distributed geographically in Indian soil. In comparison with non-mining areas, mining and quarrying regions have reported comparatively higher fluoride concentrations in groundwater are reported. The Indian, states Andhra Pradesh (Adimalla et al., 2019), Rajasthan (Arif et al., 2013), Gujarat (Gupta and Despande et al., 2005), and Madhya Pradesh (Avtar and Kumar et al., 2013) reported exceedance fluoride level is (> 1.0 mg/L), whereas the states like Jharkhand (Pandey and Shekhar et al., 2012), Bihar (Kumar and Singh et al., 2019), Uttar Pradesh (Ali et al., 2017), and Haryana (Haritash and Soni et al., 2018) revealed dispersed pockets of fluoride-rich groundwater. Studies have revealed that almost 80 percent of total fluoride accumulated in the human body (mg/kg/day) is by ingestion is through drinking water (Ambastha and Haritash, 2021). Therefore, it is necessary to analyse the health risk posed by fluoride-rich groundwater. Out of the total fluoride ingested, about 60% is absorbed; whereas, the absorption is about 100% on empty stomach (WHO, 2004).

Table 2.6 Endemic fluoride concentration in groundwater in different states of India

State	Source	Range of Fluoride reported	Reference
Jammu and Kashmir	Fluoride rich bed rocks at Quarrying region and effect on water	0.5-7 mg/L	Jamwal et al., 2019
Himachal Pradesh	Fluoride rich bed rocks and effect on groundwater	0.3-4 mg/L	Sharma et al., 2017
Punjab	Predominant deposit of fluoride rich bed and its effect on water	0.2-5mg/L	Ahada and Suthar, 2019
Uttrakhand	Fluoride rich bed rocks on Indo gangtic planes of Uttrakhand	0.01- 2 mg/L	Amiya et al., 2020
Haryana	Quarrying effect on aquifer bed which increase fluoride contamination in the region	0.5- 11 mg/L	Ambastha and Haritash, 2021
Delhi	Predominant biotite and phlogopite to kaolinites minerals induce fluoride concentration in water	0.1-4 mg/L	Ali et al., 2021
Rajasthan	Predominant deposit of fluoride rich bed and its effect on water	0.04- 8.2 mg/L	Keesari et al., 2021
Uttar Pradesh	Fluoride rich bed rocks on Indo gangtic planes	0.03 - 4 mg/L	Sahu et al., 2018
Gujarat	biotite, apatite, fluorite and fluoride rich calcretes beds which contaminates ground water	0.1 -9.6 mg/L	Senthilkumar et al., 2021
Madhya Pradesh	Predominant deposit of fluoride rich bed	0.2-6 mg/L	Ali et al., 2019
Chhattisgarh	Fluoride rich bed rocks	0.4- 5.4 mg/L	Kashyap et al., 2020
Bihar	Host rocks and weathering of fluorite	0.38-8.56 mg/L	Mridha et al., 2021

Jharkhand	Host rocks and weathering of fluorite	0.2-18.5 mg/L	Thapa et al., 2019
West Bengal	Host rocks and weathering of fluorite	0.9-4 mg/L	Farooq et al., 2018
Assam	Host rock (fluorite)with sediments of Bhramputra	0.1-16.6 mg/L	Hanse et al., 2019
Arunachal Pradesh	Fluorite bearing rocks	0.2- 17.5 mg/L	Dutta and Gupta, 2022
Sikkim	Predominant bed of the fluoride rich rocks	0.01- 2.1 mg/L	Dutta et al., 2022
Meghalaya	Fluorite-bearing granite from the Assam Meghalaya Gneissic Complex	0.01-3 mg/L	Sahoo et al., 2022
Nagaland	Predominant bed of the fluoride rich rocks	0.1-2.5 mg/L	Pamei et al.,2020
Manipur	Predominant bed of the fluoride rich rocks	0.1-2 mg/L	Alam et al., 2020
Mizoram	Host rocks and weathering of fluorite	0.1-1 mg/L	Laskar et al.,2022
Tripura	Host rocks and weathering of fluorite	0.1-2.3mg/L	Bhattacharya et al., 2020
Odisha	Host rocks Singbhum Granites and fluoride rich bed is responsible for ground water contamination	0.1- 4.0 mg/L	Sahu et al., 2021
Maharashtra	Predominant bed of the fluoride rich rocks	0.2- 2.36 mg/L	Mukate et al., 2022
Telangana	Predominant bed of the fluoride rich rocks and hard rock terrain	0.1- 8.7 mg/L	Adimalla et al., 2019
Andhra Pradesh	Predominant bed of the fluoride rich rocks	0.4-5.6 mg/L	Adimalla et al., 2019

Tamil Nadu	Host rocks and weathering from primary rock which contains fluorite of fluorite	0.01- 5 mg/L	Raja and Neelakantan., 2021
Goa	Rocky terrain of western ghat which contains fluoride beds	0.1-1 mg/L	Podgorski et al., 2018
Karnataka	Predominant bed of the fluoride rich rocks and hard rock terrain	0.2- 5.2 mg/L	Chandan et.al., 2022
Kerela	Predominant bed of the fluoride rich rocks and hard rock terrain	0.1- 6.3 mg/L	Shaji et al., 2018
Puducherry	Fluoride rich predominant beds	0.01-5.0 mg/L	Khan et al., 2021

The rate of fluoride dissolution from soil rises when conditions are acidic through AMD or there is greater soil-water interaction. Such situations are common in mining sites and are caused by acid mine drainage. Impurities-laden surface runoff from overburden, haul road, and stockpiles get collected in low-lying mine pit areas from where percolation of water takes place and it may enhance soil-water interaction during seepage. Different mining operations (drilling and blasting) may result in the formation of vertical cracks in the subsurface impervious rock stratum resulting in an easy introduction of contaminants into the groundwater (Muralidhara & Sunitha, 2020). In the quarrying process sandstone mechanical drills and pinpoint explosive is used to break the rocks into smaller fragments, this causes the formation of fracture and cracks in the subsurface aquifer which increases the fluoride concentration in that vicinity. It has been reported that the groundwater around sand stone mining remains contaminated by nitrate (NO3-), fluoride (F-), or pathogens (Singh et al., 2018)

2.4 Impact of mining on soil

Sandstone has been utilized for construction, monuments, and sculpture for many years since it is common in the earth's crust. Due to demand from the civil sector, the sandstone quarrying and processing sector has seen immense of pressure because urbanization and population growth in the last several decades. Due to the compaction of silt particles and rock grains, sedimentary rocks are formed and sedimentary rocks are one of its types. Because of silt deposition, their composition varies on the elemental framework and geological features. These geological features include quartzite, arkose, sub-arkose, and greywacke (Kumar et al., 2018). India alone produces more than 27% of the world's sandstone and accounts for more than 11% of total stone exports (Madhavan, 2005). Sandstone quarrying and processing are significant economic activities that provide a large number of jobs globally. However, the industry's dark side is its unsustainable quarrying processes, which generates large volumes of waste by-products dust emission from the quarrying, cutting, and finishing operations, including scrap stone, waste stone slurry, and dry-stone dust (Kumar et al., 2017a).

By removing topsoil and contaminating the soil, mining operations have a negative influence on soil fertility (Table 2.7) illustrate the effects of quarrying on soil worldwide. "Mining activities commonly change the surrounding landscape by revealing previously undisturbed soil elements," claims research commissioned by the European Union. Surface water bodies become highly laden with sediment as a result of erosion of exposed soils by air and runoff, leftover excavated raw ore, tailings coming from underground mining, and runoff from waste rock piles, also affect the drainage pattern locally. Additionally, "soil contamination can result from spills and leaks of hazardous products, the deposition of contaminated windblown dust, water runoff, and leaching" (Environmental Law alliance worldwide, 2018).

One of the most significant and ancient human activities is quarrying, which have continuously affected the landscape and vegetation. Is not studied the effects of quarry exploitation or its restoration post exploitation on soil much, despite being a necessary and non-renewable resource. The uncontrolled rise in human population are seriously threatened and depleted resources caused social unrest, and environmental degradation. Essentially, sustainable life on earth depends on multiple factors like the health of the soil. It is a primary source for the production of food and fibre and acts as a sink for preserving the balance of the planet and the proper functioning of its ecosystems. The sustainable agriculture practices ascertain the improved quality of the air and water. Since the health of plants, animals, and people are interrelated with the health of soils.

The capacity of soil to perform as an active system within ecological and with land-use constraints, supporting life stock and plant productivity, preserving and improving quality of water and air, and also encouraging plant and animal health are the indicators of soil health. . Soil health fluctuates throughout time as a result of human exploitation and management as well as occurrences of natural events. Anthropogenic activities degrade soil health and certain elements of soil quality are a significant ecological problem. The region of study is surrounded by agricultural land to check the soil suitability for agricultural activities in mining region sieve analysis is the primary method for separating particle sizes in aggregate materials (Allen, 1997; Handreck, 1983). It would be beneficial to evaluate the physical properties of soilless substrate materials. According to (Doran et al., 1996), the challenge for the future is to build sustainable management systems that are at the forefront of soil health; soil quality indicators are only a means to that aim According to a study, the challenge ahead in sustaining life on planet Earth will require a new vision, holistic approaches for ecosystem management, and a renewed partnership between science and society (Doran and Zeiss *et al*. 2000).

Quarrying and mining diminish the flora in the region, which affects the soil's organic matter and vital nutrients, biological activity, and productivity—especially in places where agriculture is the predominant industry. Chemical components of such soil become more concentrated due to parent rock weathering. A high concentration of trace metals has been observed in soil in and around mining/quarrying areas (Cappuyns et al., 2006). The process of crushing and cutting requires water and results in significant volumes of dust waste stone slurry mixing with soil and disturbing the properties (Kumar et al., 2017a). About 50 to 90 percent of the stone that is mined is rejected as scrap stone and slurry (Kumar et al., 2017b; Papantonopoulos and Taxiarchou, 2005; Singhal and Goel, 2020). Water and dust are combined to form the waste stone slurry (Almeida et al., 2007). According to numerous studies (Al-Joulani, 2008; Bhadra et al., 2007; Shrestha and Lal, 2011; Zia-Khan et al., 2014; Chenot et al., 2018; Odell et al., 2018), opencast quarrying activities have negative effects on the environment as they destroy vegetation, remove topsoil, change the physicochemical properties of soil, and disturb nearby ecosystems. These open cast quarry studies analysed for effects of marble, limestone, and granite processing on the soil environment (Yavuz Celik and Sabah., 2008; Chang et al., 2010; Souza et al., 2010; Khyaliya et al., 2017; Tugrul Tunc., 2019; Tugrul Tunc and Esat Alyamac., 2019; and Li et al., 2019). However, relatively few studies have attempted to explore sandstone waste and quarrying, as well as its environmental effects.

The change in physicochemical properties of soil leads to infertile or barren soil that does not support growth of vegetation for years (Jha and Singh *et al*., 1991) and adversely affects agricultural production as well slate quarrying is responsible for the change in soil properties which is also responsible for the change in the rate of agricultural productivity in and around the mining area (Singh et al., 2007). The hazardous concentrations of minerals can degrade soil fertility, increase input into the food chain, induce a build-up of toxic metals in food products, and eventually jeopardize human health, the chemical makeup of the soil, particularly its metal content, is crucial for the ecosystem. Dust and waste from sandstone quarries have contaminated the neighbouring agricultural area (Ahmad, 2015; Singhal and Goel, 2020). According to a time-series research, sandstone quarrying intensities, and areas grew dramatically between 1990 and 2016, destroying 71 hectares of agricultural land (Singhal et,al., 2018).

Soil in quarrying region contains lowest carbon composition and increases with the distance. Even the dust accumulation on soil decreases with the distance. Important constituent and nutrient of soil which are important for agricultural output increases in the soil with distance from mining region. The organic carbon and nitrogen content in the soils of nearby agricultural fields is being affected by the explosives and crushed rock debris that have been dumped nearby. The depletion of soil fertility is caused by runoff from dumps and waste materials during raining. The distance from quarrying and crushing operations resulted in an increase in the NPK values. (Sheoran et al., 2010)

Table 2.7 Effect of quarrying on soil in different region of world

Source	Issue	Country	Reference
Stone quarrying	The quality of soil due to deposition of dust particle (decrease in TOC, Low phosphate and chloride)	South Africa	Agwa-Ejon and Pradhan., 2018
	Heavy metals which gives adverse effect on soil properties and quality	Portugal	Almeida et al., 2007
	Topsoil erosion , deposits of anthropogenic materials due to quarrying	France	Chenot et al., 2018
	Leaching with soil laden with dust minerals also degrade the quality of the ground water	Turkey	Sivrikaya et al., 2014
	At an opencast stone quarrying site, the effects of vegetation and physicochemical characteristics on solute transport	United Kingdom	Wheater and Cullen., 1997
	Sandstone wastes as aggregate increases the porosity of the soil	India	Kumar et al., 2018
	yield of the soil may decrease due to excessive mixing of stone and dust	India	Shrestha and Lal., 2011

Stone quarrying	Loss of vegetation and loss of top soil is reported during quarrying	India	Bhadra et al., 2007
	Land degradation , effect on farming yield and increase in chemical composition , heavy metal composition in soil near quarrying site	India	Sheoran et al., 2010
	Physical and chemical properties change in soil around surface mining	India	Shrestha and Lal., 2008
	Decrease in the productivity of agricultural land in the vicinity of mining area	Lebnon	Darwish et al.,2011
	Stone mining severely effect and degrade quality of soil	Nigeria	Ako et al., 2014
	Increase in salinity of soil near quarrying site	Ethiopia	Melaku., 2001
Coal Mining	Dust deposition and resuspension of dust containing minerals degrade the soil quality.	China	Zhen et al., 2017
Magnesium oxides mines	PH of the soil changes because of mining activities	Spain	Machin and Navas., 2000
Mining	Heavy metal get mixed with water and soil and their traces is studied on plants around that area	Spain	Casas et al., 2003

The addition of contaminants to the soil might be caused by the entry of dirt and dust from the mining region, in addition to transportation by runoff and mechanical mechanisms. The minerals found in rocks and anthropogenic activity in the area are the sources of trace elements. The settled airborne dust due to gravity and runoff through overburden laden with dust particles the explosive chemicals, waste oil, and other chemical constituents into the mining area degrades the physical and chemical properties of the soil. The toxins have the potential to spread to other sections of the ecosystem and represent a major hazard to those living nearby. Reduced productivity is linked to a change in the soil's characteristics. Stones are the prime constituent of construction and it is exploited since long ago, the main constituent minerals found in the study area have been thoroughly analysed, making the current study significant. In Haryana, agriculture represents major fraction of the land,. Many studies related to the degradation of soil around mining area is available, but they lack the details study in an agricultural region.

2.5 Impact of stone quarrying on vegetation

Due to quarry activities, the terrestrial ecology faces the most damage, as seen by the loss of flora in all quarry areas (Lameed and Ayodele, 2010). At the time of excavation work and while the trucks are traveling off-road, vegetation and soil may be impacted. The process of clearing land resulted in a negative imparts including the loss of vegetation cover, soil removal, vulnerable geomorphology to erosion, a problem with land stability where rocks fall on slope feet, and land degradation (Gabarrón et al., 2019; Martínez-Ruiz et al., 2007; Okafor, 1988; Sinha et al., 2000). The emissions from marble processing plants have a significant influence on the foliage depending upon their leaf structure and sensitivity level (Noor *et al.,* 2017). Several facets of the ecosystem are seriously threatened by air pollution are listed in Table 2.8. The industrial revolution has been responsible for the quick rise in air pollution. (Vailshery *et al.,* 2013). There are no practical chemical or physical methods to efficiently minimise air pollution, which creates severe issues for vegetation in the vicinity of mining industries and the vehicles linked with them. Earlier, the purpose of planting trees was purely aesthetic however this perception was quickly reviewed to achieve the dual possibilities – bio aesthetics and abatement of pollution, be it air or noise (Pathak *et al.,*2011). Plants being an integral part of the environment, play crucial roles depending upon their susceptibility (Shannigrahi and Agrawal., 1996) *vis-à-vis* the pollutants released in the air. The effectiveness of green belts to barricade and hold back aerial pollutants rely on various factors such as size, shape, texture, moisture level, nature of the pollutant (gas or particulate), and the part of the plant involved in their activity (Ingold, 1971). Plants can curb air pollution either: directly through the leaves or indirectly by increasing the acidity of the soil (Kumar, 2013). The dust settlements affect the plant's metabolism when particulate matter undergoes dry deposition around the mining area, the leaves provide a large surface area which facilitates the deposition, concentration, and incorporation of the pollutants within itself thereby bringing down the level of pollutants in the atmosphere (Rawat and Banerjee., 1996; Escobedo *et al.,* 2008). The gaseous pollutants, gas transfer from the atmosphere before ending up in the stomatal pores stimulating intracellular reactions resulting in damage to the plant tissue (Currie and Bass., 2008; Jim and Chen., 2009). The plants which are abundantly found in the study area are observed to be prime receptors of air pollutants (Liu *et al.,* 2008). It is frequently observed that alterations at the stomatal level, membrane rupture, changes in catalytic processes, biochemical interferences, and plant mortality occur. It is essential to recognize and then classify plant species according to how well they can withstand air pollution. Air pollutant-tolerant species, act as a sink for minimising air pollutants, and sensitive plants to air pollution act as bio-indicators. Since APTI and API are derived from biological and socioeconomic characteristics, they may be used in conjunction to assess the appropriateness of trees. A suitable biological method of planting trees to ameliorate the air quality around urban and industrial areas has been widely studied and suggested (Prajapati and Tripathi, 2008; Rai, 2013). Numerous studies have been conducted to evaluate how well trees and greenbelts are in reducing air pollution in and around cities, roads, and industrial environments.

According to (Joshi and Swami, 2007; Iqbal et al., 2015; Pathak et al., 2015; Molnár et al., 2018), and other studies, dust deposition on the surface of leaves and SO_2 pollution decrease in chlorophyll concentration. An antioxidant, ascorbic acid is found in higher concentrations in areas with higher levels of industrial and vehicle pollution (Babu et al., 2013; Mukherjee and Agrawal, 2015; Gupta et al., 2016; Nadgórska-Socha et al., 2017; Girish et al., 2017). Acidic air pollution lowers the pH of leaf extract (Joshi and Swami, 2007; Girish et al., 2017). Based on general tolerance, relative water content indicates that different plant species respond to pollution differently, yet increased water content supports the physiological balance of stressed plants (Tanee and Albert, 2013; Nadgórska-Socha et al., 2017). In relative water content indicates High transpiration rates can lead to desiccation when exposed to air pollution. The more water the plant has in its body, the better it can fight stress and maintain its physiological balance. Maintenance of plant RWC is an important parameter in air pollution management because it could affect the relative tolerance of plants towards air pollutants.

As urbanization and industrial operations can result in severe air pollution (Simon et al., 2011; Baranyai et al., 2015; Simon et al., 2016), it was discovered that APTI and varied among land use categories. In general, plants become more tolerant to pollution caused near urban and industrial locations. However, there is no data on how APTI and other land use forms relate to one another. Furthermore, it is yet to be studied to connect the link between APTI and environmental factors of the mining region. APTI study is conducted for urban pollution and is reported in many literature but study related to the mining region is very limited. The impact of higher concentration of dust in mining region and seasonal variation impact on vegetation is yet to be explored. The mining operation put an immense load on the vegetation near the mining activity region and impact the productivity of the plant. The resilient plant/trees species in developing the green cover around the mining region can curb the dust pollution around the area.

The resilient plant/ trees are selected by API calculation can also be used to determine the most suitable plant species for eco-management. API is a valuable tool for selecting plant species that can improve air quality in two ways by reducing atmospheric pollutants and promoting recreational activities. Classification of vegetation is done by combining the APTI and API values of different plant species and some biological and socio-economic characteristics, which include plant habit, laminar structure, canopy structure, types of plants, and economic value.

Trees/vegetation impart the economic and aesthetic importance simultaneously curtaining the pollutants in industrial/urban areas (Shannigrahi *et al.*, 2004). From the perspective of air pollution abatement, the keystone plants act as the best species for the expansion of a better environment, to find their place in the green belt in and around an urban area (Prajapathi and Tripathi., 2008). Moreover, frondescence is essential for improving the air quality along roadsides (Jyothi and Daya., 2010). Broader leaves and thick canopy species had higher tolerance compared to species with narrow and cylindrical canopies, which can consequently be adapted (Deepika *et al.*, 2016). The use of tolerant plant species as an indicator of air quality can provide lasting solutions to the threat caused by air pollutants to humans.

Table 2.8 Effect of quarrying on vegetation in different countries of world

Source	Issue	Country	Reference
Stone quarrying	Air pollution tolerance index (APTI) of road side tree vegetation around mining region	India	Ambastha and Haritash et al., 2020
Coal Mines	Impact and assessment dust on plants pigments and pollution resistances of plants	India	Hariram et al.,2018
Road side	wet deposited atmospheric inception on the road side vegetation	France	Gonze and Sy.,2016
	Analysing the stress of roadside pollution on the plants species and their physiological responses	India	Joshi and Swami., 2007
	Analysis of plant and their APTI planted on road side	India	Girish et al., 2017
	Dust deposition on plants leaf and their performance analysis	Hungary	Margitai et al., 2017
	Analysis of roadside leaf on chlorophyll-a content	Hungary	Molnár et al., 2018
	Impact of dust and its pollution indices on vegetation	India	Gupta et al., 2016

	Roadside tree vegetation's dust collecting capability and air pollution tolerance index (APTI)	India	Rai and Panda., 2014
Road side	Roadside tree tolerance levels to air pollutants based on relative growth rate and air pollution tolerance index	Indonesia	Sulistijorini et al., 2006
	Evaluating the air pollution tolerance index and expected performance index of tree species to monitor the health of the environment	Nigeria	Ogunkunle et al., 2015
Industrial area	Effect of dust on plants photovoltaic capacity	Poland	Jaszczur et al., 2019
	An assessment of air pollution tolerance indices of plant species in industrial area	India	Hazarika et al., 2018
	APTI of plants growing near an industrial site	India	Bharti et al., 2018
	Steel industries impact on air pollution tolerance index of plants	China	Liu and Ding., 2008
	APTI around steel factory	China	Liu and Ding, 2008
	Development of the green belt and assessment of specific tree species' anticipated performance indices	India	Pathak et al., 2011

2.6 Impact of quarrying on human health

There are multiple sources from where dust emission takes place in the mining region. Major sources are pit operation, resuspension of dust from unpaved roads, crushing of raw materials, and transportation. The possibility of employees inhaling discharged dust poses serious health risks. While dust deposition causes skin and eye problems, inhaling the dust can result in serious health issues, including respiratory and pulmonary issues (Mengeshe & Bekele, 1998). Exposure Standards for total dust was 1026 µg/m3 over an 8-hour time-weighted average, respirable dust levels are 503 µg /m3 and respirable quartz dust levels are 200 µg/m3 (Glass et al., 2003). The 50 stone crushing facilities in Pammal, Tamil Nadu, which produced a lot of dust near the crusher plants and in the neighbourhoods around them (Sivacoumar, 2006 & Nwibo et al.,2012). A study on pulmonary issues among quarry employees discovered that the workers experienced a variety of respiratory issues, including chest pain, coughing, wheezing, and shortness of breath. According to the study, up to 98.3% of the workers lacked safety precautions (Sivacoumar, 2006). Consuming tobacco or using cigarettes while working for longer hours enhanced the chance of developing respiratory issues and reduced lung function from exposure to dust due to rock crushing (Nemery et al., 2001). According to (Ugbogu et al., 2009) study on the prevalence of respiratory and skin disorders among stone workers reported up to 85% of manual stone workers experienced respiratory symptoms, and 77% had skin infections,. The survey also found that, despite a high degree of awareness of the negative health effects of dust, use of protective gear and clothing was not common.

Dust-related problems on workers and their effect worsened in the case of absence of safety equipment to protect their employees (Ilyas & Rasheed, 2010). According to the survey, self-medication is the most popular form of therapy, and the workers had no access to health insurance and good medical facility in a remote location.Compared to developed countries, developing countries are more vulnerable to environmental and health problems. This is a result of the inadequate quality of the working environment and the lack of adequate healthcare in developing nations (Ilyas & Rasheed, 2010). Poor working conditions, and particulate matter concentration in mining areas, affecting the respiratory health of miners and nearby populations, which is brought on by many forms of environmental pollution. Evidence indicated that children engage in the small-scale mining sector, suffers from dust-related illnesses rather fast in comparison to adults (ILO-IPEC, 2007).

2.6.1 Presence of silica crystals and its effect on human health

Numerous studies have demonstrated that different types of rock contain crystalline silica in varying amounts. For instance, basalt and limestone contain up to 40% and 1% of crystalline silica, respectively, while granitic rock has up to 71% of crystalline silica (HSE UK, 1992). The analysis of limestone rock samples from the Kajiado Area report shows variable silica concentrations, with the sample from the Kenya Marble Quarry having the highest silica percentage at 11.38%. (Matheson, 1966).

Inhaling crystalline silica, the main cause for concern as it settles in human lungs and causes respiratory and pulmonary damage such as silicosis, bronchitis, pneumonia, tuberculosis, and lung cancer (Last, 1998). Cancer being incurable once they start, but the diseases associated with silica are curable. For respirable quartz containing silica, the National Institute of Occupational Safety and Health (NIOSH, 2002) suggests an exposure limit of $0.005 \mu g/m^3$. The overall dose and the length of exposure are related to the risk of developing a disease. The sickness may not manifest for several years after exposure. Background exposure levels appear to pose a modest risk of developing a silica-related disease (OEHHA, 2005), while environmental exposure risks around peak sites, such as crushing facilities, and thus continue to be of great concern (Roperto et al., 1995). The size of the particle, the amount of silica in the air, the length of exposure, the surface properties of the particles, including their age, and the quantity of trace metals like iron are all significant factors in the development of silica illness (NIOSH, 2002).

Health and Safety Executive (HSE 2000) defines silicosis as the hardening or scarring of the lung tissue with a subsequent loss of lung function brought on by prolonged exposure to crystalline silica dust. According to the amount of crystalline silica in the air that a worker is exposed to, three different forms of silicosis have been described in a study by (Azandand et al., 2006). There are three different forms of silicosis: accelerated, chronic, and acute. Acute silicosis can develop after very brief exposure to very high concentrations, accelerated silicosis can occur after a shorter exposure to higher concentrations, and long-term exposure to low concentrations can cause silicosis on the quarrying sector in the Delhi area (NIOSH, 2002). Generally, chronic silicosis develops 10 or more years following exposure. Increased exposures because of accelerated silicosis, which takes five to ten years to manifest. Acute silicosis develops in areas of high exposure and shows the symptoms in prolonged exposure of up to five years. The American Lung Association estimates (Lesley, 2011) that 200 persons each year pass away from silicosis. An estimated 2 million employees around the globe are exposed to free crystalline silica dust because of that about 200 deaths yearly are reported and many more suffer from silicosis. According to longitudinal studies, exposure to silica dust at concentrations between 0.1 µg/m^3 and 0.2 µg/m^3 results in the loss of lung function (Lesley, 2011). It is also crucial to point out that studies which examined how lung cancer risk changed in proportion to changes in exposure to crystalline silica have generally concluded that lung cancer risk does not rise with higher silica exposure (Soutar et al., 2000; Hessel et al., 2000). Further disproving the associated carcinogenicity of crystalline silica (Hessel et al., 2000).

Several studies has shown that populations exposed to crystalline silica can experience psychological changes, illness, and even death (Goldsmith, 2006; McDonald et al., 2005; Steen Land, 2001). Numerous respiratory illnesses, including silicosis, lung cancer, kidney cancer, chronic obstructive pulmonary disease (COPD), and rheumatoid arthritis, may be potentially induced by exposure (Bridge, 2009). According to a study concerning the connection between exposures to in silica dust and developing lung cancer, the risk may only apply to people who have silicosis and is not directly related to breathing in silica dust (Ulm et al., 1998). The employees exposed to silica likely to develop lung cancer due to silicosis than from the substance itself. Therefore, focusing on silicosis prevention is necessary to decrease the incidence of lung cancer in silica-exposed employees (Kurihara & Wada, 2004).

2.6.2 Health impacts due to water pollution

Ignorance leads to the contamination of many water resources, making them unsuitable for drinking and other purposes. The discharge of untreated pollutants, chemicals, and hazardous waste from thousands of industries directly into the water body is causing a gradual pollution of the remaining freshwater resources causing health issues on relying population. A significant source of all around the world of drinking water is groundwater (Li et al., 2018a; Su et al., 2019). About two-thirds of cities in developing countries use groundwater as their main source of water (Zhang et al., 2020). In addition, groundwater is a crucial resource for urbanization, agricultural production, irrigation, and other socially relevant activities (He and Wu, 2019a; He et al., 2019a; Li et al., 2016a; Oişte, 2014; Velis et al., 2017; Zhang et al., 2018). The demand for clean, fresh water has grown, and water scarcity in arid and semi-arid zones is giving big stress on available resources because of that economic growth of the region is getting halted and even growing population demand is giving so much stress on freshwater resources (Su et al., 2019). The quality and availability of groundwater resources in mining and agricultural region are particularly impacted by over-extraction of groundwater and wastewater effluents which gives serious health effects to consumers (Mohabansi et al., 2011). Groundwater is a resource that sustains life, is a crucial part of agricultural output, and is a contributor to the health of many ecosystems. However, there is evidence of unsustainable groundwater depletion on both a regional and a global level causing contamination resulting in relying population had serious water related health complications (Rodell et al., 2009; Gleeson et al., 2012; MacDonald et al., 2016). Water is used for a variety of purposes, groundwater quality is just as important as its quantity (Kumar et al., 2009; Subramani et al., 2005). Groundwater contamination (Table 2.9) has become a serious issue in recent years due to mining, intensive agricultural activities, domestic and industrial discharge, over-exploitation, uneven rainfall, and poor groundwater management (Jain et al., 2010; Salifu et al., 2013; Fianko et al., 2010). As per the study conducted by World Health Organization, water-borne diseases around the globe is the primary source of the death of over 3.4 million people annually.

One of the most important elements influencing how water tastes is the quantity of total dissolved solids (TDS), which also contains essential ions including calcium, magnesium, potassium, and sodium(Islam, 2016; USEPA, 2018; WHO, 2017).However, water with high TDS readings typically indicates contamination from human activities, including soil and agricultural runoff from irrigation, uncontrolled animal grazing and wildlife impacts, harmful farming practices like slash-and-burn agriculture, and the excessive use of nitrate-based fertilizers (Wei et al., 2013; Rosca et al., 2020). These elements gradually accumulate over time and affect the local water sources (Rosca et al., 2020). Higher particle concentration in groundwater from wells with high salt concentrations, as well as water flows via natural springs and streams with high concentrations of organic salts can cause some digestion issue to consumers (USGS, 2019). The high salt concentration in water makes it unsuitable for drinking and also hinders the growth of agricultural crops. This condition is present in the semi-arid region of India. The intrusion of excessive salt into groundwater near aquifers causes agricultural crops to be inhibited, and direct mixing in fresh water makes it unfit for use. Exposure to harmful inorganic compounds, heavy metals, bacteria, and other pathogens, elevated nitrogen concentrations, and other trace chemicals and micronutrients in drinking water supplies are among the common drinking water issues in the vicinity of quarrying. Since unfavourable health consequences from chemical pollution are typically tied to prolonged exposure, microbial contamination effects are frequently acute.

Chemical contamination is sometimes given less attention than microbial contamination. Small concentrations of synthetic and natural pollutants may exert adverse effects when present in mixtures, and accumulation of these pollutants can cause acute and chronic effects on human health. Whether the chemicals are produced naturally or as a result of pollution, they can have a very substantial negative impact on one's health. One of pollutants that one should be concerned about is long-term nitrate exposure, especially for young infants who are prone to the sickness known as "blue baby syndrome," is brought on by exposure to nitrate-contaminated drinking water. (Mencio et al., 2016; Tian and Wu, 2019; He et al., 2019b; Li et al., 2019a). Studies has reported that youngsters were at higher risk than adults when they were exposed to the polluted water. In mining regions, water contamination occurs through runoff from overburden and pesticides that contain storm water from agricultural land collected in leftover mining pits this results in pollution in both the groundwater aquifer and the water accumulated in the pit. The use of pesticides in agricultural practice leads to direct exposure and health risks for workers, and excessive use of pesticides leads to water pollution. Furthermore, fluoride-related waterborne illnesses are typically localized to a certain location (Mahvi et al., 2012). Dental and skeletal fluorosis will result from consuming water that contains fluoride over the long term (1 mg/L for the BIS standards and 1.5 mg/L for the WHO recommendations) (Ambastha and Haritash, 2021; Edmunds and Smedley, 2013). Fluoride levels in drinking water are typically regulated by both natural and anthropogenic pollution, including fluoride-bearing minerals (Adimalla et al., 2018; Borgnino et al., 2013; Li et al., 2014a, 2019b). According to the study (Ambastha and Haritash, 2021; Haritash et al., 2018), there is a direct correlation between fluoride content and fluorosis prevalence other than F^-, some heavy metals like arsenic (As) and hexavalent chromium (Cr^{6+}). Inflicts permanent harm to humans (Kumar et al., 2010; He and Li, 2020). For instance, the presence of arsenic in drinking water induced cancer and several other skin conditions in living organisms, and neurological and digestive issues. Cr^{6+} exposure over an extended period may lead to delicate and brittle skin and respiratory systems (El-Sikaily et al., 2007; He et al., 2020a). According to a study (Liu et al., 2003), arsenic has been noted as a significant risk factor for black foot illness.

Table 2.9. Effect of mine contaminated water on human health

Source	Issue	Country	Reference
Other Minerals Mining	Mining activities influence increase in TDS and TSS in water sources	United stated	Butler and Ford., 2018
	Higher calcium and magnesium cause cardiovascular and oncological diseases, and diseases of the gastrointestinal and respiratory systems	Slovakia	Rapant et al., 2017
	impact of mining on surface and groundwater because of mining negative impact increases the total hardness	India	Jhariya et al., 2016
	Total alkalinity increases due to mine overburden intermixing with water	India	Nagaraju et al., 2014
	Sodium and potassium excess in the water may create issue of heart and kidney problem or insomnia	India	Banerjee and Prasad., 2020
	Zinc mining and its impact on water and human health	China	Zhang et al.,2012
Iron ore mining	Mining area of East singhbhum, ground water chemistry and human health	India	Singh et al., 2018
Gold Mining	Arsenic in ground water causes serious health issue	Ghana	Smedley et al., 1996
	Metal concentration on drinking water and human health around gold mines area	Nigeria	Adewumi, and Laniyan, 2021

2.7 Impact of mining project on social values

Stages of mining, like claim staking, permission, exploration, construction, excavation maintenance of the area, expansion of mining, abandonment of mining, decommissioning, and repurposing of a mine are mining processes that have huge positive and negative consequences on social and environmental systems around mining region. The primary social effects of mining include changes in the demographics (such as the size and composition of the local population), economics (such as new employment and income patterns), the environment (such as changes in land use, loss of natural habitat, and hydrological regimes), lifestyle and cultural effects, and health effects (UNEP, 2002). Displacement and resettlement are the key effects that influence society.

In mining, physical relocation of residents and occupation of cultural heritage and land are the worst side effects of mining operations. This is a significant threat to human rights and leads to societal harm. According to a study (Downing, 2011) in India, over 2.55 million people were shifted because of mining activity between 1950 and 1990. The movement loses not just their houses but often their land and means of subsistence, forcing the whole community to relocate. The majority of the population that has been relocated are being resettled in stressed resource areas and regions adjacent to contaminated mining operations. When indigenous people are forcibly relocated, it can be especially devastating since they have deep cultural and spiritual links to the lands and forests of their ancestors and may struggle to live when these ties are severed (Singh et al., 2015). Mining may have both positive and negative consequences on people and society. Examples of detrimental consequences include those on people's health and level of living (Loayza and Rigolini., 2016). Other social effects of mining, such as those on public health and human welfare (Hilson., 2002; Zhang et al., 2012; Hossain et.al., 2015, Nakazawa et al., 2016), disputes over land usage, and effects on traditional practices of Indigenous peoples living in surrounding communities have also been documented (Gibson and Klinck,2005)]. In terms of beneficial effects, mining frequently generates local employment and might boost the economy of the local and regional areas (Fleming and Measham, 2014; Knobblock and Pettersson, 2010). Environmental systems may benefit when possible environmental hazards are mitigated, for instance by ecological restoration and water treatment (Jain et al., 2016). Mine closure, decommissioning of operations, and repurposing have consequences on society. Losses of employment and local identities are examples of negative repercussions (Keeling and Sandlos, 2011), whereas opportunities for new economic activity are examples of positive benefits (Mitchell and O’Neill, 2017).

CHAPTER 3

MATERIALS AND METHODS

Mining and its associated activities give immense pressure on different biotic and abiotic parameters of the environment, and heavy vehicle movement degrade the air quality. Mining also disturbs water bodies and groundwater flow, degrades soil quality, and also affects vegetation growth in nearby locations. This study assesses and analyses the impact of mining on air, soil, water, and vegetation. To achieve the objectives, a field sampling was conducted in the Bakhrija quarry region. From the collected samples, analysis was done to determine the influence of quarry activities on the air, water, soil, and vegetation. Primary samples were collected and data was analysed subjected to an exploratory approach to laboratory testing to arrive at conclusions and address the research question. The district of Mahendragarh contains various quarry sites, however, Bakhrija has the largest quarrying operations in terms of area. For successful study outcomes, this work concentrates on analyzing the impact on the surroundings regions of Bakhrija quarry sites throughout the year.

3.1 Methodology

Qualitative and quantitative analysis was done to obtain results in this study, to gather information about the study area, primary and secondary pollution sources were analysed. Data obtained by direct field sampling, observations made according to timetables, etc. were used as primary sources. Various reports, records, literature, papers, maps, charts, pictures, and other materials were considered secondary sources and were gathered from both public and private entities.

The following activities were conducted for data collection;

Sample were collected around mining areas for air, water, and soil to study spatial and temporal variability. A survey of mining area was done to determine the pollution source and identify the primary and secondary sources. Setting up of sampling locations on the specific source to analyse the air quality was done along with collection of groundwater samples around the mining region. The seasonal analyses of the mining area pollution source and survey of the local vegetation, and soil within a radius of 100 m from the limits of the mining regions to assess the effects of mining on the local environment. Based on collected data human impact assessment, and suggests management and mitigation plan to restrict the pollution level within the range of suggested policies.

3.2 Study area

This study was conducted in Bakhrija, Mahendragarh district, Haryana. Haryana is situated between 27° 37’ to 30° 35’ N latitude and between 74° 28’ to 77° 36’ E longitude. Haryana, an agriculture-based state known for its agricultural products in North India, area of Haryana state is 44,212 km^2, and about 6% the of area falls under wastelands. Haryana state has two types of ecosystem, the North-East part comes under sub-Himalayan Terai, and the South-West part comes under the Indo-Gangetic plain that jointly makes Haryana. The plain land of Haryana is fertile and the slope of the state is from North to South, at an average of 213m to 274m AMSL. The geographically South-West part of Haryana is semi-arid, sandy, and infertile, and there is no perineal river there. Among 22 districts of Haryana, Mahendragarh is one of them that share the district boundary with Rajasthan. The district has a population of 912,680 (2011 census) and an area of 1,899 km^2. Over the past three decades, the district has seen significant LU/LC changes. Human socio economic development effect on agricultural patterns, rise in population, spike in consumption, effect due to urbanization, economic development, etc., has significant changes in land use/land cover (LU/LC). In Haryana mining operation takes place in six districts Faridabad, Gurugram, Bhiwani, Narnaul, Panckula, and Mahendragarh, all of them comes in ranges of Aravalli. The state is a major producer of Tin (64%), quartz-silica sand (52%), and quartzite (49%), which make up the majority of resources. Mahendragarh and Gurugram districts are known for slate mining, Ambala, Bhiwani, Gurugram, and Panchkula districts are famous for limestone, Bhiwani, Faridabad, Gurugram, and Mahendragarh districts excavate quartz/silica sand, and quartzite. The state has almost 6% (2,540.10 km^2) of the area is considered wastelands, out of which approximately 57.08 km^2 is coming under mining out of which, about 35.05 km^2 lies within the Mahendragarh district. In the Mahendragarh district, mining is done for other minerals such as marble, calcite, barytes, and felspar. There are also zones where the copper mineral is found in districts of Bhiwani and Mahendragarh, whereas dolomite, granite, tin and tungsten are found in the Tosham area of the Bhiwani district (Indian Minerals Year Book, 2012). To understand the interactions and connections between natural resources and human resources, it is essential to have current, reliable information on LU/LC change detection in the study location (Table 3.1). The district has 9 mines (Table 3.2), famous for stone mining and the biggest mine present in the all those major nine mining sites among them Bakhrija stone mine is the largest with an area of about 66 km^2 (Mines and Geology Department, Haryana, 2018). The Bakhrija mines are known for their calcite, limestone, and mica quarrying and are located at 76.34 North longitude and 29.19 East latitude. Bakhrija is the nearest village from the study area where human population lives along with Meghot halla, Megot Binja, Dholera, Nujota, and Khojpur Naglia are the nearby villages that surround the Bakhrija stone mines.

3.3 Geomorphology and soil type of Mahendragarh

The district is formed under part of under the Indo-Gangetic plains. South-Western part of Haryana comes under the semi-arid region rich in blown sand and alluvium. Study area has significant alluvial and sandy soil deposits. There are strike ridges scattered around the region which are periodically buried in blowing sand. The sand dunes can reach heights of up to 30m, but on average they stand at roughly 7m. The area is distinguished for its hill ranges, which are a component of the massive Aravali group. The Dhosi hill is 740m above sea level. The primary slope of the region faces north in the district. Two principal rivers, Dohan and Krishnawati, flows from south to north, in the district. The district is known to be completely flooded by these streams during the monsoon season and dry for much of the rest of the year. Most of the district is composed of light-coloured and dry soils. In the subsurface horizon, these soils contain calcareous lime nodules. The majority of the soils are medium textured with the predominant texture being loamy sand.

Table 3.1. Land Use and Land Cover classification of Mahendragarh District

S. No.	Categories	Area (km^2) of administrative blocks				
		Ateli Mandi	Kanina Khas	Mahendragarh	Nangal Choudhary	Narnaul
1.	**Built-Up**	7.78	17.19	6.80	15.07	11.41
2.	**Agricultural land**	293.34	283.58	347.23	338.33	**474.70**
3.	**Forest**	2.73	6.70	0.45	4.27	6.5
4.	**Grass/ Grazing**	9.17	5.58	13.14	8.97	12.29
5.	**Wasteland**	8.17	8.11	5.79	5.59	**63.69**
6.	**Water bodies**	0.80	0.83	1.30	1.78	0.37
	Total	**322.0**	**374.00**	**569.00**	**320.00**	**314.00**

Source: Mines and Geology Department, Haryana, 2018

Table 3.2. Particulars of Mines in Mahendragrah District

S.No	Place	No. of Mines	Area (km^2)	Major Mineral
1.	Narnaul	1	19.8	Sand Stone
2.	Rajawas	1	53.03	Sand Stone
3.	Amarpur Jorasi	1	10.72	Sand Stone
4.	Bakhrija Plot 1	1	**11.26**	Sand Stone
5.	Bakhrija Plot 2	1	**21.65**	Sand Stone
6.	Bakhrija Plot 3	1	**34.65**	Sand Stone
7.	Garhi	1	6.7	Sand Stone
8.	Karota	1	9.5	Sand Stone
9.	Mukandpur	1	3.25	Sand Stone
Total			**170.56**	

Source: Mines and Geology Department, Haryana, 2021

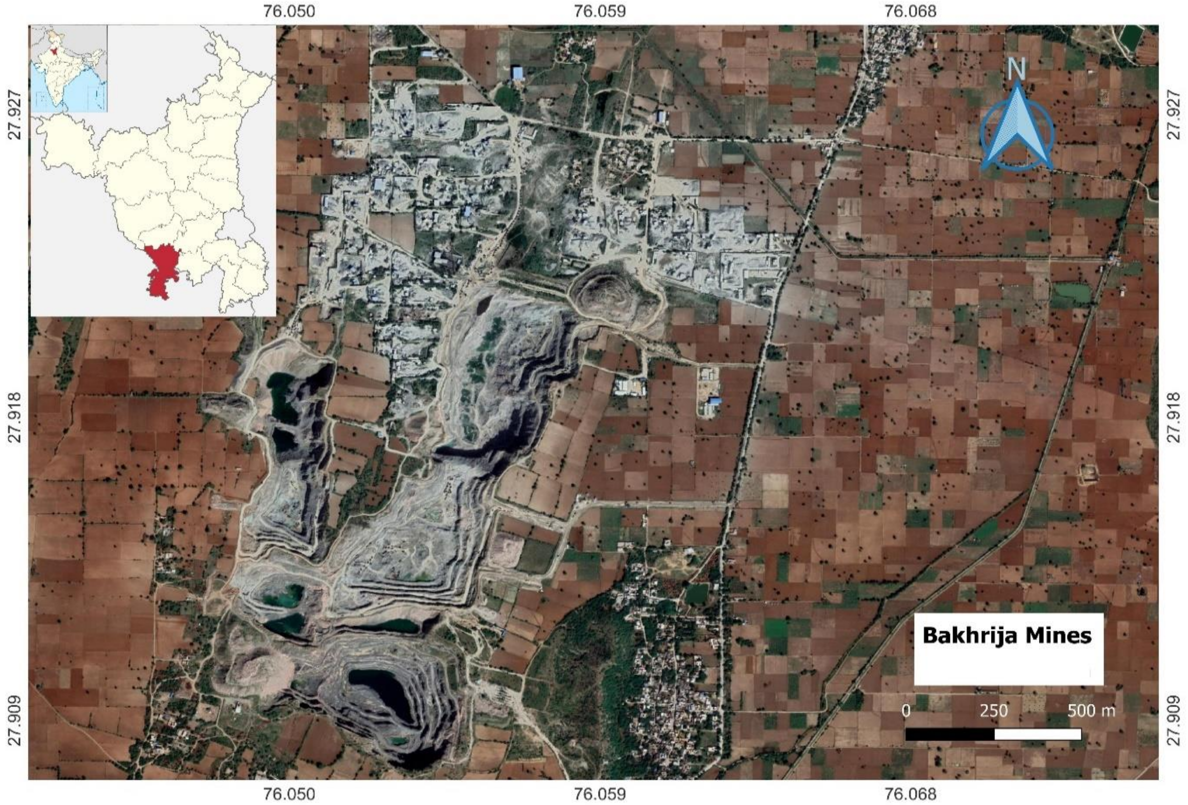

Fig. 3.1 Location of Bakhrija Mines in Mahendragarh district, Haryana

The study was initiated in the June (pre-monsoon season), 2019 and in February, (winter) 2022, to access the environmental impact assessment over a radial distance of 5 km surrounding the quarrying area due to mining and its associated activities.

3.4 Meteorology of Mahendragarh district

Meteorologically Mahendragarh district has a tropical dry climate, which comes under semi-arid and hot climate climatic conditions when is very hot in summers and chilly in winters, except the monsoon season, when the district receives moisture laden air from the ocean. A year has four distinct seasons. The South-West monsoon, which lasts till September, comes after the hot summer, which begins in mid-March and lasts until the ends of June. The post-monsoon season is the transitional period from September to October. The winter season begins at the end of November and lasts until the first week of March. Each year, the region normally receives 500 mm of rain (Table 3.3), which is unevenly distributed over 26 days. 84% of the annual precipitation is brought on by the South-West monsoon, which lasts from the last week of June till the end of September. The wettest months of the year are July and August. The remaining 16% of precipitation falls outside of the monsoon season, after western disturbances and thunderstorms. In the area, rainfall typically advances from South-West to North-East.

Table 3.3 Meteorological details of Mahendragarh District (CGWB, 2021)

Particulars	Parameters
Average Maximum Temperature	41°C (May-June)
Average Minimum Temperature	5.6°C (January)
Average Annual Rainfall	500 mm
Normal monsoon Rainfall	420 mm
Normal Rainy days	26

The wind rose for the Narnaul metrological station displays the number of hours the wind blows in the designated direction annually (Fig. 3.2). Circular format of the wind rose shows direction of the wind flows and each spoke around the circle represents how often the wind blew from that direction, and different colour of each spoke provide the wind speed from each direction.

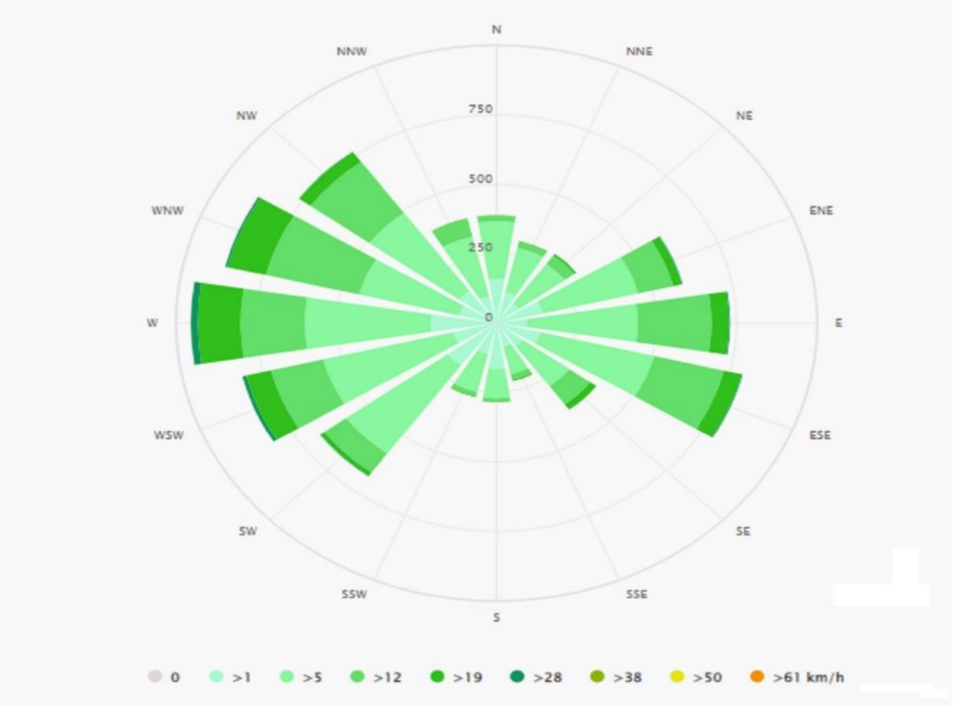

Fig. 3.2 Wind Rose diagram of Narnaul district

3.5 Sampling location around Bakhrija mines for air quality

Based on the meteorological data collected from the weather station in Narnaul, wind-rose was plotted year-wise to arrive at the predominant wind direction (Fig.3.2). Mapping/marking of the sample collection sites was done according to wind-rose with reference of predominant wind direction. According to the wind direction, locations were identified (Fig.3.3) where the air quality analysing apparatus was fixed for 9 hours. In this case, both PM_{10} and $PM_{2.5}$ were analysed in all the locations for the 9 hours. One sampling location was set up in upwind direction of the quarry to check the background air quality and the rest of the sampling stations were downwind of the quarry at the distance of 100 meters, 500 meters, and 1.0 Km, respectively. This sampling sites were located at upwind, mine pit, crusher, roadside, and downwind with respect to the mine. The sampling was done on a seasonal basis namely pre-monsoon (summers) and winters. In both the season same location were selected to analyse the quality of the air. The samples were collected for 9 hours in every season to get average concentration as per the ambient air quality standard established by regulating authorities.

Fig. 3.3 Sampling location (n=5) around Bakhrija mines for air quality

3.6 Analysis and dispersion modelling of particulate matter by HYSLPLIT

National Oceanic and Atmospheric Administration (NOAA) developed the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), it is used for the simulation studies of dust movement, dispersion, and deposition in the presence of wind. With available metrological data and reference of time, the model simulation calculates the distance, direction, and particle deposition. The average change in position of the particle (P_{mean}) with time ($t + \Delta t$) is given by eq. (4)

$$P_{mean}(t + \Delta t) = P_{mean}(t) * 1/2[V(P_{mean,\,t}) + V(\{P_{mean}(t) + [V(P_{mean}, t)]\}, t + \Delta t)]\,\Delta t \tag{4}$$

Where 'V' represents the average of the three-dimensional velocity vectors and it is determined at the original and first-assumed positions (Draxler and Hess, 1998). In this model, the particles or puffs are first released into the Lagrangian system and carried to HYSPLIT and Global Eulerian model (GEM). The GEM and computations take into account advection, horizontal and vertical mixing, dry and wet precipitation, and the radioactive decay of particles released (Draxler, 2007).

3.7 Sample collection for Particulate Matter (HAZDUST-EPAM)

The quarrying site at Bakhrija is surrounded by many stone crushing units. In pre-monsoon (June, 2019), sampling of airborne particulate matter ($PM_{2.5}$ and PM_{10}) was done. To access the concentration, collection of sample from five locations is done around Bakhrija mines. The ambient temperature ranged from 43 to 45° C, and the recorded wind speed was 1.4 to 2.2 m/s with moisture content approximately 20%, and wind was blowing from North-West to South-East direction. The sample of dust ($PM_{2.5}$ and PM_{10}) was collected using the portable microprocessor based particulate monitor (HAZDUST-EPAM 5000 model) operated for four(4) hours in one cycle at the flow rate of 4.0 l/minutes. Five locations were identified to record dust levels namely, upwind due to natural background, crushing activity in the mining vicinity, mining operations (drilling, blasting, loading, etc.), and vehicular movement. These locations determine the relative contribution of particulate matter from each activity. The air pollution analysing apparatus was positioned in an open area at 1.5m above the ground surface, away from any obstructions to the wind's natural movement. Before the commencement of a fresh set of observations, a manual zero was conducted. The values of $PM_{2.5}$ and PM_{10} were noted at regular intervals of 60 seconds, and related activities were noted at each location to link variations in suspended particulate matter (SPM) concentration due to realted activities.

3.8 Sampling of PM and PNC (GRIMM)

For the season of winters, a portable aerosol spectrometer is used called GRIMM (Model 1.108, GRIMM Aerosol Technik GmbH & Co. KG, and Germany) PM_{10}, $PM_{2.5}$, and $PM_{1,}$ concentrations were measured in real time. A laser photometer was used in the GRIMM aerosol spectrometer to measure PM mass and count concentrations based on 90° light scattering (GRIMM apparatus manual 2010). The aerosol is continually fed between the measurement cell and a replaceable PTFE filter by an internal non-pulsing volume-flow regulated pump. To protect the laser optics and other optical components from contamination, the air is then cleaned using a micro filter and utilized again as continuous rinsing air. GRIMM has a mass mode measurement accuracy of 5% and a count mode measurement precision of 2%. The data logging period was set to 1 minute and the flow rate to 1.2 l/minute. The instrument's weight is 2 kg and measuring repeatability (USEPA and EU standards) has made it a commonly utilised equipment for air quality. The spectrometer was calibrated before the experiment started. It does a 30-second self-test for optical, pneumatic, and electrical components before starting a measurement. To measure the mass and concentration of particulate matter (PM) GRIMM is used, or particles between 1 to 10 µm in size, in real time.

The apparatus has 32 distinct size ranges that can also be monitored in real-time by these optical laser light aerosol spectrometers, which concurrently convert the data to inhalable, thoracic, and alveolic fractions by European and American legislation. With GRIMM particulate matter sampling was done in winter season (February,2022). PM samples were collected at the identified sites throughout the day for 9 hours at each location. During the monitoring period, all samples were taken at 1-minute intervals at each station under winter weather conditions. The monitoring station (n=5) were aligned based on the mining site's dominant activity in downwind direction, and station were placed at distance of 100m, 500m, and 1km along the sections.

3.9 Measuring the Air quality Index

The Air Quality Index (AQI) was calculated using air pollution breakpoint concentrations and transformed to an AQI scale of 0–500 for each pollutant's sub-index (Ip) value (CPCB 2014). AQI category was used to understand the health statement (Table 3.4) because of poor air quality in the area surrounding the mine and its impact on health of people residing nearby. The category was used to make decisions that can help in health protection of people by minimising exposure to air pollution and altering activity levels.

Table: 3.4. The categories of AQI, ranges, and health effects associated with air quality (CPCB, 2014)

AQI category	Range (µg/m^3)	Colour code	Associated health impacts
Good	(0–50)	🟩	Minimal effect
Satisfactory	(51–100)	🟩	May get breathing discomfort only for sensitive people
Moderate	(101–200)	🟨	Persons with lung illness, such as asthma, may experience breathing difficulties, as well as people with heart disease, children, and the elderly.
Poor	(201–300)	🟧	People with heart problems may experience breathing difficulties as a result of long term exposure.
Very poor	(301–400)	🟥	People who are exposed for a long period of time may develop respiratory illnesses. People with lung and heart issues may experience a larger effect.
Severe/ Hazardous	(> 401)	🟥	Even healthy persons may have respiratory problems, and patients with lung/heart issues may experience major health consequences. Even during little physical activity, the health effects might be noticed.

This range is used when high values are reported. The equation (5) was used to determine the sub-index (I_p) for a given pollutant concentration (C_p).

$$I_P = [\{(I_{HI} - I_{LO})/ (B_{HI} - B_{LO})\} * (C_P - B_{LO})] + I_{LO} \qquad (5)$$

Whereas, B_{HI} = Breakpoint concentration more than or equal to the stated concentration, B_{LO} = Breakpoint concentration that is less than or equal to the stated concentration, and I_{HI} is the value that corresponds to the AQI value. AQI value for B_{HI}/I_{LO} = AQI value for B_{LO} finally, the air quality index (AQI) is based on the equation (6).

$$AQI = Max\ (I_p)\ \text{(where; } p = 1, 2, \ldots, n\text{; denotes } n \text{ pollutants)} \qquad (6)$$

because the study focus was confined to particulate matter alone, the above-mentioned idea was employed to establish AQI using just two pollutants.

3.10 Sampling of airborne ultrafine particles (SMPS)

Atmospheric nanoparticles were monitored at an interval of 7 minutes with a 0.75 l/minute inlet flow and a 0.25 l/minute CPC flow using a Nano Scan Scanning Mobility Particle (SMPS- scanning mobility particle sizer) Sizer model 3910 (TSI Inc.). This apparatus employs isopropyl alcohol as a condensation solvent, with particles ranging in size from 10 to 420 nm spread throughout 13 channels. Meteorological conditions including humidity, temperature, wind speed, and wind direction were recorded every hour during the day. Sampling was done on a building terrace in February, 2022, at a height of 1.5 m above the ground level. (Limitation: SMPS functioning required a supply of energy and a suitable place for installation). Traffic movement was also considered during the measurement time; it was measured as the number of vehicles passing per hour, and it was continually monitored during the mining activities.

3.11 Calculation of UFPs

An hourly average of the concentrations, as well as the size distribution of air nanoparticles, was computed for each sample location. The meteorological and hourly parameters of these particles were measured to determine the key factors that lead to the formation of nanoparticles. For statistical analysis, Microsoft (MS) office excel and Statistical Package for Social Science (SPSS) was used. To evaluate the modal distribution of the particle sizes, particle size parameterization of the Particle Number Distribution (PND) the use of a multi-standard function was applied (Hussein et al., 2005). PNDs are believed to consist of several Log normal modes by equation (7):

$$B\ (D_P)\ /\ \text{measured} \longrightarrow dN\ /\ d\ (\log\ (D_P)) \qquad (7)$$

$$\sum_{i=1}^{n} = \frac{N_i}{\sqrt{2\pi}\log(\sigma_{gi})}\exp\left[-\frac{\log(Dp)-\log(\bar{D}_{p,g,i})^2}{2\log^2(\sigma_{g,i})}\right] \qquad (8)$$

$$\sum_{i=1}^{n} = N_i A_i\left(Dp, \bar{D}_{pyi}\ \ \sigma_{gi}\right) \qquad (9)$$

In the above formula, B (eq.7) is the observed and measured as PND for a particular particle diameter Dp (nm). The following are the three parameters that define an individual mode i: the mode number concentration Ni (cm^3) (eq.8 and 9); the mode geometric variance 2g,i (dimensionless); the mode geometric mean diameter Dp,g,i (nm); and the number of individual modes n. This formulation is used to evaluate the model distribution of particle size.

3.12 Collection of ground water samples around mining region

Groundwater samples were collected during the summer (n=15) and winter (n=11) seasons from the vicinity of the mining area. (Fig.3.4). Every sample was collected from tube and bore wells. Samples were collected in 1-litre capacity of pre-rinsed fresh polypropylene sampling bottles

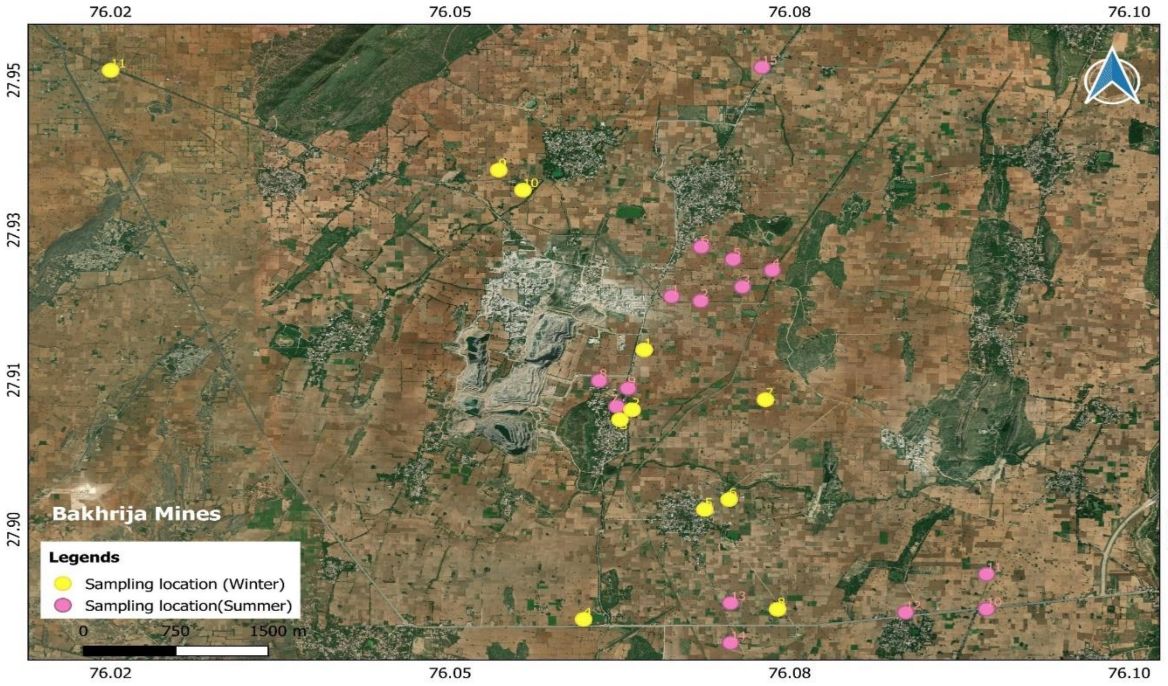

Fig. 3.4 Ground water sampling locations during summer (pink) and winters (yellow) around Bakhrija mines

The samples were stored in an ice box where low temperature is maintained and transported to the laboratory within 6 hrs for their chemical analysis. The samples were characterized for different parameters, in triplicates, following the standard methods as prescribed by APHA (2012). Based on results obtained from chemical analysis all sampled groundwater sources were also evaluated for suitability by comparing the observed values against standard prescribed values of BIS 2012 and WHO 2004.

3.13 Water quality analysis

To analyse the quality of water from the water sources in India, BIS-10500 is the prescribed standard for different parameters to check whether the water is fit for drinking or not. The acceptable and permitted limits in the absence of a backup source are specified by this standard BIS-10500 (2012) (Table 3.5). Since levels beyond those listed under "unacceptable" limit the water is unsuitable, it is advised that the acceptable limit be put into place. However, in the lack of a substitute source, such a value may be accepted. However, the sources will need to be disregarded if the permissible limit goes beyond the upper bounds listed under "the permissible limit in the absence of another source. Countries developed regulations aiming to preserve public health as a response to the problem of improving water quality. The World Health Organization (WHO) has created several normative "guidelines" in response to this, which provide an official evaluation of the health risks associated with exposure to health hazards through water. So those parameters which are not listed in the BIS, their values and standard are referred from the WHO standards (Table 3.6). Understanding the health and functioning of both surface water and groundwater is possible through the chemical analysis of water. It also demonstrates the boundaries of a water body's capacity to withstand a certain amount of pollution without endangering the water system, its aquatic life, and humans who could access the water. Most of the hand and bore pumps in the research area, which were utilized for irrigation and drinking water, were deeper than 100 to 150 meters. The groundwater samples were examined several hydro chemical characteristics, such as total hardness (TH) as $CaCO_3$, cations [calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+})], and anions [chloride (Cl^{-}), bicarbonate (HCO_3^{-}), sulphate (SO_4^{2-}), nitrate (NO_3^{-}) and Fluoride(F^{-}). The pH/EC/TDS meter was used to test the EC, TDS, and pH of water samples as soon as they were collected in the field.

Table-3.5. Physico-chemical and biological parameters for drinking water

S.No.	Parameters	Unit	Standard limits (IS 10500 : 2012)	
			Acceptable Limit	**Permissible Limit**
1	Odour	-	Agreeable	Agreeable
2	Taste	-	Agreeable	Agreeable
3	pH	-	6.5 to 8.5	No relaxation
4	TDS	mg/L	500	2000
5	Hardness (as $CaCO_3$)	mg/L	200	600
6	Alkalinity (as $CaCO_3$)	mg/L	200	600
7	Nitrate	mg/L	45	No relaxation
8	Sulphate	mg/L	200	400
9	Fluoride	mg/L	1	1.5
10	Chloride	mg/L	250	1000
11	Turbidity	NTU	5	10
12	Arsenic	mg/L	0.01	0.05
13	Copper	mg/L	0.05	1.5
14	Cadmium	mg/L	0.003	No relaxation
15	Chromium	mg/L	0.05	No relaxation
16	Lead	mg/L	0.01	No relaxation
17	Iron (mg/L)		0.3	No relaxation
18	Zinc (mg/L)		5	15
19	Fecal Coliform (cfu)		0	0
20	E. Coli (cfu)		0	0

Table 3.6 WHO 2004 standard (Selective) for drinking water quality

S.No.	Parameters	Unit	Standard limits as per WHO guidelines (mg/L)
1	pH	-	6.5-8.5
2	Total dissolved solids	mg/L	1000
3	Turbidity (NTU)		5
4	Ammonia	mg/L	1.5
5	Arsenic	mg/L	0.01
6	Calcium	mg/L	500
7	Chloride	mg/L	200 - 300
8	Chlorine	mg/L	5
9	Chlorite	mg/L	0.7
10	Chromium	mg/L	0.05
11	Copper	mg/L	2
12	Fluoride	mg/L	1.5
13	Iron	mg/L	2
14	Lead	mg/L	0.01
15	Manganese	mg/L	0.4
16	Mercury	mg/L	0.006
17	Nickel	mg/L	0.07
18	Barium	mg/L	0.5
19	Zinc	mg/L	3
20	Nitrate	mg/L	50
21	Nitrite	mg/L	3
22	Sodium	mg/L	200
23	Sulphate	mg/L	400
24	Uranium	mg/L	0.015

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Titrimetry was used to measure Ca^{2+} and Mg^{2+} using regular EDTA. $AgNO_3$ titration was used to measure the chloride. Using the conventional approach, a titration method was used to measure HCO_3^-. A flame photometer (Model 130 Systronics Flame Photometer) was used to test Na^+ and K^+. A UV-visible spectrophotometer was used for colorimetry to measure SO_4^{2-} and NO_3^-. Using a fluoride ion-selective electrode, the amount of fluoride in water was measured electrochemically (APHA 1985).

3.13.1 pH

Determination of pH is the one of the most important and frequently used test in water chemistry, to analyse the surface and ground water sources .The measurement of hydrogen ion activity in the solution is known as "pH.". During experimentation, pH was measured using bench top multi-parameter (Labman scientific instrument, LMMP 30) in the lab. pH meter has the glass electrode filled with KCl solution. The pH meter was calibrated using the known standard having pH 4.0, 7.0 and 10.0 to carry out three point caliberation. Since, measuring pH directly is exceedingly challenging, rapid and precise pH determination requires specialized electrodes pH meter.

Apparatus and chemical required- pH meter, pH electrode filled with KCL solution, buffer solutions of pH 4, 7 and 10, clean beakers, tissue papers, distilled water.

Procedure- Plug in the pH meter to power source and let it warm up for 5 to 10 minutes after that wash the glass electrode with distilled water and clean slowly with a soft tissue. Calibrate the meter with buffer solution then take out the electrode, wash with distilled water and clean. Repeat the steps with other buffer solution, after calibration the pH examination can be done for the collected ground water sample.

3.13.2 Electrical conductivity

The electrical conductivity of water can easily measure and track with bench-top multiparameter ((Labman scientific instrument, LMMP 30). Electrical conductivity can be measured using a probe. The probe consists of two metal electrodes spaced 1 cm apart (thus the unit of measurement is µS/cm or mS/cm). A constant voltage is applied across the electrodes resulting in an electrical current flowing through the aqueous sample.

Apparatus and chemical required- The probe was calibrated with the conductivity buffer solution KCl 0.1N.

Procedure: Samples are aligned in the test tube stand and with the electrode probe all the analyses are done. After the test of one sample readings are noted and the electrode is rinse with distilled water. The test was conducted to analyse salt concentration in the sample.

3.13.3 Total dissolved solids

Total dissolved solids (TDS) are a measurement of the total amount of inorganic and organic compounds that have been dissolved and are suspended as molecules, ions, or microscopic granules (colloidal solution) in a liquid. Dissolved solids are usually present in water in the form of ions and ions conduct electricity. This principle is utilized in finding the TDS of water. TDS meter tip is dipped inside water which measures the amount of electricity getting conducted and this electricity value is calibrated to TDS value in ppm or mg/L. Results of this test are approximate because all the dissolved solids present in water are not present as ions. This experiment was done with the bench-top multi-parameter (Labman scientific instrument, LMMP 30), in the experimental set up the probe, is calibrated with buffer solution of 692 ppm and 7230ppm as NaCl of thermos scientific, orion application solution , and then it was rinsed with deionised distilled water. Then the sample was analysed and result were recorded.

3.13.4 Flame photometry of Sodium, Potassium, calcium and Lithium

Flame photometer is an analytical instrument used in chemistry to measure the concentration of ions such as sodium, potassium, lithium, and calcium in water sample. Flame photometry is a common technique for determining sodium, potassium, lithium, and other alkali and alkaline earth metals in aqueous solutions. When a sodium-containing solution is introduced into a flame, the heat of the flame excites the sodium atoms, causing them to emit light at a specific wavelength. The emitted light's intensity is proportional to the concentration of sodium in the sample. The cations concentration of an unknown sample can be determined by calibrating the photometer with standard solutions of known mineral ion concentration. During the study cations concentration was measured using flame photometer (Systronics 128µC). The sample is introduced into a flame, where the elements are vaporized and ionized, producing light of a characteristic wavelength. The intensity of the light emitted is proportional to the concentration of the element in the sample, which is then measured by a photodetector and used to determine the element's concentration. All the Dilute a stock solution with deionized or distilled water to make standard solutions with known mineral concentrations. Use a concentration range that encompasses the expected concentration range of the drinking water sample. Assemble the flame photometer according to the instructions and calibrate it with the prepared standard solutions. Using the calibrated flame photometer, the water sample is analysed. If necessary, dilute the sample to bring the sodium concentration within the photometer's calibrated range. Take note of the sodium content of the water sample.

3.13.5 Total Iron

The iron test in the water sample is conducted to identify the concentration of $Fe2^+$ and total dissolved iron. Solutions containing iron ions are colourless, but upon addition of ortho-phenanthroline, the Fe^{2+} ions in the sample react immediately to produce a complex ion, which is orange in colour. The more Fe^{2+} ions in a sample will result in a deeper orange colour while less Fe^{2+} ions result in a fainter orange colour. Before the experimentation work the spectroscope is adjusted at the wavelength to 510 nm. 25 ml of sample of water is taken for the Fe^{2+} experiment. The instrument used in visible beam spectrophotometer (Labtronics India, Model LT-290) which was calibrated using standard solution having strength ranging between 0.1 mg/L to 1mg/L.

Reagent required and Preparation:

Hydrochloric acid, HCl, conc., containing less than 0.5 ppm iron. *Hydroxylamine solution*: Dissolve 10g of $NH_2OH.HCl$ solution in 100 mL of water.
Ammonium acetate buffer solution. Dissolve 250g $NH_4C_2H_3O_2$ in 150 mL water. Add 700 mL conc. glacial acetic acid. Because even a good grade of $NH_4C_2H_3O_2$ contains a significant amount of iron, prepare new reference standards with each buffer preparation.
Sodium acetate solution: Dissolve 200 g $NH_4C_2H_3O_2.\,H_2O$ in 800 mL water.
Phenanthroline solution. Dissolve 100 mg 1, 10-phenanthro- line monohydrate, $C_{12}H_8N_2.\,3H_2O$, in 100 mL water by stirring and heating at 80°C but do not boil. Discard the solution if it darkens. Heating is unnecessary if 2 drops conc. HCI are added to the water.

Potassium permanganate, 0.IN: Dissolve 0.316 KMnO4 in reagent water and dilute to 100 mL.

Procedure: In 25 ml of sample, 25ml of phenanthroline is added after that 5ml of ammonium acetate is added to the sample. The sample is diluted to make it 50 ml and absorbance is taken at 510 nm to get Fe^{2+}. For total dissolve iron 25ml of the sample is taken, 1ml of HCl is added into the solution after that 1ml of $NH_2OH.HCl$ is added after that 25ml of phenanthroline is added after that 5ml of ammonium acetate is added to the sample. The sample is diluted to make it 50 ml and then examined at spectrophotometry at 510 nm this give total dissolve iron concentration in the ground water sample. From the standard curve and observed values the concentration of iron is determined.

3.13.6 Silicate

Silicon does not occur free in nature, but rather as free silica (SiO_2) in coarsely crystalline (quartz, rock crystal, amethyst, etc.) and microcrystalline (e.g., flint, chert, jasper) varieties of quartz, the major component of sand and sandstone. Silicon is found in combination with other elements in silicates, represented by feldspar, hornblende, mica, asbestos, and other clay minerals. Silicates also occur in rocks, such as granite, basalt, and shale. Silicon therefore is usually reported as silica (SiO_2) when rocks, sediments, soils, and water are analysed.

Reagent required and Preparation:

Ammonium molybdate solution: Dissolve 52 g ammonium molybdate in water, adjust the pH to between 7 and 8 with 1OM NaOH, and dilute to 1 L with demineralized water.

Hydrochloric acid: Mix 86 mL concentrated HCl with demineralized water and dilute to 1 L.

Oxalic acid: 50 g of reagent grade oxalic acid dehydrate with 500 ml of deionized water and dilute it to 1L.

Procedure: This experimentation is carried out with a spectrophotometer to analyse the presence of silica in ground water, during the experiment initially 25 ml of sample is taken then mixed with 0.5 ml of HCl and 1ml of ammonium molybdate a fade yellow colour will form, then allow the mixture to be still for 5 minutes then 1ml of oxalic acid is added into the sample and left the sample still for 5 minutes. Then the sample is analysed in 410nm absorbance in a spectrophotometer. With graph curve and observed value the concentration of silica in ground water is determined.

3.13.7 Phosphate

The phosphates were analysed using visible beam spectrophotometer (Labtronics India, Model LT-290). The instrument was calibrated using standard solution of 0.1, 0.2, 03,….1.0 mg/L. Phosphorus occurs in natural waters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates), and organically bound phosphates. In this experiment, observation was taken at 690nm. Phosphates react with ammonium hepta molybdate to form a phosphor-molybdic acid, measured concentration of molybdenum blue by spectroscopy stoichiometrically determines the concentration of phosphates in the water sample.

Reagent required and Preparation:

Molybdate solution was prepared by dissolving 25 g ($(Na_4)_6Mo_7O_{24}$, H_2O) in 175 ml of distilled water, transfer the solution to another flask then 400ml of distilled water, take 250 ml conc. Sulphuric acid into the flask and made it 1000ml solution by adding distilled water.

Prepare freshly 1:1 HCl+Stannous chloride crystal.

Procedure: The phosphate ions in the drinking water sample react with molybdenum to form a blue complex in this method. At first 25ml of the sample is taken with a mixing of 1ml of ammonium molybdate and then 2ml of 0.25N sulphuric acid and disodium hydrogen phosphate then all the solution is mixed and left for 10 min for settling down then all the sample was analysed in spectroscopy at 690nm of absorption to get the concentration of phosphate.

3.13.8 Sulphate

Sulphate are found in appreciable quantity in all natural waters, particularly high in arid and semi-arid regions where natural waters in general have high salt content. Sulphate salts are mostly soluble in water and impart hardness. Water with high concentrations has a bitter test. Sulphate may cause intestinal disorders. The turbid metric method depends on the fact that barium sulphate formed following barium chloride addition to a sample tends to precipitate in a colloidal form and this tendency is enhanced in the presence of an acidic buffer (consists of magnesium chloride, potassium nitrate, sodium acetate, and acetic acid). These precipitates need to be separated through filtration (using a filter) before sample is analysed for sulphate concentration. The experiment was conducted in double beam UV-Vis spectrophotometer (LabIndia analytical UV-Vis spectrophotometer, UV 3092) for suitable screening of water.

Reagent required and Preparation:

Buffer Solution A: Dissolve 30 g magnesium chloride ($MgCl_2.6H_2O$), 5 g sodium acetate ($CH_3COONa.3H_2O$), 1.0 g potassium nitrate (KNO_3), and 20 ml acetic acid (CH_3COOH; 99%) in 500 ml distilled water and make up to 1000 ml.

Buffer solution B: Dissolve 30 g magnisum chloride, 5 g sodium acetate, 0.111g sodium sulphate, and 20 mL acetic acid (99%) in 500 mL disttiled water make up to 1000 mL. Dry Barium Chloride ($BaCl_2$) crystals.

Standard Sulphate Solution: Dissolve 0.1479 g of anhydrous sodium sulphate in distilled water and make the volume 1 L. This solution contains 100 mg sulphate/L (i.e., 1 ml=100µg

SO_4^{2-}). Prepare standards of various strengths (preferably from 0.0 to 40.0 mg/L at the intervals of 5 mg/L by diluting this stock solution was prepared). Above 40 mg/L accuracy decreases and $BaSO_4$ suspensions lose stability. Plot a standard sulphate calibration curve on a graph paper from these absorbance values putting strengths (mg/L) on X-axis and absorbance at 420 nm on Y-axis. Through calibration curve sulphate concentration can be determined.

Procedure: Filter the sample though filter paper (Whatman No. 1) and take 50 mL of filtrate in an Erlenmeyer flask. Add 20 ml buffer solution and mix in stirring apparatus. While stirring, add 0.15 g of barium chloride to the sample and stir the sample with the help of magnetic stirrer for about an hour. Measure the absorbance against a distilled water blank at 420 nm using spectrophotometer. Absorbance for the blank sample is taken to correct for sample colour and turbidity. Process the standard solution of different strengths in similar way and record the absorbance for each solution.

3.13.9 Nitrate

Determination of nitrate (NO_3^-) is difficult because of the relatively complex procedures required, the high probability that interfering constituents will be present, and the limited concentration ranges of the various techniques. The experiment was conducted in double beam UV-Vis spectrophotometer (LabIndia analytical UV-Vis spectrophotometer, UV 3092) which was calibrated with known NO_3^- standard strength of 1, 2, 3, 4 and 5mg/L. An ultraviolet (UV) technique that measures the absorbance of NO_3^- at wavelength 220 nm is suitable for screening uncontaminated water (low in organic matter).

Reagent required and Preparation:

Nitrate - free water: Use redistilled or distilled, deionized water of highest purity to prepare all solution sand dilutions. Stock nitrate solution: Dry potassium nitrate (KNO_3) in an oven at 105°C for 24h. Dissolve 0.7218g in water and dilute to 1000 ml; 1.00 ml = 100 g NO_3^-N. Preserve with 2ml $CHCl_3$/l. Intermediate nitrate solution: Dilute 100ml stock nitrate solution to 1000ml with water; 1.00 ml 10.0 g NO_3^-N. Preserve with 2ml $CHCl_3$/l. Prepare Hydrochloric acid solution, HCl, 1N.

Procedure: Buffer NO_3^- was prepared for the calibration of standards in the range 0 to 5mg/L. All the buffer solution strength of 1, 2, 3, 4 and 5mg/L were taken and 1ml of HCl was added to it. After that in standard calibration graph of NO_3^- was made as per the absorbance of spectrophotometer. Treat NO_3^- standards in same manner as samples. 50 mL of clear sample is taken, filtered if necessary, add 1mL of HCl solution and mix thoroughly. Absorbance was recorded against redistilled water set at zero absorbance or 100% transmittance. Use a wavelength of 220 nm to obtain NO_3^- reading.

3.13.10 Fluoride

Too much or too little fluoride may be risky to individuals and the environment. Precise fluoride measurement by municipalities, potable water facilities, and bottled water makers promotes quality water for consumption and helps in environmental protection. The F^- concentration was measured using (ISE- Orion scientific equipment, Benchtop meter) handheld multi-parameter.

Reagent required and Preparation:

To initiate the test procedure of fluoride, standard preparation should be made in volumetric flask of 50 ml for 1mg/L fluoride standard. It was diluted serially in volumetric flask to get the 1mg/L and 0.1 mg/L strength of standard F^- solution. Dilute with deionized water to taste. Mix the solution thoroughly. Add 30 mL of the 0.01 ppm fluoride standard to a 50 mL beaker with a graduated cylinder or an automated pipette and label the beaker. Add 30 mL of each of the 1 ppm fluoride standard and 2 ppm fluoride standard to separate 50 mL beakers with a graduated cylinder or automated pipette and label the beakers.

Procedure: All the water sample is arranged and after every sample determination the probe was rinsed with distilled water. The fluoride concentration was determined using an ion-specific electrode (ISE- Orion scientific equipment).

3.13.11 Chloride

Chloride in the form of chloride (Cl^-) ion is one of the major inorganic anions in water. In potable water, the salty taste produced by chloride concentration is variable and depends on the chemical composition of water. Some waters containing 250 mg/L Cl^- may have a detectable salty taste if sodium cation is present. On the other hand, the typical salty taste may be absent in waters containing as much as 1000 mg/L when the predominant cations are calcium and magnesium. In addition, a high chloride contents may harm metallic pipes and structures as well as growing plants. The chloride ions in the water sample react with the added $AgNO_3$ to form a white precipitate of silver chloride in this method.

Reagent required and Preparation:

Potassium chromate indicator solution, standard silver nitrate as a titration agent, here 5g of silver nitrate crystals mixed with 1L of deionised water.

Procedure: 25 ml of sample in a conical flask is taken and 1.0 ml indicator solution, (Potassium chromate) is added initial colour of the mixture is slight yellow then, it was titrated with standard silver nitrate solution to brick red end point and noted down volume of titrant used. The appearance of the reddish-brown precipitate of silver chromate indicates the titration's endpoint when all of the chloride ions in the water sample have reacted with the silver ions and no more precipitate forms. It represents presence of salinity in the water.

3.13.12 Alkalinity as carbonate and bicarbonates

Alkalinity is primarily a way of measuring the acid neutralizing capacity of water. In other words, its ability to maintain a relatively constant pH. The possibility to maintain constant pH is due to the hydroxyl, carbonate and bicarbonate ions present in water. The ability of natural water to act as a buffer is controlled in part by the amount ofcalcium and carbonate ions in solution. Carbonate ion and calcium ion both come from calcium carbonate or limestone. So water that comes in contact with limestone will contain high levels of both Ca^{2+} and CO_3^{2-} ions and have elevated hardness and alkalinity.

Reagent required and Preparation:

Standard sulphuric acid, Phenolphthalein indicator, Mixed Indicator, Bromocresol Green, Methyl Red, Ethyl alcohol, Distilled Water.

Sulphuric Acid Solution (0.02N):

Take approximately 500 mL of distilled water in a 1000 mL volumetric flask. Pipette out 20 mL of 0.1 Normality sulphuric acid and add slowly along the sides of the volumetric flask. Then make up the volume up to 1000 mL mark. Now the strength of this solution is 0.02 N.

Phenolphthalein Indicator Preparation:

Weigh 1g of phenolphthalein and add to 100 mL of 95% ethyl alcohol or to 100 mL of distilled water.

Mixed Indicator Preparation:

Dissolve 100 mg Bromocresol green and 20 mg of methyl red in 100 mL of 95% ethyl alcohol.

Procedure: Rinse the burette with 0.02N Sulphuric acid and discard the solution. Fill the burette with 0.02N sulphuric acid and adjust it to zero. Fix the burette in the stand. Using a measuring cylinder exactly measure 100 mL of sample and pour it into a 250 mL of conical flask. Add few drops of phenolphthalein indicator to the contents of conical flask. The colour of the solution will turn to pink. This colour change is due to alkalinity of hydroxyl ions in the water sample. Titrate it against 0.02N sulphuric acid till the pink colour disappears. This indicates that all the hydroxyl ions are removed from the water sample. Note down the titter value (V1). This value is used in calculating the phenolphthalein alkalinity. To the same solution in the conical flask add few drops of mixed indicator. The colour of the solution turns to blue. This colour change is due to CO_3^{2-} & HCO_3^{-} ions in water sample. Continue the titration from the point where it was stopped previously for the phenolphthalein alkalinity. Titrate till the solution becomes red. The entire volume (V2) of sulphuric acid is noted down and it is accountable in calculating the total alkalinity.

$$\text{Phenolphthalein alkalinity} = \frac{(\text{Vol. of } H_2SO_4\ (V_1)\ (\text{ml}) \text{ X Normality } 50 \text{ X } 1000)}{\text{Vol. of sample taken (ml)}} \quad (10)$$

$$\text{Total alkalinity} = \frac{(\text{Vol. of } H_2SO_4\ (V_2)\ (\text{ml}) \text{ X Normality } 50 \text{ X } 1000)}{\text{Vol. of sample taken (ml)}} \quad (11)$$

3.13.13 Total Hardness

Total hardness is defined as the sum of the calcium and magnesium ion concentrations, which is expressed as calcium carbonate in mg/L. When hardness (numerically) is greater than the sum of carbonate and bicarbonate alkalinity, amount of hardness equivalent to the total alkalinity is called “Carbonate hardness”. When the hardness is numerically equal to or less than the sum of carbonate and bicarbonate alkalinity all of the hardness is carbonate hardness and there is no non carbonate hardness.

Reagent required and Preparation-

EDTA solution: Take 4gm EDTA salt and 0.1gm magnesium bicarbonate and dissolve it in 800 ml distilled water. Eriochrome Black-T: 0.4gm Ericrome Black T, 4.5 gm hydroxylmine hydrochloride add in 100ml 95% ethyl alcohol. Ammonia Buffer: Stock A: 16.9gm of NH_4CL in 143ml of conc. NH_4OH, Stock B: 1.25gm magnesium salt of EDTA dissolve in 50 ml distilled water. Mix both stock solutions and dilute to 250ml with distilled water.

Procedure-

The burette is filled with standard EDTA solution to the zero level. Then take 50ml sample water in conical flask. If sample having high calcium content then take smaller volume and dilute to 50ml. Add 1ml ammonia buffer. Add 5 to 6 drop of Ericrome black – T indicator. The solution turns into wine red colour. Note the initial reading. Titrate the content against EDTA solution. At the end point colour change from wine red to blue colour. Note the final reading and record it together volume of EDTA consumed during titration. Repeat the process till we get concordant value.

$$\text{Hardness as mg } CaCO_3/L = A \times B \times 1000 / \text{mL sample} \qquad (12)$$

Where: A- mL of titrant EDTA consumed during titration for sample and B- mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant.

3.14 Analysis of Soil

3.14.1 Collection of soil samples

The sampling of soil was carried out at four locations (Fig.3.5) near the Bakhrija stone quarry located in Mahendragarh district of Haryana state. Samples were collected from specific location where air quality analyses apparatus were set up. The sites were identified and marked with GPS to obtain the exact coordinates of the sampling location. The soil sample were collected from the study area and for experimentation the sample was mixed with distilled water and changed into the solution by mixing it with water the ratio 1:10 (soil: water). After that it was kept for saturation in an orbital shaker for 5-6 hours. After that, the saturated sample was allowed to settle down. Extraction of the centrifuged supernatant from the settled saturated sample was done.

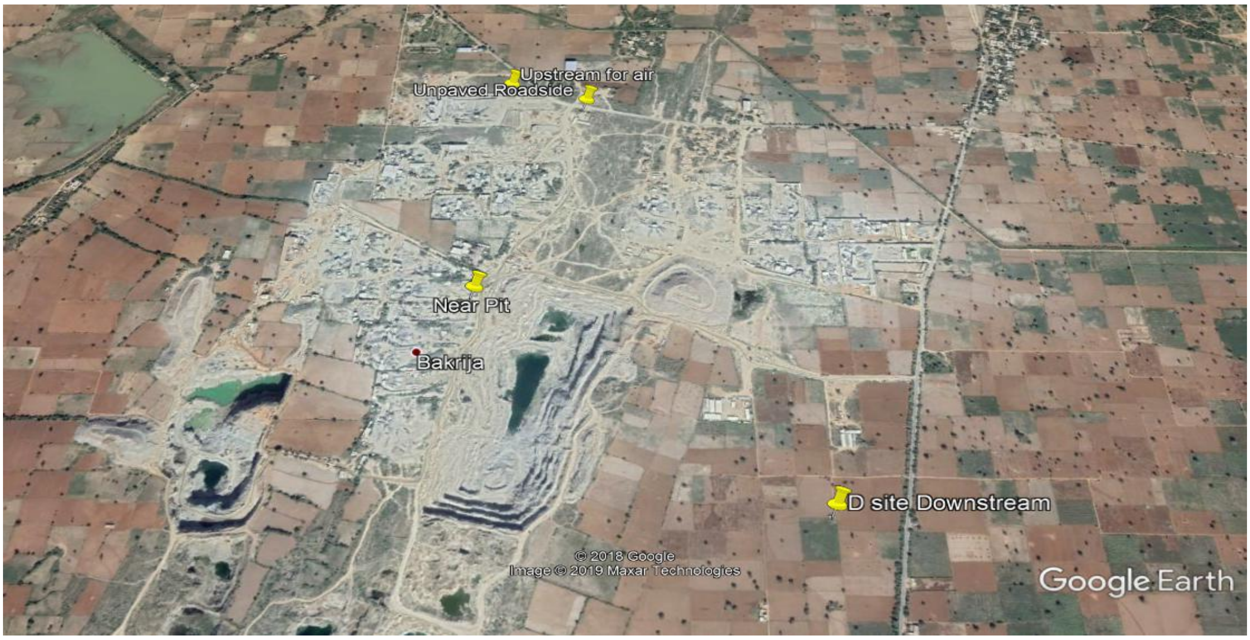


Fig: 3.5 Soil Sampling locations at Bakhrija mines.

The collected sample were taken to the laboratory for analysis included analysis of Alkalinity, and chloride ions was performed by volumetric analysis. Sulphate, and Phosphate ions were recorded using the spectrophotometer method. Analysis included the use to measure pH and electrical conductivity. Sample physical test is conducted with same method by making suspension of soil and water.

3.14.2 Water holding capacity

The field capacity or the water holding capacity (WHC) is the amount of water that can be held by a soil sample. To conduct this experiment a filter paper (Whatman Filter paper) was taken to make a funnel shape and it was placedt on a 100ml measuring cylinder. Take 25g of the sample and put it on the filter paper then take 50 ml of distilled water and pour it into the funnel, and note down the time required for water to drain from the funnel. Take down the reading when the water level will reach saturation. Repeat the step for accuracy and all the samples.

3.14.3 Particle size analysis

Soil consists of an assembly of ultimate soil particles (discrete particles) of various size. The object of a particle size analysis is to group these particles into separate ranges of sizes and so determine the relative proportion by weight of each size range. The method employs sieving of a soil to separate the particles of defined size as per the seive. This test is used to assess the proportion of different grain sizes present in the soil. The method of mechanical or sieve analysis is used to identify the distribution of coarser, larger-sized particles, whereas the hydrometer approach is used to detect the distribution of tiny particles.

Apparatus required: Sieve, Sieve shaker, oven and soil sample.

Procedure: The soil sample is taken and kept into the oven for 24 hour at 120^o C. 1kg of the dried soil sample is taken for the sieve analysis, and the larger opening of the sieve placed above the smaller opening of the sieve. . I.S sieves are selected and arranged in the order as 4.75, 3.36, 2.40, 1.46, 0.60 and 0.075. The soil sample is separated into various fractions by sieving through above sieves placed in the above mentioned order. The weight of soil retained on each sieve is recorded. After the shaking for 15 min, all stack of each sieve mass was measured to check the soil retained.The proportion of soil sample retained on 75 micron I.S sieve is weighed and recorded weight of soil sample is as per I.S 2720.

3.14.4 Chemical properties of soil

Determination of cations

Flame photometer is an analytical instrument used in chemistry to measure the concentration of ions such as sodium, potassium, lithium, and calcium in water sample. Flame photometry is a common technique for determining sodium, potassium, lithium, and other alkali and alkaline earth metals in aqueous solutions. When a sodium-containing solution is introduced into a flame, the heat of the flame excites the sodium atoms, causing them to emit light at a specific wavelength. The emitted light's intensity is proportional to the concentration of sodium in the sample. The cations concentration of an unknown sample can be determined by calibrating the photometer with standard solutions of known mineral ion concentration. During the study cations concentration was measured using flame photometer (Systronics 128µC). The sample is introduced into a flame, where the elements are vaporized and ionized, producing light of a characteristic wavelength. The intensity of the light emitted is proportional to the concentration of the element in the sample, which is then measured by a photodetector and used to determine the element's concentration. All the Dilute a stock solution with deionized or distilled water to make standard solutions with known mineral concentrations. Use a concentration range that encompasses the expected concentration range of the drinking water sample. Assemble the flame photometer according to the instructions and calibrate it with the prepared standard solutions. Using the calibrated flame photometer, the water sample is analysed. If necessary, dilute the sample to bring the sodium concentration within the photometer's calibrated range. During the experimentation, all the diluted sample of soil is taken in the 100ml beaker and analysed for the presence of cations in the sample.

Determination of anions in soil sample

3.14.5 Alkalinity as carbonates and bicarbonates

Before starting test the soil sample was washed with distilled water and mixture is centrifuged at 5000 rpm for 10 min. After that supernatant was recovered and the test was conducted on the supernatant.

Reagent required and Preparation:

Standard sulphuric acid, Phenolphthalein indicator, Mixed Indicator, Bromocresol Green, Methyl Red, Ethyl alcohol, Distilled Water.

Sulphuric Acid Solution (0.02N):

Take approximately 500 mL of distilled water in a 1000 mL volumetric flask. Pipette out 20 mL of 0.1 Normality sulphuric acid and add slowly along the sides of the volumetric flask. Then make up the volume up to 1000 mL mark. Now the strength of this solution is 0.02 N.

Phenolphthalein Indicator Preparation:

Weigh 1g of phenolphthalein and add to 100 mL of 95% ethyl alcohol or to 100 mL of distilled water.

Mixed Indicator Preparation:

Dissolve 100 mg Bromocresol green and 20 mg of methyl red in 100 mL of 95% ethyl alcohol.

Procedure: Rinse the burette with 0.02N Sulphuric acid and discard the solution. Fill the burette with 0.02N sulphuric acid and adjust it to zero. Fix the burette in the stand. Using a measuring cylinder exactly measure 100 mL of sample and pour it into a 250 mL of conical flask. Add few drops of phenolphthalein indicator to the contents of conical flask. The colour of the solution will turn to pink. This colour change is due to alkalinity of hydroxyl ions in the water sample. Titrate it against 0.02N sulphuric acid till the pink colour disappears. This indicates that all the hydroxyl ions are removed from the water sample. Note down the titter value (V_1). This value is used in calculating the phenolphthalein alkalinity. To the same solution in the conical flask add few drops of mixed indicator. The colour of the solution turns to blue. This colour change is due to CO_3^{2-} & HCO_3^- ions in water sample. Continue the titration from the point where it was stopped previously for the phenolphthalein alkalinity. Titrate till the solution becomes red. The entire volume (V_2) of sulphuric acid is noted down and it is accountable in calculating the total alkalinity.

$$\text{Phenolphthalein alkalinity} = \frac{\text{(Vol. of } H_2SO_4\text{ (}V_1\text{) (ml) X Normality 50 X 1000)}}{\text{Vol. of sample taken (ml)}} \qquad (13)$$

$$\text{Total alkalinity} = \frac{\text{(Vol. of } H_2SO_4\text{ (}V_2\text{) (ml) X Normality 50 X 1000)}}{\text{Vol. of sample taken (ml)}} \qquad (14)$$

For conversion of values from mg/L to mg/g of soil following formulation is used

$$\text{X mg/L x 1L/1000 g = X mg/1000 g as litres cancel} \qquad (15)$$

3.14.6 Sulphate

Sulphate are found in appreciable quantity in all natural waters, particularly high in arid and semi-arid regions where natural waters in general have high salt content. Sulphate salts are mostly soluble in water and impart hardness. Water with high concentrations has a bitter test. Sulphate may cause intestinal disorders. The turbid metric method depends on the fact that barium sulphate formed following barium chloride addition to a sample tends to precipitate in a colloidal form and this tendency is enhanced in the presence of an acidic buffer (consists of magnesium chloride, potassium nitrate, sodium acetate, and acetic acid). These precipitates need to be separated through filtration (using a filter) before sample is analysed for sulphate concentration. The experiment was conducted in double beam UV-Vis spectrophotometer (LabIndia analytical UV-Vis spectrophotometer, UV 3092) for suitable screening of water.

Reagent required and Preparation:

Buffer Solution A: Dissolve 30 g magnesium chloride ($MgCl_2.6H_2O$), 5 g sodium acetate ($CH_3COONa.3H_2O$), 1.0 g potassium nitrate (KNO_3), and 20 ml acetic acid (CH_3COOH; 99%) in 500 ml distilled water and make up to 1000 ml.

Buffer solution B: Dissolve 30 g magnisum chloride, 5 g sodium acetate, 0.111g sodium sulphate, and 20 mL acetic acid (99%) in 500 mL disttiled water make up to 1000 mL. Dry Barium Chloride ($BaCl_2$) crystals.

Standard Sulphate Solution: Dissolve 0.1479 g of anhydrous sodium sulphate in distilled water and make the volume 1 L. This solution contains 100 mg sulphate/L (i.e., 1 ml=100µg

SO_4^{2-}). Prepare standards of various strengths (preferably from 0.0 to 40.0 mg/L at the intervals of 5 mg/L by diluting this stock solution was prepared). Above 40 mg/L accuracy decreases and $BaSO_4$ suspensions lose stability. Plot a standard sulphate calibration curve on a graph paper from these absorbance values putting strengths (mg/L) on X-axis and absorbance at 420 nm on Y-axis. Through calibration curve sulphate concentration can be determined.

Procedure: Filter the sample though filter paper (Whatman No. 1) and take 50 mL of filtrate in an Erlenmeyer flask. Add 20 ml buffer solution and mix in stirring apparatus. While stirring, add 0.15 g of barium chloride to the sample and stir the sample with the help of magnetic stirrer for about an hour. Measure the absorbance against a distilled water blank at 420 nm using spectrophotometer. Absorbance for the blank sample is taken to correct for sample colour and turbidity. Process the standard solution of different strengths in similar way and record the absorbance for each solution.

3.14.7 Chloride

Chlorides can be readily measured using Argentometric method. This method recommends the use of 0.0141N solution of silver nitrate for titration.1 ml of this silver nitrate solution is equivalent to 0.5 mg of chloride ion. The chloride ion precipitates as white silver chloride during the titration.

Reagent required and Preparation:

Potassium chromate indicator solution, standard silver nitrate as a titration agent, here 5g of silver nitrate crystals mixed with 1L of deionised water.

Procedure: 25 ml of sample in a conical flask is taken and 1.0 ml indicator solution, (Potassium chromate) is added initial colour of the mixture is slight yellow then, it was titrated with standard silver nitrate solution to brick red end point and noted down volume of titrant used. The appearance of the reddish-brown precipitate of silver chromate indicates the titration's endpoint when all of the chloride ions in the water sample have reacted with the silver ions and no more precipitate forms. It represents presence of salinity in the water.

$$Ag^{+} + Cl^{-} \leftrightarrow AgCl \qquad (16)$$

For the detection of the endpoint in the test potassium chromate indicator is used to detect the presence of excess Ag^{+} in the sample. The indicator normally used is potassium chromate; which supplies the chromate ions. As the concentration of chloride ions stated disappearing the concentration of silver ions rises to the point where the solubility product of silver chromate is surpassed, and forms reddish-brown precipitate.

$$2Ag^{+} + CrO4^{-2} \leftrightarrow Ag_2CrO_4 \qquad (17)$$

The appearance of the reddish-brown precipitate of silver chromate indicates the titration's endpoint when all of the chloride ions in the water sample have reacted with the silver ions and no more precipitate forms. This is interpreted as proof that all of the chloride has been precipitated..

3.14.8 Total Phosphate

The phosphates were analysed using visible beam spectrophotometer(Labtronics India, Model LT-290). The instrument was calibrated using standard solution of 0.1, 0.2, 03,…. 1.0 mg/L. Phosphorus occurs in natural waters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates), and organically bound phosphates. In this experiment, observation was taken at 690nm. Phosphates react with ammonium hepta molybdate to form a phosphor-molybdic acid, measured concentration of molybdenum blue by spectroscopy stoichiometrically determines the concentration of phosphates in the water sample.

Reagent required and Preparation:

Molybdate solution was prepared by dissolving 25 g $(Na_4)_6Mo_7O_{24}$, H_2O) in 175 ml of distilled water, transfer the solution to another flask then 400ml of distilled water, take 250 ml conc. Sulphuric acid into the flask and made it 1000ml solution by adding distilled water.
Prepare freshly 1:1 HCl+Stannous chloride crystal.

Procedure: The phosphate ions in the drinking water sample react with molybdenum to form a blue complex in this method. At first 25ml of the sample is taken with a mixing of 1ml of ammonium molybdate and then 2ml of 0.25N sulphuric acid and disodium hydrogen phosphate then all the solution is mixed and left for 10 min for settling down then all the sample was analyzed in spectroscopy at 690nm of absorption to get the concentration of phosphate.

3.14.9 Total organic carbon (TOC) - %

The Walkley-Black (WB) titration method was performed for analysing organic carbon (OC) in soils and sediments.

Reagent required and Preparation:

Potassium dichromate, Weigh 49.04 g potassium dichromate (previously dried for 2 hours at 100 °C) into a 1 liter volumetric flask. Dissolve and dilute to volume with deionized water and mix well.

0.5 N Ferrous Ammonium Sulphate, Slowly add 20 mL sulphuric acid to a 1 liter volumetric flask containing 800 mL deionized water. Add 196.1 g ferrous ammonium sulphate. Dissolve, dilute to volume with deionized water, and mix well.

Diphenylamine Indicator: Dissolve 0.500 g diphenylamine in 20 mL deionized water. Slowly add 100 mL sulphuric acid. Carefully mix with a glass stirring rod.

Procedure: In the experimentation weigh 1.00 g soil into a 500 mL erlenmeyer flask. Add 10 mL of 1 N potassium dichromate solution. Add 20 mL sulphuric acid and mix by gentle rotation for 1 minute, taking care to avoid throwing soil up onto the sides of the flask. Let stand for 30 minutes. Dilute to 200 mL with deionized water. Add 10 mL phosphoric acid, 0.2 g ammonium fluoride, and 10 drops diphenylamine indicator. Titrate with 0.5 N ferrous ammonium sulphate solution until the colour changes from dull green to a turbid blue. Add the titrating solution drop by drop until the end point is reached when the colour shifts to a brilliant green. Prepare and titrate a blank in the same manner. The average oxidation number for organic carbon is zero, and the following processes are included in the WB titration method**:**

$$C^0 + 2H_2O \rightarrow CO_2 + 4H^+ + 4e^- \qquad (18)$$

$$Cr_2O7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \qquad (19)$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^- \qquad (20)$$

3.14.10 Total Kjeldahl's Nitrogen (TKN)

This method is used to determine the nitrogen content in the soil by titration method.

Reagent required and Preparation:

Borax (4%), 4g of $Na_2B_4O_7$ in 100ml of distilled water then boil it, then for boric acid and indicator solution, 100 ml of distilled water is taken and 4g of boric acid is added into it and then 5ml of MI indicator.

MI indicator is mixture of bromocresol green (0.5%) and methyl red (0.1%), in 2:1 ratio (50:25) mix it with alcohol solution

Direct titration to determine nitrogen. The chemical reaction is sped up when boric acid is employed as the receiving solution instead of a standardized mineral acid.

$H_3 + H_3BO_3 \rightarrow NH_4^+ : H_2BO_3^- + H_3BO_3$ (colour change) (21)

The formation of ammonium-borate complex happens when boric acid capture ammonia gas,. The colour of the receiving solution changes as the ammonia accumulates.

$2NH_4H_2BO_3^- + H_2SO_4 \rightarrow (NH_4)\ 2SO_4 + 2H_3BO_3$ (colour change in reverse) (22)

The addition of sulphuric acid exactly neutralizes the ammonium borate complex, and a reverse colour change is produced.

Procedure: Overall, the Kjeldahl’s method is divided into three main steps. The method has to be carried out in proper sequence. The steps include digestion, distillation, and titration.

Digestion: In this method, a certain substance or sample is heated in the presence of sulphuric acid. The acid breaks down the organic substance via oxidation and reduced nitrogen in the form of ammonium sulphate is liberated. Potassium sulphate is usually added to increase the boiling point of the medium. Catalysts like mercury, selenium, copper, or ions of mercury or copper are also used in the digestion process. The sample is fully decomposed when we obtain a clear and colourless solution.

Distillation: The distillation of the solution now takes place and a small quantity of sodium hydroxide is added to convert the ammonium salt to ammonia. The distilled vapours are then trapped in a special trapping solution of HCl (hydrochloric acid) and water.

Titration: The amount of ammonia or the amount of nitrogen present in the sample is then determined by back titration. As the ammonia dissolves in the acid trapping solution some HCl is neutralized. The acid that is left behind can be back titrated with a standard solution of a base such as NaOH or other bases.

3.14.11 Cation exchange process

This method is used to measure the total negative and positive ions present in the soil. Cation-exchange capacity is defined as the amount of positive charge that can be exchanged per mass of soil.

Reagent required and Preparation:

Sodium acetate (Na_4OAc), 1.0 N: Dissolve 136 g of $NaC_2H_2O_2.3H_2O$ in water and dilute it to 1,000 mL. The pH of this solution should be 8.2. If needed, add a few drops of acetic acid or Na_4OH solution to bring the reaction of the solution to pH 8.2.

Ammonium acetate (NH4OAc), 1 N: Dilute 114 mL of glacial acetic acid 4 (99.5%) with water to a volume of approximately 1 liter. Then add 138 mL of concentrated ammonium hydroxide (NH4OH) and add water to obtain a volume of about 4 1,980 mL. Check the pH of the resulting solution, add more NHOH, as needed, to 4 obtain a pH of 7, and dilute the solution to a volume of 2 liters with water.

Isopropyl alcohol: 99%.

Procedure:

Weigh 4 g of medium- or fine-textured soil or 6 g of coarse-textured soil and transfer the sample to a 50-mL, round-bottom, narrow-neck centrifuge tube. (A fine soil has >50% of the particles <0.074 mm, medium soil has >50% >0.425 mm, while a coarse soil has more than 50% of its particles >2 mm. Add 33 mL of 1.0 N NaOAc solution, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear. Add 33 mL of 99% isopropyl alcohol, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear. Add 33 mL of NH_4OAc solution, stopper the tube, shake it in a 4 mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear. Decant the washing into a 100-mL volumetric flask.

3.15 Analysis of Vegetation

Monitoring of air pollutants in remote areas is a little difficult, because of the unavailability of resources. Monitoring is costly; nevertheless, vegetation has been found to provide a simple and cost-effective technique for monitoring air quality across the study area. The area is semi-arid it lacks sensitive plant species which act as bio-indicators. Pollution from quarrying source give stress to plants and certain compounds from particulate matter effect the growth of plants, pigmentation, and photosynthetic activities.

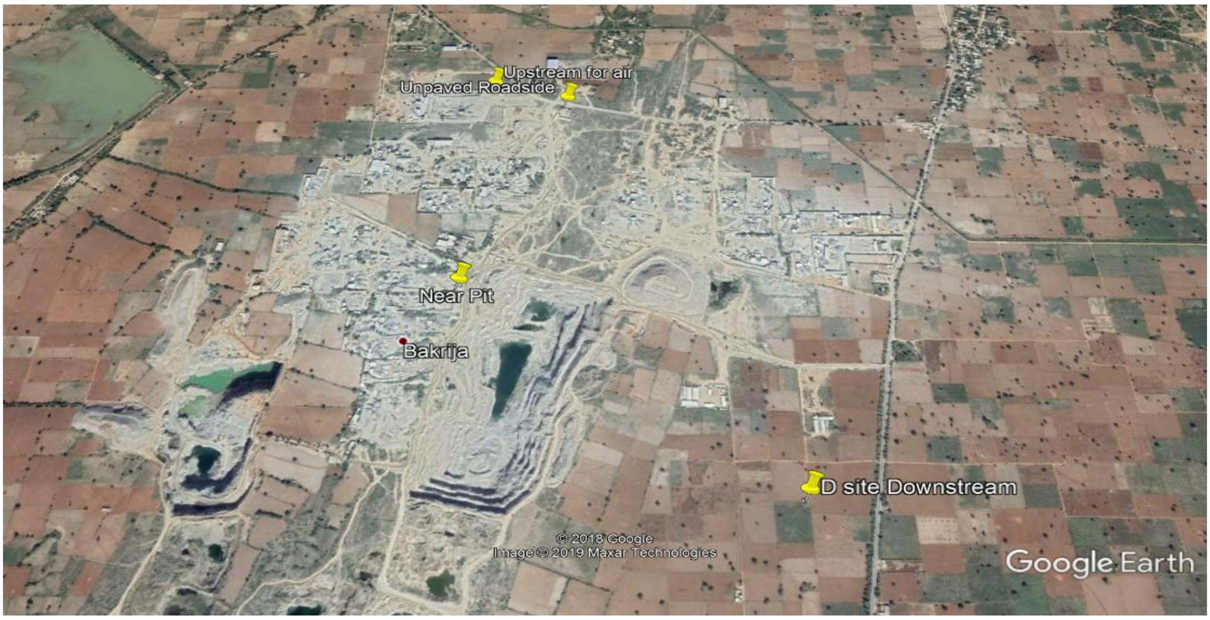


Fig. 3.6 Sampling locations of vegetation around Bakhrija mines

3.15.1 Collection of samples

Leaves samples were collected from four identified locations (Fig.3.6) namely the crushing zone (C), the mine/pit (M), on the upwind side of the mine (U), and along the roadside areas (R). The plant species sampled belonged to *Azadirachta indica* (Neem), *Syzygium cumin* (Jamun), *Millettia pinnata (Karanja)*, *Dalberga sissoo* (Sheesham), *Albizia lebeck* (Siras), *Ficus benghalensis* (Bargad) *and Melia azedarach* (Bakain). Representative samples of mature leaves were collected and stored in clear zip lock bags at 4°C and sent to the laboratory.

3.15.2 pH

The leaves samples were subjected to physical and biochemical analysis for determining the pH of the cell sap, Relative Water Content (RWC), Chlorophyll concentration (TCh), and Ascorbic Acid (AA) concentration as per the standard methods. Fresh mature leaves were plucked, and 0.5 grams of weighed leaves were ground and homogenized in 10 ml of deionized water. The extract was centrifuged at 5000 rpm for 10 minutes. The supernatant obtained was used to measure the pH with a digital pH meter (Labman scientific instrument, LMMP 30). The pH of the leaf extract was determined by the method.

3.15.3 Relative Water Content (RWC)

The fresh weight (FW) of the samples was noted, and leaf samples were then immersed in water overnight before being blotted down dry and noting down the turgid weight (TW). The samples were then dried in a hot air oven overnight at 70°C and the dry weight (DW) of the same was noted to calculate the RWC.

3.15.4 Total Chlorophyll

The Total Chlorophyll content (*TCh*) was carried out during the present study. 500 mg of representative samples were blended followed by its extraction with 10 ml of 80 percent acetone. The leaf samples were taken, and centrifuged at 5000 rpm for 10 minutes. The optical density of the supernatant was determined with the help of a Visible Spectrophotometer at 645 and 663 nm for chlorophyll a and b, respectively. The concentration of TCh was calculated as follows:

$$TCh = 20.2\ (\text{O.D } 645) + 8.02\ (\text{O.D } 663) \qquad (23)$$

$$Chlorophyll\ `a' \text{ (mg/g)} = \{12.3 * \text{O.D } 663 - 0.86 * \text{O.D } 645\}/1000 * W * \text{V} \qquad (24)$$

$$Chlorophyll\ `b' \text{ (mg/g)} = \{19.3 * \text{O.D } 645 - 3.6 * \text{O.D } 663\}/\ 1000 * W * \text{V} \qquad (25)$$

Where, O.D 645 = optical density at 645 nm; O.D 663nm = Optical density at 663nm; V = Final volume of leaf extract; W = Dry weight of leaf.

3.15.5 Ascorbic Acid

Ascorbic Acid Content (mg/g) was determined using the method in which 2.5 g of fresh leaves were weighed and ground in a mortar and pestle. To the mixture, 30 ml of 0.03M H_2SO_4, 20 ml distilled water, and 0.5 g Oxalic acid was added. The mixture was stirred for about 20 minutes in a shaker and immediately centrifuged at 5000 rpm for 10 minutes to obtain the leaf extract. Titration of the supernatant was carried out against 0.001 N Iodine solution using 5 % starch as an indicator.

$$\text{AAC (mg/L)} = N * V * EW\ /Volume\ of\ extract \qquad (26)$$

$$\text{AAC (mg/L)} = \{\text{AAC (mg/L)} * 1000\}/1000 \qquad (27)$$

Where, N = Normality of titrant; V = Volume of sample (ml); Volume of extract in ml; E W is equivalent weight of Ascorbic Acid.

3.15.6 Calculation of APTI and API

Air pollution tolerance index (APTI) was performed to assess the tolerance of the plants against pollution. The mathematical expression is as follows:

$$APTI = [(T + P) + R]/10 \qquad (28)$$

The ascorbic acid content in mg g-1 of fresh weight; T is the Total Chlorophyll Content in mg/g of fresh weight; P is the pH of the leaf extract and R is the Relative Water Content (RWC) in percentage. The classification (Table. 3.7) of plants based on APTI is done using the criteria as given below.

Table. 3.7 Classification of plants based on APTI

Category Criterion for Assessment	Range	Category Criterion for Assessment
Tolerant	45-100	APTI > Mean APTI + SD
Moderately Tolerant Mean	30-44	Mean API < APTI < Mean APTI + SD
Intermediate Mean	17-29	APTI – SD < APTI < Mean APTI
Sensitive	1-16	APTI < Mean APTI – SD

3.15.7 Anticipated Performance Index (API)

The APTI values are limited to biochemical parameters whereas the API is a more useful tool when it comes to air pollution reduction and other ecological and economic services as well offered by the plant species since it is based on relevant biological and socio – economic characters such as the plant habit, canopy structure, type of plant, laminar structure and economic values. Based on the criteria (Table 3.8), the plants are assigned different grades (+ or -), therefore helping in categorizing the plants according to their performance. Thus, with the help of obtained assessment and category, suitable plants can be recommended for developing a more reliable green belt to attenuate the pollution level. With the evidence and criteria given above, the proof of APTI as a valuable indicator of fluctuations in air quality can be revealed. The biochemical composition of plants is influenced by unique characteristics of mining activities. APTI values of regionally typical plant species, as plant tolerance levels adjusted to a specific environment, were used to calculate different pollution levels in crushers, roadside upwind, at pit, and downwind.

Table: 3.8 Gradation of plant species based on air pollution tolerance index (APTI) twinned with biological parameters and socioeconomic importance.

Grading character			Pattern of assessment	Grade allotted
a)	**Tolerance (APTI)**		0 – 9.1	+
			9.1 – 18.0	++
			18.1 – 27.0	+++
			27.1 – 36.0	++++
			36.1 – 45.0	+++++
b)	**Biological and Socio-Economic**			
	i.	**Plant Habit**	Small	-
			Medium	+
			Large	++
	ii.	**Canopy structure**	Sparse/Irregular/Globular -	-
			Spreading crown /open/semi dense	+
			Spreading dense	++
	iii.	**Type of plant**	Deciduous	+
			Evergreen	++
	iv.	**Laminar structure**	Small	-
		Size	Medium	+
			Large	-
		Texture	smooth	+
			Curvaceous	++
		Hardiness	Delineate -	-
			Hardy	+
	v.	**Economic Value**	Less than three uses	-
			Three or more uses	+
			Five or more uses	++

Maximum grades that can be scored by a plant = 16

Table. 3.9 Classification of tree species contrary to API

Grade	Score (%)	Assessment category
0	Up to 30	Not recommended
1	31 – 40	Very poor
2	41 – 50	Poor
3	51 – 60	Moderate
4	61 – 70	Good
5	71 – 80	Very good
6	81 – 90	Excellent
7	91 – 100	Best

On the basis of API score, grade and category (Table 3.9) the species of plant will be suggested in the region of mining. Which have good tolerance level to curb the pollution level.

3.16 GIS – Geographical information system for spatial distribution

A computer-based tool known as a GIS was used to store, analyse, control, and display geographic information, usually on a map. GIS, in general, is a computer program used to store geographic data. Manage, analyse, and display this information as spatial data. Data that has positional x, and y coordinates is referred to as spatial data. GIS uses digital maps to represent our world. Recent years have seen a rise in the usage of geographic information systems (GIS) in several fields that need the analysis and administration of geographical data. Environmental data management is one of the key GIS applications. To prevent a potential environmental disaster, it may be utilized in a variety of scenarios for the spatial distribution of the data and to forecast future trends of the data. To determine the extent, origins, and causes of environmental contamination and to determine how many pollutions there are, geospatial data mining can be employed.

In the current work, QGIS- open source software is used to analyse the quality of water and concentration of air with the plugin of Inverse distance-weighted (IDW). IDW data is used in vector data which is collected from the field during sampling or processed in the lab. Using the spatial analysis module of QGIS, inverse distance-weighted interpolation of the chemical data was carried out (version 3.10). IDW method interpolation was the interpolation method employed in the analysis. The World Health Organization and the Bureau of Indian Guidelines' standards for the quality of drinking water were used to evaluate the outcomes at the end (WHO 2004; BIS 2012). Using QGIS 3.10 software, the Bhuvan and Survey of India toposheets were used to digitize the base map for the Bakhrija mine. The sample sites were precisely found using a GPS device (Garmin eTrex 30) and uploaded into a GIS platform. To model the space and determine the spatial distribution, the inverse distance-weighted (IDW) approach was utilized as an interpolation technique. A vector data model or a raster data model controls the spatial data in a GIS. Using geographic points, the vector data model creates spatial elements such as lines, points, and regions. The spatial characteristics are created by the raster data model utilizing grid cells that are arranged in rows and columns.

3.17 MODFLOW simulation

In this study, a groundwater model was created using numerical groundwater modelling techniques. MODFLOW is used to simulate the steady and nonsteady flow in the aquifer which can be confined and unconfined. All the hydrological data is taken form CGWB, 2018 year book of Haryana. Based on that, hydrological setting of the region and the available field derived characteristics, conceptual models were developed. The USGS (MODFLOW, PHAST, and SUTRA) groundwater packages' graphical user interface, ModelMuse 3.5.1, was utilized for groundwater simulation. The first stage in the groundwater modelling process is to create a database for the model. The information is gathered from multiple primary and secondary sources, formatted according to specifications, and utilized as input for groundwater models. In a GIS context, the acquired data are processed. The database created in this way contains data on a variety of well characteristics, including soil type, hydraulic heads, daily rainfall, geology, geomorphology, specific storage, hydraulic conductivity, and well output. The information was gathered from sources including Bhuvan, maps from the Geological Survey of India (GSI), the Central Groundwater Board's annual report, and others. Each parameter's scale and units are changed to fit the needs of the model. Modflow is used to understand the regional flow of ground water.

CHAPTER 4

RESULTS AND DISCUSSION

Quarrying activities have negative environmental effects on the air, water, and land, Mining-related activities and result in land degradation, land subsidence, landslides, and noise pollution also affect miners and workers occupationally and results in health issues. Quarrying activities have the potential to negatively affects pre-existing ecosystems, ambient air quality, hydrogeological patterns, and hydrological regimes. These negative effect of stone quarrying result in poor air and water quality, groundwater depletion, the loss of nutrient-rich topsoil, the degradation of forests, loss of aquatic biodiversity, flora, and a affect impact on public health.

4.1 Effect of stone quarrying on environment

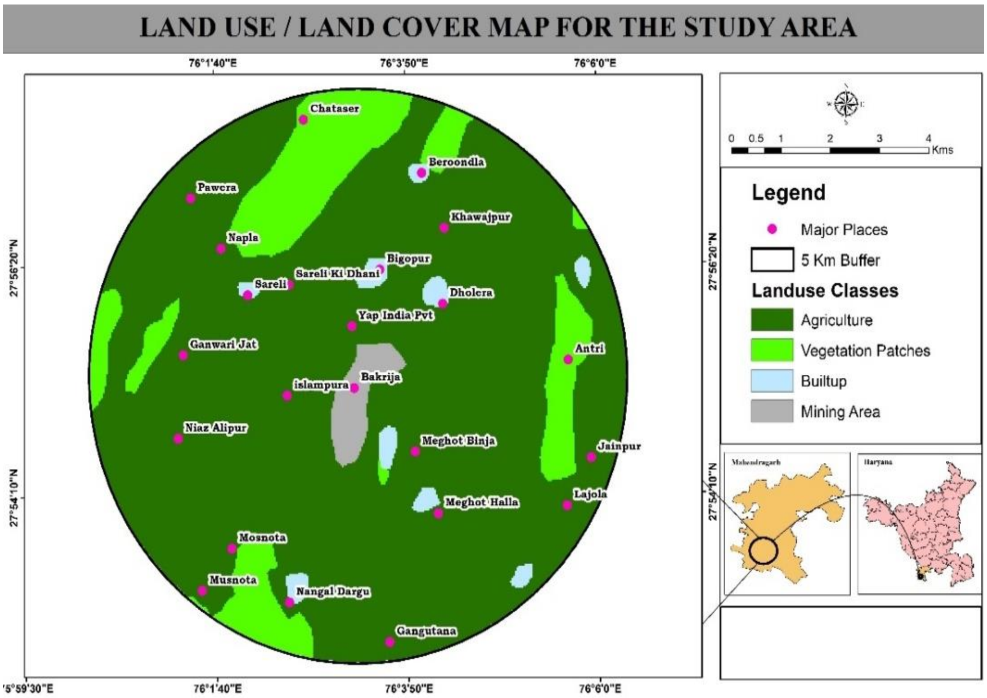
Quarrying operations contribute a high volume of particulate matter in ambient air through crushing, blasting, excavation, and transportation of raw material. These are the major sources of particulate matter emission in the air. Crushing and resuspension of particulate matter from roadside are the one of the prime sources which contribute to fugitive dust in the surrounding of quarrying region. Mining activities affect the source of water, deplete the groundwater table, degrade the quality of surface and subsurface water, and it also disturbs the hydrological regime pattern around the mining region. Parameters of water quality exceed the desirable range of IS-10500, whereas in air pollution the concentration of PM_{10} and $PM_{2.5}$ surpasses the limits of daily concentration NAAQS in the study area. Air and water sectors are affected by mining activities and other anthropogenic activities. Data of LULC are used to analyze the impact through anthropogenic and mining activities. Bakhrija is surrounded by agricultural land and this region is known for its Kharif and Rabi harvest as well as cash crops-such as vegetable and fruits. The fugitive dust and poor water quality is gradually affecting the yield as well as the soil carbon around the quarrying region. Settled dust on vegetation also affect growth and yield of the crops.

As per the studies, EMP is suggested to restrict or minimise the impact of quarrying on air, water, soil, and vegetation. A good plan may help to minimise the impact of pollutants on settlements near the quarrying region. The analysis of APTI help to suggest the tolerant species of vegetation which can handle the particulate matter pollution and it will also help to make the green cover around the mining region which will help in minimising the particulate matter concentration.

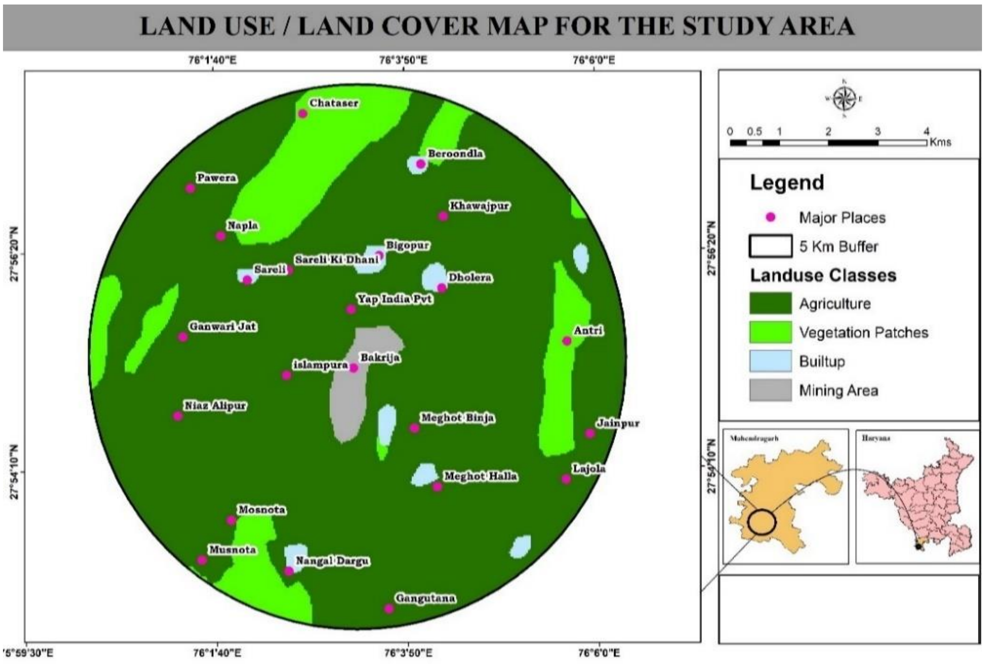
4.1.1 Effect of quarrying on Land use and Land cover

Decadal Land use/land cover (LU/LC) change analysis around Bakhrija Mines

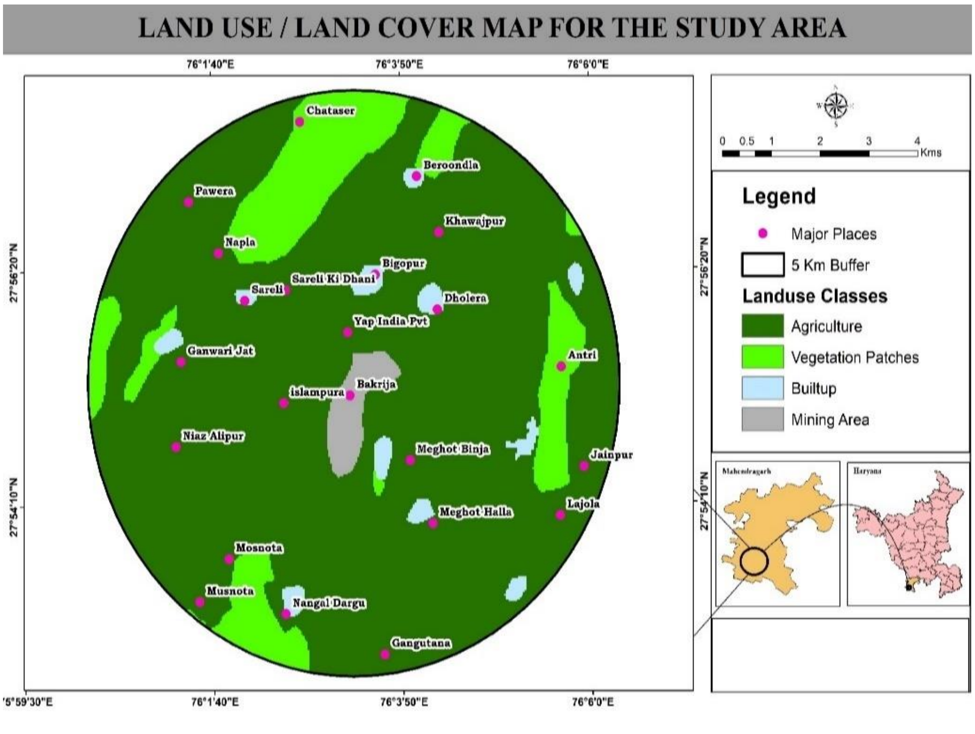
Based on the land use/land cover maps generated for the two decades utilizing multi-date satellite imagery from 2000 to 2020, the conclusions listed below have been drawn. The table shows how different land use and land cover map classifications were distributed in the research region in 2000, 2010, and 2020. Fig. 4.1 (a-c) presents a map of land use and land cover depicting the extent and spatial distribution of various land use and land cover classes. Land cover classes are mapped using remote sensing and GIS techniques, and temporal changes in each class between 2000 and 2020 were computed (Table 4.1). Results indicate that due to surface mining operations, there have been significant changes in land cover over the past few decades. The area of sandstone quarries was 138.06 ha (1.76%) in the year 2000; this number climbed to 138.1 ha (1.80%) in the following two decades, 2010 and 2020. In a period of 20 years, the extent of vegetation patches changed from 13.4 ha (13.1%) to 13.2 ha (13.2%). This indicates that between 2000 and 2020, there was a (-) 0.1 % change in the overall vegetation patches. On the other hand, it is evident from field surveys that the change in the water area is related to mining activities since the abandoned mine pits are filled with water.



(a) 2000



(b) 2010



(c) 2020

Fig : 4.1 5KM radius LU/LC classes map of Bakhrija mines(a-c)

Table: 4.1 The status of LULC around Bakhrija mine from 2000 to 2020 (5km)

	2000			**2010**			**2020**			**Change in area (%)**
Landuse Classes	**Area(m^2)**	**Area(Ha)**	**Percentage**	**Area(m^2)**	**Area(Ha)**	**Percentage**	**Area(m^2)**	**Area(Ha)**	**Percentage**	
Agriculture	65219400	6521.94	83.2	65205900	6520.6	83.13	64953900	6495.4	82.8	- 0.7
Vegetation Patches	10433700	1043.4	13.4	10412100	1041.2	13.3	10352700	1035.3	13.2	- 0.1
Built-Up	1420200	142.02	1.81	1420200	142.0	1.8	1758600	175.9	2.2	+ 0.4
Mining Area	1380600	138.06	1.76	1380600	138.1	1.8	1380600	138.1	1.8	+ 0.04
Total	78453900	**7845.4**	**100**	78453900	**7845.4**	**100**	78453900	**7845.4**	**100**	

These important findings demonstrate that the study region is still being impacted by human activity and that the majority of the land there is being used for agriculture while still being degraded by mining. Excavating open pits and dumping overburdened rock mass in the shape of heaps, topography and the landscape are altered. Due to the usage of the land for mining, dumping, and other mining and related operations, the land-use pattern changes. The effects of mining on the water regime may have an impact on how the land is used in the surrounding areas because the mining project does not require the relocation of habitat or the appropriation of agricultural land, the impact of mining on the social demographic profile is favourable.

4.2 Effect of mining activities on air quality

The problem of air pollution and its consequences on air quality had been acknowledged for a long time. Particulate matter and gases are the two main states through which contaminants enter the atmosphere due to this local air quality may become uncertain due to the ongoing mixing, transformation, and transboundary movement of air contaminants. To assess the state of the air and prepare necessary control measures, sampling stations were set up. The sampling in mining regions (core zone) was done in the year 2019, in June and February 2022. The findings revealed that different operations in mining/quarrying have been responsible for the generation of fine particles. The concentration of PM_{10} and $PM_{2.5}$ significantly varied seasonally. The concentration was relatively higher in February for both the forms of particulate matter, and lower in June at all the locations. The concentration of $PM_{2.5}$ and PM_{10} recorded at different locations at the Bakhrija stone quarry is given in Table 4.2. In June 2019, the concentrations of $PM_{2.5}$ ranged between 2 to 921 $\mu g/m^3$ and there was a notable variation based on location and activity. The average concentration of $PM_{2.5}$ recorded upwind of crusher was 3 $\mu g/m^3$. The maximum concentration of 921 $\mu g/m^3$ was recorded at the roadside (haul road) of the study area, which may be due to re-suspension of the dust due to vehicular movement on the unpaved road. At the mine pit, concentration of PM_{10} was 224 $\mu g/m^3$ and at the downwind location it was 43 $\mu g/m^3$. PM_{10} concentration was higher than $PM_{2.5}$ at all the locations, it was significantly higher in the fraction at the stone-crushing site thus, indicating that crushing activity is primarily responsible for the generation and emission of fine dust at stone quarrying in Bakhrija, Mahendragarh. The PM_{10} concentrations for all stations ranged from 2 to 3359 $\mu g/m^3$. The significant difference in PM_{10} concentrations was observed at different locations, with the highest concentrations of 3359 $\mu g/m^3$ recorded at road side followed by the crusher (when operational) with level of 484 $\mu g/m^3$.

Table 4.2 Concentration of the particulate matter at different location of Bakhrija stone quarrying, Mahendragarh (June 2019)

S. No.	Location	Size	Concentration (µg/m^3)			PM Ratio ($PM_{2.5}/PM_{10}$)
			Minimum	Maximum	Mean ± SD	
1	**Upwind** (Near Crusher)	$PM_{2.5}$	2	6	3.1 ± 1.8	1
		PM_{10}	3	7	3.2 ±1.81	
2	**Crusher** (Crushing only)	$PM_{2.5}$	8	348	64.0 ±91.1	0.71
		PM_{10}	10	484	90.2 ± 121.9	
3	**Mine Pit** (Drilling, Blasting & loading)	$PM_{2.5}$	10	221	53.0 ± 43.8	0.52
		PM_{10}	12	224	62.1 ± 54.1	
4	**Road side** (Transportation and vehicular movement)	$PM_{2.5}$	2	921	182.3 ± 215.6	0.85
		PM_{10}	6	3359	353.2 ± 559.1	
5	**Downwind** (No activity)	$PM_{2.5}$	2	43	8.1 ±10.7	0.13
		PM_{10}	40	103	61.1 ± 14.9	

The mean PM concentrations in the February 2022 (Table 4.3) at the upwind location were observed as 65.39 µg/m^3 for PM_{10} and of 43.2 µg/m^3 for $PM_{2.5.}$ At the mining pit, because of blasting, drilling and other pit activities, the maximum $PM_{2.5}$ concentration was 315 µg/m^3, and PM_{10} was 837 µg/m^3, crusher emitted maximum fugitive dust into the air and the maximum concentration recorded for PM_{10} was 8129 µg/m^3 and $PM_{2.5}$ 1506 µg/m^3, at crushing site. The concentration along the roadside fluctuates because of the scheduled spraying of water on the roadside restricting the resuspension of fugitive dust due to heavy vehicular movement. The maximum concentration of PM_{10} and $PM_{2.5}$ recorded at the roadside is 2929 and 551 µg/m^3. The observed average concentration range of PM_{10} was 411 µg/m^3 and $PM_{2.5}$ was 202 µg/m$^{3.}$ PM_{10} and $PM_{2.5}$ concentrations are way higher in the core mining area from the upwind sampling site. With prevailing wind, PM concentration follows decreasing trends with distance and time. At the crushing site mean PM_{10} concentration was observed 80 times higher than the values threshold value set by NAAQS (2009) which is 100 µg/m^3 for 24-h average and Approximately 50-52 times higher as per the NAAQS of US which is 150 µg/m^3 for 24-h average.

Table 4.3 Concentration of the particulate matter at different location of Bakhrija stone quarrying, Mahendragarh (February 2022)

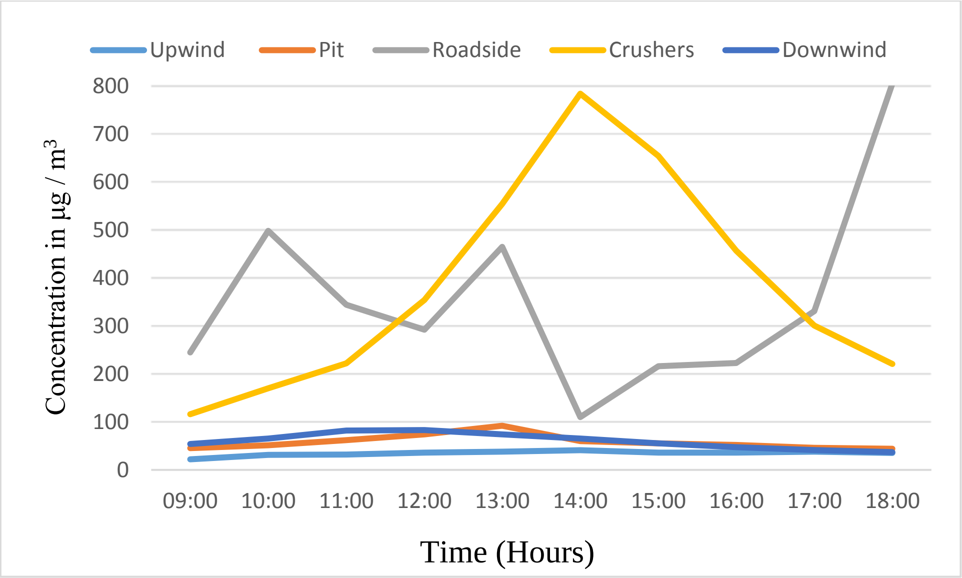
S. No.	Location	Size	Concentration (µg/m^3)			PM Ratio ($PM_{2.5}/PM_{10}$)
			Minimum	Maximum	Mean ± SD	
1	**Upwind** (Near Crusher)	$PM_{2.5}$	23.6	75.2	43.2 ± 14.8	0.65
		PM_{10}	33.1	98.6	65.3 ± 17.5	
2	**Crusher** (Crushing only)	$PM_{2.5}$	38.5	1506.2	342.2 ± 279.8	0.33
		PM_{10}	80.3	8129	1232.1 ± 1213.3	
3	**Mine Pit** (Drilling, Blasting & loading)	$PM_{2.5}$	16	315	81.0 ± 38.6	0.51
		PM_{10}	84.2	837.3	188.4 ± 143	
4	**Road side** (Transportation and vehicular movement)	$PM_{2.5}$	32	551	202.1 ± 269.4	0.49
		PM_{10}	68	2929	411.2 ± 661.3	
5	**Downwind** (No activity)	$PM_{2.5}$	40.2	60.1	48.8 ± 3.9	0.75
		PM_{10}	52.6	94.7	65.3 ± 9.8	

The ratio of $PM_{2.5}$ to PM_{10} concentrations reveals the relative contribution of various sources of particulate matter in the air. $PM_{2.5}$ to PM_{10} particles are typically emitted by quarrying activity. A ratio of 1, indicates a higher concentration of finer particles in the ambient air which is observed in June at specific sources, especially near the roadside and crushers, and in downwind locations in the February. Exposure to fine particles at stated locations will also affect human health. The $PM_{2.5}/PM_{10}$ ratio can change depending on the source of the pollutants and other environmental factors. In general, the ratio is higher near of the quarrying region. It is important to note that the $PM_{2.5}/PM_{10}$ ratio cannot provide a complete picture of the sources of particulate matter in the air or the health risks associated with exposure. Other factors, such as particle chemical composition, particle size distribution, and exposure duration, all contribute to the health effects of particulate matter. Regardless of the $PM_{2.5}$ to PM_{10} ratio, it is critical to limit particulate matter exposure as much as possible. The findings of the current study show that mining and related activities are responsible for the emission of particulate matter that has a range of respirable sizes and may have detrimental effects on health. Both of these particulate matter sizes are hazardous to human health because they can be inhaled deep into the lungs and can cause respiratory and cardiovascular issues.

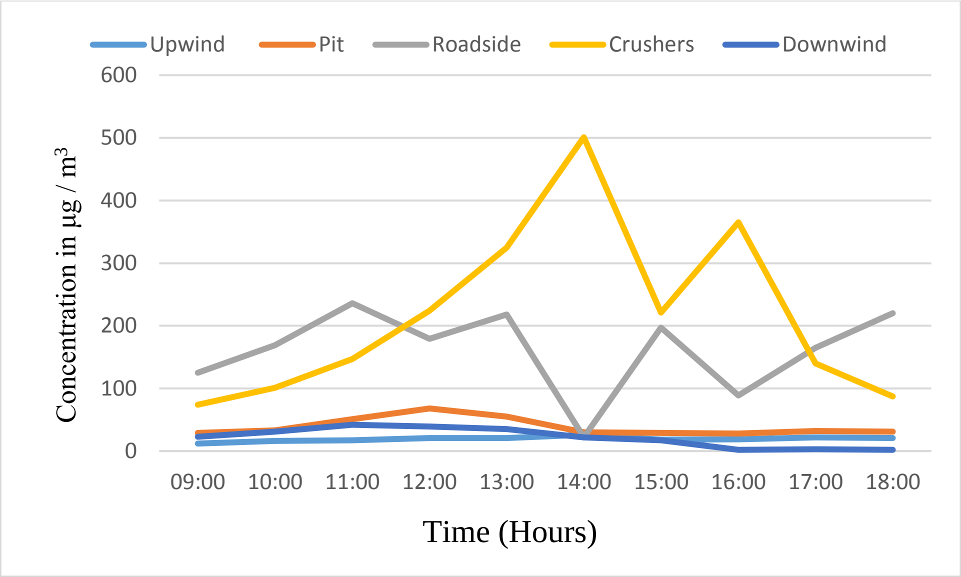
4.2.1 Diurnal variation of $PM_{2.5}$ and PM_{10}

Summer season

The data collected on particulate matter was expressed for 9 hours during the daytime (9AM to 6PM) to overlap the period of operation at the site to determine trends in the hourly fluctuation of particulate matter, understand the causes of pollution and to suggest mitigation. As per the obtained data, it was observed that from roadside and crushing locations, higher fluctuation is there in the summer season. While at other locations concentration of PM_{10} was lower than average daily concertation as per NAAQS (2009). The concentration of PM_{10} and $PM_{2.5}$ on the road side ((Fig.4.2 (a-b)) going up morning to again in afternoon (between 9 AM to 2 PM) when heavy vehicles carrying raw material to the crushers and taking back the aggregate size stone from the crushers or moving out from the mining region. Increasing concentration of PM from crushers starting from 9AM is observed, then attaining peak at 2PM and going down to minimum concentration of the day by 6PM, when it is operating for longer uninterrupted duration. The haul road also shows lots of fluctuation when a series of trucks pass through. Comparison of particulate matter concentration of winter and summer seasons show differences in upwind and downwind locations. This may happen because of meteorological conditions.



(a) PM_{10}

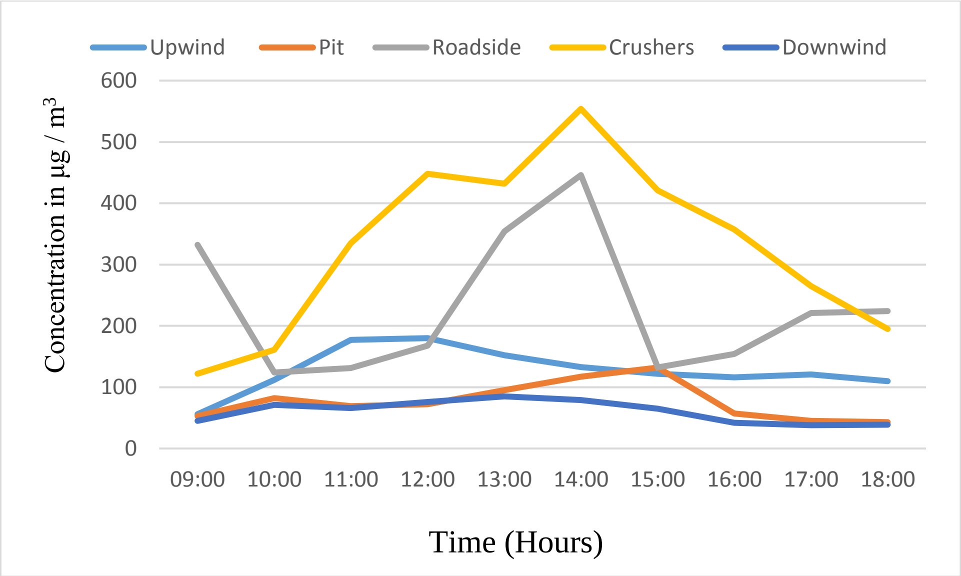


(b) $PM_{2.5}$

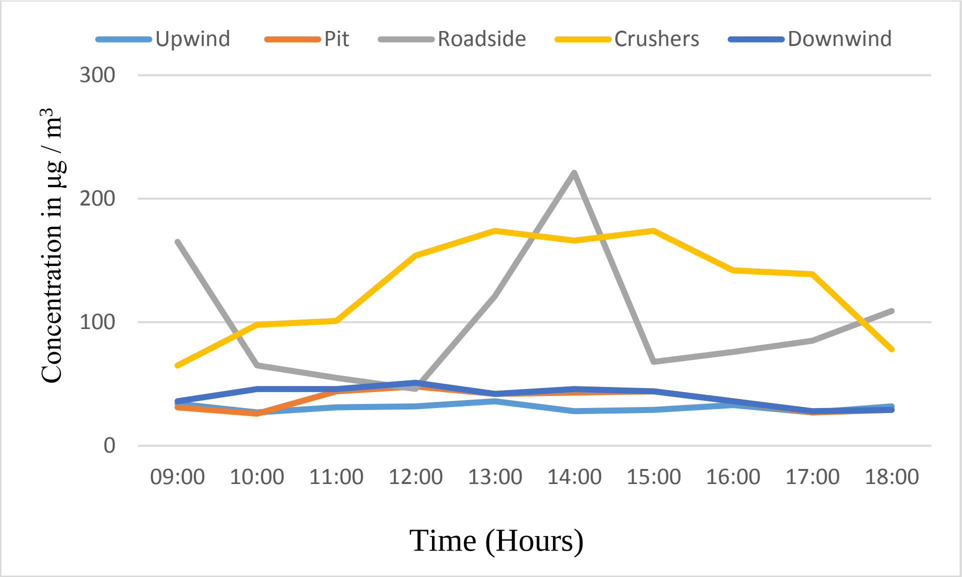
Fig.4.2 Diurnal variation of particulate matter (a-b) summer season

Winter Season

In mining region at the roadside and crushers ((Fig 4.3 (a-b)) show similar trends as were in the summer season. Higher concentration were observed at roadside location and crushing site, and observation shows fluctuation (12 PM to 3PM) because of regular interval sprinkling of water on the haul road, which minimizes the resuspension of dust into the ambient air. In the winter season, a condition known as a temperature inversion can cause cold air to be held close to the ground. Operation of crusher started at 10AM and concertation of particulate matter stated increasing attaining the highest point between 2PM to 3PM and then gradually goes down to minimum at 6PM.



(a) PM_{10}



(b) $PM_{2.5}$

Fig.4.3 Diurnal variation of Particulate matter (a-b) winter season

This may increase PM emissions during this season, which can be suspended in the air for a longer time but settle more quickly because of meteorological conditions. As a result, air layer that is stable is formed, preventing vertical mixing, which might cause PM to build up near the ground rather than dispersion. Another reason might be people use wood-burning stoves for space heating, which contribute to PM in the air.

Both the seasons exhibit significant concentration of particulate matter. Crusher and roadside location are responsible for emission of maximum dust in the ambient air around mining region. Increase PM emission can be seen in both season during morning hours when the crushing activities takes place with loading, unloading and transportation of raw material. In winter season atmospheric factor also plays a vital role in the dispersion and suspension of the particulate matter. In the winter season, when the temperature lowers, there may be less air turbulence and vertical mixing, which might lead to PM settling more quickly. Because cooler air is denser and heavier than warmer air, PM particles may settle closer to the ground as a result. The behaviour of PM may be influenced by a variety of factors, of which the most dominant is temperature. The behaviour of PM in the atmosphere can also be influenced by other elements, including wind speed, humidity, and the size and makeup of the particles. The behaviour of PM can also be complicated and can change based on the precise source of the particles as well as the local meteorological conditions. During the summer season, high temperatures and low humidity can promote evaporation and make PM particles lighter, allowing them to be suspended in the air with greater ease. On the other hand, cold and high humidity levels can make PM particles heavier and settle closer to the earth. PM particles can accumulate and stay concentrated in one place when the atmosphere is steady and there is no turbulence or mixing. PM particles may, however, be more easily dissipated when the atmosphere is more unstable, with more mixing and turbulence. The dispersion and suspension of PM particles in the air can be influenced by a complex interaction of meteorological conditions. For forecasting and reducing the effects of PM pollution on both human health and the ecosystem, it is critical to comprehend these elements.

4.2.2 Spatial distribution of PM

The IDW approach was evaluated in this study for predicting PM values at sampled locations during the study region. Interpolation is based on estimating the unknown value from known values (Sampling location data) that mimic site data with distance at every interpolation point. On the other hand, the interpolation depends on minimum error factors, to overcome this error smoothing of data is done. The IDW approach was evaluated in this study for predicting PM values at sampled locations in the study region. For the research period and to examine concentration of PM for the research period the spatial distribution maps were created using the IDW model. Figure no. 4.4 (a & b) shows the spatial distributions of particulate matter concentrations.

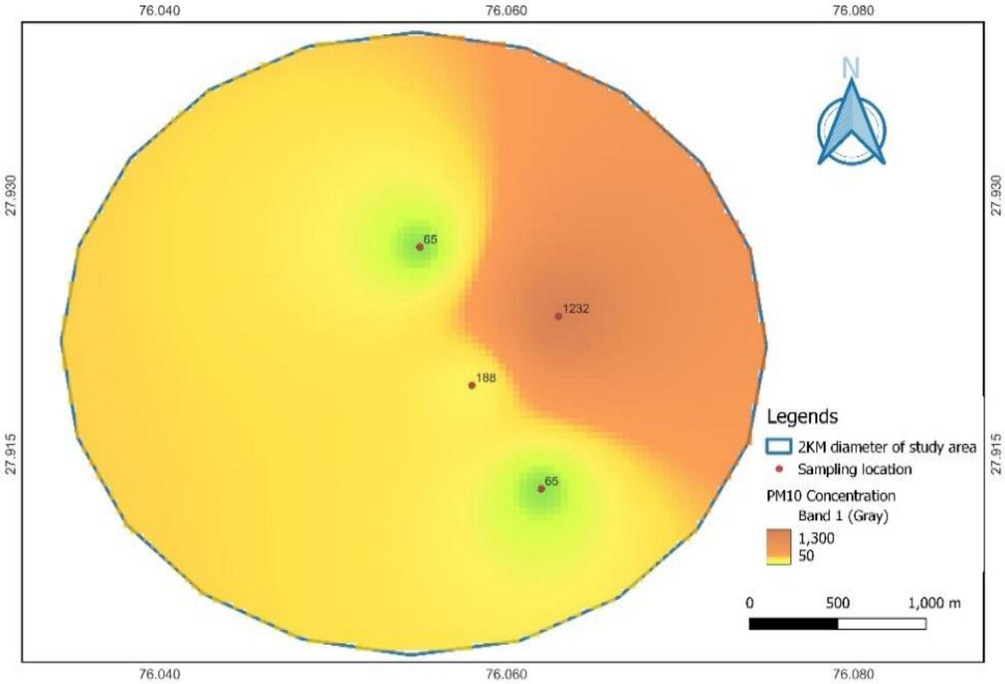


Figure 4.4 Possible dispersion pattern and sources of particulate matter (a) PM_{10}

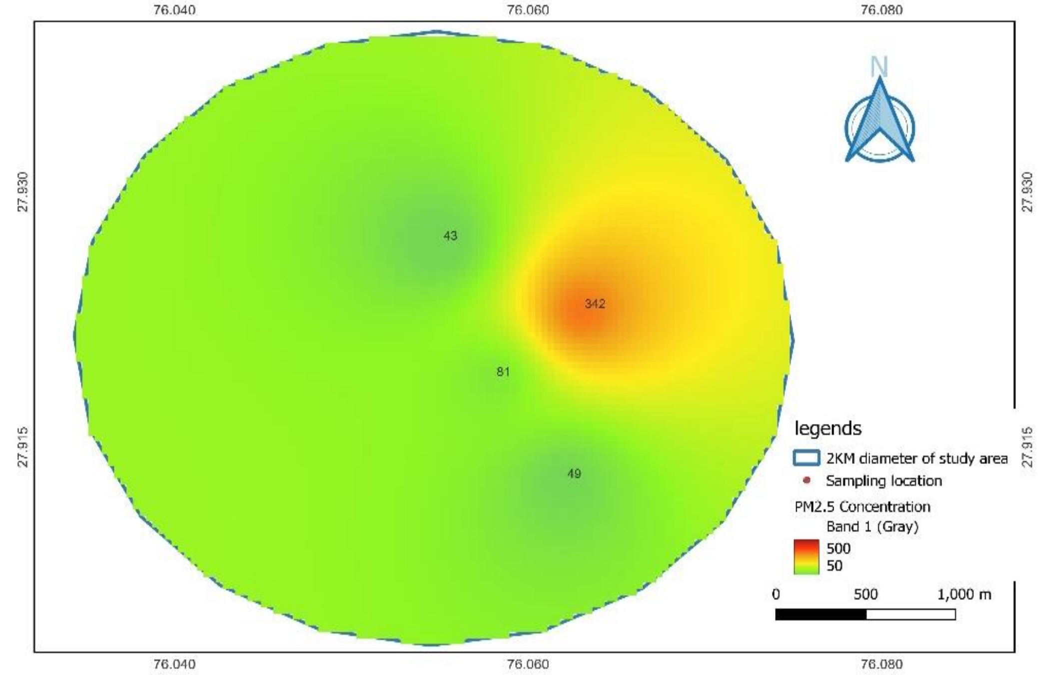


Figure 4.4 Possible dispersion pattern and sources of particulate matter (b) $PM_{2.5}$

Because of the meteorological conditions, the spatial distributions of PM_{10} and $PM_{2.5}$ concentrations do not exhibit consistent patterns of dispersion, (Fig 4.4) it also shows that the mean PM_{10} and $PM_{2.5}$ concentrations in the study region surpassed the 24-hour average standard concentration of 100 $\mu g/m^3$, 60 $\mu g/m^3$ respectively (CPCB 2014). The images represent the major points of particulate matter emission into the air which were mine pit, crushing unit, and haul road. The IDW technique is used to predict the value of unknown locations, and to determine impact of particulate matter on the population adjacent to the mining area.

4.2.3 Spatial and temporal distribution of $PM_{2.5}$ and PM_{10}

Box and Whisker plots were used to display the distribution of the data at each study location in terms of the median, lowest, and maximum values as well as the lower and upper quartiles. This was done to show how the concentrations of air pollutants vary. Using these five limits, the Box plot effectively provides a brief sketch of the distribution of the underlying data.

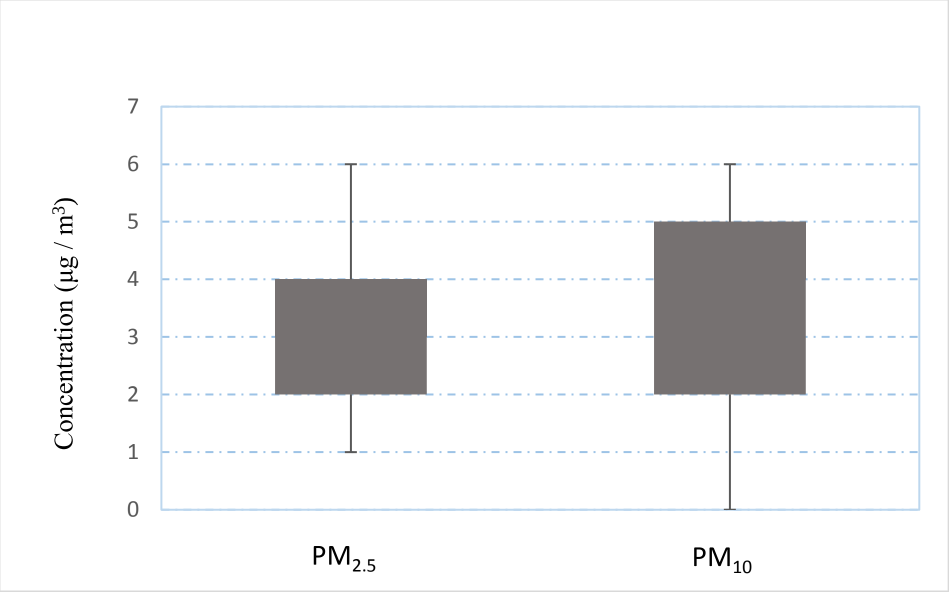


Fig.4.5 The plot of $PM_{2.5}$ and PM_{10} at Upwind (June 2019)

Upwind Plot (Fig.4.5) revealed that the concentration of $PM_{2.5}$ and PM_{10} both show almost the same result where the maximum values are lying between 2 µg/m^3 to 6 µg/m^3, which is safe as per NAAQS.

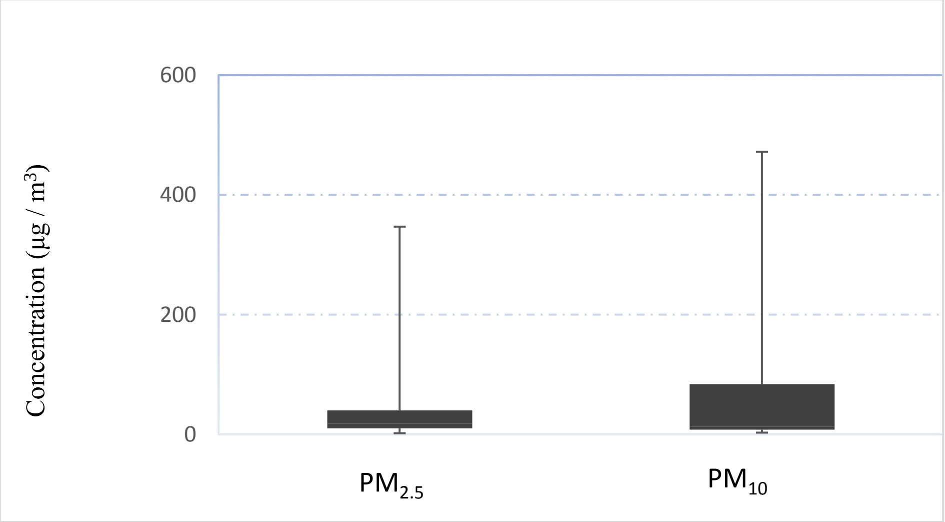


Fig.4.6 The concentration plot of $PM_{2.5}$ and PM_{10} at the crusher (June 2019)

At the crusher location, the average concentration of $PM_{2.5}$ and PM_{10} is less than 100 µg/m^3. As per the plot (Fig.4.6), around 35% of $PM_{2.5}$ observed data is falling under 50 µg/m^3, and about 45% of data of PM_{10} falls under 100 µg/m^3. The maximum values of $PM_{2.5}$ and PM_{10} are 348 and 484 µg/m^3, respectively.

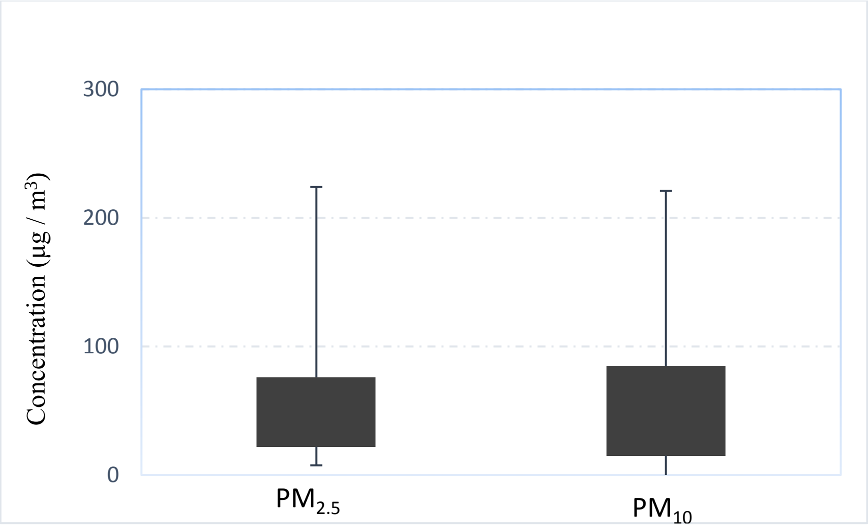


Fig.4.7 The concentration plot of $PM_{2.5}$ and PM_{10} at mine pit (June 2019)

Operations at mining pit like drilling, loading, and resuspension of dust due to operation of heavy vehicles etc. attribute to higher concentrations of $PM_{2.5}$ and PM_{10} (Fig.4.7). The average range of around 40% of values of $PM_{2.5}$ falls under 80 µg/m^3 and around 60% value of PM_{10} falls under 90 µg/m^3, maximum concentration for both the parameters recorded is more than 200 µg/m^3 during the observation.

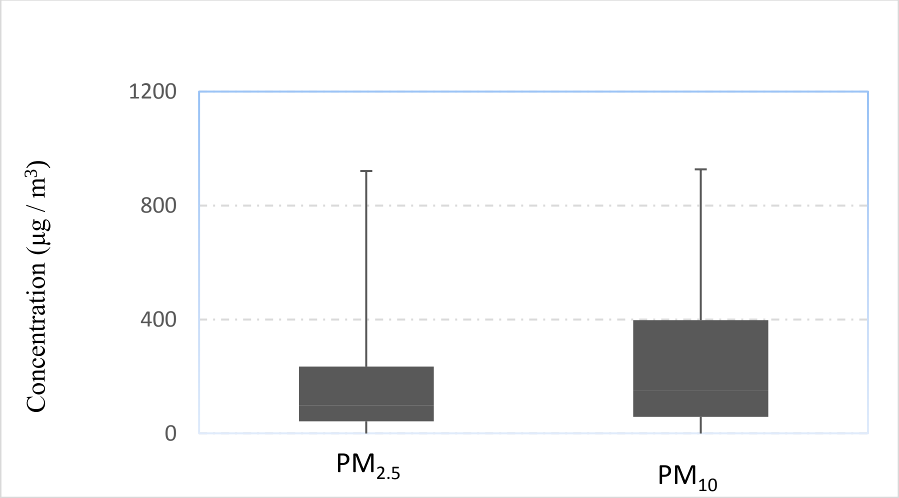


Fig.4.8 The concentration plot of $PM_{2.5}$ and PM_{10} at haul road (June 2019)

The haul road (Fig.4.8) had the highest concentration for $PM_{2.5}$ (921 µg/m^3), and PM_{10} (3359 µg/m^3). As per the plot, the average concentration of around 50% of observed data of $PM_{2.5}$ was under 200 µg/m^3 and 70% of PM_{10} was under 400 µg/m^3. Heavy vehicle movement is responsible for higher resuspension concentration at the road side.

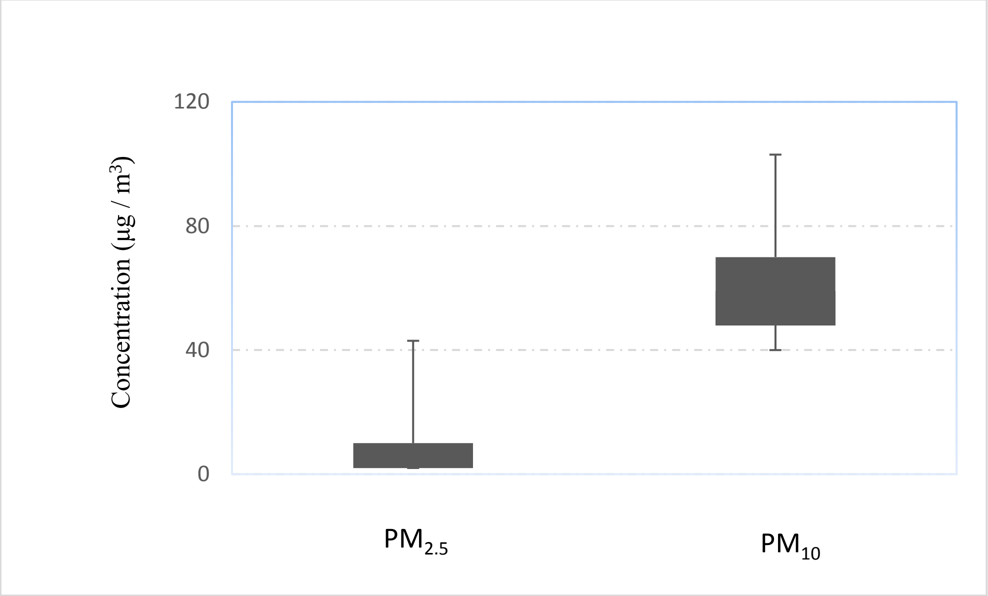


Fig.4.9 The concentration plot of $PM_{2.5}$ and PM_{10} at downwind (June 2019)

At downwind (Fig. 4.9) around 80% of the average $PM_{2.5}$ concentration was less than 10 µg/m^3, the maximum concentration of $PM_{2.5}$ was 43 µg/m^3, in the case of PM_{10} around 85% of observed data concentration falls below 70 µg/m^3, the maximum concentration at this location was 103 µg/m^3. Elevated concentration of PM_{10} may be because of depression by wind. Even though the concentration of PM_{10} was practically at par with or higher than that of $PM_{2.5}$ at all of the locations, it was significantly higher at the stone-crushing site, indicating that the crushing operation is primarily responsible for the production and emission of fine dust at Mahendragarh's stone quarries.

During February 2022, the trend of Particulate matter in both parameters changed drastically. Due to the meteorological condition, dispersion of particulate matter was not fluent. Due to meteorological factors, uninterrupted electricity supply, generator sets, and steps taken by mining industries to curb the pollution fluctuation in the concentration is observed around the mining region. Due to low temperature in the February month, the PM dispersion was not seen because of cold air that form temperature inversion in the atmosphere. In this condition, particulate matter movement is not easy. So the chances of dispersion to far distance is very less.

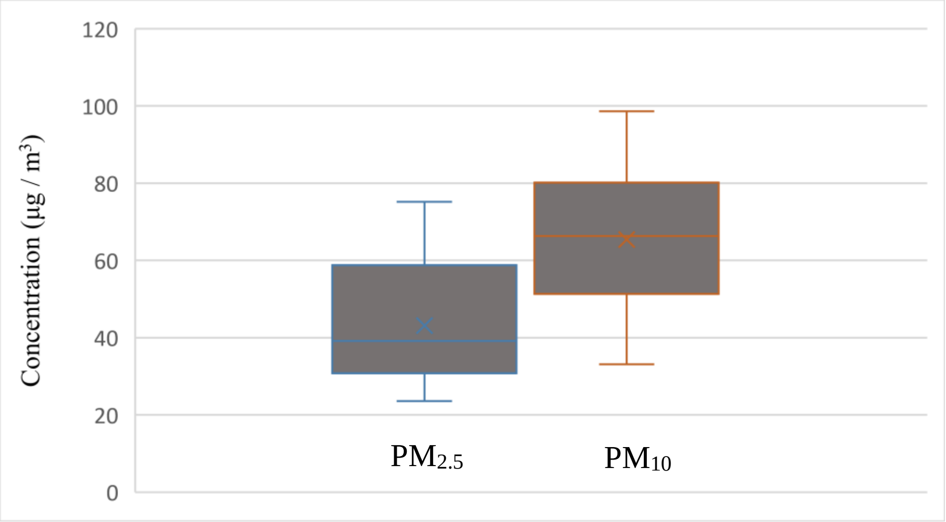


Fig.4.10 The concentration plot of $PM_{2.5}$ and PM_{10} at upwind location (February 2022)

On the other hand, during winter of 2022, the levels were higher at all the location. At the upwind location (Fig.4.10) the mean of $PM_{2.5}$ is recorded 43 µg/m^{3}and PM_{10} was 65 µg/m^3. The average concentration indicates 70% of $PM_{2.5}$ concentration under 30-60 µg/m^3 and 60 % of PM_{10} was under 50-80 µg/m^3. In June 2019 the upwind shows lower values of both parameters. In such cases local disturbance can be responsible due to meteorological conditions. Due to higher humidity and low temperature the particulate matter gets entrapped in the location and doesn't move easily. Burning bonfire is a regular practice in the rural region of India, during winter and it may be responsible for a higher average concentration in upwind location during February 2022.

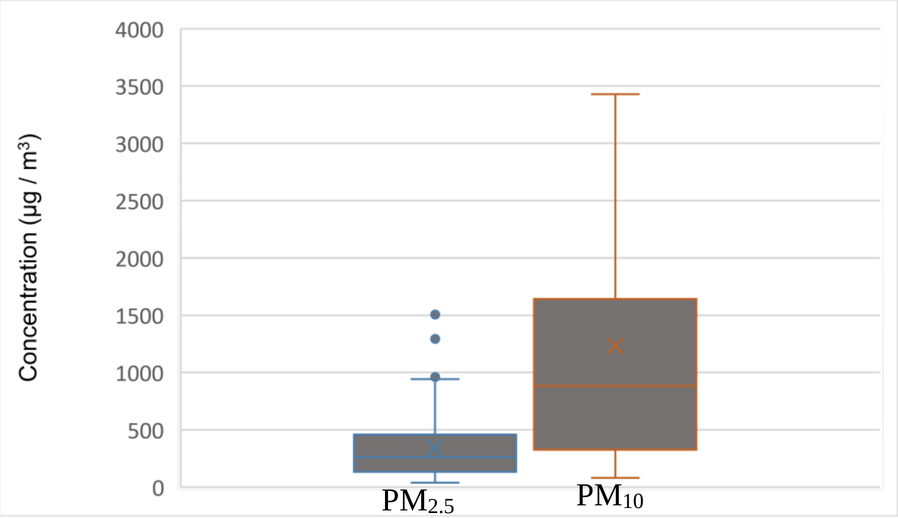


Fig.4.11 The concentration plot of $PM_{2.5}$ and PM_{10} at Crusher (February 2022)

The crusher location (Fig.4.11) had mean concentration higher than the NAAQS standard. The mean $PM_{2.5}$ concentration mean was 342 µg/m^3 and PM_{10} was 1232 µg/m^3. Crushers recorded the maximum concentration of particulate matter at all times. Around 75% of $PM_{2.5}$ is within the range of 100-490 µg/m^3, and for PM_{10}, around 90% of data falls in the range of 400-1600 µg/m3. At the crushing location loading and unloading of raw materials, movement of heavy and small vehicles, generator operation, and crushing activity contribute a huge amount of particulate to the atmosphere.

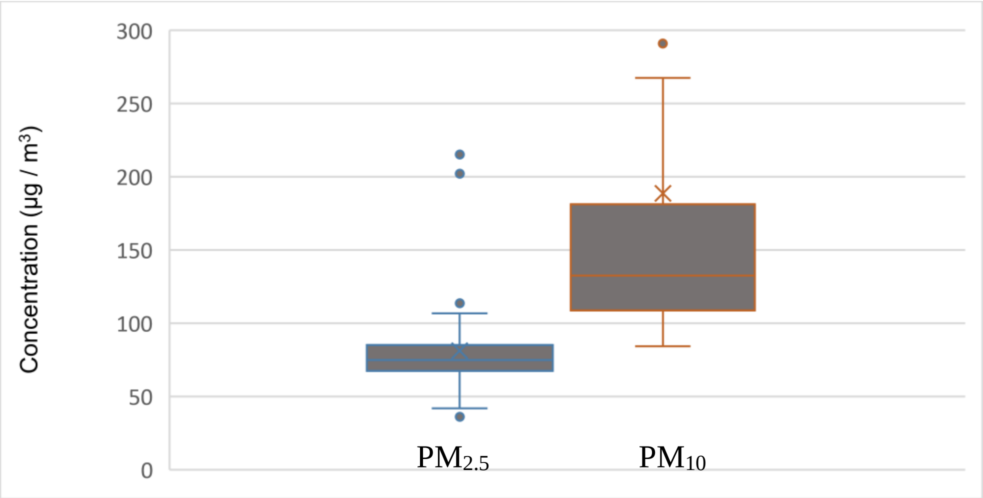


Fig.4.12 The concentration plot of $PM_{2.5}$ and PM_{10} at the mine pit (February 2022)

The concentration of particulate matter at the mine pit (Fig.4.12) was higher. Around 65 % of $PM_{2.5}$ average concentration was between 60-90 µg/m^3 and around 80 percent of PM_{10} was within 110- 160 µg/m^3 range. Due to the depth of pit, intermixing of particulate matter in the ambient air being lesser, the mean of $PM_{2.5}$ and PM_{10} was recorded at 81 and 188 µg/m^3. The low temperature with high humidity in the morning hours help the particulate matter to settle down quickly in the mining pit addition to the inversion and depth of the pit is not allowing the dispersion of dust.

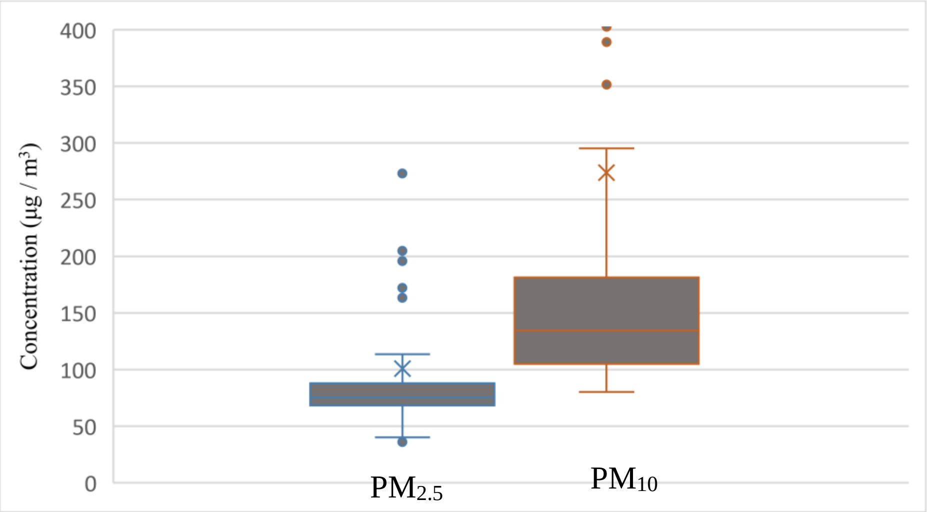


Fig.4.13 The concentration plot of $PM_{2.5}$ and PM_{10} along the haul road location (February 2022)

The PM concentration at haul road location (Fig.4.13) in February 2022 was little less because of regular interval sprinkling of water on the unpaved road. The mean of $PM_{2.5}$ and PM_{10} was 202 and 411 µg/m^3. About 60% of the average concentration of $PM_{2.5}$ was between 70-90 µg/m^3 and around 85% of PM_{10} values were between 110-180 µg/m^3. Due to low ambient temperature, the rate of water evaporation was slower and less. So the unpaved road was wet for a longer time which doesn't allow the roadside dust to re-suspend in the air again.

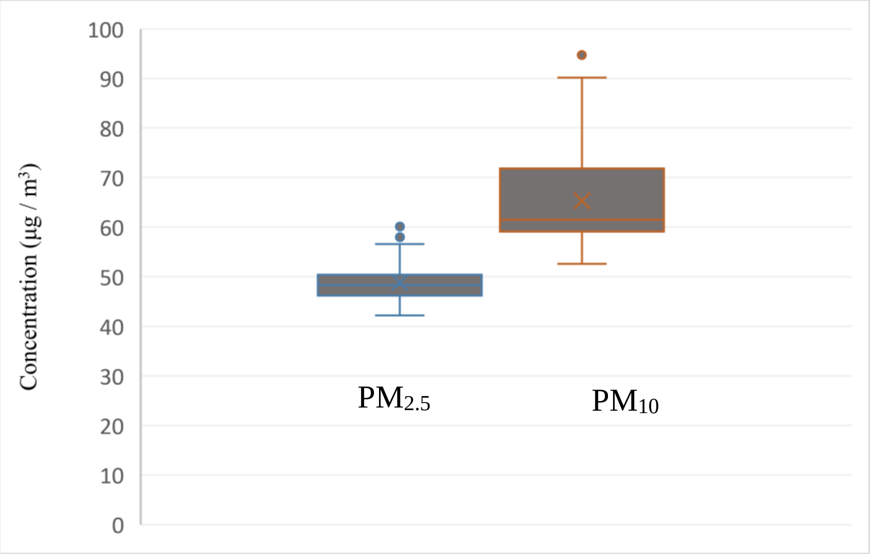


Fig.4.14 The concentration plot of $PM_{2.5}$ and PM_{10} at downwind location (February 2022)

At the downwind location (Fig. 4.14) the concentration receded because of the atmospheric conditions. At this location, the mean of $PM_{2.5}$ and PM_{10} was 48 and 65 µg/m^3. Around 80% of

$PM_{2.5}$ is recorded between 35-55 µg/m^3 and about 90% of PM_{10} values are in between 58-72 µg/m^3. The concentration of particulate matter is higher than the standard of NAAQS at the crushing zone, mining pit, and haul road. These three locations contribute a significant amount of particulate matter into the ambient air which can deteriorate the quality of air and can also induce health issues to workers. To examine it further the amount of ultrafine particles emitted from the mining area was analysed with the help of the SMPS apparatus. The study of ultrafine particles was done in February 2022 only.

4.2.4 Particle number distribution

The particle number concentration of different size fractions always gives a clear picture of air quality monitoring and its effect. Figure 4.15 shows the relationship between UFP concentrations with time. The concentration metrics displayed (during the crushing operations) significant variation with time. The spikes of the whole day indicate that UFPs concentration is higher during mining and crushing operations. The spikes of UFPs during the noon are higher, which may be because of their smaller size which keeps these particles suspended in air for a longer duration, and later with time subsidence is observed, that is possible because the particle and particulate both can be blown away with the prevailing wind and relatively lower intensity of operations (drilling, blasting, crushing etc.) in the evening hours. The crushed material basically transported same day during evening hours, to save the storage space for next day’s operations that might increase the particle concentration.

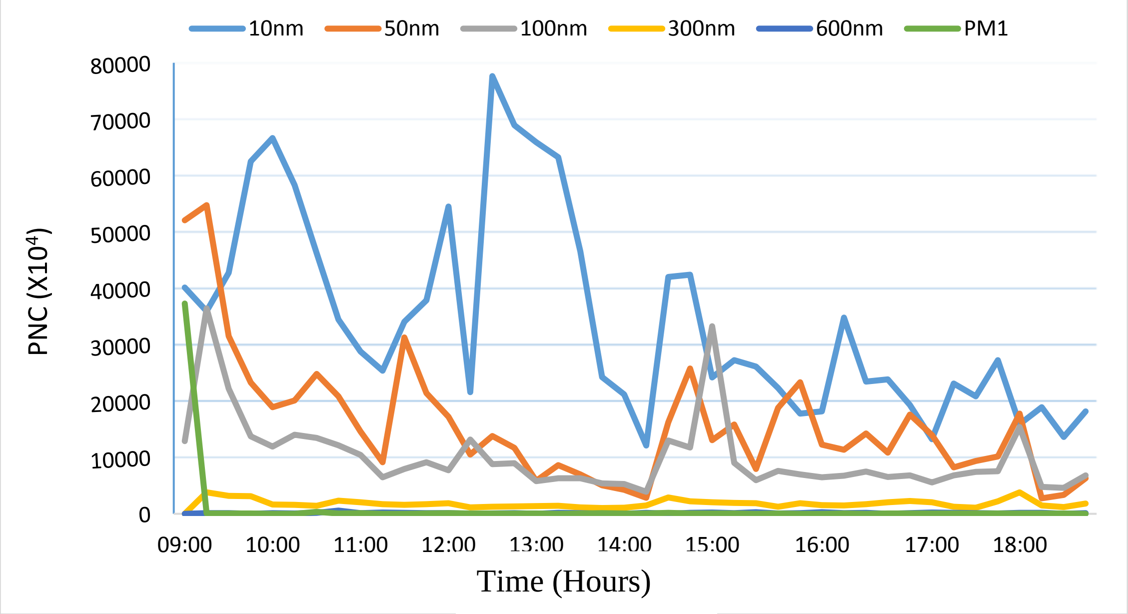


Fig.4.15 The concentration of PNC vs Time at crushing zone of Bakhrija mines

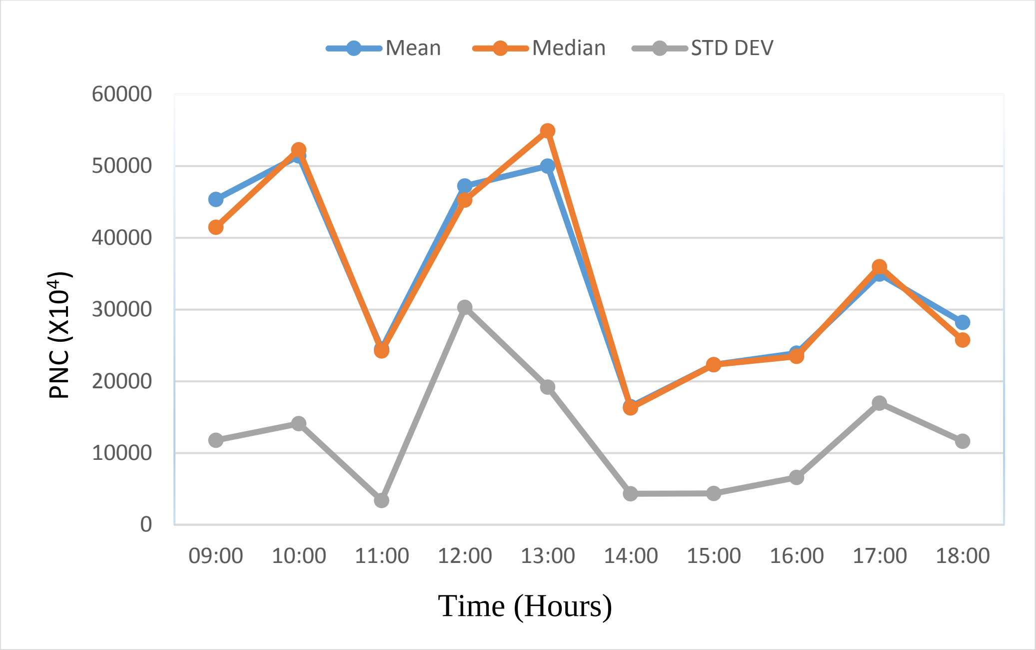


Fig. 4.16 Diurnal concentration of UFPs

The sum of lognormal distributions is used to explain the particle size distribution (Hussein et al., 2005; Rodrıguez et al., 2005). Three characteristics described by mean, median diameter, standard deviation, and particle concentration. Figure 4.16 shows these parameter trends with hourly changes in the concentration of UFP. The particle size ranged from 10 nm to 396 nm. The monitoring of PNC conducted throughout the day for 9 hrs, starting from 09:00 AM to 06:00 PM. To see the variation in particle distribution, every hourly mean, median and standard deviation is compared for all the size range of UFPs. As indicated in Figure 4.16, between the mean and median, it appears that there was no discernible difference in the particle size distribution at the site under study. Even though the sampling site was all near to the crusher site, variations in the size distribution may develop as the distance from the source increases, where vehicular activity and operation of heavy machinery were observed. Furthermore, the spikes in observation can be seen when the crushing of stones takes place and vehicular movement coincides with it. Super fine particles (<500 nm) made of elemental carbon, a portion of sulphuric acid (H_2SO_4), and organic molecules (unburned oil, etc.) can be directly discharged from vehicle exhaust or machines in the particle phase (Reche et al., 2011) or may be generated through the dilution and cooling of exhaust pollutants in the environment. The spikes in the figure show that the UFPs originated from the direct source, and because of low temperature and humidity, the gas-to-particle conversation also occurs. In the current study, the gas-to-particle conversion also takes place through photochemical and chemical reaction which occurs when day temperature rises under solar radiation. Similarly, during the crushing operation, the concentration of LDSA particles (Figure 4.15) increases. The size range of 10nm – 400 nm spikes can be seen and these particles can get deposited in the lung alveoli thus causing serious occupation hazards.

4.2.5 Dry deposition of dust

To understand the sources of the emission in the study region, a one-day (9-hour) forward trajectory is run using the NOAA-HYSPLIT model. The GDAS (Global Data Assimilation) dataset was used as the meteorological input for the trajectory model. These trajectories were calculated at three different elevations (500, 100, and 50 meters). Local pollution from sources including quarrying, crushing unpaved road, and vehicle exhaust played a role in the rise in particulate matter concentrations. The trajectory indicates (Fig.4.17) that the dust is flowing with the wind and towards the downwind direction from the source and settling quickly at a shorter distance because of the higher concentration of PM_{10}.

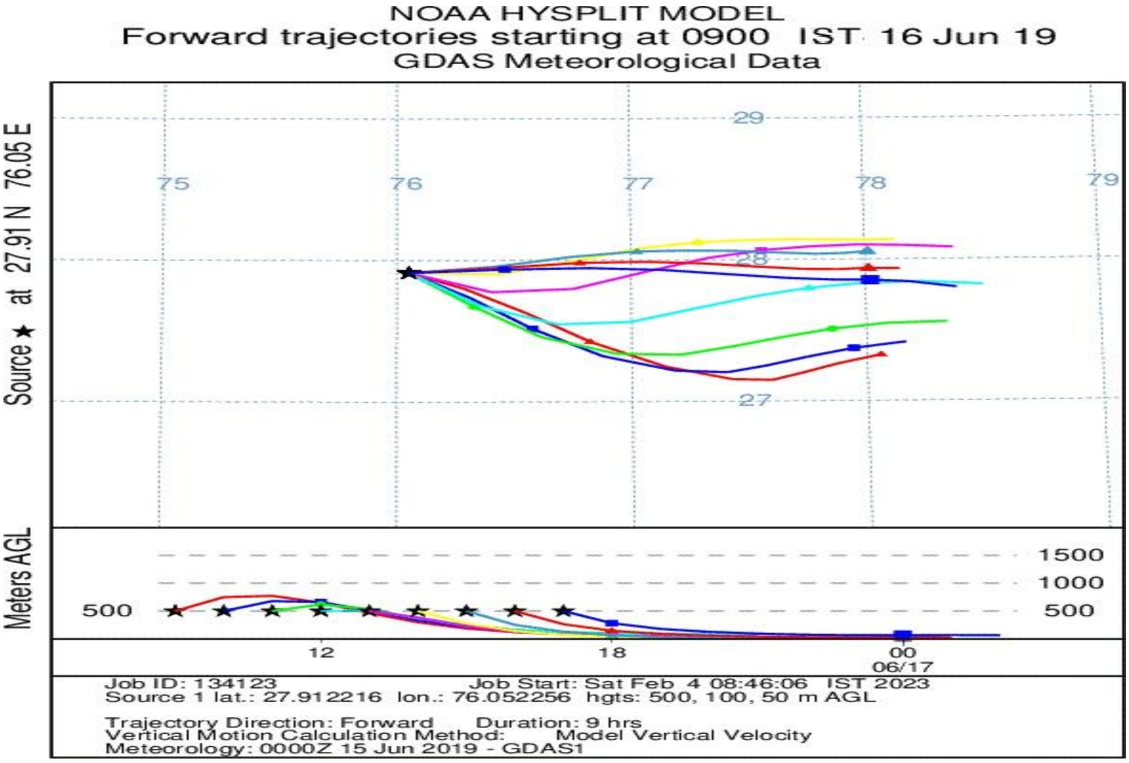


Fig.4.17 Dust dispersion of 9 hours at Bakhrija mines, Mahendragarh Haryana

In the month of June, high temperatures play an important role in heating and lifting loose material because of warm winds and higher values. Water soluble aerosols increase hygroscopically in the presence of water vapour throughout the hot sunny day, contributing to greater PM levels in the study region, whereas settling of dust increases with time and distance.

4.3 Seasonal variation of air quality

The particulate matter concentrations in the winter and summer seasons varied significantly (Table 4.4). The site assessment indicates a general trend of higher concentration of PM during winters as compared to summers season. During the winter season, the average concentration of PM_{10} in upwind location was found to be 63.39 µg/m^3, and $PM_{2.5}$ was 43.08 µg/m^3, whereas in the summer season it was recorded at only 3 µg/m^3 and 2 µg/m^3 for PM_{10} and $PM_{2.5}$, respectively. At Crusher location, in the winter season, the average concentration of PM_{10} and $PM_{2.5}$ is higher i.e. 1232.17 µg/m^3 and 342.28 µg/m^3, in comparison to the concentration of summer season which was 90 µg/m^3 and 64 µg/m^3. At mine pit PM_{10} was 188.49 µg/m^3 and $PM_{2.5}$ was 81.05 µg/m^3, and in summers it was observed 62 µg/m^3 and 53 µg/m^3, respectively. The concentration of PM_{10} downwind, for both seasons was almost the same and but there was a difference in $PM_{2.5}$ concentration.

Table 4.4 Seasonal variation of particulate matter around Bakhrija mines, Mahendragarh

S. No	**Location/Source**	**Size**	**Concentration (µg / m^3)**	
			Summer Season (June 2019) Mean ± SD	**Winter Season (Feb 2022) Mean ± SD**
1.	**Upwind**	$PM_{2.5}$	2.1 ± 1.8	43.0 ± 14.8
		PM_{10}	3.2 ±1.8	65.3 ± 17.5
2.	**Crusher**	$PM_{2.5}$	64.0 ±91.1	342.2 ± 279.8
		PM_{10}	90.2 ± 121.9	1232.1 ± 1213.3
3.	**Mine pit**	$PM_{2.5}$	53.4 ± 43.8	81.0 ± 38.6
		PM_{10}	62.6 ± 54.0	188.4 ± 143.0
4.	**Road side**	$PM_{2.5}$	182.1 ± 215.6	202.1 ± 269.4
		PM_{10}	353.5 ± 559.1	411.3 ± 661.3
5.	**Downwind**	$PM_{2.5}$	8.0 ± 10.7	48.8 ± 3.9
		PM_{10}	61.0 ± 14.9	65.3 ± 9.8

Similarly, at the mine pit where crushing takes place in the winter season concentration of PM_{10} in $PM_{2.5}$ was observed higher. The standard deviation of the PM_{10} and $PM_{2.5}$ values during the summer season was lower than in the winter season. The higher standard deviation values for $PM_{2.5}$ during winter demonstrate the complicated PM dispersion phenomena caused by inversion circumstances, suspension of small particles for longer hours of the day, low wind speed, and particulate matter build–up under favourable calm conditions.

4.3.1 Seasonal variation in PM

Descriptive analysis of particulate matter concentration specifically PM_{10} and $PM_{2.5}$ during the study period shows significant differences in comparison with the season at all the monitoring locations. During the summer season the upwind location, concentration of PM_{10} ranged between 3.1 -7 μg/m^3, whereas mean was 3 μg/m^3 and SD was 1.81 μg/m^3. Similarly, $PM_{2.5}$ ranged between 2 -6 μg/m^3 and mean concentration was 3 μg/m^3 and SD was 1.8 μg/m^3 (Table.4.5). In winter season, the upwind concentration was in the range of 33.1 - 98.6 μg/m^3 for PM_{10} with the average concentration of 65.39 μg/m^3 . Similarly, $PM_{2.5}$ ranged between 23.6 - 75.02 μg/m^3, with average concentration of 43.08 μg/m^3 (Table 4.6). Significant difference in concentration was observed in both season which attributes towards meteorological factors, such as transportation and dispersion of particulate matter with air that occurs very easily in summer season where as in winter season due to moisture and temperature difference, the movement of particulate matter is restricted leading to the spike in the winter season. In the summer season at mine pit due to activities such as blasting, drilling etc a significant variation in concentration of PM was observed. The concentration of PM_{10} range 10 - 484 μg/m^3, with mean ± SD 90 ± 122.03 μg/m^3, whereas the $PM_{2.5}$ ranged from 8- 348 μg/m^3, with mean ± SD as 64 ± 92 μg/m^3 (Table 4.5) and in winter season observed range of PM_{10} was 84.1- 837.3 μg/m^3, and mean ± SD 188.49 ± 143.03 μg/m^3, $PM_{2.5}$ concentration was between 36- 315 μg/m^3, mean ± SD was 81.05 μg/m^3 ± 38.62 μg/m^3 . The average concentration for PM_{10} and $PM_{2.5}$ at mine pit was higher than daily average of NAAQS of India, (Table 4.6). The change in ambient air quality during both the seasons was observed to be less significant, due to the depth of the mining pit and intermixing of particulate matter into the ambient air. Crushers contribute high particulate matter concentration into the ambient air. In both seasons, during operation time, crushers contribute a higher amount of fugitive dust in the ambient air.

Table 4.5 Descriptive analysis of PM_{10} and $PM_{2.5}$ Summer season (June 2019)

Sampling Location	Parameter	PM concentrations (µg/m^3)		PM ratios
		PM_{10}	$PM_{2.5}$	$PM_{2.5}/PM_{10}$
Upwind	**Mean ± SD** **(Min–Max)**	3 ± 1.9 (3 - 7)	3 ± 1.8 (2 - 6)	1 ± 1.16 (0 - 1.75)
	Lower - Higher Quartile	2 - 5	2 - 5	0.6 – 1.5
	Quartile Range	4	3	1
	Coefficient of variation	1.8	1.76	1.69
Mine Pit	**Mean ± SD** **(Min–Max)**	62.3 ± 52.2 (12.0 – 224.0)	53.2 ± 43.4 (10.1 – 221.1)	0.5 ± 1.7 (0.2 - 1.8)
	Lower - Higher Quartile	15 - 85	22 - 76	0.3 – 1.9
	Quartile Range	50	36.5	1.18
	Coefficient of variation	53	43	1.67
Crusher	**Mean ± SD** **(Min–Max)**	90.1 ± 121.9 (10.2 - 484.2)	64.1 ± 91.1 (8.2 – 348.5)	0.71 ± 2.25 (0.3 - 14)
	Lower - Higher Quartile	11 – 131	20 - 39	0.4- 5.6
	Quartile Range	35	24	1.3
	Coefficient of variation	119	89	4.17
Roadside	**Mean ± SD** **(Min–Max)**	253 ± 559 (6 - 3359)	182 ± 215.4 (2 - 921)	0.85 ± 0.35 (0.004- 0.93)
	Lower - Higher Quartile	58-397	42-234	0.064-0.52
	Quartile Range	149	98	0.25
	Coefficient of variation	553	213	0.3
Downwind	**Mean ± SD** **(Min–Max)**	60 ± 14 (40 - 103)	8 ± 10 (2 - 43)	0.13 ± 0.71 (0.05- 0.41)
	Lower - Higher Quartile	48-70	2-10	0.04-0.14
	Quartile Range	22	8	0.36
	Coefficient of variation	24	134	5.58

*SD= Standard deviation

The concentration of particulate matter in both seasons is above the average daily limit as prescribed by the NAAQS. At crushers the observed PM_{10} concentration in summer season ranged between 10 – 484 µg/m^3, concentration of mean ± SD was 90 ± 121.95 µg/m^3, and the concentration of $PM_{2.5}$ was between 8 - 348 µg/m^3, mean ± SD was 64 ± 91.12 µg/m^3 (Table.4.5). During winter season at crushers, PM_{10} concentration was between 80.3- 8129.5 µg/m^3, concentration of mean ± SD was 1232.17 ± 1213.31 µg/m^3 which was higher than standard of CPCB (2009), $PM_{2.5}$ concentration was between 38.5 - 1506.9 µg/m^3, mean concentration of mean ± SD 342.28 ± 279.87 µg/m^3 ((Table.4.6).

Table 4.6 Descriptive analysis of PM_{10} and $PM_{2.5}$ in winter season (February 2022)

Sampling Location	**Parameter**	**PM concentrations (µg/m^3)**		**PM ratios**
		PM_{10}	**$PM_{2.5}$**	**$PM_{2.5}$/PM_{10}**
Upwind	**Mean ± SD (Min–Max)**	65.39 ± 17.54 (33.1- 98.61)	43.08 ± 14.87 (23.6 - 75.02)	0.65 ± 0.11 (0.40 - 0.85)
	Lower - Higher Quartile	51.35 - 80	30.85 - 59	0.52 - 0.73
	Quartile Range	29	28	0.2
	Coefficient of variation	27	35	17.4
Mine Pit	**Mean ± SD (Min–Max)**	188.49 ± 143.03 (84.1-837.3)	81.05 ± 38.62 (36 - 315)	0.51 ± 0.17 (0.10 - 0.82)
	Lower - Higher Quartile	110.3 - 180	67.95 - 85	0.35 - 0.64
	Quartile Range	69	17	0.28
	Coefficient of variation	76	48	34.58
Crusher	**Mean ± SD (Min–Max)**	1232.17 ± 1213.31 (80.3 - 8129.5)	342.28 ± 279.87 (38.5 - 1506.9)	0.33 ± 0.09 (0.18 - 0.63)
	Lower - Higher Quartile	336.4 - 1640	133 - 454	0.25- 0.39
	Quartile Range	1303	321	0.13
	Coefficient of variation	98	82	29.03
Roadside	**Mean ± SD (Min–Max)**	411 ± 661.3 (68 - 2929)	202 ± 269.4 (32 - 551)	0.58 ± 0.37 (0.10- 0.80)
	Lower - Higher Quartile	106-179	68-89	0.37-0.63
	Quartile Range	134	75	0.54
	Coefficient of variation	89	443	0.17
Downwind	**Mean ± SD (Min–Max)**	65.33 ± 9.86 (54.6-94.7)	48.85 ± 3.97 (42.2- 60.1)	0.75 ± 0.05 (0.63 - 0.86)
	Lower - Higher Quartile	59 - 71	46 - 50	0.71 - 0.80
	Quartile Range	12	4	0.08
	Coefficient of variation	15	8	7.9

*SD = Standard deviation

During the summer season due to power failure operation of crushers was intermittent, whereas the number of operation hours in the winter season was higher. Roadside also contributed a significant amount of particulate matter in the air. The resuspension of dust from haul roads contributed immense amount of PM into the ambient air during the study period in both the seasons. It was observed that during the winter season, the resuspension of dust was lesser than the summer season, because of regular sprinkling of water on the haul road which restricted the dust resuspension. The observed concentration range of PM_{10} in the summer season was 6- 3359 $\mu g/m^3$, concentration of mean ± SD was 353 ± 559.16 $\mu g/m^3$, whereas the concentration of $PM_{2.5}$ was between 2 – 921 $\mu g/m^3$, mean ± SD 182 ± 215.61 $\mu g/m^3$ (Table.4.5). During the winter season, (Table 4.6) it was observed concentration of PM_{10} was between 68- 2929 $\mu g/m^3$, mean ± SD 411 ± 661.3 $\mu g/m^3$, whereas during the sampling the concentration $PM_{2.5}$ was between 32 - 551 $\mu g/m^3$ mean ± SD was 202 ± 269.4 $\mu g/m^3$. PM_{10} and $PM_{2.5}$, concentrations increased from upwind to the core mining area due to activities of excavation/crushing and with the distance, the PM concentration tends to decrease. At the crushing site the mean PM_{10} concentration was 80 times higher than the threshold value set by the CPCB (2009).

The mining activity and crushing contribute maximum PM concentration for all sizes of particle and the concentration of particulate matter decreases with the distance due to dust dispersion with wind and settling due to gravity, the observed concentration at downwind location in summer season for PM_{10} range was 40- 103, with mean ± SD 61 ± 15$\mu g/m^3$ and for $PM_{2.5}$ was between 2 - 43 with mean ± SD 8 ± 10.7 $\mu g/m^3$.In the winter season observed PM_{10} concentration at downwind was between 54.6 - 94.7 $\mu g/m^3$, mean ± SD 65.33 $\mu g/m^3$ ± 9.8 $\mu g/m^3$, $PM_{2.5}$ concentration was 42.2 - 60.1 $\mu g/m^3$, mean ± SD 48.85 ± 3.97 $\mu g/m^3$. On average, at the crushing location, the ratio of $PM_{2.5}$ in PM_{10} contributes 33%, Upwind of $PM_{2.5}$ in PM_{10} contributes 65% of the concentration, and at the downwind location the $PM_{2.5}$ in PM_{10} contributes 75% (Table.4.6). The concentration of fine particles is more at upwind, crusher, and roadside and the ratio of $PM_{2.5}/PM_{10}$ in the summer season is near 1 indicating a higher concentration of finer particles ($PM_{2.5}$ and lesser than that). At minepit and downwind locations the mean ratio is 0.52 and 0.13 respectively, which indicates the presence of a higher concentration of coarser particles at those location. The ratio of $PM_{2.5}/PM_{10}$ during the winter season indicates the presence of a higher concentration of finer particles at upwind and downwind; and at all the other locations the ratio of $PM_{2.5}/PM_{10}$ was close to 0.5 which means the presence of coarser particle too at pit, crusher and roadside. The lesser ratio recorded is because of metrological parameters and a regular sprinkling of water which minimise the resuspension of dust from the haul road.

4.3.2 Seasonal source contribution of particulate matter

An analysis of air quality showed substantial seasonal fluctuations of particulate matter (PM_{10} and $PM_{2.5}$) during period of study (Table 4.4). In comparison to summer, concentrations of all forms of particulate matter were higher during the winter season. The prominent sources of fugitive dust were from fully functional crushers and mine-related activities such as, blasting, mineral hauling, mechanical handling operations, raw material stockpiles, site restoration, loading, and unloading etc. Particulate matter (PM_{10}) contributions ranged from 56% (Crusher) to 21% (Mining pit) during the summer season and 80% (Crusher) to 12% (Mining pit) in the winter season. The average PM_{10} concentrations at Bakhrija mines pit and crushers during the winter and summer, respectively, were 1232.2 $\mu g/m^3$ and 328.2 $\mu g/m^3$, which is three and twelve times higher than India's NAAQS (100 $\mu g/m^3$) norms of CPCB (2009).

During mining activities, the variation in PM_{10} concentrations were higher, which may be attributed to location, season, and site. PM_{10} concentration varied due to mechanical operations such as crushing, grinding, and abrasion of surfaces, evaporation of sprays from crushing units and re-suspension of dust in quarrying regions. Winter $PM_{2.5}$ concentrations were 66% and 16% near crushers and mining pit, respectively. The average concentration at the crusher and mine pit were 342.18 $\mu g/m^3$ and 81.05 $\mu g/m^3$, respectively, which is 5.8 and 1.3 times higher, than the NAAQS of 60 $\mu g/m^3$ (CPCB 2009). Similarly, crushers and mine pits had $PM_{2.5}$ values of 66% and 16%, respectively, throughout the summer. The average concentration was 136.93 $\mu g/m^3$in the crushing area and 32.75 $\mu g/m^3$at the mining pit, both of which were 2.4 times higher than the (NAAQS; 60 $\mu g/m^3$) of CPCB (2009). Crushing and re-suspension of dust brought about by vehicle movement activities are significant.

4.3.3 PM_{10} and $PM_{2.5}$ Air quality mapping

The Air Quality Index (AQI) is an indicator for evaluating and reporting air quality on daily basis. It indicates if the air is clean or unhealthy, as well as making recommendations for groups that may be susceptible to pollution. Table 4.7 shows the AQI estimated for the examined site throughout the winter season. Near the mining pit, air quality was poor, hazardous at the crushing area, and satisfactory at downwind and upwind (Table 4.7 & 4.8). As per the indexing of both seasons, it can be seen clearly at the mining pit, at the crusher, and on the unpaved roadside, the index of both parameters PM_{10} and $PM_{2.5}$ is hazardous in the health category. Three places in the mining region showed maximum concentration of PM in ambient air which is responsible for the degradation of air quality.

Table 4.7 Air Quality index (Summer 2019) (Colour code source CPCB 2014)

Site	**Sub Index**		**AQI**	**Health Statements for AQI**
	IPM10	**IPM2.5**		
Upstream	5	7	7	Satisfactory
Mine Pit	90	87	90	Poor
Crusher	90	180	180	Hazardous
Roadside	484	403	484	Hazardous
Downstream	60	12	60	Satisfactory

Table 4.8 Air Quality index (winter 2022) (Colour code source CPCB 2014)

Site	**Sub Index**		**AQI**	**Health Statements for AQI**
	IPM10	**IPM2.5**		
Upstream	67	72	72	Satisfactory
Mine Pit	133	152	152	Poor
Crusher	484	403	484	Hazardous
Roadside	303	348	348	Hazardous
Downstream	63	81	81	Satisfactory

But due to presence of coarser particles the settling of fugitive dust is quick and it doesn't show any significant effect in downwind location in both of the seasons.

4.3.4 Source responsible for degrading air quality

All particulate matter (PM_{10} and $PM_{2.5}$) showed substantial seasonal fluctuations over both monitoring seasons (Figures 4.18, 4.19, 4.20 & 4.21). In comparison to summer, concentrations of both forms of particulate matter were higher during the winter. The main sources of fugitive dust are fully functional crushers and surface mine-related activities such as removal, blasting, mineral hauling, mechanical handling operations, raw material stockpiles, site restoration, loading, and unloading activity.

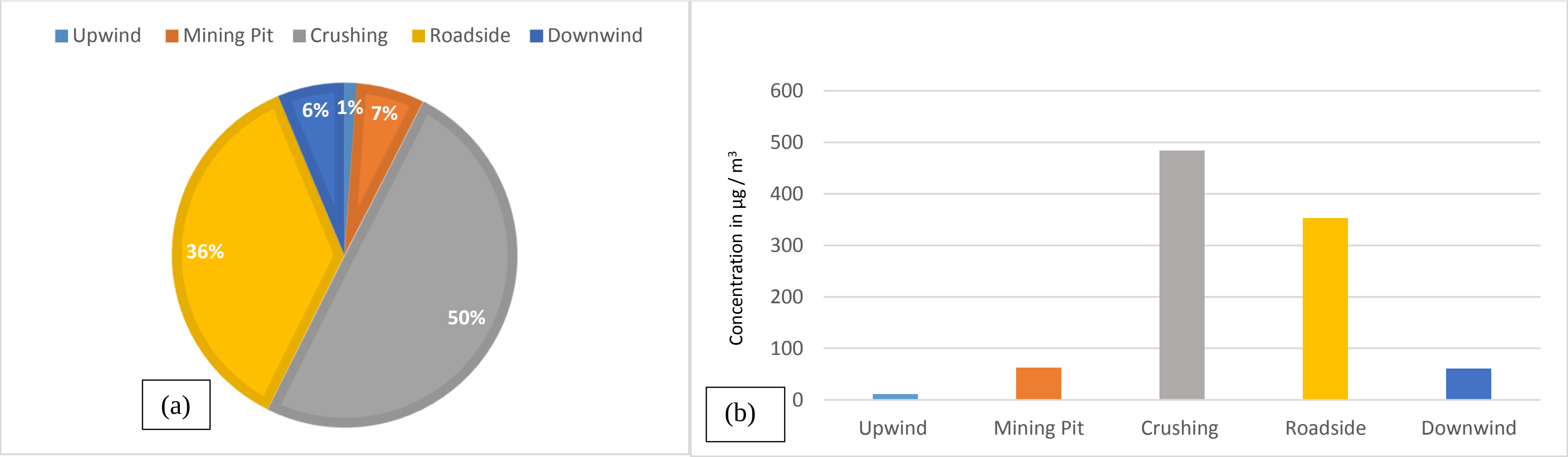


Fig. 4.18 Source contribution of PM_{10} (a) percentage (b) average concentration, summer (2019)

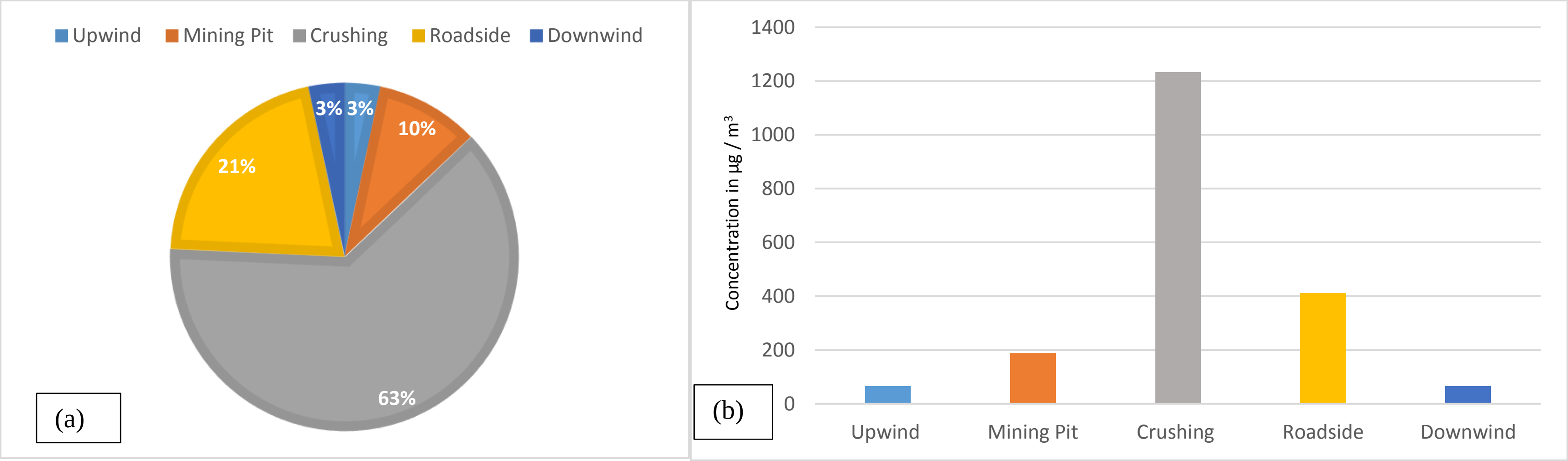


Fig. 4.19 Source contribution of PM_{10} (a) percentage (b) average concentration, winter (2022)

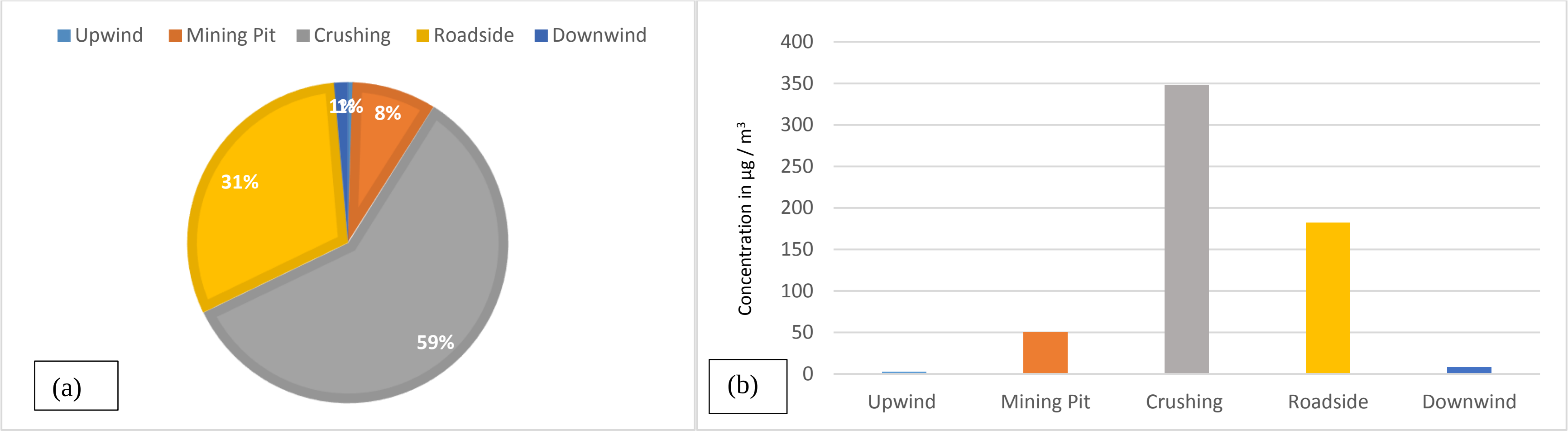


Fig. 4.20 Source contribution of PM2.5 (a) percentage (b) average concentration, summer (2019)

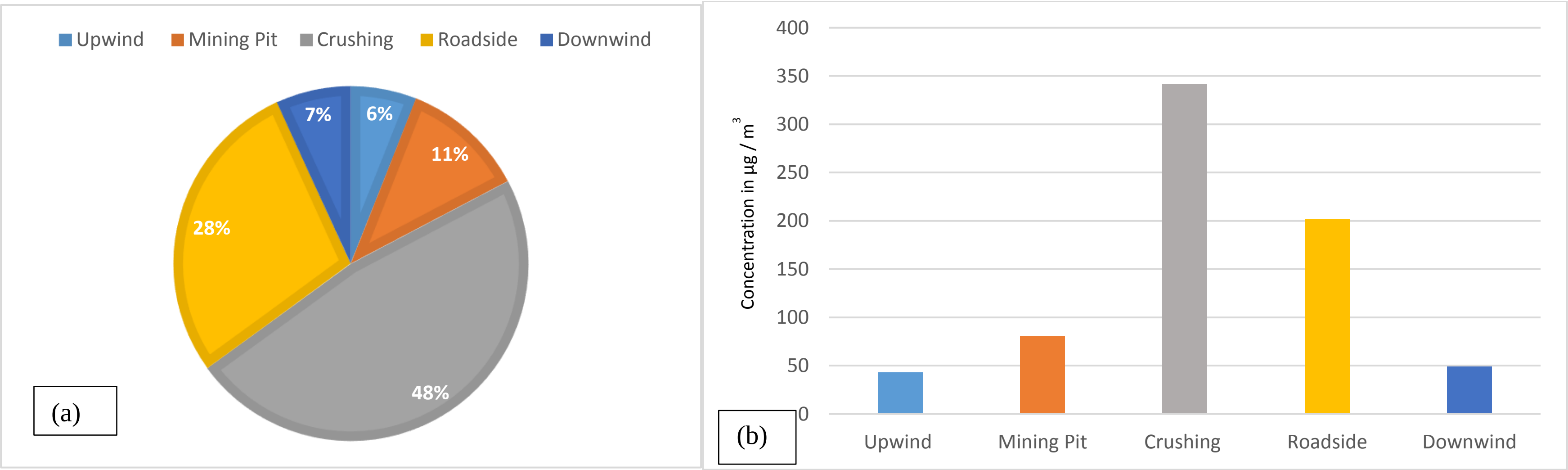


Fig. 4.21 Source contribution of PM2.5 (a) percentage (b) average concentration, winter (2022)

In both the seasons, the amount of particulate matter is varying at the source level. In the summer season, the concentration contribution (Fig.4.18 (a)) of PM_{10} at the crusher was 50%, 36% from road side, 7% from the mining pit, 6 % from the downwind, and 1% from the upwind, whereas the maximum concentration (Fig.4.18 (b)) recorded at crusher was 484 $\mu g/m^3$ and average concertation at road side was 353 $\mu g/m^3$, at mining pit 62 $\mu g/m^3$ at downwind and upwind 61 $\mu g/m^3$ and 3 $\mu g/m^3$, respectively. Whereas, for the $PM_{2.5}$, contribution (Fig.4.20 (a)) at the crusher was 59%, at roadside 31%, at the mining pit it was 8%, and at downwind and upwind 1%. The concentration range of (Fig.4.20 (b)) of $PM_{2.5}$ was highest at crushing (348 $\mu g/m^3$), and the average concentration at the mining pit was 53 $\mu g/m^3$, at the roadside it was observed 182 $\mu g/m^3$, at upwind it was 3 $\mu g/m^3$ and downwind it was recorded 9 $\mu g/m^3$.

Due to the location, season, and site-season interaction, PM_{10} concentration varied substantially at the site. Due to mechanical disruption (such as crushing, grinding, and abrasion of surfaces), evaporation of sprays, and re-suspension of dust in quarrying regions, there were large proportions of coarse particles in the quarrying zone. In the winter season, the source contribution of particulate matter is different in comparison to the summer season. Percentage of PM_{10} out of total PM at crushing area was (Fig.4.19 (a)) 63%, at the roadside 21%, 10% at mine pit, 3% at downwind and upwind . The average concentration at (Fig.4.19 (b)) crusher was found to be 1232 $\mu g/m^3$ and the average concertation at the roadside was 411 $\mu g/m^3$, 188 $\mu g/m^3$ at mining pit, and 65 $\mu g/m^3$ for both downwind and upwind. Winter $PM_{2.5}$ percentage (Fig.4.21 (a)) at crusher was 48%, 28% at the roadside, at pit it was 11%, and 7%, and 6% at downwind and upwind, respectively. The average concentration of $PM_{2.5}$ (Fig.4.21 (b)) at the crusher area was 342 $\mu g/m^3$, 81 $\mu g/m^3$ at mine pit, 202 $\mu g/m^3$ at the roadside, at downwind 48 $\mu g/m^3$ and upwind it was 43 $\mu g/m^3$. Concentration values crushing and roadside was 5.8 and 1.3 times higher than the NAAQS (60 $\mu g/m^3$; CPCB 2009) recommendations for $PM_{2.5}$. Crushers and mining pit had $PM_{2.5}$ values of 66% and 16%, respectively throughout the summer. The average concentration was 136 $\mu g/m^3$in the crusher area and 32 $\mu g/m^3$at the mining pit, both of which were 2.4 higher than the relevant NAAQS (60 $\mu g/m^3$; CPCB 2009) limits for $PM_{2.5}$.

PM_{10} and $PM_{2.5}$ roadside concentration came down drastically in the winter season. The difference in both seasons PM_{10} is near about 15% which happened because of regular sprinkling on the roadside which restricted the resuspension of dust. $PM_{2.5}$ also shows the same results with the difference between both seasons as 3%. But in crushing activity, the percentage jumped for PM_{10} in both season. It increased by 13% for PM_{10} and in the case of $PM_{2.5}$ it decreased by 11%. In both season, the chemical reactions that result from the nucleation, condensation, coagulation, and evaporation of fog and cloud droplets produce fine particles ($PM_{2.5}$), in which gases also dissolve and react. A major source of fine and ultrafine particles is the crushing and re-suspension of dust brought about by vehicle movement.

4.4 Effect on water quality

In groundwater hydrology, water analyses is used to provide information on water quality. The quality of groundwater in the study area is critical in evaluating its appropriateness for drinking, household, agricultural, and industrial uses. According to the results (Table 4.9) values obtained during physicochemical characterization, the groundwater indicate that the majority of the cations, and anions are above detectable concentrations during the first sampling (June 2019).

Table 4.9 Physico- Chemical characteristics, Suitability for drinking, and potential effect of ground water around Bakhrija Mines (June 2019)

Parameters	Minimum	Maximum	Mean ± SD	Desirable limit	Exceedance (%)	Potential effect
pH	7.08	8.6	7.6 ± 0.36	6.5-8.5	–	Taste, corrosion
TDS (mg/L)*	366	2610	1083 ± 541	500	93*	Gastrointestinal irritation
TH (mg/L)	300	3020	886 ± 688	300	100	Kidney Stones
NO_3^- (mg/L)	5.64	17.67	11 ± 5	45	0	Methaemoglobin-aemia
SO_4^{2-} (mg/L)	33	597	129 ± 140	150	33	Laxative effect
Cl^- (mg/L)	39	900	231 ± 229	250	33	Anaesthetic effect, Salty taste
K^+ (mg/L)*	3	22	8 ± 5	--	40*	Bitter taste
F^- (mg/L)	0.5	11	2.5 ± 2.7	1	66	Dental and Skeletal fluorosis
Ca^{2+} (mg/L)	80	344	117 ± 55	75	100	Scale formation
Mg^{2+} (mg/L)	196	2676	769 ± 648	30	100	Nausea and vomiting
Na^+ (mg/L)*	159	681	326 ± 150	30-60	100*	Hypertensive effects

*As per WHO (2004); TH- Total hardness as $CaCO_3$; TDS- Total dissolved solids

All of the groundwater samples were found to be somewhat alkaline because basic minerals (calcium, magnesium, carbonate, and bicarbonate) are predominately in dissolved form, and the pH of groundwater is typically alkaline. Based on TDS, the majority of the samples (93%) exceeded the permitted limit of 500 mg/L, and all of the collected samples were categorized as hard. The higher TDS may be due to mining activities and sandy subsurface profile which get contaminated by percolation due to mining operations of drilling and blasting which cause cracks in the subsurface system and degrade the groundwater quality. Similar to this, all the collected samples exceeded the prescribed limit for calcium and magnesium, thus confirming the hard nature of the groundwater. Unlike calcium and magnesium, chloride and sulphate exceeded the specified limit in 33% of samples collected indicating that the hardness was dominantly contributed by carbonate and bicarbonate salts of the cations. Nitrate levels in all groundwater samples were below the permitted level, suggesting that anthropogenic addition by fertilizer or wastewater discharge are not causing groundwater pollution in the studied region. Fluoride is another major anion that may have health problems in the exposed population. It was found to be higher in 66% of the groundwater samples analysed. Fluoride levels that are relatively higher in some areas are a reason for worry due to its toxicity and health effects.

Table 4.10 shows the lowest, maximum, average concentration, and standard deviation of physicochemical water quality parameters including pH, Electrical conductivity (EC), Total dissolved solids (TDS), Total hardness (TH), and major cations and anions during second sampling (February, 2022). The study area's groundwater samples are alkaline. The pH values ranges from 6.4 to 7.4, with an average of 6.8, indicating slightly acidic conditions. Electrical conductivity ranged from 787 to 5740 µS/cm in the season, with an average value of 2919 µS/cm. According to WHO (2009), the EC was over the desired level (500 µS/cm) in 100% of groundwater samples. Higher EC is responsible for gastrointestinal irritation in human beings. TDS ranged from 363 to 2980 mg/L during the season. Because of salt encrustations, the distribution of TDS values clearly indicates that the TDS in study is in the higher range. Total hardness ranged from 132 to 640 mg/L, with an average of 500 mg/L. In the study area cations are dominated by Na^+ (254 to 1003 mg/L with an average of 581 mg/L) followed by Ca^{2+} (235 to 413 mg/L with an average of 317 mg/L), Mg^{2+} (24 to 134 mg/L with an average of 71 mg/L) and K^+ (7 to 32 mg/L with an average of 17 mg/L). Among the anions HCO_3^{2-} is dominant anion (359 to 738 mg/L with an average of 2115 mg/L) followed by concentration of Cl^- (74 to 755 mg/L with an average of 390 mg/L), followed by SO_4^{2-} (160 to 319 mg/L with an average of 245 mg/L), followed by NO_3^- (4.5 to 80 mg/L with an average of 35 mg/L) and F^- (1 to 20 mg/L with an average of 5.4 mg/L).

Table 4.10 Physico- Chemical characteristics of groundwater and potential effect (February 2022)

Parameters	Minimum	Maximum	Mean ± SD	Desirable limit	Exceedance (%)	Potential effect
pH	6.44	7.48	6.8 ± 0.34	6.5-8.5	–	Taste, corrosion
TDS (mg/L)*	363	2980	1490 ± 765	500	91*	Gastrointestinal irritation
TH (mg/L)	132	640	500 ± 133	300	91	Kidney Stones
EC (µS/cm)	787	5940	2919 ± 1523	500	100*	Gastrointestinal irritation
NO_3^- (mg/L)	4.5	80	35 ± 24	45	20	Methemoglobinemia
HCO_3^{2-} (mg/L)	359	738	2115 ± 1053	–	–	Upset stomach
SO_4^{2-} (mg/L)	160	319	245 ± 57	150	100	Laxative effect
Cl^- (mg/L)	74	755	390 ± 210	250	72	Anaesthetic effect, Salty taste
K^+ (mg/L)*	7	32	17 ± 8.2	–	–	Bitter taste
F^- (mg/L)	1	20	5.4 ± 5.2	1	90	Dental and Skeletal fluorosis
Ca^{+2} (mg/L)	235	413	317 ± 66	75	100	Scale formation
Mg^{+2} (mg/L)	24	134	71 ± 34	30	80	Nausea and vomiting
Na^+ (mg/L)*	254	1003	581 ± 249	30-60	100*	Hypertensive effects

*As per WHO (2004); TH- Total hardness as $CaCO_3$; TDS- Total dissolved solids

Weathering of carbonate rocks and dissolution of silicate minerals provide cation and anion availability. Weak acids dissolve carbon dioxide from the air to generate carbonic acid. (Chitrakshi and Haritash 2018; Subba et al., 2017). The dominance of cation and anions was observed in the following order $Na^+ > Ca^{+2} > Mg^{+2} > K^+$ and $HCO_3^{2-} > Cl^- > SO_4^{2-} > NO_3^- > F^-$, respectively. The fluoride concentration in the study area is observed to exceed the desirable limit in 90% of sample which may cause adverse health effects on the humans.

4.4.1 Ground water quality

Quarrying can have a significant effect on the surrounding groundwater system, causing changes in water quality, contaminant runoff, and changes in water flow patterns. The concentrations of different water quality parameters, such as pH, total dissolved solids, and chloride, in groundwater at different distances from the quarry were represented using box and whisker plots. The plots revealed that the concentration of some parameters in close proximity to quarries was higher, indicating potential impacts from quarry operations.

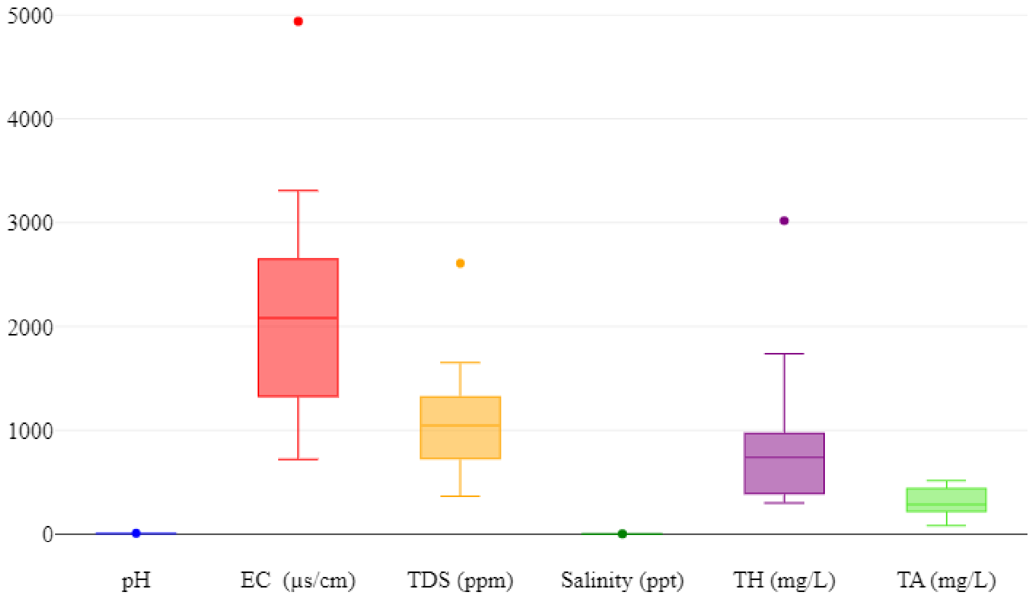


Fig.4.22 Ground water quality around Bakhrija Mines (June 2019)

During the first sampling, the (Fig. 4.22) pH values at each location are fairly similar, with the majority of them falling between 7.1 and 8.6, salinity in the range of 0.3 to 1.2, For EC 90% of the samples recorded between 1200 to 2600 mg/L , and for TDS, 80% of values were recorded between 600 to 1400 mg/L. The higher TDS in all the water samples was because of percolation of water around mining region, water coming through runoff and getting accumulated in the mine pit recharges the groundwater. Due to mining operations or excavation of the surface to extract the stones, thinning of the subsurface or aquifer occurs, which leads to a level of groundwater becoming shallow around the mining pit. The leftover mining pit act as a recharging zone, and because of the accumulation of water from runoff and other sources which contains a high amount of TDS and TSS gets passage into the ground water system. For total Hardness, 90% values were between 400 to 950mg/L, whereas for carbonate, total alkalinity, and sodium about 80% of values were between 200 to 500 mg/L.

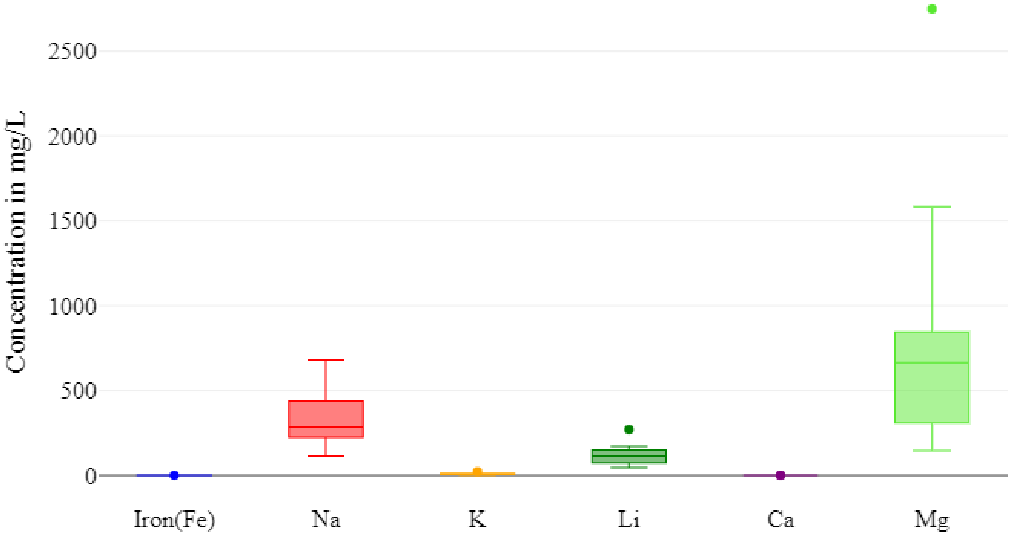


Fig.4.23 Ground water quality cations Bakhrija Mines (June 2019)

Iron was 0.003 to 0.1 mg/L, phosphate 0.66 to 0.55 mg/L, (Fig. 4.23) although highest values in some sampling region were above from desirable limit of BIS-10500. For most of the parameters, 60 % of the value falls under the desirable limit as per the standard limits. For Magnesium, 70% of values were in the range of 400- 900 mg/L. The variations and values surpassing the desired limit (IS-10500) may be due to mining activities. Potassium at maximum locations ranging from 1mg/L to 8.3 mg/L, Lithium at all location observed between 0.05-0.1mg/L, About 80% of values for calcium were within 80 to 160 mg/L.

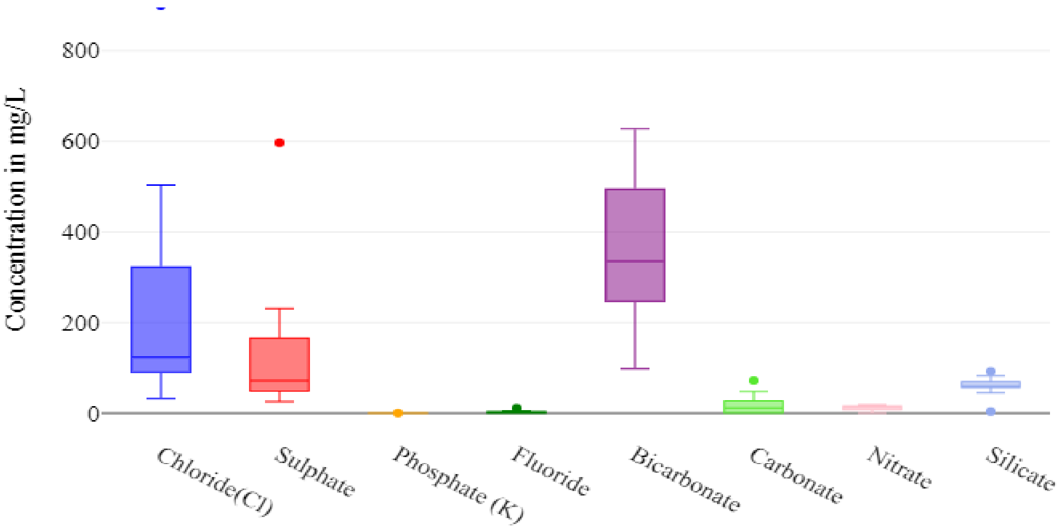


Fig. 4.24 Ground water anions around Bakhrija Mines (June 2019)

About (Fig. 4.24) 90% of values for chloride were within 100 to 350mg/L, for sulphate, values were between 80 to180 mg/L. All these values were the median range of the 2nd quartile of the plot. fluoride was 0 to 2mg/L, Nitrate was 0.12-11 mg/L. The results of maximum parameters exceed the desirable limit of IS-10500.

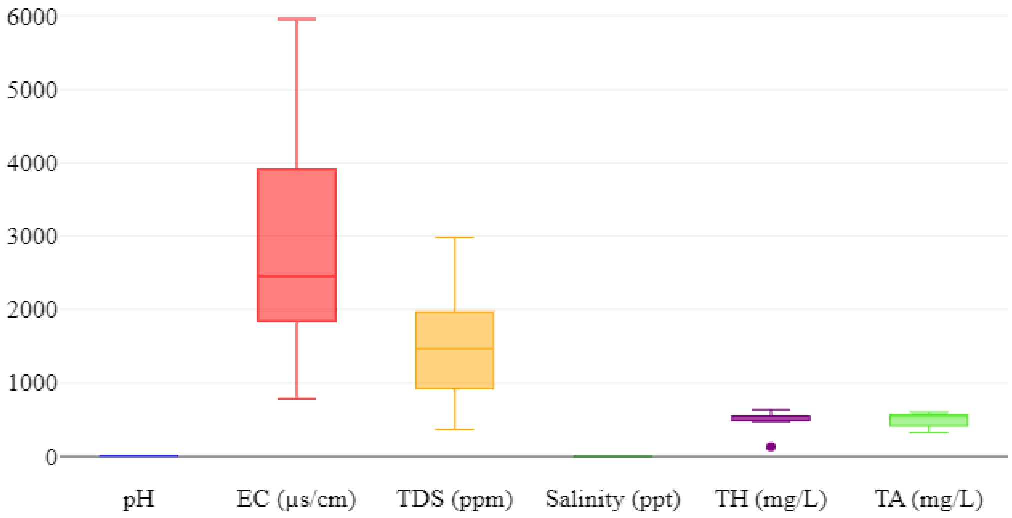


Fig. 4.25 Ground water quality around Bakhrija Mines (February 2022)

In February 2022, all water quality results (Fig. 4.25) are falling under 70-80% of the bracket. pH was in the range, EC was well in the higher range because of higher TDS in the water, and the hardness and alkalinity of water were on the higher side of the desirable limit of the standard. Because of mining and practices of agricultural activities, the water is found higher in TDS around the vicinity of the mining zone.

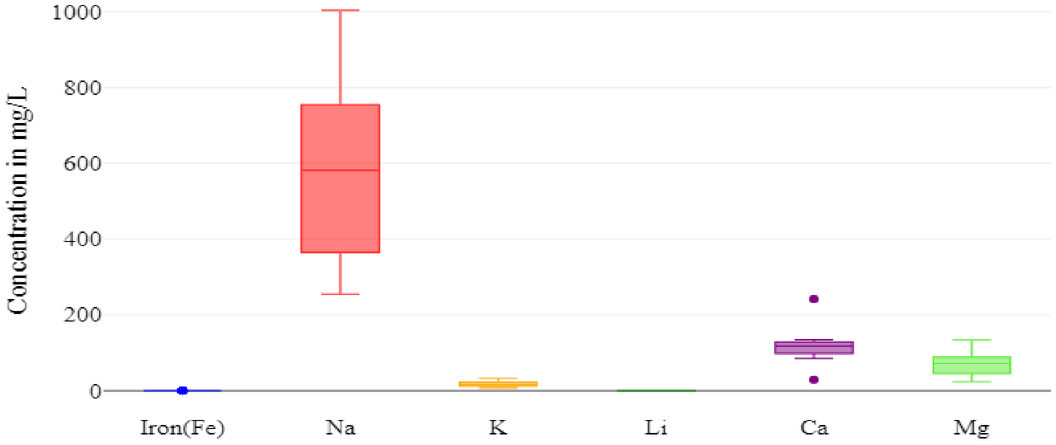


Fig. 4.26 Ground water cations around Bakhrija Mines (February 2022)

For cations (Fig.4.26), about 90% of observation of calcium were within 300 to 800 mg/L and 90% of chloride value were within 100 to 350mg/L, for sulphate the values were are between 80 to180 mg/L. All these values were around the median range of the 2nd quartile of the plot. The presence of higher sodium in the groundwater may be due to interaction with the exposed rock of the mining area. The results of the most of the parameter exceed the desirable limit of IS-10500.

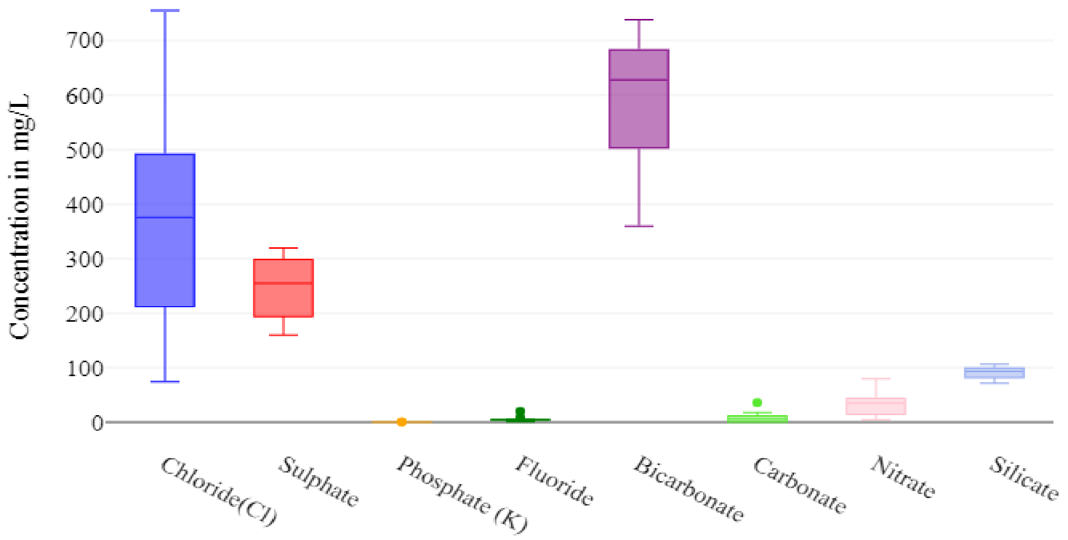


Fig. 4.27 Ground water anions around Bakhrija Mines (February 2022)

4.4.2 Seasonal variation of water quality

Table 4.11 below lists the physicochemical characteristics of the samples of groundwater taken during the summer season. According to Table 4.11, the pH of water samples ranges from 7.1 to 8.6 in the summer season and 6.4 to 7.5 in the winter season, making them somewhat alkaline. The recommended pH range for drinking water is 6.5-8.5, according to BIS guidelines. Thus the pH level of the groundwater sample was within the acceptable limit for drinking during both seasons. In the summer season, TDS levels in groundwater varied from 366 to 2610 mg/L, with an average of 1083 mg/L, while in the winter, they range from 363 to 2980 mg/L, with an average of 1490 mg/L. All samples had TDS levels higher than the allowable TDS limit for drinking water (500 mg/L). The higher evaporation rate and increased SO_4^{2-} concentration are likely to be responsible for the higher TDS. TH is a crucial indicator for tracking the quality of water since it shows the total amount of Ca^{2+} and Mg^{2+} in the water. Water can be categorized as either soft (TH< 75 mg/L), mild (75 mg/L to 150 mg/L), moderately hard (150 mg/L to 300 mg/L), hard (300 mg/L to 450 mg/L), or extremely hard

Table: 4.11 Statistical analysis of physico-chemical characteristics of Groundwater during June 2019, (summer) and February 2022, (winter)

Parameter	Unit	Maximum		Minimum		Mean		SD		Permissible Limit
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	
pH	--	8.6	7.4	7.0	6.4	7.6	6.8	0.37	0.34	6.5-8.5
EC	mS/cm	4940	5960	718	787	2115	2919	1054	1523	400*
TDS	mg/L	2610	2980	366	363	1084	1491	541	765	500
Salinity	mg/L	3	3.16	0.06	0.32	1	2	0.64	0.84	NA
Total Hardness	mg/L	1510	640	150	132	468	499	340	132	600
Total Alkalinity	mg/L	515	605	80	325	310	498	135	96	200
Mg^{2+}	mg/L	325	134	17	24	95	72	75	34	30
Na^{+}	mg/L	681	1004	113	254	326	581	150	249	30-60*
K^{+}	mg/L	22	32	1	7	9	17	5	8	NA
Ca^{2+}	mg/L	270	414	45	235	117	317	56	66	75
Li^{+}	mg/L	0.25	0.20	0.05	0.05	0.12	0.13	0.04	0.05	NA
Fe^{+}	mg/L	0.14	0.05	0	0.02	0.04	0.04	0.03	0.01	0.3
F^{-}	mg/L	11	20	0	1	2	6	3	5	1
NO_3^{-1}	mg/L	19	80	0.12	4	12	35	5	24	45
$SiO_4\ ^{-2}$	mg/L	92	106	4	72	60.	90	19	11	50*
$SO_4\ ^{2-}$	mg/L	597	319	25	160	129	245	141	57	150
PO_4^{-3}	mg/L	0.47	0.84	0.07	0.03	0.18	0.23	0.12	0.31	1
HCo^{3-}	mg/L	628	738	98	360	342	590	162	116	NA
CO_3^{-2}	mg/L	72	36	0	0	18	8.73	20	11	NA
Cl^{-}	mg/L	893	755	25	74	225	390	229	210	250

*As per WHO (2004)

(TH > 450 mg/L). According to the BIS, the maximum amount of TH that can be consumed is 600 mg/L. Common water quality indicators include SO_4^{2-} and Cl^-, neither of which typically pose any health risks (WHO 2011). In certain cases, they are signs of anthropogenic water contamination and may affect the taste of drinking water. In the current study research, SO_4^{2-} concentrations varied from 25 to 597 mg/L during the summer season and from 160 to 319 mg/L during the winter. Cl^- concentrations ranged from 25 to 893 mg/L during the summer season and from 74 to 755 mg/L during the winter.

The agricultural production depends heavily on nitrogen and its components. The maximum allowed limits for NO_3^- are 45 mg/L, according to the BIS. Nitrate concentration is frequently used to depict nonpoint agricultural pollution in agricultural regions. According to this study, the ground water NO_3^- concentration is low in the dry season and varies from 0.12 to 19 mg/L, indicating that it is appropriate for domestic uses The sample's NO_3^- concentrations range from 5 to 80 mg/L over the winter. One sample had a higher concentration of NO_3^- than the standard limit of IS-10500 which make it unfit for portable use. The water quality represent variations during the summer season and winter seasons. The parameters show fluctuation. Higher variations of EC and TDS were observed because of mining activities. In the winter season, the observed value of fluoride was higher than the desirable limit of IS-10500. As per the geological study (CGWB, Mahendragarh district 2018), the area is categorized by rocks from the Delhi Supergroup, a Proterozoic-age rock unit that is part of the Aravalli Mountain Range. The Delhi Super-group rocks in the Bakhrija mines are made up of quartzite, phyllite, and slate and are generally folded and faulted as a result of the region's tectonic activity. The area is well-known for mineral mining operations such as silica sand, quartz, and feldspar. Concerns have been raised about the impact of mining activities on groundwater resources, which is the primary source of water for the local population. The study clearly says the study states that the geological feature of study area is composed of faults which introduce certain chemicals into the water through percolation, whereas mining also plays a crucial role in altering the various water quality chemical parameters. Activities such as drilling and blasting may widen the gaps of faults of aquifer around mining region which may increase the input of these chemicals to the groundwater aquifer value of parameters. But in the winter season, the quality of groundwater is improving because of the canal irrigation which ultimately decreased the dependency of groundwater to some extent. Still, the zone of contamination is present and the water quality of certain pockets is not good.

4.4.3 Base Exchange and Ground water genesis

The prevailing dominant soil water faces in the study area were determined based on the concentration (in mEq/L) of selected dominating anions (Cl^- and SO_4^{2-}) and a cation (Na^+). The following equation was used to classify groundwater (all units are in meq/l).

Base Exchange (base exch)= $Na^+ - Cl^- / SO_4^{2-}$ meq/l (Matthess 1982) (29)

In the aforementioned equation (26), base exchange value more than one indicates that the groundwater of the Na^+- HCO_3^- type; and base exchange values less than one indicate that the groundwater is of the Na^+- SO4 $^{2-}$ type. The base exchange index plot demonstrated that the majority of the samples (87%) in the research area belonged to the Na^+-SO4 $^{2-}$ type, while only 13% belonged to the Na^+- HCO_3^- type. It's widely known that the Na^+ -SO4 $^{2-}$ water component accelerates the carbonate mineral deposition of calcite and is associated with the release of fluoride from minerals in gneissic basement rocks and granite accumulation due to the dissolution of silicates and, consequently, a rise in the concentration of fluoride in groundwater (Ambastha and Haritash, 2021). Na^+ (aq), a conjugate base of the strong acid fluoride that does not react with water, is released when NaF(s) dissolves. The F^-ion is created when the salt NaF is dissolved in water (Mamatha and Rao et al.2010; Haritash et al. 2018). The main elements in the research region that result in a high level of fluoride are the ion-exchange reactions followed by the mineral reaction.

$$\underset{\text{(Water)}}{Na_2SO_4} + \underset{\text{(rock)}}{CaF_2} \rightarrow \underset{\text{(Water)}}{2NaF} + \underset{\text{(Rock)}}{CaSO_4} \qquad (30)$$

These are the major elements for carbonate weathering because they are abundant in carbonate rocks like limestone, dolomite limestone, and dolomite. During groundwater percolation, the carbonates that are found in these rocks are dissolved in the water. The main chemical factors determining the groundwater carbonate equilibrium are calcium (Ca^{2+}), magnesium (Mg^{2+}), their molar ratio (Ca / Mg), and hydrogen carbonate (HCO_3^-). In general, the lithological makeup of groundwater recharge sites determines the molar ratio between calcium and magnesium in groundwater. For example, if the Ca/Mg molar ratio is equal to 1, dolomite is likely present, but a greater molar ratio shows that calcite crystals are dissolving. Carbonate dissolution is the main process that affects the chemical quality of the groundwater in the study region, as shown in Fig.4.28 (a) of Mg^{2+}/Na^+ vs Ca^{2+}/Na^+. Once more, the cross plot of the variables (Fig. 4.28 (b)) ($Ca^{2+}+ Mg^{2+}$) ($HCO_3^- + SO_4^{2-}$) (Fig. 4.26-a-b) is seen and suggests that the majority of the samples with more than 1.0 mg/L fluoride concentration are found above equilline, which further suggests that higher F^- and HCO_3^- concentrations in the groundwater are the result of carbonate dissolution, weathering, and the movement of ions in the area.

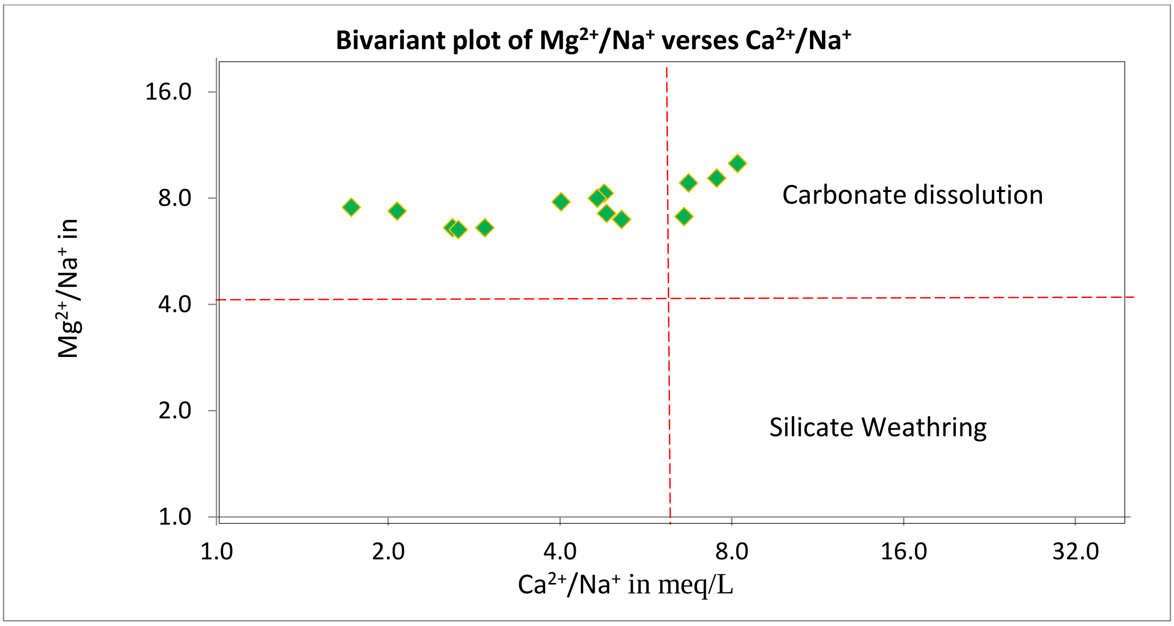


Fig 4.28 (a) Bivariant plot of Mg^{2+}/Na^+ verses Ca^{2+}/Na^+

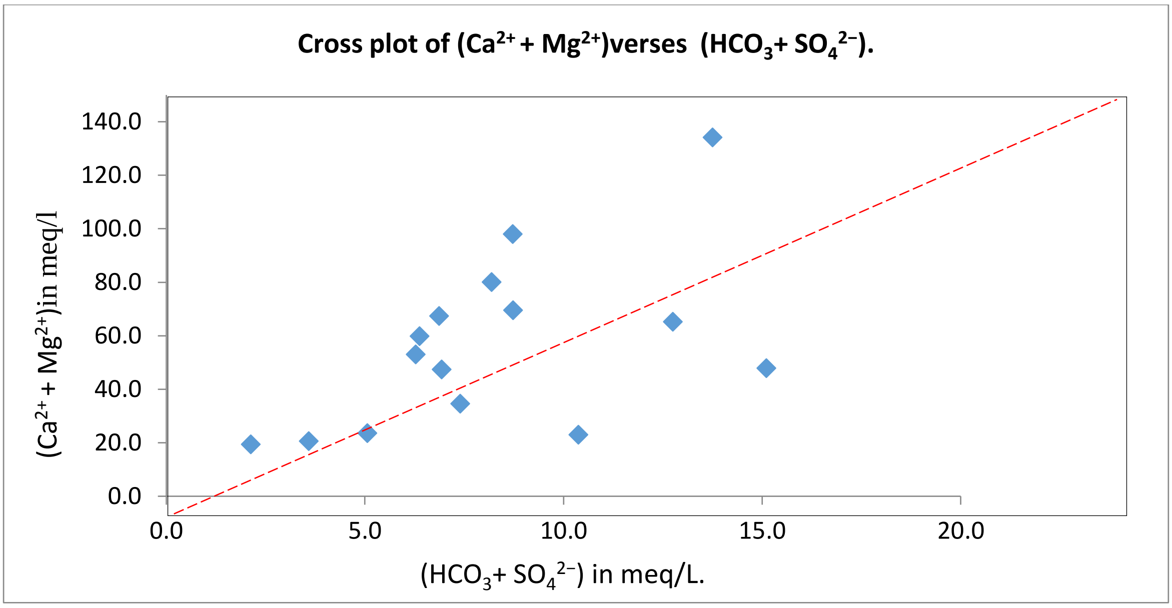
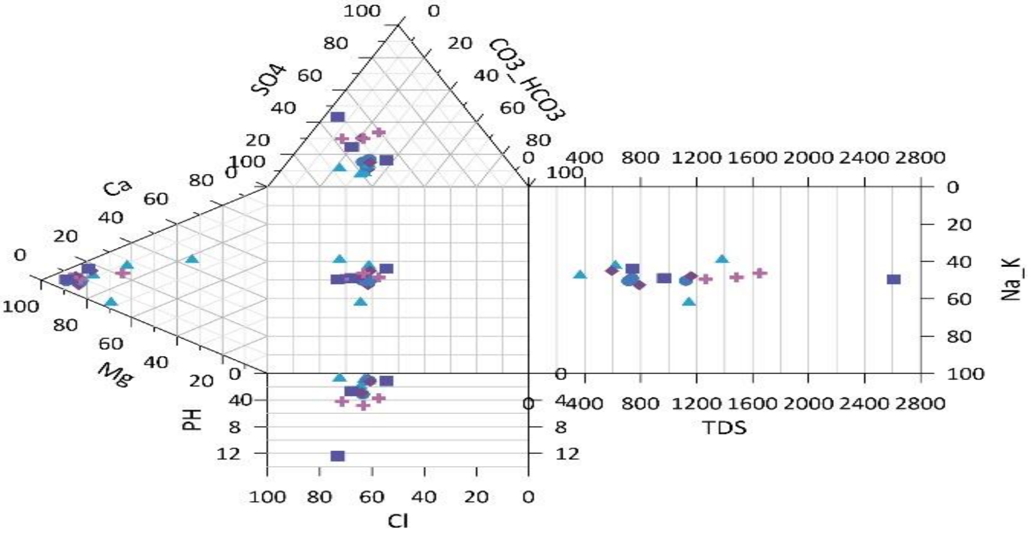


Fig 4.28 (b) Cross plot of (Ca^{2+} + Mg^{2+}) verses (HCO^{3-} + $SO4^{2-}$).

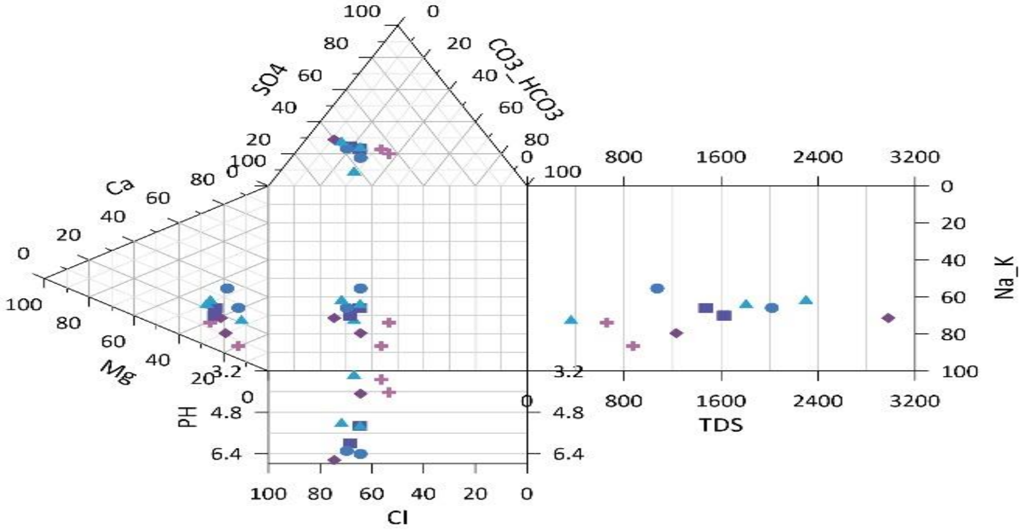
It is generally known that a rise in pH (also known as an alkaline state), sodium, and bicarbonate ion concentrations eventually elevate the concentration of fluoride in groundwater as a result of the aforementioned reactions and processes. In general, the interaction of rock and water caused by a longer stage of transition and the ion exchange mechanism means that when fluoride-bearing minerals in rock layers are weathered and dissolved under alkaline conditions, higher concentrations of fluoride are released into the groundwater or aquifer.

4.4.4 Classification of Ground water

The Durov diagram (Durov 1948) is a mixture plot consisting of two ternary charts in which the percentages of cations of choice are contrasted against those of anions of choice, and the sides of both ternary plots create a center rectangle plot displaying total cation versus total anion concentration (Patolia and Sinha, 2017).



(a)



(b).

Fig. 4.29 Durov's classification of the ground water around Bakhrija mines (a. summer season and b. winter season)

A subdivision of the core rectangular plot, in particular, might show the types of hydro-chemical processes involved, such as mixing or dissolving, ion exchange, and reverse ion exchange. The majority of the sample plots lie in the centre of the rectangle plot, indicating that dissolution and mixed kinds of water are the dominant water types (Figure 4.29).

Few samples fall on either side of the middle rectangular pattern, indicating ion exchange and reverse ion exchange, implying Na^+, Cl^-, and HCO_3^- dominance (Lloyd and Heathcote, 1985). In the present study, reverse ion exchange (Na^+ replaced by Ca^{2+}) might have resulted in the formation of Ca-Cl water. The probable factors that might be responsible for the formation of Ca-Cl water could be due to the breakdown of rock minerals and the mixing of fresh water with additional mining water accumulated in the pit.

4.4.6 Spatial distribution of fluoride and its effect

The concentration of fluoride in water samples ranged between 1–20 mg/L. As per Indian standards and WHO the maximum permissible limit of F^- is 1 mg/L and 1.5 mg/L respectively.

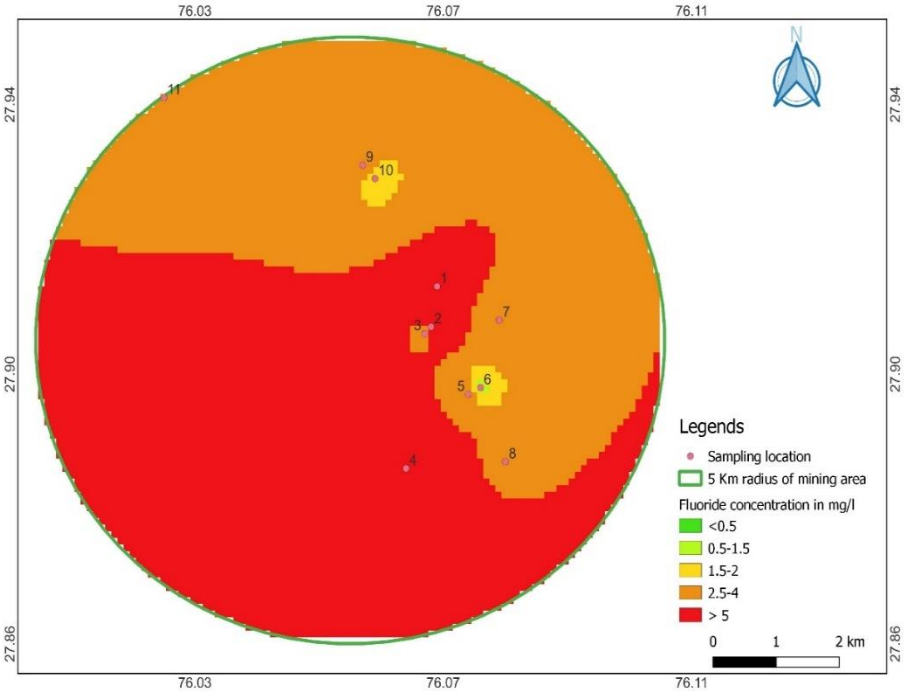


Fig. 4.30 Spatial distribution of Fluoride concentration (mg/L) in groundwater.

In prolonged exposure of fluoride under 1 mg/L in water may weaken bones and stimulates decay of tooth. It causes dental fluorosis when taken in high doses (>1.5 mg/L), and very high concentrations (>3.0 mg/L) might cause skeletal fluorosis. Groundwater samples are divided into four classes based on fluoride content and medical issues linked with it: (A) low (0.6 mg/L); (B) acceptable (0.6–1.5 mg/L); (C) high (1.5–3 mg/L); and (D) very high (>3 mg/L). The fluoride content in groundwater at several locations is represented in Figure 4.30, Location 4 contains high fluoride of order 20 mg/L in the southern and western parts of the study area, whereas only location 6 has a low fluoride concentration that is 1mg/L. Among all the collected samples fluoride concentrations was less than 1.5 mg/L, at only one location indicating that the water was safe for human consumption in that pocket. Among all the samples 90% of the samples surpasses the desirable limit of IS-10500.

4.4.7 Fluoride exposure and health implication

Health risk assessment has great importance for determining the extent and possibility of health consequences of people living in the region which is vulnerable to life-threatening contaminants by drinking water. The oral ingestion of excess fluoride by drinking water plays a crucial role and can pose a non-carcinogenic health risk to the population. Accordingly, the concentration of non- carcinogenic fluoride to human health is estimated in terms of daily intake or hazard quotient (Table 4.12). Hazard quotient of the fluoride for the collected samples lies between 0.4 to 8.8 and the mean F^- concentration of the all collected samples is 2 mg/l which is higher than the permissible limit of BIS (2012).

Fluoride concentration of more than 1.5 mg/l has been found in groundwater of Bakhrija village (Fig 4.31) with maximum concentration of 11 mg/l and high value of HQ. Bakhrija is the nearest village from the mining area. Other villages *viz*. Dholera, Meghot Binja, and Meghot Halla represented groundwater fluoride concentration between 2.5- 4 mg/l and maximum concentration of 5 mg/l (Meghot Binja). Hazard quotient was in between 0.8 – 4.0 for these villages. Nujota and Khojpur Nagalia represented groundwater fluoride concentration within the permissible range. Human population living in the villages where the concentration of fluoride is recorded above the permissible limit are more likely to be exposed to potential health risks.

Table 4.12: Prevalence of fluoride and associated health risk in groundwater of different villages around Bhakrija mine, Mahendragarh.

S. No.	**Village**	**pH**	**TDS**	**Risk Assessment**			
				F^- (mg/L)	**CDI (Water)**	**HQ**	**Inference**
1	Bakhrija	8.6	340	11	0.44	8.8	Severe Dental and Skeletal Fluorosis
2		7.4	440	3	0.12	2.4	
3	Dholera	7.7	720	2	0.08	1.6	Dental and skeletal Fluorosis on prolonged Exposure
4		7.9	300	5	0.2	4	
5		7.8	760	2	0.08	1.6	
6		7.6	840	2	0.08	1.6	
7	Meghot Binja	7.6	920	2	0.08	1.6	Dental and Skeletal Fluorosis on prolonged Exposure
8		7.3	1020	2	0.08	1.6	
9		8.0	320	5	0.2	4	
10	Nujota	7.4	660	0.5	0.02	0.4	No Effect
11		7.5	1280	0.5	0.02	0.4	
12		7.0	1740	0.5	0.02	0.4	
13	Meghot Halla	7.1	640	1	0.04	0.8	No Effect
14		7.6	880	3	0.12	2.4	Dental & Skeletal Fluorosis
15	Khojpur Naglia	7.6	3020	0.5	0.02	0.4	No Effect

CDI- Chronic daily intake; HQ- Hazard quotient

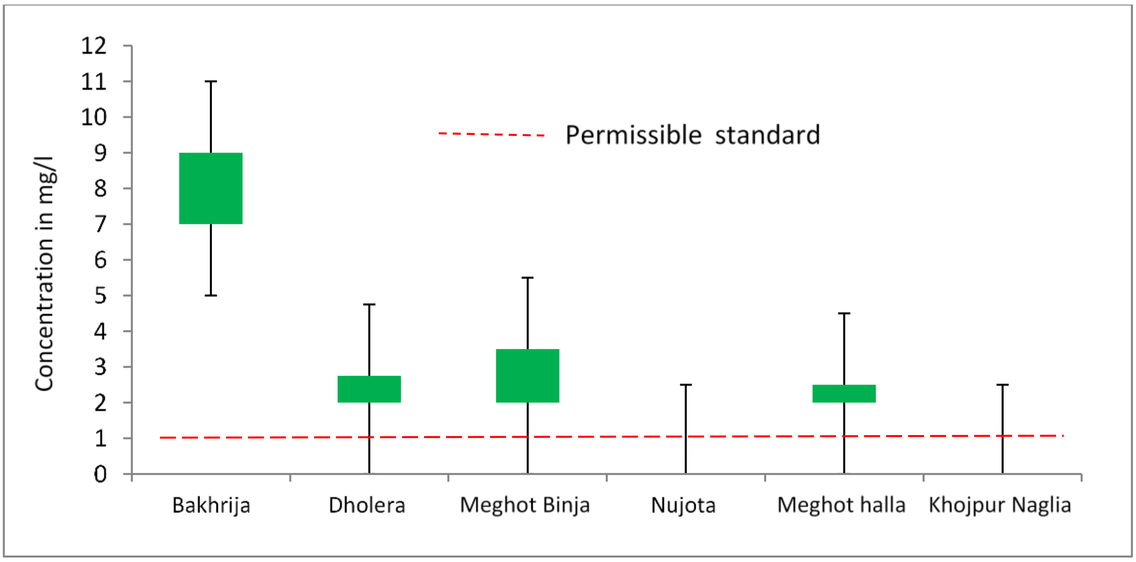


Fig. 4.31 Spatial variation of fluoride in groundwater around Bakhrija mine, Mahendragarh

Fluorosis is a chronic disease involving the human population and is exacerbated through the intake of a higher volume of fluoride through food and drink (Nuccio 2016). Children are more susceptible to higher fluoride as compared to adults. Lower body weight than adults could be the cause of higher risk from the exposure of fluoride (Kumar et al. 2016). Exposure to fluoride (0.5 - 1.0 mg/l) is very important in early phase of life as it can stop caries, but higher level (>1.5 mg/l) can lead to dental and skeletal fluorosis.

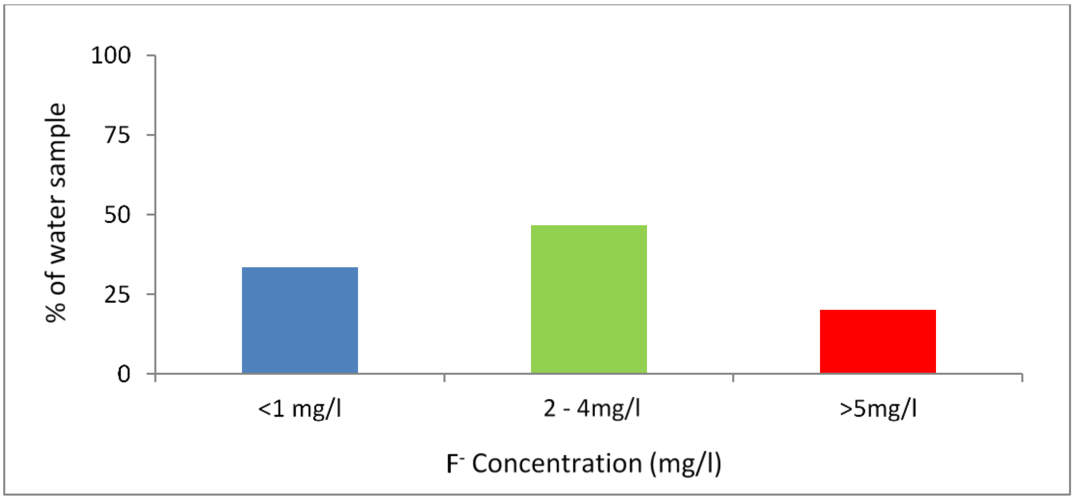


Fig. 4.32 Classification of groundwater sample with respect to risk of fluorosis in village around Bakhrija mine, Mahendragarh

Fluoride consumption for the first three years of life is the most important in fluorosis aetiology (Levy et al. 2002). The groundwater of the study area was classified into three classes *viz.* 0-1 mg/l as safe; 1-4 mg/l causing dental fluorosis; and more than 5 mg/l causing skeletal fluorosis. About 33% samples fall in Class-I groundwater samples and can be considered safe for drinking; while 46% and 20% of groundwater come under Class II and Class III, respectively, and can cause dental and skeletal fluorosis (Fig. 4.32).

Chronic intake of excessive F^- water (*i.e.* 1.5–4.0 mg/l) can lead to fluorosis of the enamel and bone, and in severe cases (*i.e.* 4–10 mg/l), skeletal fluorosis associated with joint weakness, ligament calcification, and some osteosclerosis of the pelvis and vertebrae may be observed (Liang et al. 2017; Narsimha and Sudarshan 2016; Podgamy and McLaren 2015). This occurs mostly because F^- is highly electronegative and has a comparable ionic radius (133 pm) to that of hydroxyl ion (140 pm), which contributes to hydrogen fluoride formation (Kumar et al. 2016). Fluoride compound in the human body, in fact, easily diffuses through the intestines, dissolves in the blood and accumulates in calcified tissues (Dey and Giri 2016). Health related problems in and around the impacted fluoride areas are primarily non-carcinogenic in nature, especially in the areas examined, where fluoride in drinking water does not reach 10 mg/l. However, higher doses (> 10 mg/l) can be correlated with debilitating fluorosis and carcinogenic risk (Ali et al. 2019). Confined studies on this aspect indicate that fluoride may allow cells to develop faster enough that will become cancerous over time, but it is controversial since there is no reliable correlation between fluoride and the influence of carcinogenicity (Bajpai 2013).

4.4.8 Simulation of regional flow of the study area

This study uses the MODFLOW interpretation of regional flow. Regional flow denoted the trend and direction of groundwater flow in an area. The packages include those for boundary conditions, wells, time variant-specific packages, and recharge. The Well (WEL) package in MODFLOW is used to simulate groundwater abstraction. The well package is made to imitate wells that take water from aquifers at a set rate that is unaffected by the size or head of the cell. The recharge package is used to simulate a defined flow that is dispersed over the model surface and that is specified in length/time units. In this model, all these package parameters are used to analyse and interpret the regional flow of the area. Volumetric flow rates were calculated in MODFLOW by multiplying these rates by the horizontal area of the cells to which they are applied. 20% of the total precipitation, in this case, was considered for total infiltration of the research region.

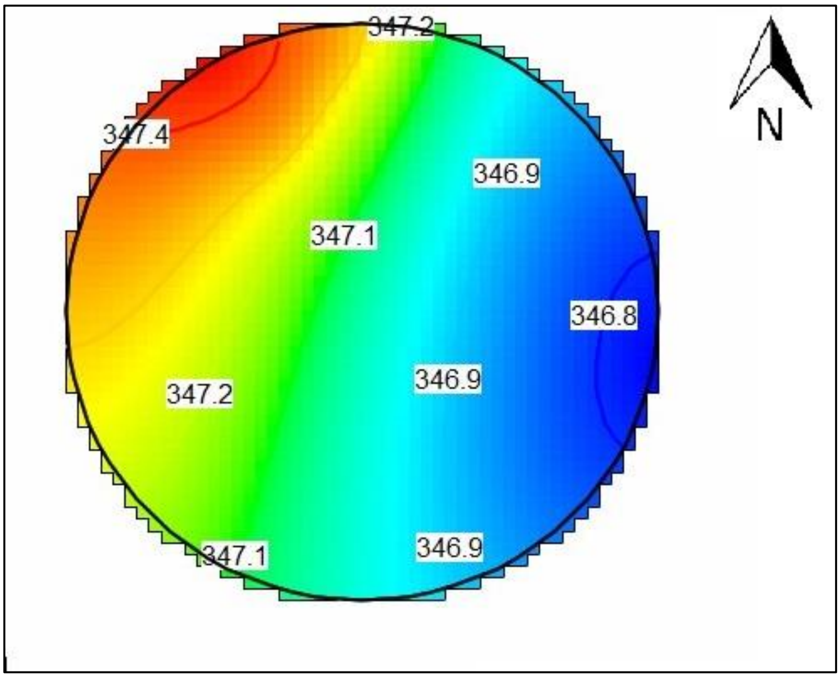


Fig. 4.33 Simulated groundwater flow contour map

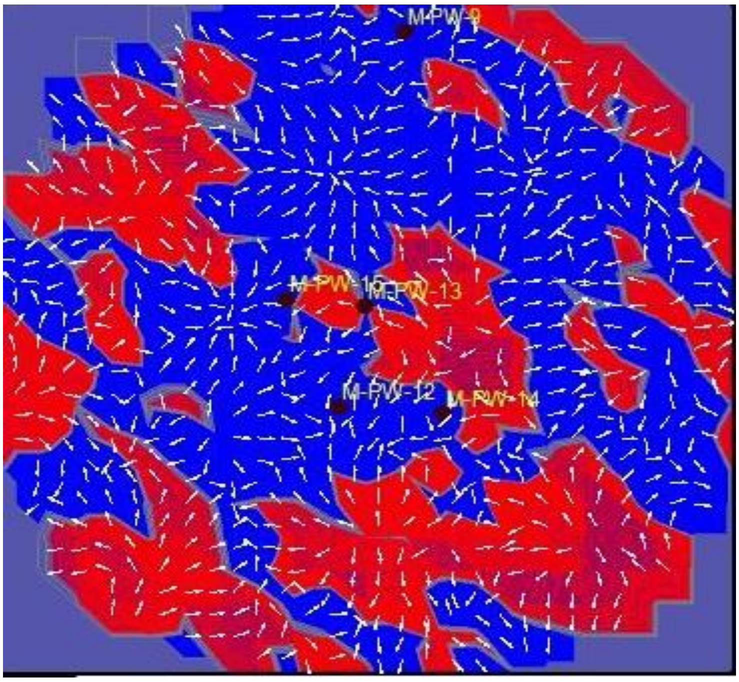


Fig 4.34 Groundwater velocity vector map for Study area

Time-Variant Specified- To mimic changing head borders throughout or between stress episodes, head packages were employed. Water exits the system as a function of the head in the cell inside the evapotranspiration border due to the evapotranspiration package. In this case, the top layer of the model is given as evapotranspiration value.

Furthermore, the MODFLOW model was simulated using the ModelMuse interface to produce three-dimensional groundwater models to generate regional flow contours for the study area. The simulated groundwater level contour and the simulated aquifer of the study (Figure.4.33 and 4.34) depicts the area's groundwater velocity vector of the area. Figure 4.33 shows that the groundwater is entering the 5KM area of the study area from North West direction and leaving the area in the East direction. According to the flow direction, it is evident that the contaminant transport and accumulation of fluoride will be higher (Fig.4.34) in south-west direction of the study area. The water velocity of the aquifer also shows the change in the flow at the mining region and it’s not flowing through the general regional flow. The general trend is disturbed by the mining activity and results in disturbance in the hydraulic head also. Because of that it also changes the infiltration condition of the area which will lead towards change in the chemical and physical properties of water. During infiltration, water may pass through different types of rocks present in aquifers laden with different chemicals which may alter the quality of water.

4.4.9 Factors regulating the ground water quality

Stone quarrying may also have a considerable impact on water quality in the surrounding areas. Large volumes of rock and soil are removed during the extraction process, which can modify the hydrological properties of the area and cause changes in the flow and quality of water. For example, removing vegetation can increase soil erosion and sedimentation in neighbouring water sources, resulting in increased levels of turbidity, and dissolved and suspended particles resulting in poor water quality.

Temperature, precipitation, runoff, and other elements that affect the flow and quality of water in a specific location can all cause seasonal variations in water quality. Increased rainfall and runoff, for example, during the rainy season, can result in greater amounts of silt, nutrients, and pollutants in streams and rivers. On the other hand, during the dry season, lower water levels and lean flow can concentrate pollutants, resulting in increased concentrations of dissolved pollutants and contaminants.

The influence of stone quarrying on groundwater quality indicated a considerable rise in the concentration of several contaminants around quarrying sites. Contaminants such as nitrates and fluoride were found in higher amounts throughout the summer and winter seasons when groundwater levels were lower and pumping rates were higher. The existence of neighbouring agricultural operations, as well as the usage of fertilizers and pesticides, might potentially increase the effects of quarrying on groundwater quality. During the rainy season, the concentration of different contaminants in surrounding water sources increased significantly. This is because of increased erosion and runoff induced by large rain events, as well as pollution released by quarrying activities. The study highlighted a considerable seasonal change in groundwater quality around quarrying operations. The concentrations of different contaminants in groundwater were found to be higher during the summer season when pumping rates were higher and groundwater levels were lower during the rainy season. Pollutants with increased concentrations during the dry season included nitrates and total dissolved solids (TDS), fluoride, carbonates, and bicarbonates, and in a few pockets, higher values of sodium, potassium, and chloride were observed. Increased pollutant concentrations are attributed to several causes, including increased pumping rates, lower recharge rates, and pollution discharge from quarrying operations. Because of the presence of neighbouring agricultural operations, as well as the usage of fertilizers and pesticides might enhance the effects of quarrying on groundwater quality. Changes in precipitation, recharge rates, and other variables that govern the flow and quality of water in the subsurface can cause seasonal variations in groundwater quality. Increased rainfall and recharge, for example, during the rainy season, can dilute groundwater and reduce concentrations of dissolved solids and other contaminants. In contrast, decreased recharge rates and increased pumping during the dry season might result in more concentrated pollutants and higher amounts of dissolved solids. Precipitation and recharge rates are often higher during the monsoon and winter seasons, which can assist to dilute contaminants in groundwater and enhance the overall water quality. Nevertheless, the winter season can provide additional issues for groundwater quality, especially if quarry activities generate runoff or erosion from rainfall events.

Stone quarrying has negative effects on groundwater quality. Excavation of rock and soil, for example, might modify the hydrogeological properties of the area, affecting the flow and quality of groundwater. Quarrying activities may also lead to the discharge of pollutants and toxins into groundwater, such as heavy metals, which can have long-term consequences for both human health and the ecosystem. Generally, the influence of seasons on groundwater quality varies depending on factors, like location of the quarry, the type of rock being quarried, the volume of water utilized or pumped, and the existence of other pollution sources in the region. The study emphasizes the necessity of frequent water quality monitoring and evaluation around stone quarrying sites, as well as the need for appropriate mitigation strategies to decrease the consequences of quarrying on water resources and human health. Using best management practices, such as effective erosion control measures, stormwater management systems, and frequent water quality monitoring, can help to detect and treat any possible concerns.

4.5 Effect of quarrying activities on vegetation and soil

The generation of dust and particulate matter from stone quarrying activities can have a substantial impact on air quality. The effect on air quality is frequently more obvious in dry and windy conditions, as these variables increase the quantity of dust generated and its capacity to cover the distance before getting settled. Quarrying processes notably drilling, blasting, and crushing, can generate significant amounts of dust. This dust may contain hazardous particles such as silica, which settle out on the leaves and can alter the biological properties of exposed vegetation. Quarrying activities can also emit particulate matter, which can comprise both fine and coarse particles ($PM_{2.5}$ and PM_{10}). These particles settle out on leaves can disturb the photosynthetic activities of all exposed vegetation. These activities are carried out using heavy machinery such as excavators, bulldozers, crushing machines, and trucks, all of which emit pollutants such as diesel exhaust and other. Quarrying's influence on air quality severely effect the growth and bio-chemical properties of vegetation.

Stone quarrying may have a major influence on groundwater quality, primarily the area’s hydrology, pollution from chemicals and other pollutants, and disturbance of the aquifer recharge zone. Quarrying activities can disrupt the aquifer's recharge zone, causing changes in the quality and flow of groundwater. It may influence the groundwater quality and can also have social and economic consequences for nearby populations. If groundwater quality is bad, for example, it may have an influence on the health and quality of life of surrounding inhabitants and employees, as well as the availability of water resources for agriculture and other economic activities.

Quarrying for stone may have a substantial impact on vegetation, especially through habitat loss, soil degradation, and air pollution. Quarrying activities can result in the significant destruction of flora and habitat, which influences the biodiversity of the surrounding region.

Such activities can cause soil erosion, compaction, and degradation, reducing the soil's ability to sustain plants. This can reduce plant diversity and production while also increasing the danger of soil erosion. Quarrying cause the release of dust, particulate matter, and other pollutants into the atmosphere, affecting the health and growth of plants. Air pollutants can also diminish photosynthetic potential of the plant, resulting in decreased growth and yield. It can also result in significant levels of noise pollution, which can have a direct influence on plant growth and production. Extended exposure to loud noise can also cause stress in plants, resulting in diminished growth and susceptibility to disease.

4.5.1 Effect of quarrying on vegetation

The Air Pollution Tolerance Index (APTI) assesses plants' capacity to withstand air pollution. It is computed and used to measure air quality in a region based on the presence or absence of specific plant species. Dust, gases, and other pollutants related to quarrying activities may have an impact on air quality in a quarrying zone. The APTI can be used to evaluate the effect of these contaminants on local vegetation. The pH, RWC, chlorophyll, and ascorbic acid concentrations of the trees obtained after the chemical analysis are given in Table 4.13 for the summer season and Table 4.14 for the winter season. The description of the individual parameters is given below.

pH

The pH of leaf sap was determined to be mildly acidic, with a mean value of 6.51. *Millettia pinnata* near the crusher had a maximum pH of 6.9, whereas *Syzygium cumini* also identified near the crusher had a minimum pH of 5.96. According to the study, a low pH of cell sap suggests vulnerability to air contaminants. In contrast, the high pH of the leaf extract is thought to aid reduce sensitivity when exposed to acidic contaminants.

Relative Water Content (%)

The RWC of the plants was found to be between 52.8% (*Millettia pinnata*) and 85.8%. (*Azadirachta indica). Azadirachta indica*, a prominent plant in the study region, has a wide range of RWC, with a minimum of 66.9% and a maximum of 85.8%. The minimal RWC was measured upwind of the mine, whereas the maximum RWC was measured near the crusher.

Table. 4.13: Biochemical characterisation of vegetation around Bakhrija mines, (June 2019)

S. No.	Plant species	Location#	pH	Relative water content (%)	Total Chlorophyll (mg/g fresh wt)	Ascorbic Acid (mg/g dry wt)	APTI	Inference*
1.	*Syzygium cumini*	C	6.0	75	2.77	2.53	10	IT
2.	*Azadirachta indica*	C	6.7	86	0.70	3.28	14	IT
3.	*Millettia pinnata*	C	6.9	62	1.36	9.30	14	IT
4.	*Melia azedarach*	C	6.5	68	11.13	7.13	19	MT
5.	*A. lebbeck*	C	6.7	58	10.36	5.35	15	IT
6.	*Azadirachta indica*	M	6.0	78	9.49	3.49	13	IT
7.	*Syzygium cumini*	M	6.8	84	12.34	5.34	19	MT
8.	*Millettia pinnata*	M	6.4	53	21.70	13.7	44	T
9.	*Millettia pinnata*	U	6.9	74	11.90	2.90	13	IT
10.	*Azadirachta indica*	U	6.5	67	15.66	5.66	19	MT
11.	*Azadirachta indica*	R	5.9	70	18.91	7.91	27	MT
12.	*Dalbergia sissoo*	R	6.7	73	15.18	3.18	14	IT
13.	*Ficus benghalensis*	R	6.7	82	15.66	2.66	14	IT

*Where *T- Tolerant; MT- Moderately Tolerant; IT- Intermediate Tolerant;*

 # C- Crushers; M – Mine pit; U- Upwind; R- roadside

Water is essential for plants to maintain a normal and healthy state. In a polluted state, the plant normally experiences stress, and under such conditions, the rate of transpiration increases, triggering drought-like conditions.

High RWC is frequently used to assess cell permeability; a permeable cell tends to lose water and nutrients, resulting in early leaf aging. In the current study, decreased water content in particular regions/species may be related to low leaf permeability caused by dust deposition, which plugs the stomatal pores. Increased RWC is proven to benefit plants during drought; plants demonstrate increased tolerance. As a result, plants with high RWC exhibit tolerance to harmful elements in the environment.

Table. 4.14: Biochemical parameters and APTI values for different crop species and trees Collected around Bakhrija mines, Mahendragarh Haryana (February 2022)

S.No	**Plant/Tree species**	**Location#**	**pH**	**Relative water content (%)**	**Total Chlorophyll (mg g^{-1} fresh wt)**	**Ascorbic Acid (mg g^{-1} dry wt)**	**APTI**	**Inference***
1.	*Triticum aestivum*	U	6.37	78	6.4	7.0	12	IT
2.	*Brassica nigra*	U	6.38	76	6.4	5.3	11	IT
3.	*Brassica nigra*	R	6.8	89	6.8	3.5	11	IT
4.	*Millettia pinnata*	C	6.2	51	16.2	12.6	39	T
5.	*Spinacia oleracea*	D	6.7	80	6.7	2.6	9	IT
6.	*Brassica nigra*	R-D	5.8	89	5.8	2.6	10	IT
7.	*Raphanus sativus*	D	6.5	94	6.5	4.4	12	IT
8.	*Triticum aestivum*	R-D	6.4	74	6.4	6.2	11	IT

*Where *T- Tolerant; IT- Intermediate Tolerant;*

 # U- Upwind; C- Crushers; ; R- roadside; D- Downwind; R-D- Roadside downwind

Total Chlorophyll

The total chlorophyll (TCh) among all the species, observed concentration was 1.12 mg/g on fresh weight basis. *Azadirachta indica* was found to have a minimum of 0.70 mg/g TCh in two locations: near the crusher and along the road side. *Syzygium cumini* near the crusher had the highest concentration of 2.77 mg/g . The total chlorophyll concentration serves as an indication for growth, development, and photosynthesis-related activities, and it is likely to vary based on species, leaf age, pollution level, and other biotic and abiotic factors. The degradation of chlorophyll content is evidence of poor air quality. Also, the TCh Content is low in plants with increased dust deposition. The dust particles create a covering, preventing sunlight from reaching the plant and so impeding the coloring process. Injury at the frondescence level as a result of alkaline dust deposition, yellowing of leaves, early leaf fall, and stunted development are only a few of the impacts observed.

Ascorbic Acid Content (AA)

The mean ascorbic acid concentration was 5.57 mg/g, and lowest 2.53 mg/g for *Syzygium cumini* which was located near the crusher, and a high of 13.70 mg/g for *Millettia pinnata* near the mine. Ascorbic acid, an antioxidant, is essential for the proper growth of plants. It is also known to have an influence on plant defence systems. A high amount of Ascorbic Acid is connected with the high degree of pollution, whereas a low quantity is associated with a weakening of plant defences. A high quantity of AA is useful for protecting the thylakoid membrane from oxidation reactions under restricted water settings. Ascorbic acid boosts plant resilience to contaminants while also scavenging reactive oxidizing species (ROS), the creation of which occurs in mineral-deficient environments. The action of Ascorbic acid is pH dependent. Plants' Ascorbic acid concentration is frequently higher at higher pH and lower at lower pH. As a result, leaf extracts with higher pH are more resistant to air pollution. According to APTI, *Millettia pinnata* had the highest APTI score and rooted near the mine pit. The equation given by Singh and Rao (1983) was used, and it was finally determined that *M. pinnata* belongs to the tolerant group. Also, *M. azedarach* and *S. cumini*, both with APTI values of 19, and found at the crusher and mine pit, belonged to the moderately tolerant group. *A. indica* with an APTI value of 19 on the upwind side and a value of 27 (Fig.4.35) on the roadside was found to be moderately tolerant. The remaining species, which were sparingly scattered in four sites, namely near the crusher, mine, upwind region, and roadside, belonged to the intermediate category. When the APTI is low, it signifies poor air quality and the possibility of harm to human health and the environment. In such circumstances, actions to minimize pollution and enhance air quality should be implemented.

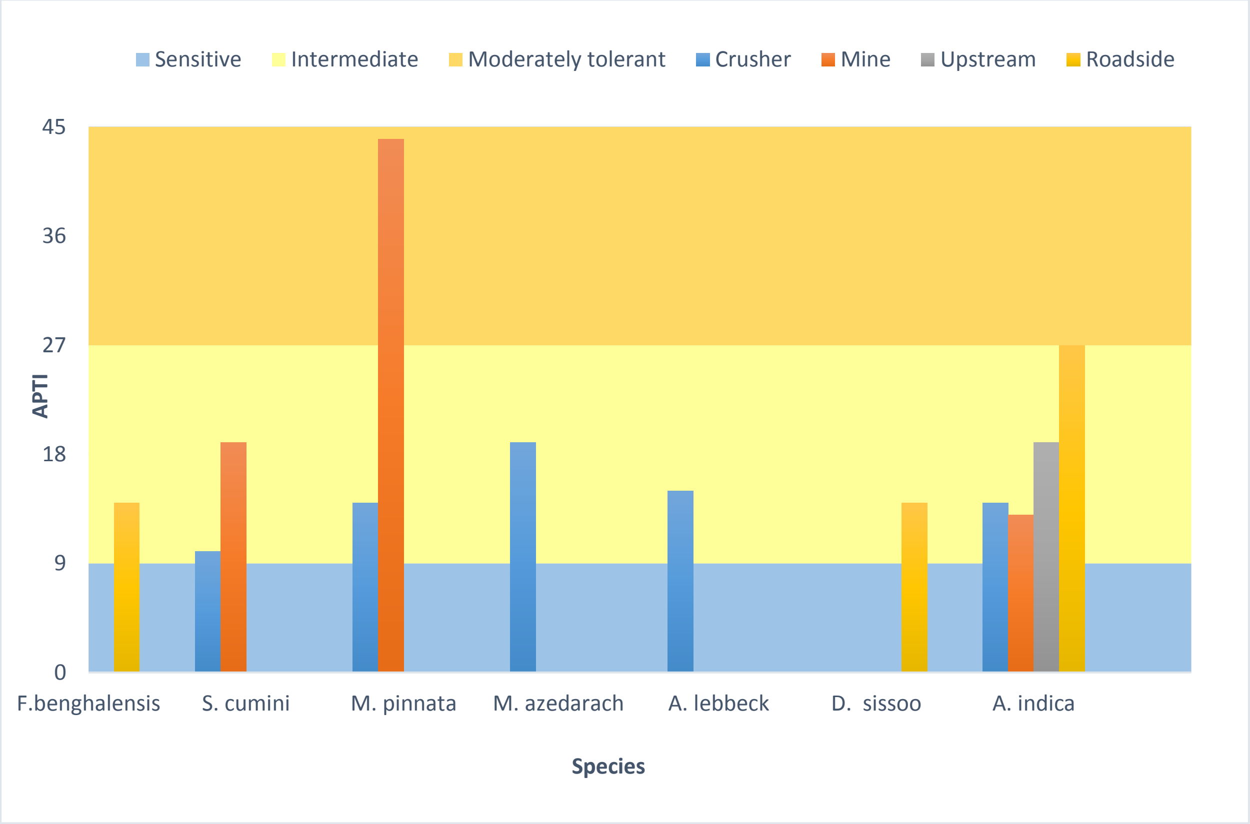


Fig. 4.35 Categorization of tree species against APTI for different locations

As per the analysis and Grading of the tree species Fig. 4.35, Additionally, Table 4.15 summarizes the different species, the anticipated performance and their assessment with respect to air pollution abatement. The best performers among the representative samples collected were found to be *Syzygium cumini*, *Millettia pinnata*, *Dalbergia sissoo* and *Ficus benghalensis* with an Anticipated Performance grade of 4 (very good category) while *Azadirachta indica* and *Melia azedarach* displayed slightly less tolerance with an API grade of 3 (Moderate category). A very poor performance was recorded for *A. lebbeck* therefore not recommended for the green belt development.the species. *Milletia pinnata* is the tolerant species in the mining region because of good APTI score, whereas during winter season the APTI of different species of plants and trees were determined. After analysing all the test under APTI, all the plants were intermediate tolerant except *Milletia pinnata*. Low score of APTI may lead to slow growth of plants or poor yield. To restrict fugitive dust pollution the tolerant plant should be planted around the mining region to restrict the dispersion of dust.

Table: 4.15: Evaluation of API of plant species based on their APTI values

Plant species	APTI	Tree Habit	Canopy structure	Type of tree	Size	Texture	Economic Importance	Hardness	Total Plus	% score	API Grade	Assessment
S. cumini	++	++	++	+	+	-	+	+	10	62.50	4	Good
A. indica	++	++	+	+	-	-	++	+	9	56.25	3	Moderate
M. pinnata	++	+	++	+	++	-	++	+	11	68.75	4	Good
M. azedarach	+++	+	+	+	-	-	++	+	9	56.25	3	Moderate
A. lebbeck	++	+	+	-	+	-	+	-	6	37.50	1	Very poor
D. sissoo	++	++	++	+	+	+	+	+	11	68.75	4	Good
F. benghalensis	++	++	+	+	++	+	+	+	11	68.75	4	Good

4.6 Effect of quarrying on soil

Mining activities destroy the landscape. Mining can cause geology and soil-plant stability circuits to get disrupted, system imports to grow, and the soil organic pool to decrease, among other effects. Since soil is the primary repository for all the contaminants created during mining, studying how mining influences soil characteristics is essential.

As a result of mining, clearing vegetation in the mining area, decreases the soil organic matter and necessary nutrients, biological activity, and productivity, especially in places where agriculture is the dominant occupation. These soils tend to concentrate on the chemical elements found in the parent rock and have the potential to contaminate groundwater. Changes in the physicochemical properties of soil result in infertile or barren soil, which for years cannot support conventional plant development and affects the agricultural output as well. In other words, the area will become wastelands due to mining.

4.6.1 Physical properties of soil

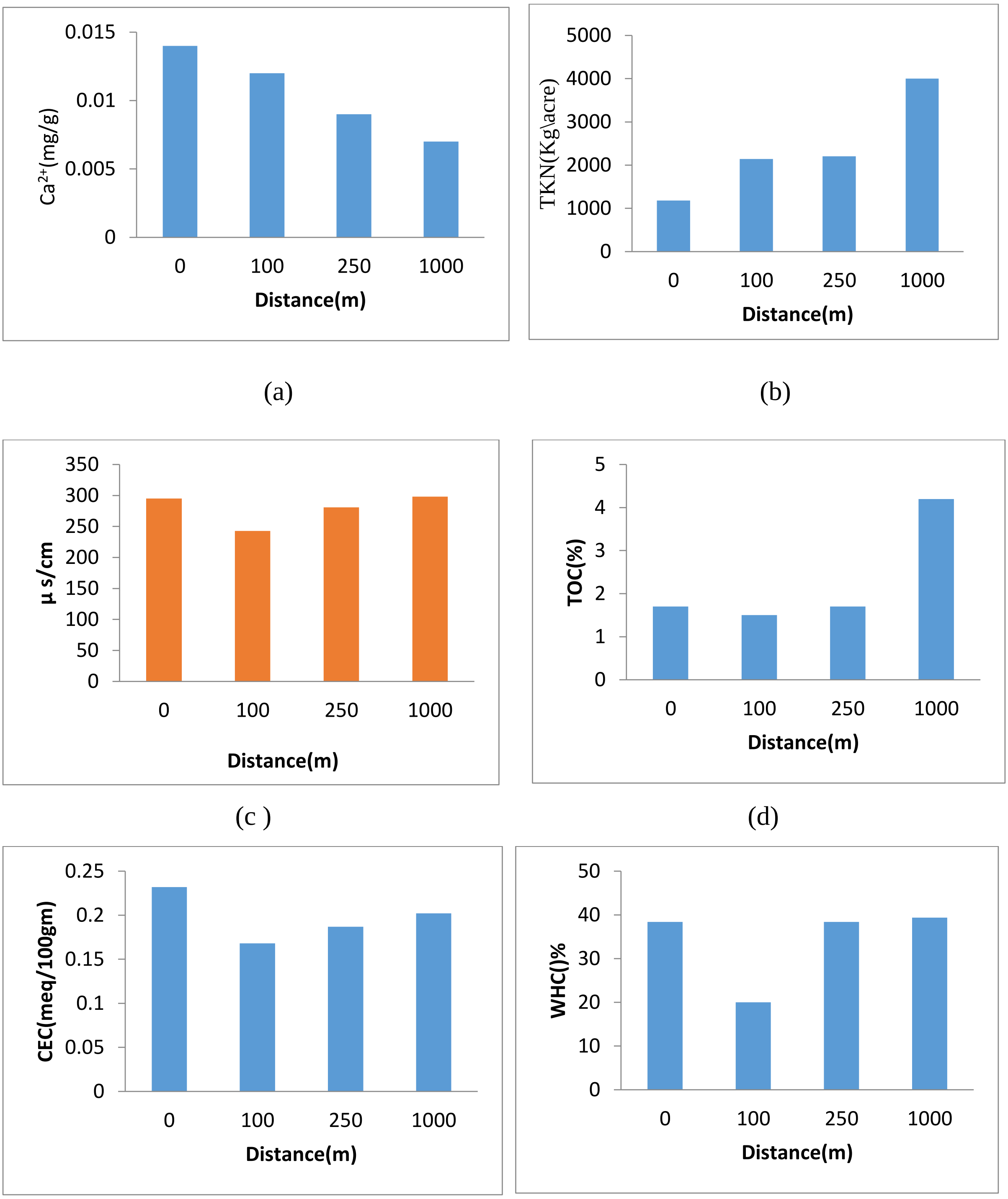
The soil around the mining area was found to be slightly alkaline (pH 7.4–7.7). The alkalinity can be attributed to the hydroxyl (OH^-), carbonate (CO_3^{2-}), and bicarbonate (HCO_3^-) ions found in rocks as a significant components of minerals related to the rocks. The electrical conductivity (EC) of soil ranges from 243-298 µs/cm (Table 4.16). The proportion of sand decreased with distance from the mining region, which might be attributable to the larger size of soil particles in the mining area compared to dirt in locations distant from it. The soil, based on soil texture, was found to be silty sand. It was also helped by an increase in organic materials. Increased organic matter enhances metabolic activity in the soil and causes particle aggregation, increasing porosity. Foreign particles, such as leaves and twigs, enhance water retaining capacity by increasing distance. They coupled with the partially decomposed organic matter, provide greater space, improved porosity, and aeration, and are responsible for the increased WHC reported in the observed data.

Table 4.16: Physico-chemical characteristics of the soil around Bakhrija mines

Parameters	**Sample 1 (Mine pit)**	**Sample 2 (100m)**	**Sample 3 (250m)**	**Sample 4 (1000m)**
Soil Type	Silty sand	Silty sand	Silty sand	Silty sand
pH	7.4	7.8	7.6	7.6
EC (µS/cm)	295	243	281	298
Total Hardness (mg/g)	3	2	2	3
Carbonate (mg/g)	0.03	0	0	0
Bicaarbonate(mg/g)	0.061	0.256	0.817	0.353
Na^+ (mg/g)	0.009	.01	0.104	0.005
K^+ (mg/g)	0.0062	0.0044	001.03	0.0152
Ca^{2+}(mg/g)	0.014	0.012	0.009	`0.007
Mg^{2+}(mg/g)	0.013	000.7	0.007	0.013
Li^+(mg/g)	0.006	0.004	0.004	0.006
Cl^-(mg/g)	0.05	0.05	0.04	0.20
SO_4^{2-}(mg/g)	0.01	0.002	0.006	0.015
PO_4^{3-}(mg/g)	0.05	0.02	0.13	0.4
TKN (Kg/acre)	1179	2145	2207	4001
Water Retention Capacity (%)	38.4	20	38.4	39.4
Total Organic Content (%)	1.7	1.5	1.7	4.2
CEC(meq/100 g soil)	0.232	0.168	0.187	0.202

4.6.2 Chemical properties of soil

Soil samples collected near to the mining area were found higher in concentration of sodium. It was found 0.5-1.4mg/g, and for potassium 0.44-1.52mg/g. On the other hand, the CO_3^{2-} ion concentration was high in the mining region but below the detection range at a distance of 100 m and over it. These ions were discovered to be essential components of minerals present in the mined material, such as calcite and dolomite. Concentration less than the detection limit at a distance of 100 m indicates that the dispersion was restricted to a distance less than 100 m (Jung, 2008). A study also revealed that dust dispersion in quarrying was limited to roughly 100 m. Vehicles working in the mining region were found to be responsible for the dispersal of mined dust to far-flung locations. Sulphate (SO_4^{2-}) was in concentration 1mg/g in the mining area. It was higher (1.5mg/g) in the non-mining area.



(a) (b)

(c) (d)

(e) (f)

Fig 4.36 Soil analysis of (a)Ca^{2+}, (b)TKN, (c)EC, (d)TOC, (e)CEC, (f)WHC

Percentage of nitrogen [Total Kjeldahl's nitrogen (TKN)], too, followed a similar trend. It was minimum in the mining area (1179kg/acre) and maximum (4001kg/acre) 1 kilometre away from the mining area ((Fig.4.36 (b)). It might be attributable to vegetative input as well as fertilizers in field away from mining zone. As the ionic species and organic matter content of the soil rose with distance, it also increased its cation exchange capacity (CEC) (Fig.4.36). It was minimum (0.168 meq/ 100 g soil) at the site 100m away from the mining area and maximum (0.232 meq/100 g soil) at mining pit. Improvement in the properties of soil with distance from the mining area leads to improvement of vegetation cover. Good WHC ((Fig.4.36 (f)) and nutrient level of such areas favours the growth of vegetation and add organic matter to soil establishing positive feedback and improving the quality of soil further. Physico-chemical parameters of the soil samples analysed are presented in Table 4.14.

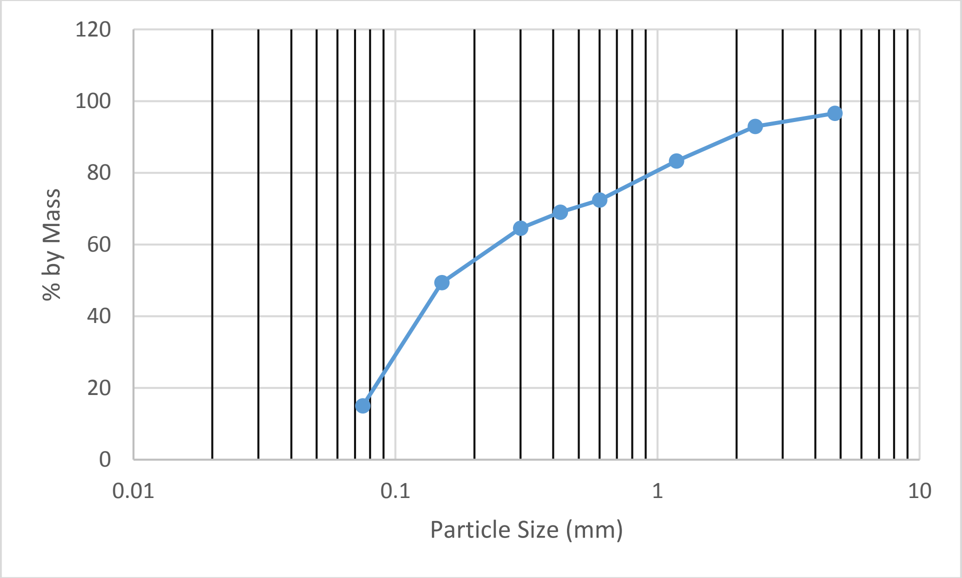


Fig 4.37 Grain size Distribution curve (soil sample 4)

The water retention capacity of the topsoil also increases because of intermixing of silt or dust coming out from the quarrying activities, Even the concentration of total carbon increases in the soil with the distance from the mining area ((Fig.4.36(d)). The concentration of calcium decreases with the distance ((Fig.4.36 (a)) higher near the mining activities and lowest far from the mining area. The grain size distribution also shows the core type of soil found near the mining area (Fig. 4.37) represents the percentage of sand, silt, and clay found in the study area.

4.6.3 Mineralogical composition of dust and its effect on soil

The fine dust generated from Bakhrija stone quarries with respect to particle size was modelled to deposit over the ground with distance. The settling dust induce physico- chemical alteration in properties of soil, thereby resulting in reduced porosity and altered pH, and reduction in total organic carbon (TOC), and it also adversely affects cation exchange capacity (Haritash et al. 2007 ; Chitrakshi and Haritash, 2018). The Fourier Transform InfraRed (FTIR) spectroscopy of dust (Fig. 4.38) from the study area revealed presence of Gypsum ($CaSO_4 . 2H_2O$), calcite ($CaCO_3$) and Kaolinite ($Al_2Si_2O_5$ (**OH**)$_4$) minerals (Fig. 4.35).

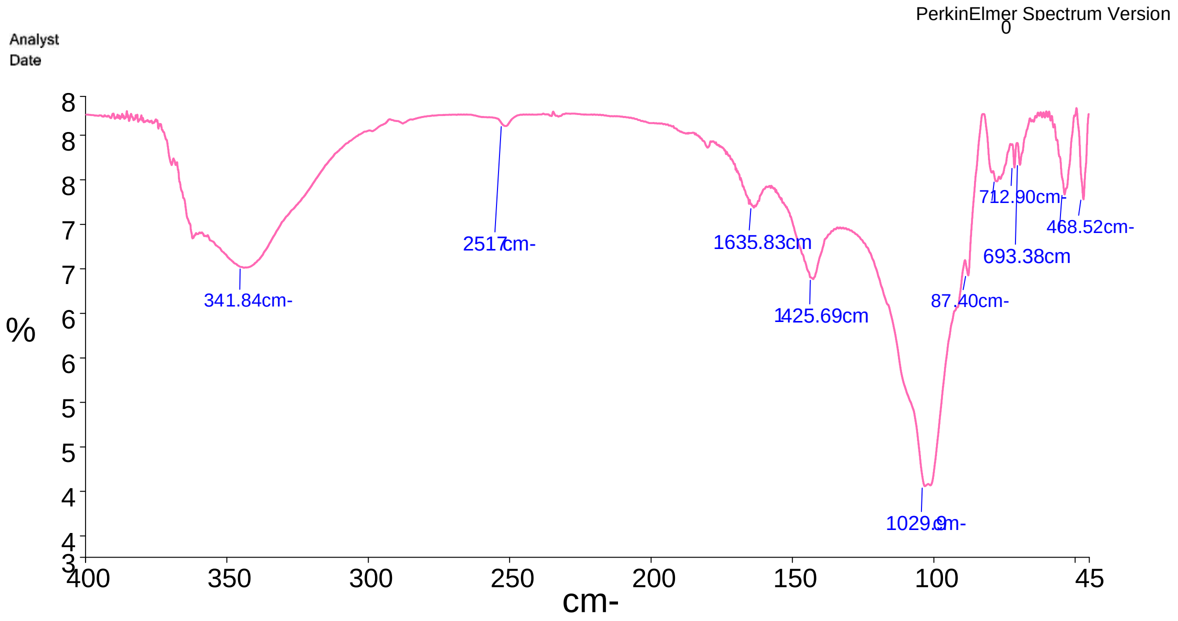


Fig. 4.38 FTIR spectrum of mine dust representing the presence of Calcite (712, 876, 1425, 2517) and Gypsum (1635, 3441) minerals

As a result, the risk of hazardous contaminants penetrating the soil through settled dust is eliminated. Furthermore, the addition of 'Ca' and 'Mg' to soil would significantly increase cation exchange capacity, resulting in increased soil production. Simultaneous addition of finer dust to soil (mostly aeolian sand) results in greater water retention capacity and better crop yield by maintaining a near neutral pH. According to the findings, stone quarrying and crushing have no substantial negative impact on the quality of agricultural soil near the Bakhrija stone quarries.

4.7 Environmental management plan (EMP) for quarrying region

Mining has an impact on multiple environmental sectors, including those that are physical, social, economic, agricultural, and aesthetic. Drilling, blasting, loading, and transport of the overburden and ore are all part of opencast mining. Trucks will be used to deliver the unearthed stone. The operations may cause environmental disruption in the area in several ways, including mass removal, changes to the landscape, local flora and fauna, surface drainage, and changes to the quality of the air, water, and soil. The mining industries is are necessary for human development and economic uplift, but these industries must be environmentally friendly. To plan for environmentally sustainable mining in the region, it is crucial to evaluate the effects of mining on several environmental factors before mining activities begin.

Mining activities help society to grow in the nearby region by improving the socio-economic status of the region, it provides jobs to unskilled workers or labour who work for daily wages. But the social status progress is very limited and the negative impacts associated with mining activities are much larger. It changes the geography of the region, altering land use pattern, resettlement, loss of agricultural land, and displacement loss of specific species of plants and animals. Resettlement of the population faces cultural changes and loss of their cultural identity. But specifically mining activities affect water and air quality. Because excavation and extraction of ore pollute the soil, air, and water in nearby regions.

"Mitigation measures" are put into place to prevent, stop, lessen, regulate, or make up for the negative effects of mining as well as to improve impacted systems (Jain et al., 2016). Environmental and social impact assessments, must be done before significant operations related to resource extraction. Adverse environmental consequences on the livelihood of local populations and biodiversity can be positively or negatively impacted by mitigation efforts to maintain air, water, vegetation, and soil quality (Jain et al. 2016). To remediate polluted waterways, a variety of modern engineering methods should be used (e.g. constructed wetlands) (Gandy et al., 2016), reactive barriers treating groundwater (Obiri-Nyarko et al., 2014), and conventional wastewater treatment plants. The area of study should go for the phytoremediation of polluted land (Mahar et al., 2016). Due to their interdependence, environmental components are impacted by mitigation measures taken. For a sustainable environment, it is crucial to safeguard the purity of the air, water, and soil. Air pollution might be restricted with green belt development to minimize carbon footprint. The significance of carbon dioxide sinks in the ecology and aesthetics of revegetated mine wastes has been reported earlier studies too (Tripathi et al., 2011, 2014). These sector-wise mitigation measures for an effective environmental management plan as discussed below.

4.7.1 Mitigation of Land degradation

There are no forests within or in the proximity of project area. It consists of habitations that are close to agricultural lands. To reduce the impact, a pre-operational, operational, and post-operational land use plan should be implemented for the mining area.

Impact	**Mitigation**
Land degradation due to:	
1. Loss of vegetative cover	• Development of green-belt around the area with tolerant, native species. • Compensatory afforestation and transplanting the trees to another area.
2. Excavation	• The exposed area may be covered with grasses tuff and scrubs
3. Overburden	• Sprinkling water to restrict the emission of dust particles. • Exposed overburden should be covered by plantation or covered with grass tuff. • The overburden may be used for filling up of the abandoned mine pits, filling roads, etc. • Pilling of overburden to allow the movement of run-off such that minimum/no water is collected to serve as a breeding ground for mosquitoes.

4. Mine pits	• May be used as a water storage facility, further water stored can be used to sprinkle at the mining site or used to recharge aquifer
5. Undulatory landscape	• Grading of the undulatory land using overburden. • Plantation of scrubs and grasses to improve the landscape
6. Mine tailings	• May be used for road construction in the mine area and filling of low-lying areas. • Use for small and leftover low lying area/pits as storage of mine tailing and dried tailing can be used in construction.
7. Deposition of dust	• Can be reduced by sprinkling of water periodically during the excavation process. • Installation of bag filters at crushing site. • Development of greenbelt. • Plantation with tolerant, native species of trees, scrubs and grasses.
8. Soil erosion	• Plantation and grading of surface to minimise the soil erosion.
9. Water logging	• Grading of undulating surface to avoid water collection. • Formation of channels following the contour of land so as the direct the water into mine pits to collect and store water for reuse.

4.7.2 Mitigation of water pollution

Impact	Mitigation Measures
1. Water logging	- Grading of undulating surface to avoid water collection. - Formation of channels following the contour of land so as the direct the water into mine pits to collect and store water for reuse.
2. Uncontrolled/ unmanaged surface runoff, higher rate of erosion and increased load of suspended sediments.	- Channeling the runoff to recharge the mine pit. - Incorporating vegetative cover by planting tolerant species.
3. Collection of runoff in mine pits and contamination of groundwater.	- Monitoring of the groundwater must be done periodically. Further, best use must be designated. - Majority of the water collected in the mine pits must be used for sprinkling at the crushing area.
4. Higher rate of soil erosion and dissolution of nutrients.	- Grading and afforestation on overburden.
5. Eutrophication (excess of nutrients)	- Construction of a riparian zone between the water body and terrestrial land to restrict the flow of nutrients to the water body.
6. Higher rate of weathering and loss of contaminants to surface/ groundwater.	- Construction of buffer zone by planting trees, grasses and building boundary at the surface water bodies to restrict the contaminant flow. - Management and safe disposal of solid waste from the mining area

4.7.3 Mitigation of Air and Noise pollution

Impact	Mitigation Measures
1. Emission of Dust	• Regular sprinkling of water via mobile water sprinkles at the source of emission.
2. Emission of SO_2, NOx and other gases	• Heavy vehicles for transportation and generators for power backups need to be well maintained. Retrofitting of generators and pollution checks of heavy vehicles to be done periodically. • Proper tuning of vehicles to control gas emissions, scraping of old and polluting fuel running vehicles and equipment to minimize air pollution.
3. Fugitive dust	• Sprinkling of water • Development of green belt • Construction of enclosures • Road scraping to be done periodically to take out settled dust. • Construction of water bound Macadam.
4. Drilling and blasting	• Formation of greenbelt to restrict dispersion of dust. • Wet drilling to minimize dust generation.
5. Loading and unloading	• Water sprinkling on raw material during loading and unloading.
6. Crushing	• Using mist sprayer over the conveyer belt, loading & unloading zone. • Installation of screen around the crusher to minimize particulate concentration.
7. Transport of material over poor haul roads	• Scraping and sprinkling of water on the haul roads.

	• Tarpaulin covers on transport vehicles.
8. Poor control measures	• Installing continuous monitoring stations at the source location. • Vehicles and generators must be equipped with catalytic converters. • Covering the exposed soil with laterite. • Paving the haul roads with stabilized material. • Use of dust extractors.
9. Loss of vegetative belts	• Development of greenbelts with native species.
10. Noise and vibrations	• Well maintained vehicles to be used to lower noise level. • Pressure horns in heavy vehicles should be avoided. • Development of vegetative belts. • Installation of enclosures at the source.

4.7.4 Mitigation measures for conservation of biodiversity

Impact	Mitigation Measures
Effect on terrestrial flora	
1. Deforestation in the mining area	• Compensatory afforestation should be done. • Development of vegetative belts on the boundaries of the mining site • Available land to be covered with grass species native to the site. • Revegetation of native plant species to restore the landscape at abandoned mining sites.
2. Deposition of dust and pollutants on the exposed surfaces of vegetation like leaves, stem, etc	• Installation of dust suppressants, misting systems, bag filters at the crushing site • Scraping and sprinkling of water on the haul roads.

	• Construction of enclosures • Regular sprinkling of water via mobile water sprinkles at the source of emission. • Road scraping to be done periodically to take out settled dust.
3. Removal of top soil and overburden, decline availability of essential nutrients.	• Removal and stockpile topsoil from mining areas before excavation may be done and to reintroduce topsoil to facilitate plant growth.
4. Soil erosion, change in hydrology and water pollution	• Installing silt fences, and stabilizing slopes to prevent soil erosion • Management and safe disposal of waste from the mining area. • Construction of buffer zones at site to avoid the transport of mine tailings into the water bodies. • Management of storm water by channeling it to recharge wells to avoid pollution of water resources. • Implement habitat restoration programs at abandoned mining sites to minimise erosion.
Effect on Fauna	
1. Habitat Loss	• Formation of buffer zones before starting the mining process. • Establishment of migration corridors for local wildlife. • Implementing restrictions on the mining process during migratory periods and breeding season of the local fauna.
2. Drilling and blasting	• Installation of barriers and animal friendly enclosures at the mining site.

	- Control of fugitive emissions during the process by using enclosures.
3. Dust and fugitive emissions	- Regular sprinkling of water during the blasting and crushing process.
4. Noise and Vibrations	- Development of green belt and buffer zones at the mining site to decrease the noise pollution levels. - Using vehicles with proper pollution checks and directing minimum honking by the drivers.

4.7.5 Occupational health and safety

Occupational health and safety (OHS) is a multidisciplinary area concerned with promoting and maintaining employees' physical, mental, and social well-being in a variety of sectors. It includes policies, practices, and procedures aimed at preventing workplace accidents, injuries, and diseases while also guaranteeing regulatory compliance. OHS include identifying workplace hazards, assessing risks, putting preventative measures in place, providing employees with appropriate training and education, and putting in place effective mechanisms for incident reporting and investigation.

Impact	Mitigation Measures
1. Effects of Noise from drilling and blasting	- The effect of noise pollution should be regulated by the use of PP kits. - Equipment used must be timely checked and maintenance done regularly. - Installation of barriers and enclosures around the drilling area. - Rotate employees between noisy and quieter job tasks to limit the exposure. - Schedule shifts to minimize the number of workers exposed to higher noise levels for longer duration.

	• Use of personal dosimeters to check individual workers' exposed noise level. • Use of protective gear to avoid inhalation of fugitive dust emissions.
2. Loading	• Lubrication of machinery to avoid friction related noise. • Use of water sprinklers to avoid the amount of dust related hazards • Ear plugs to curb down the effect of noise pollution.
3. Transportation	• Maintenance of vehicles to be done regularly. • Checking of engines for leakage and short circuits • Safety signs at every required location within the vicinity.
4. Crushing	• Fugitive emissions should be controlled by sprinklers and proper PP kits must be provided. • Baseline health studies of workers must be performed followed by periodic health checkups to determine the effect of dust and noise pollution. • Workers must be trained to properly use the PP kits and maintain precautions at site.

Program for Training and Education

All employees will be subjected to a pre-employment and ongoing awareness training on the health and safety risks associated with stone mining and related operations. They would also receive sufficient training and be made aware of the health consequences of breathing excessive concentrations of dust-laden air. All employees will also receive first-aid training.

Medical Examinations and Surveillance

To assess the effects of stone mining project operations on worker health, baseline health studies will be performed on each worker before they begin their jobs.

- Determining baseline conditions for monitoring changes in health and identifying workers with conditions that could be exacerbated by dust and noise exposure.
- Assessing the impact of noise, water, and dust pollution on employees
- Permitting the taking of remedial action when required
- The medical surveillance program will include the following components:
    - Before joining the employee should go for pre-employment medical examination.
    - To access the employees health a periodic medical camp should be examination
    - Regular training on health and safety awareness
    - Training Record keeping
- In accordance with the Mining Regulations, employees' health during mining must be protected. - **Mines Act, 1952 Mine Rules – 1955.**

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the findings of the study, it is observed that stone quarrying in Mahendragarh, Haryana has associated environmental impacts. There is scientific evidence where different activities of stone quarrying have effects on the quality of air, water, vegetation, etc., and subsequently detrimental to the health of the exposed population. The sector-specific conclusions inferred from this study are as given below:

1. Based on the LULC pattern over past twenty years, there is no significant change in landuse except a slight loss of agricultural land and vegetative cover. Since the region represents semi-arid climate, even a slight loss of vegetative cover may lead to significant changes in respect of soil erosion, groundwater recharge, and biodiversity of the region. This may result in significant loss of agriculture production, thereby affecting the economy since almost 83% of land in the 5 Km radius is used for agriculture.

2. Based on the monitoring of $PM_{2.5}$ and PM_{10}, it is inferred that crushing causes major direct emission, and transport of material over haul roads lead to fugitive emission of dust. Both the activities were responsible for generation of finer particles, dominantly, which have the potential to penetrate to alveolar region of respiratory system. Continuous exposure of workers in the quarry can significantly compromise with their pulmonary health. It is therefore very important to contain the finer PM with technological interventions; and protect/safeguard the health of employs at crushing site with suitable PPEs.

3. The fine and ultra-fine PM emitted from crushers and haul roads had high particle number concentration and it is associated with nucleation and aggregation. Despite that, the concentration builds up and compromises the health of exposed population during winter. Owing to stable atmospheric conditions, it is very important to restrict the working hours of crushers and reduce the fugitive emissions too. Since the dispersion is limited to 5 Km, control of PM level is easy.

4. Although the sandstone quarry had no direct significant effect on groundwater the subsurface geology represented carbonate weathering resulting in release of fluoride from natural subsurface minerals. Since the dissolution of fluoride is enhanced through exposed and fragmented minerals in stone quarries at Mahendragarh, it is suggested to monitor the quality of groundwater regularly to minimize exposure, and to screen the contaminated sources.

5. The soil around the quarries is affected due to generation of finer particles, dust deposition, etc. leading to low permeability, reduced gaseous exchange, low water holding capacity, etc. The deposition of dust leads to higher level of Ca and Mg and low levels of TOC, TKN, etc. in the quarrying region, whereas, the physical and chemical health of soil is improved with distance away from it. The dust generated from Calcite and Dolomite minerals of the mine and crushed materials leads to alkaline pH and higher CEC which adds to the soil health and agricultural production.

6. Screening of local vegetation indicated that *Milletia pinnata* is the best performing towards ameliorating the dispersion if dust and restricting air pollution. Apart from it, *Syzygium cumini*, *Azadirachta indica* and *Melia Azedarach* and suitable species to be preferred for developing a green belt around the quarry in order to maintain better air quality. The vegetative cover can also help to reduce soil erosion, enhance recharge, improve slope/ground stability, maintain local biodiversity, improve aesthetics and restrict propagation of noise. The vegetative cover will also be helpful in boosting soil health around the quarrying by improving TOC, TKN, nutrient level, water holding capacity, soil aggregation, etc.

5.2 Recommendations

Based on the major outcomes of the study, these are some interventions which can prove useful in improving the quality of environment and life around the stone quarries in Mahendragarh, Haryana.

The interventions are related to development of physical infrastructure, natural biological system, chemical testing based exploratory analysis, or an effective training and capacity building exercises. The sector-wise recommendations for the same are given below:

1. To improve the vegetative cover in and around the mining region. The major areas for improving vegetation are mine overburden, mine tailings, natural and denuded hills around the regions, and barren lands available. The local vegetation with good tolerance to air pollution (like *M. pinata, A. indica, M. Azedarach*, etc.) be preferred for greenbelt development around the quarry.

2. It is recommended to establish/construct physical enclosures around the crushers to contain the dust. Moreover, the fugitive emissions during the transport of material be restricting by using covered haulers and regular sprinkling of all roads to minimize the suspension. The state pollution control board with the help of the association of contractors to install a continuous monitoring station for $PM_{2.5}$ and PM_{10}. So that the air quality levels are regularly monitored and instant interventions/ remedial measures can be adopted.

3. Based on value of AQI in the zone of quarrying, it is advised to restrict working of crushers to limited hours/days based on the production of materials, particularly during winters. The operation may be ceased during the days when the air quality is severe or hazardous and should be restricted/ regulated if AQI is poor and very poor.

4. Screening of groundwater be carried out on regular basis to ensure its quality for drinking. Since, fluoride is endemic to the region, the monitoring of groundwater table is recommended since fluoride concentration in groundwater is directly associated with depth of the water table. Therefore, it is suggested to choose sources with shallow groundwater table.

5. It is suggested to restore soil health around the quarries with organic amendments since all other parameters were representing good health of soil. The transfer of dust from mining and crushing be avoided using the enclosures.

6. It is suggested to develop a green belt around the quarry to restrict the transfer of dust and noise. The vegetative cover over the mine tailings and overburden is also recommended to ensure the stability of pile and preventing soil erosion. The local plants like *Milletia pinnata, Syzygium cumini, Azadirachta indica* and *Melia Azedarach* are recommended for the development of green belt.

5.3 Future scope of work

(1) Simulation studies through modelling software to predict the future concentration of particulate matter in and around mining area may be taken up as future scope of this work. (2) Simulation studies of groundwater by to analyse contaminant transport and flow may also be opted. (3) The impact of mining activities on cash crops is yet to be studied and it can be good indicator of soil and plant health. (4) Prolonged study of polluted soil and heavy metal concentration can studied. (5) Detailed and prolonged exposure of dust on workers and villagers living adjacent to mining area can be done to examine the impact of particulate matter on human health.

6. REFERNCES

Abiye, T.; Shaduka, I. Radioactive Seepage through Groundwater Flow from the Uranium Mines, Namibia. *Hydrology* **2017**, *4*, 11. https://doi.org/10.3390/hydrology4010011

Ab Razak, N.H., Praveena, S.M., Aris, A.Z., Hashim, Z., (2015) Drinking water studies: a review on heavy metal, application of biomarker and health risk assessment (a special focus in Malaysia). Journal of epidemiology and global health 5 (4), 297–310.

Abu-Allaban M., S. Hamasha, and A. Gertler (2006),, Road Dust Resuspension in the Vicinity of Limestone Quarries in Jordan, J. Air & Waste Manage. Assoc. 56 pp. 1440–1444.

Adamu CI, Nganje TN, Edet A (2015) Heavy metal contamination and health risk assessment associated with abandoned barite mines in Cross River state southeastern Nigeria. Environmental Nano technology, monitoring and management 3:10–21.

Adator S, Wu Q, Lambongang M, Otoo LP, Bosah CP, Nimako K,(2023) “Farmers' perception of the impact of gold mining on shrinking agricultural land and their livelihood in the Asutifi-North District”, Resources Policy, Volume 81, 2023, 103379, ISSN 0301-4207, https://doi.org/10.1016/ j.resourpol.2023.103379.

Adamczyk, A.F., Motyka, Jacek, Wilk, Zbigniew, and Witczak, Stanislaw, (1988), Mine drainage of a karstic aquifer and the related protection problems – Olkusz Mining District, Poland: Proceedings if the IAH 21st Congress, Guilin, China, Geologic Publishing House, Bejing, China, pp. 1097-1104.

Adewumi, A. J., & Laniyan, T. A. (2021). Ecological and human health risks associated with metals in water from Anka Artisanal Gold Mining Area, Nigeria. *Human and Ecological Risk Assessment: An International Journal*, *27*(2), 307-326.

Adimalla N, Dhakate R, Kasarla A, Taloor A,(2020) “Appraisal of groundwater quality for drinking and irrigation purposes in Central Telangana, India, “Groundwater for Sustainable Development”,Volume10,2020,100334,ISSN 2352-801X, https://doi.org/10.1016/ j.gsd.2020. 100334 .

Adimalla N, Vasa SK, Li P (2018) Evaluation of groundwater quality, Peddavagu in Central Telangana (PCT), South India: an insight of controlling factors of fluoride enrichment. Model Earth Syst Environ 4(2):841–852. https ://doi.org/10.1007/s4080 8-018-044.

Adimalla, N., Qian, H.(2019) Hydro-geochemistry and fluoride contamination in the hard rock terrain of central Telangana, India: analyses of its spatial distribution and health risk. SN Appl. Sci. **1**, 202 (2019). https://doi.org/10.1007/s42452-019-0219-8.

Adimalla, N., Venkatayogi, S. & Das, S.V.G.(2019) Assessment of fluoride contamination and distribution: a case study from a rural part of Andhra Pradesh, India. Appl Water Sci **9**, 94 (2019). https://doi.org/10.1007/s13201-019-0968-y.

Agwa-Ejon, J.F., Pradhan, A., (2018). Life cycle impact assessment of artisanal sandstone mining on the environment and health of mine workers. Environ. Impact Assess. Rev. 72, 71–78. https://doi.org/10.1016/j.eiar.2018.05.005.

Ahada, C.P.S., Suthar, S. (2019) Assessment of Human Health Risk Associated with High Groundwater Fluoride Intake in Southern Districts of Punjab, India. Expo Health **11**, 267–275 (2019). https://doi.org/10.1007/s12403-017-0268-4.

Ahmad, A., (2015) A Study of Miners, Demographics and Health Status in Jodhpur District of Rajasthan (India), 3, 113-121. International Journal of Development Studies and Research.

Akcil A, Koldas S,(2006) “Acid Mine Drainage (AMD): causes, treatment and case studies”, Journal of Cleaner Production, Volume 14, Issues 12–13, 2006, Pages 1139-1145, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2004.09.006.

Ako TA, Onoduku US, Oke SA, Essien BI, Idris FN, Umar AN, Ahmed AA (2014) Environmental effects of sand and gravel mining on land and soil in Luku, Minna, Niger State, North Central Nigeria. J Geosci Geomat 2(2):42–49.

Alam, W., Singh, K.S., Gyanendra, Y. et al. (2020) Hydrogeochemical assessment of groundwater quality for few habitations of Chandel District, Manipur (India). Appl Water Sci **10**, 123 (2020). https://doi.org/10.1007/s13201-020-01208-0.

Ali, S., Kumari, M., Gupta, S. K., Sinha, A., & Mishra, B. K. (2017). Investigation and mapping of fluoride-endemic areas and associated health risk—a case study of Agra, Uttar Pradesh, India. *Human and Ecological Risk Assessment: An International Journal*, *23*(3), 590-604.

Ali S, Fakhri Y, Golbini M, Thakur S K, Abdolazim Alinejad, Iman Parseh, Shashank Shekhar, Prosun Bhattacharya,(2019) Concentration of fluoride in groundwater of India: A systematic review, meta-analysis and risk assessment, Groundwater for Sustainable Development, Volume 9, 2019,100224,ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2019. 100224.

Ali, S., Shekhar, S., Chandrasekhar, T. et al. (2021) Influence of the water–sediment interaction on the major ions chemistry and fluoride pollution in groundwater of the Older Alluvial Plains of Delhi, India. J Earth Syst Sci **130**, 98 (2021). https://doi.org/10.1007/s12040-021-01585-3.

Al-Joulani, N., (2008). Soil contamination in Hebron district due to stone gutting industry. Jordan J. Appl. Sci. - Nat. Sci. 10, 37–50.

Al-Khater, K. and Naser, K. (2003), "Users' perceptions of corporate social responsibility and accountability: evidence from an emerging economy", *Managerial Auditing Journal*, Vol. 18 No. 6/7, pp. 538-548. https://doi.org/10.1108/02686900310482678

Almeida I.T., S.M. Eston, and J.V. de Assuncao, (2002), Characterization of suspended particulate matter in mining areas in São Paulo, Int. J. Surf. Min. Reclam. Environ. 16(3) pp. 171–179.

Almeida, N., Branco, F., Santos, J.R., (2007). Recycling of stone slurry in industrial activities: application to concrete mixtures. Build. Environ. 42, 810–819. https:// doi.org/10.1016/j.buildenv.2005.09.018.

Altheeb A, (2022) Quarry dust waste-based cementitious composites – A comprehensive review, Construction and Building Materials, Volume 350, 2022, 128817, ISSN 0950-0618, https://doi.org/10.1016/j.conbuildmat.2022.128817.

Ambastha, S.K., Haritash, A.K.(2022) Emission of respirable dust from stone quarrying, potential health effects, and its management. Environ Sci Pollut Res 29, 6670–6677 (2022). https://doi.org/10.1007/s11356-021-16079-4.

Ambastha, S.K., Haritash, A.K.(2021) Prevalence and risk analysis of fluoride in groundwater around sandstone mine in Haryana, India. Rend. Fis. Acc. Lincei **32**, 577–584 (2021). https://doi.org/10.1007/s12210-021-00997-z.

Ambastha, S., Negi, S., Singh, A., Ghunasham, M., & Haritash, A. K. (2020). Evaluation of Air Pollution Tolerance Index and Anticipated Performance Index of trees in and around the stone quarrying region of Mahendragarh, Haryana. *Indian J Air Pollut Control, 20*(1-2), 17-27.

Amitshreeya R, Panda RB (2012) Dust pollution in stone crusher units in and around Balasore, Orissa, India. J Ind Pollut Control 28(1):41–44.

Amiya K. Samal, Praveen K. Mishra, Arkoprovo Biswas,(2020) Assessment of origin and distribution of fluoride contamination in groundwater using an isotopic signature from a part of the Indo-Gangetic Plain (IGP), India, Hydro Research, Volume 3, 2020, Pages 75-84, ISSN 2589-7578, https://doi.org/10.1016/j.hydres.2020.05.001.

APHA (2012) Standard Methods for the Examination of Water and Waste Water. 22nd Edition, American Public Health Association, American Water Works Association, Water Environment Federation.

Arends, G., Bielecki, R., Castle, J., Drabek, S., Haack, A., Ned-bal, F., Sterling, R. (2004): Risk Budget management in pro-gressing underground works: International Society for Trenchless Technology (ISTT) and International Tunnelling Association (ITA) Joint Working Group Report. Tunnelling and underground space technology, 19, 1, 29-33.

Arif M, Husain I, Hussain J, Kumar S.(2013) Assessment of fluoride level in groundwater and prevalence of dental fluorosis in Didwana block of Nagaur district, Central Rajasthan, India. Int J Occup Environ Med. (2013) Oct;4(4):178-84. PMID: 24141866.

Aryafar, A., Yousefi, S., & Doulati, A. F., (2012). The weight of interaction of mining activities: groundwater in environmental impact assessment using fuzzy analytical hierarchy process (FAHP). Environmental Earth Sciences, 68(8), 2313–2324.

Ashok K. Singh, R.V.K. Singh, Mahendra P. Singh, Hem Chandra, N.K. Shukla,(2007) Mine fire gas indices and their application to Indian underground coal mine fires, International Journal of Coal Geology, Volume 69, Issue 3, 2007, Pages 192-204, ISSN 0166-5162, https://doi.org/10.1016/j.coal.2006.04.004.

Askari MS, Alamdari P (2020) Quantification of heavy metals pollution for environmental assessment of soil condition. Environmental. Monitoring and Assessment 192:162. https://doi.org/10.1007/ s10661-020-8116-6.

Avtar, R., Kumar, P., Surjan, A. et al.(2013) Geochemical processes regulating groundwater chemistry with special reference to nitrate and fluoride enrichment in Chhatarpur area, Madhya Pradesh, India. Environ Earth Sci 70, 1699–1708 (2013). https://doi.org/10.1007/s 12665-013-2257-7.

Azandand, S.A. & Ashish, M. (2006).The stone quarrying industry around Delhi-impact on workers and the environment.

Babu, G.B., Parveen, S.N., Kumar, K.N., Reddy, M.S., (2013). Evaluation of air pollution tolerance indices of plant species growing in the vicinity of cement industry and Yogi Vemana University Campus. Indian J. Adv. Chem. Sci. 2 (1), 16–20.

Backman B, Bodis D, Lahman P, Rapant S, Tawvainin T (1997) Application of groundwater contamination index in Finland and Slovakia. Envi Geol 36:55–64.

Bada B.S., K.A. Olatunde, and O.A. Akande, (2013) Air quality assessment in the vicinity of quarry site, Environ. Nat. Resour. Res. 3(2) (2013), pp. 111–115.

Bagherpour, R., Yarahmadi, R., Khademian, A., and Almasi, S. N. (2015): Safety survey of Iran’s mines and compari-son to some other countries. International journal of injury control and safety promotion, 1-7.

Bai, S., Hua, Q., Cheng, L., Wang, Q., Elwert, T., (2019). Improve sustainability of stone mining region in developing countries based on cleaner production evaluation: Methodology and a case study in Laizhou region of China. J. Cleaner Prod. 207, 929–950. https://doi.org /10.1016/j. jclepro.2018.10.026.

Bajpai J (2013) Fluoride carcinogenesis: The jury is still out! *South Asian J Cancer*. 2(4):192. doi: 10.4103/2278-330X.119881.

Baklanov, A., (1984). Determining the propagation of impurity in the atmosphere of a pit on the basis of mathematical models. Soviet Mining Science 20 (5), 402–407.

Baklanov, A., (1986). A method of evaluating the energy characteristics of the air in an open pit mine. Soviet Mining Science 22 (1), 66–70.

Baklanov, A., (1995). Numerical modelling of atmosphere processes in mountain cirques and open pits. In: Proceedings of International Conference on Air Pollution. Porto Carras, Greece, pp. 231–238.

Baklanov, A., Rigina, O., (1995). Research of local zones atmosphere normalization by artificial currents. In: Proceedings of the 2nd International Conference on Air Pollution. Computational Mechanics Publications, pp. 553–561.

Baldauf, R.W., Lane, D.D., Marote, G.A., (2001). Ambient air quality monitoring network design for assessing human health impacts from exposures to airborne contaminants. Environmental Monitoring and Assessment 66, 63–76.

Banerjee, P., Prasad, B. (2020) Determination of concentration of total sodium and potassium in surface and ground water using a flame photometer. Appl Water Sci **10**, 113 (2020). https://doi.org/10.1007/s13201-020-01188-1.

Baranyai, E., Simon, E., Braun, M., Posta, J., Tóthmérész, B., Fábián, I., (2015). The effect of a fireworks event on the amount and elemental concentration of deposited dust collected in the city of Debrecen, Hungary. Air Qual. Atmos. Health 8 (4), 359–365. https://doi.org/ 10.1007/s11869-014-0290-7.

Barrett, D.; Couch, C.; Metcalfe, D.; Lytton, L.; Adhikary, D.; Schmidt, R.(2013) Methodology for Bioregional Assessments of the Impacts of Coal Seam Gas and Coal Mining Development on Water Resources; A Report Prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment; Office of Water Science: Canberra, Australia, 2013.

Bayram A, Onsoy H (2015) Sand and gravel mining impact on the surface water quality: a case study from the city of Tirebolu (Giresun Province, NE Turkey). Environ Earth Sci 73:1997–2011.

Bengtsson, M., Evertsson, C.M., (2006b). Measuring characteristics of aggregate material from vertical shaft impact crushers. Miner. Eng. 19, 1479–1486. https://doi.org/10.1016/ j.mineng. 2006.08.003.

Bennett, John W., John R. Harries, and A. Ian M. Ritchie.(1988) "Rehabilitation of waste rock dumps at the rum Jungle Mine site." In Proceedings of the Mine Drainage and Surface Mine Reclamation Conference, Pittsburgh, PA, USA, vol. 17, pp. 104-108. 1988.

Bewiadzi S, Awubomu R, Glover-Memi N (2018) Searching and cracking: stone quarrying livelihood and the environment in the Daglama Quarry site in the Ho municipality.West African Journal of Applied Ecology 26:149–166.

Bhadani K, Asbjörnsson G, Hulthén E, Evertsson M,(2020) Development and implementation of key performance indicators for aggregate production using dynamic simulation, Minerals Engineering, Volume 145, 2020, 106065, ISSN 0892-6875, https://doi.org/10.1016/ j.mineng.2019.106065.

Bhadra, B.K., Gupta, A.K., Sharma, J.R., Choudhary, B.R.,(2007). Mining activity and its impact on the environment: study from Makrana marble and Jodhpur sandstone mining areas of Rajasthan. J. Geol. Soc. India 70, 557–570.

Bharti, S.K., Trivedi, A., Kumar, N., (2018). Air pollution tolerance index of plants growing near an industrial site. Urban Clim. 24, 820–829. https://doi.org/10.1016/j.uclim. 2017.10.007.

Bhattacharya P, Adhikari S, Samal A C, Das R, Dey D, Deb A, Suleman Ahmed, Jakir Hussein, Ayan De, Antara Das, Madhurima Joardar, Ashis Kumar Panigrahi, Tarit Roychowdhury, Subhas Chandra Santra, (2020) “Health risk assessment of co-occurrence of toxic fluoride and arsenic in groundwater of Dharmanagar region, North Tripura (India)”,Groundwater for Sustainable Development, Volume 11, 2020, 100430,ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2020.100430.

Biagi, Paolo (2008), "Quarries in Harappa", Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures (2nd edition) edited by Helaine Selin, pp. 1856–1863, Springer, ISBN 978-1-4020-4559-2.

Birabwa, E. (2006). Small-Scale Stone Quarrying: Its Contribution to People’s Livelihoods, A case study of Kasenge Parish, Nama Sub-County, Mukono District (Uganda). An unpublished Master of Philosophy Thesis submitted to the Norwegian University of Science and Technology, [Online] Available at: http://ntn-u.divaportal.org/smash/record. jsf?pid=diva2:125974 (September 28, 2012).

BIS (2012) - Bureau of Indian Standards, IS: 10500. Indian Standard for Drinking Water Specification. Second Revision, New Delhi.

Bluvshtein, N., Mahrer, Y., Sandler, A., Rytwo, G., (2011). Evaluating the impact of a limestone quarry on suspended and accumulated dust. Atmos. Environ. 45, 1732–1739.

Borgnino L, Garcia MG, Bia G, Stupar YV, Le Coustumer P, Depetris PJ (2013) Mechanisms of fluoride release in sediments of Argentina's central region. Sci Total Environ 443:245–255. https ://doi. org/10.1016/j.scito tenv.2012.10.093.

Bowker, George & Baldauf, Richard & Isakov, Vlad & Khlystov, Andrey & Petersen, William. (2007). The effects of roadside structures on the transport and dispersion of ultrafine particles from highways. Atmospheric Environment. 41. 8128-8139. 10.1016/j.atmosenv.2007.06.064.

Bridge, I. (2009).Crystalline silica: A review of the doe response relationship and environmental risk. Air Quality and Climate Change 2009, 43(1) 17-23.

Brown CE (1998) Applied multivariate statistics in geohydrology related sciences. Springer, New York.

Butler BA, Ford RG.(2018) Evaluating relationships between total dissolved solids (TDS) and total suspended solids (TSS) in a mining-influenced watershed. Mine Water Environ. 2018 Mar 31;37(1):18-30. doi: 10.1007/s10230-017-0484-y. PMID: 29962822; PMCID: PMC6020674.

Cabboi R, Cidu R, Fanfani L, Lattanzi P, Zuddas P (1999) Environmental mineralogy and geochemistry of the abandoned Pb-Zn, Montevecchio-Ingurtosu Mining District Sardinia, Italy. Chron Rech Miniere 534:21–28.

Cappuyns V, Swennen R, Vandamme A, Niclaes M (2006) Environmental impact of the former Pb–Zn mining and smelting in East Belgium. J Geochem Explor 88:6–9.

Casas, J.M., Rosas, H., Sole, M.,&Lao, C. (2003). Heavy metals and metalloids in sediments from the Liobreget basin, Spain. Environmental Geology, 44, 325–332.

Cattle S.R., K. Hemi, G.L. Pearson, and T. Sanderson,(2012) Distinguishing and characterizing point-source mining dust and diffuse-source dust deposits in a semi-arid district of eastern Australia, Aeolian Res 6 (2012), pp. 21–29.

Central Ground Water Board (CGWB) (2013a) Groundwater Information Booklet, North Goa District, Goa, Ministry of Water Resources, Govt. of India, South West Region-Bengaluru.

Central Ground Water Board (CGWB) (2013b) Groundwater Information Booklet District Mahendragarh, Haryana. Ministry of Water Resources. Government of India

Central Pollution Control Board (2009); Comprehensive Industry Document Series on Stone Crushers: COINDS/78/2007-08.

Chaanda M S, N.G. Obaje, A.Moumouni, N.G. Goki and U.A. Lar, (2010). Environmental Impact of Artesanal Mining of Barytes in Azara area, Middle Benue Trough, Nigeria. Journal of Earth Sciences, Vol. 4, Issue 1, pp.38-42

Chakraborty M.K., M. Ahmad, R.S. Singh, D. Pal, C. Bandopadhyay, and S.K. Chaulya, (2002) Determination of the emission rate from various opencast mining operations, Environ. Model Softw. 17 (2002), pp. 467–480.

Chandan, G., Hemanth, R., Ganesh Kasaba, N., & TH Harshith, G. O. W. D. A. (2022). Ground Water Quality Analysis in Precambrian Rocks of Kolar District Karnataka.

Chang C.T., Y.M. Chang, W.Y. Lin, and M.C. Wu, (2010) Fugitive dust emission source profiles and assessment of selected control strategies for particulate matter at gravel processing sites in Taiwan, J. Air Waste Manage. Assoc. 60 (2010), pp. 1262–1268.

Chang, F.C., Lee, M.Y., Lo, S.L., Lin, J.D., (2010). Artificial aggregate made from waste stone sludge and waste silt. J. Environ. Manag. 91, 2289–2294. https://doi.org/10.1016/j.jenvman.2010.06.011.

Charron, A., and R.M. Harrison, (2005). Fine (PM2.5) and coarse (PM2.5-10) particulate matter on a heavily trafficked London highway: sources and processes Environmental Science&Technology39,7768-7776.

Chauhan, S. S. (2010) Mining, Development and Environment: A case study of bijolia Mining area in Rajasthan, India.

Chaulya, S.K., Chakraborty, M.K., Ahmad, M. et al. (2002) Development of Empirical Formulae to Determine Emission Rate from Various Opencast Coal Mining Operations. Water, Air, & Soil Pollution **140**, 21–55 (2002). https://doi.org / 10.1023/A:1020149407572.

Chaulya SK. (2004) Assessment and management of air quality for an opencast coal mining area. J Environ Manage. 2004 Jan;70(1):1-14. doi: 10.1016/j.jenvman.2003.09.018. PMID: 15125540. .

Chaulya, S.K., Chakraborty, M.K., Singh, R.S., (2001). Air pollution modelling for a proposed limestone quarry. Water, Air, and Soil Pollution 126, 171–191.

Chen, G.Z, Wang, X.M, Wang, R.W, Liu, G.J., (2019). Health risk assessment of potentially harmful elements in subsidence water bodies using a Monte Carlo approach: An example from the Huainan coal mining area, China. Ecotoxicology and Environmental Safety 171, 737–745.

Chenot, J., Jaunatre, R., Buisson, E., Bureau, F., Dutoit, T., (2018). Impact of quarry exploitation and disuse on pedogenesis. Catena 160, 354–365. https://doi.org/10.1016/j.catena.2017.09.012.Chloride, Salinity, and Dissolved Solids. 2019 Mar 1, [cited on 20 September 2020] Available from: https://www.usgs.gov/mission-areas/water-resources/science/chloride-salinity-and-dissolved-solids?qt-science_center_objects=0#qt-science_center_objects.

Chitrakshi, Haritash, A.K. (2018) Hydrogeochemical characterization and suitability appraisal of groundwater around stone quarries in Mahendragarh, India. *Environ Earth Sci* **77**, 252 (2018). https://doi.org/10.1007/s12665-018-7431-5

Clifton, J. R., Brown, P. W., & Frohnsdorff, G. (1980). Uses of waste materials and by-products in construction. Part I. *Resource Recovery and Conservation*, *5*(2), 139-160.

CMRI, (1998). Determination of Emission Factor for Various Opencast\ Mining Activities, Report GAP/9/EMG/MOEF/97, Central Mining Research Institute, Environmental Management Group, Dhanbad, India.

Cole, C., Fabrick, A., (1984). Surface mine pit retention. Journal of the Air Pollution Control Association 34 (6), 674–675.

Corti, A., Senatore, A., (2000). Project of an air quality monitoring network for industrial site in Italy. Environmental Monitoring and Assessment 65, 109–117.

Central Pollution Control Board (CPCB), (2009). National Ambient Air Quality Standards (NAAQS),Gazette Notice ,New Delhi.

CPCB, (2010). Air quality monitoring, emission inventory and source apportionment study for Indian cities. National Science Report of Central Pollution Control, India (Available http://cpcb.nic.in/Source_Apportionment_Studies.php).

Currie, B.A., Bass, B. (2008). Estimates of air pollution mitigation with green plants and green roofs using the UFORE model. Urban Ecosystem, 11: 409–422.

Cyrys, J., Stolzel, M., Heinrich, J., Kreyling, W.G., Menzel, N., Wittmaack, K., Wichmann,H.E., (2003). Elemental composition and sources of fine and ultrafine ambient particlesin Erfurt, Germany. Sci. Total Environ. 305 (1–3), 143–156. https://doi.org/10.1016/S0048-9697(02)00494-1.

Czaplicka-Kolarz, K., Burchart-Korol, D., Turek, M., Borkowski, W., (2015). Model Of Eco-Efficiency Assessment Of Mining Production Processes. Arch. Min. Sci. 60, 477–486. https://doi.org/10.1515/amsc-2015-0031.

D.M. Sadek, M.M. El-Attar, H.A.J.J.o.C.P. Ali, (2016) Reusing of marble and granite powders in self-compacting concrete for sustainable development, 121 (2016) 19- 32.

Dafter H, Kachningwe, R, Safuya, K, Chinok, OG, Mgemezulu, J, Nkhoma, S (2019) Effects of agricultural activities on water quality in rural area rivers DOI https://doi.org/10.13140/RG.2.2.19450. 44487 preprint 2019.

Dai, W., Gao, J., Cao, G., Ouyang, F., (2013). Chemical composition and source identification of PM2.5 in the suburb of Shenzhen, China. Atmos. Res. 122, 391e400.

Darwish, T., Khater, C., Jomaa, I., Stehouwer, R., Shaban, A., Hamze, M., (2010). Environmental impact of quarries on natural resources in Lebanon. Land Degrad. Dev. 22, 345–358. https://doi.org/10.1002/ldr.1011.

Das SK, Chakrapani GJ (2010) Assessment of tracemetal toxicity in soils of Raniganj Coalfield, India. Environ Monit Assess 177:63–71.

Dasgupta, A. (2012) Impact of mining on rural environmental and economy. A case study, Kota district, Rajasthan. International Journal of Remote sensing and Geoscience (IJRSG).v.2,pp.21-26.

Ogulei D, Philip K. Hopke, David C. Chalupa & Mark J. Utell (2007) Modeling Source Contributions to Submicron Particle Number Concentrations Measured in Rochester, New York, Aerosol Science and Technology, 41:2, 179-201, DOI: 10.1080/02786820601116012.

De Jesus, A. L., Rahman, M. M., Mazaheri, M., Thompson, H., Knibbs, L. D., Jeong, C., ... & Morawska, L. (2019). Ultrafine particles and PM2. 5 in the air of cities around the world: Are they representative of each other?. *Environment international*, *129*, 118-135.

De Leeuw J, Shankman D, Wu G, De Boer WF, Burnham J, He Q, Yesou H, Xiao J (2010) Strategic assessment of the magnitude and impacts of sand mining in Poyang Lake, China. Reg Environ Change 10:95–102. doi:10.1007/s10113-009-0096-6.

Deepika, Gour, P., Haritash, A.K. (2016). Air pollution tolerance of trees in an educational institute in Delhi. International Journal of Environmental Science, 6: 979–986 Energy Environment Monitoring, 12 (2): 109–116.

Degan G.A., D. Lippiello, and M. Pinzari,(2013) Monitoring airborne dust in an Italian basalt quarry: Comparison between sampling methods, Air Pollut XXI 174 (2013), pp. 75–84.

Dey S, Giri B (2015) Fluoride Fact on Human Health and Health Problems: A Review. *Med Clin Rev.*, 2:2. doi: 10.21767/2471-299X.100011

Dhar, B. B.: (1993), 'Environmental Scenario in Indian Mining Industry', in Chaudhary and Shiv Kumar (eds.), Environmental Management, Geo Water and Engineering Aspects, Balkema Rotterdam, pp. 615–619.

Dold, B.(2014) Evolution of Acid Mine Drainage formation in sulphidic mine tailings. Minerals **2014**, 4, 621–641. [CrossRef].

Doran, J.W., Sarrantonio, M. and Liebig, M.A. (1996) Soil health and sustainability. Advances in Agronomy, 56, 1-54. http://dx.doi.org/10.1016/S0065-2113(08)60178-9.

Doran, J. W., & Zeiss, M. R. (2000). Soil health and sustainability: managing the biotic component of soil quality. *Applied soil ecology*, *15*(1), 3-11. https://doi.org/10.1016/S0929- 1393(00)00067-6.

Dos Santos-Juusela, V., Petaja, T., Kousa, A., Hameri, K., (2013). Spatial-temporal variations of particle number concentrations between a busy street and the urban background. Atmos. Environ. 79, 324–333. https://doi.org/10.1016/j.atmosenv.2013.05. 077.

Downing, T.E. (2011). Avoiding New Poverty: Mining- Induced Displacement and Resettlement, IIED and WBCSD, London, 2002, Research Paper No. 58, pp. 3; S. Somayaji, S. Talwar (eds.), Development-induced Displacement, Rehabilitation and Resettlement in India, Routledge, 2011, pp. 94.

Draxler, R. R., (2007). Demonstration of a global modelling methodology to determine the relative importance of local and long-distance sources. Atmos. Environ., 41, 776–78, doi:https://doi.org/10.1016/j.atmosenv.2006.08.052.

Draxler,R. R., and G. D. Hess ., (1998). An overview of the HYSPLIT_4 modeling system for trajectories, dispersion, and deposition. Aust. Meteor. Mag., 47, 295– 308.

Drysdale, R., Pierotti, L., and Baldacci, F., 2001, Suspended sediments in karst spring waters near Massa (Tuscany), Italy: Environmental Geology, v. 40, pp. 1037-1050.

Dubey K, (2017) "Socio Economic Impact Study of Mining and Mining Polices on the Livelihoods of Local Population in the Vindhyan Region of Uttar Pradesh, Niti ayog , Govt. of India.

Dudka S, Adriano DC. Environmental impacts of metal ore mining and processing: a review. J Environ Qual. (1997); 26:59-602 https://doi.org/10.2134/jeq1 997.00472425002600030003x.

Dupery, R. L. (1968). Compilation of Air Pollutant Emission Factors. Public Health Service Publication No. 999-AP-42, US Department of Health, Education and Welfare.

Dutta N, Thakur B K, Nurujjaman Md, Debnath k, Bal D P, (2022) "An assessment of the water quality index (WQI) of drinking water in the Eastern Himalayas of South Sikkim, India", Groundwater for Sustainable Development, Volume 17, 2022, 100735, ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2022.100735.

Dutta, A., Gupta, R.K. (2022) Geochemistry and Utilization of Water from Thermal Springs of Tawang and West Kameng Districts, Arunachal Pradesh. J Geol Soc India **98**, 237–244 (2022). https://doi.org/10.1007/s12594-022-1964-7.

Duzgun, H., and Einstein, H. (2004): Assessment and manage-ment of roof fall risks in underground coal mines. Safety Science, 42, 1, 23-41.

Edmunds WM, Smedley PL (2013) Fluoride in natural waters. In: Selinus O (ed) Essentials of medical geology. Springer, Dordrecht. https ://doi.org/10.1007/978-94-007-4375-5_13.

Edwards, A.J., Hobbs, S.L., and Smart, P.L., (1991), Effects of quarry dewatering on a karstified limestone aquifer; a case study from the Mendip Hills, England, in Proceedings of the Third Conference on Hydrogeology, ecology, monitoring and management of groundwater in karst terranes, National Water Well Association, pp. 77-91.

Eeftens, M., Phuleria, H.C., Meier, R., Aguilera, I., Corradi, E., Davey, M., Tsai, M.Y., (2015). Spatial and temporal variability of ultrafine particles, NO2, PM2.5, PM2.5 absorbance, PM10 and PMcoarse in Swiss study areas. Atmos. Environ. 111, 60-70. https://doi.org/10.1016/j.atmosenv.2015.03.031.

Ekmekçi, M., 1993, Impact of quarries on karst groundwater systems, in Günay, G., Johnson, A.I., and Back, W., eds, Hydrogeological processes in karst terranes: Proceedings of the Antalya Symposium and Field Seminar, October 1990, IAHS Publication no. 207, p. 3-6.

El-Sikaily A, El Nemr A, Khaled A, Abdelwehab O (2007) Removal of toxic chromium from wastewater using green algae Ulva lactuca and its activated carbon. J Hazard Mater 148(1–2):216–228. https ://doi.org/10.1016/j.jhazm at.2007.01.146.

Emenike , E.C., Iwuozor, K.O. & Anidiobi, S.U. (2022) Heavy Metal Pollution in Aquaculture: Sources, Impacts and Mitigation Techniques. Biol Trace Elem Res **200**, 4476–4492. https://doi.org/10.1007/s12011-021-03037-x.

Emmanuel AY, Jerry CS, Dzigbodi DA. (2018) Review of Environmental and Health Impacts of Mining in Ghana. J Health Pollut. 2018 Mar 12;8(17):43-52. doi: 10.5696/2156-9614-8.17.43. PMID: 30524848; PMCID: PMC6221437.

Environmental Law alliance worldwide, 2018. (https://www.elaw.org/files/mining-eiaguidebook/Chapter1.pdf)

EOHS (2011) Mining and quarrying, Encyclopaedia of occupational health and safety, Industries based on natural resources. https://www.iloencyclopaedia.org/part-xi-36283/mining-and-quarrying.

ERM (2011) Enterprise risk Management, British Columbia report ISBN 978-0-7726-6467-9.

Escobedo, F.J., Wagner, J.E. and Nowak, D.J. (2008). Analyzing the cost effectiveness of Santiago, Chile's policy of using urban forest to improve air quality. Journal of Environmental Management, 86: 148 - 157.

Eyankware, M. O., Ephraim, B.E. (2021).Water quality assessment of Delta State southern Nigeria; a mini review. Journal of Environmental and Earth Sciences, in press view.

Fan S,WangX (2017) Analysis and assessment of heavy metals pollution in soils around Pb-Zn smelter in Baoji city, North West China. Human and ecological risk assessment an International Journal 23: 1099–1120.

Fang X,Wre PED, Nin BN, Chang PE, Wre D, Lee MK, Wolf L (2009) Environmental impact on surface water and Groundwater for expanding urban Water supply capacity using stone Quarries. World Environmental Water Resource Congress. https://doi.org/ 10.1061 /41036/342 /189.

Farooq, S.H., Prusty, P., Singh, R.K. et al. (2018) Fluoride contamination of groundwater and its seasonal variability in parts of Purulia district, West Bengal, India. Arab J Geosci **11**, 709 (2018). https://doi.org/10.1007/s12517-018-4062-9.

Fellmann, J. D., Getis, A. & Getis, J. (2005). Human Geography: Landscape of Human

Federico K, Claudio A. Belis, Carlos Francisco C. Dora, Annette M. Prüss-Ustün, Sophie Bonjour, Heather Adair-Rohani, Markus Amann, (2015) "Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level," Atmospheric Environment, Volume 120, 2015, Pages 475-483, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2015.08.087.

Fianko JR, Nartey VK, Donkor A (2010) The hydrochemistry of groundwater in rural communities within the Tema Disrict, Ghana. Environ Monit Assess 168:441–449.

FICCI (2013), FICCI's Annual Capital Markets Conference - CAPAM 2013.

Fleming DA, Measham TG. (2014) Local job multipliers of mining. Resour Policy. 2014; 41:9–15.

Gabarrón M, Zornoza R, Acosta JA, Faz Á, Martínez-Martínez S (2019) Chapter Five Mining environments. In: Pereira P (ed) Advances in Chemical Pollution, Environmental Management and Protection, vol 4. Elsevier, Amsterdam, pp 157–205.

Gaillardet J, Dupre B, Louvat P, Allegre CJ (1999) Global silicate weathering and CO2 consumption rates deduced from the chemistry of large rivers. Chem Geol 59:3–30.

Gandy CJ, Davis JE, Orme PHA, Potter HAB, Jarvis AP.(2016) Metal removal mechanisms in a short hydraulic residence time subsurface flow compost wetland for mine drainage treatment. Ecol Eng. 2016; 97:179–85.

Gemici U (2008) Evaluation of the water quality related to the acid mine drainage of an abandoned mercury mine (Alasehir, Turkey). Environ Monit Assess 147:93–106. doi:10.1007/s10661-007-0101-9.

Ghaedrahmati R, F. and DoulatiArdejani, (2012). Environmental Impact Assessment of Coal washing Plant (Alborz-Sharghi-Iran), Journal of Mining & Environment, Vol. 3, No.2, 69-77.

Ghose, M. K. and Banerjee, S. K. (1995). Status of air pollution caused by coal washery project in India. Environmental Monitoring and Assessment **38**, 97–105.

Ghose, M.K., Majee, J., (2000). Assessment of dust generation due to opencast coal mining—an Indian case study. Environmental Monitoring and Assessment 61, 255–263.

Ghose, M.K., Majee, S.R., (2002). Assessment of the status of work zone air environment due to opencast coal mining. Environmental Monitoring and Assessment 77, 51-60.

Gibson G, Klinck J. (2005) Canada’s resilient north: the impact of mining on aboriginal communities. Pimatisiwin. 2005;3:116–39.

Girish, L., Krishnankutty, K., Vaidya, S., (2017). Air pollution tolerance index of selected plants growing near road side of Navi Mumbai, Maharashtra. IJCR 9 (9), 57807–57811.

GIZ., (2015). Progress report on sustainability. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 59.

GIZ., (2016). Climate and environmental report. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 31.

Glass, W.I., McLean, D., Armstrong R., Pearce N., Thomas N., Munro G. & Walrond J. (2003). Respiratory health and silica dust levels in the extractive industry. Journal of Occupational Health Report Series, 9: 2003.

Gleeson T, Yoshihidewada BM, Beek LPH (2012) Water balance of global aquifers revealed by groundwater footprint. Nature 488:197–200.

Goldsmith, D. (2006). Relationship of exposure to crystalline silica & health effects: an epidemiologist view of the controversy**.** http://www.aiha.org/ aihce06/handouts/ rt241 goldsmith .pdf accessed on 23-6-2013.

Gonze, M.-A., Sy, M.M., (2016). Interception of wet deposited atmospheric pollutants by herbaceous vegetation: data review and modelling. Sci. Total Environ. 565, 49–67. https://doi.org/10.1016/j.scitotenv.2016.04.024.

Government of Harayana.,(2018). https://mahendragarh.gov.in/about-district/.

Gupta, G.P., Kumar, B., Kulshrestha, U.C., (2016). Impact and pollution indices of urban dust on selected plant species for green belt development: mitigation of the air pollution in NCR Delhi, India. Arab. J. Geosci. 9 (136). https://doi.org/10.1007/s12517- 015-2226-4.

Gupta, S.K., Deshpande, R.D., Agarwal, M. et al. (2005) Origin of high fluoride in groundwater in the North Gujarat-Cambay region, India. Hydrogeol J 13, 596–605 (2005). https://doi.org/10.1007/s10040-004-0389-2.

Gunn, John, and Hobbs, S.L., (1999), Chapter 6.2 Limestone quarrying: hydrogeological impacts, consequences, implications: in Drew, David, and Hötzl, Heinz, eds.: Karst hydrology and human activities – Impacts, consequences and implications, A.A. Balkema, pp. 192-201.

H.N Ezeh, (2010). Assessment of Cu, Pb, Zn, and Cd in groundwater in areas around the derelict Enyigba Mines, south eastern Nigeria. Global Journal of Geological Sciences, Vol. 8, No. 2, pp. 167- 173.

Halek, F., Kianpour-Rad, M., Kavousirahim, A., (2010). Seasonal variation in ambient PM mass and number concentrations (case study: Tehran, Iran). Environ. Monit. Assess. 169 (1), 501–507. https://doi.org/10.1007/s10661-009-1192-2.

Han, B., Zhang, G., Bi, X., Wang, X., Sheng, G., Fu, J., (2015). Pollution characteristics of atmospheric particle size and number concentrations during summer in urban area of Guangzhou. Res. Environ. Sci. 28 (2), 198–204. https://doi.org/10.13198/j.issn. 1001-6929.2015.02.05.

Hanse, A., Chabukdhara, M., Gohain Baruah, S. et al. (2019) Fluoride contamination in groundwater and associated health risks in Karbi Anglong District, Assam, Northeast India. Environ Monit Assess **191**, 782 (2019). https://doi.org/10.1007/s10661-019-7970-6.

Hariram, M., Sahu, R., Elumalai, S.P., (2018). Impact assessment of atmospheric dust on foliage pigments and pollution resistances of plants grown nearby coal based thermal power plants. Arch. Environ. Contam. Toxicol. 74 (1), 56–70. https://doi.org/10. 1007/s00244-017-0446-1.

Haritash AK, Baskar R, Sharma N, Paliwal S (2007) Impact of slate quarrying on soil properties in semi-arid Mahendragarh in India. Environ Goel 51:1439–1445

Haritash AK, Gaur S, Garg S (2016) Assessment of water quality and suitability analysis of River Ganga in Rishikesh, India. Appl Water Sci 6(4):383–392.

Haritash AK, Kaushik CP, Kaushik A, Kansal A, Yadav AK (2008) Suitability assessment of groundwater in some villages of Rewari district in Haryana. Environ Monit Assess 145(1–3):397–406.

Haritash AK, Mathur K, Priyanka S, Singh SK (2017) Hydrochemical characterization and suitability assessment of groundwater in Baga–Calangute stretch of Goa, India. Environ Earth Sci. https ://doi.org/10.1007/s1266 5-017-6679-5.

Haritash, A.K. & Aggarwal, Ankur & Soni, Jigyasa & Sharma, Khyati & Sapra, Mohnish & Singh, Bhupinder. (2018) Assessment of fluoride in groundwater and urine, and prevalence of fluorosis among school children in Haryana, India. Applied Water Science. 8. (2018). 10.1007/s13201-018-0691-0.

Haritash, A.K., Aggarwal, A., Soni, J. et al. (2018) Assessment of fluoride in groundwater and urine, and prevalence of fluorosis among school children in Haryana, India. Appl Water Sci **8**, 52 (2018). https://doi.org/10.1007/s13201-018-0691-0.

Hazarika, M., Singh, S.S., Bharti, A., (2018). An assessment of air pollution tolerance indices of some plant species grown in and around an industrial area in Guwahati, Assam, India. Ijera 8 (10), 39–48. https://doi.org/10.9790/9622-0810053948.

He S, Wu J (2019a) Hydrogeochemical characteristics, groundwater quality and health risks from hexavalent chromium and nitrate in groundwater of Huanhe Formation in Wuqi County, northwest China. Expo Health 11(2):125–137. https ://doi.org/10.1007/s12403-018-0289-7.

He X, Li P, Wu J, Wei M, Ren X, Wang D (2020a) Poor groundwater quality and high potential health risks in the Datong Basin, northern China: research from published data. Environ Geochem Health. https ://doi.org/10.1007/s1065 3-020-00520 -7.

He X, Wu J, Guo W (2019b) Karst spring protection for the sustainable and healthy living: the examples of Niangziguan spring and Shuishentang spring in Shanxi, China. Expo Health 11(2):153–165. https ://doi.org/10.1007/s1240 3-018-00295 -4.

He X, Wu J, He S (2019a) Hydrochemical characteristics and quality evaluation of groundwater in terms of health risks in Luohe aquifer in Wuqi County of the Chinese Loess Plateau, northwest China. Hum Ecol Risk Assess 25(1–2):32–51. https ://doi. org/10.1080/10807 039.2018.15316 93.

Health and Safety Executive (2000).General methods for sampling and gravimetric analysis of respirable and inhalable dust. Methods for Determination of Hazardous Substances 14/3 February 2000.

Hendryx, M., & Luo, J. (2014). An examination of the effects of mountaintop removal coal mining on respiratory symptoms and COPD using propensity scores. International Journal of Environmental Health Research. doi:10.1080/09603123.2014.938027.

Hendryx, M.; Islam, M.S.; Dong, G.-H.; Paul, G.(2020) Air Pollution Emissions 2008–2018 from Australian Coal Mining: Implications for Public and Occupational Health. Int. J. Environ. Res. Public Health **2020**, 17, 1570. https://doi.org/10.3390/ijerph17051570.

Hessel, P.A., Gamble, J.F., Gee, J.B.L., Gibb, S.G., Green, F.H.Y.,Morgan, W.K.C.& Mossman, B.T. (2000).Silica, silicosis and lung cancer; a response to a recent work group report. Journal of Occupational Environmental Medicine, July 200042(7) 704-720.

Hilson G. (2002) An overview of land use conflicts in mining communities. Land Use Policy. 2002;19:65–73.

Hinds WC (1999) Atmospheric aerosols. In: Hinds WC (ed) Aerosol technology: properties, behaviour, and measurement of airborne particles, 2nd edn. Wiley- Interscience, USA, pp 304–315.

Hobbs, S.L., and Gunn, John, (1998), The hydrogeological effect of quarrying karstified limestone: options for protection and mitigation: Quarterly Journal of Engineering Geology, v. 31, pp. 147-157.

Holmes, Nick. (2007). A review of particle formation events and growth in the atmosphere in the various environments and discussion of mechanistic implications. Atmospheric Environment. 41. 2183-2201. 10.1016/j.atmosenv.2006.10.058.

Hossain D, Gorman D, Chapelle B, Mann W, Saal R, Penton G. (2013) Impact of the mining industry on the mental health of landholders and rural communities in southwest Queensland. Aust Psychiatry. 2013;21:32–7.

Howard, Bob, and Cameron, Ian, (1998), Dust control: Best Practice Environmental Management in Mining, Environment Australia, 73 p

HSE UK (1992) “ Mannual Handling Operations Regulations 1992, ISBN-9780717666539.

Huang X, Sillanpaa M, Gjessing ET, Peraniemi S, Vogt RD (2010) Environmental impact of mining activities on the surface water quality in Tibet: gyama valley. Sci Total Environ 408:4177–4184. doi:10.1016/j.scitotenv.2010.05.015.

Hudson, T. (2012) Living with Earth, An Introduction to Environmental Geology. PHI Learning Private Limited.

Hussein, Tareq & Hämeri, Kaarle & Aalto, Pasi & Paatero, Pentti & Kulmala, Markku. (2005). Modal structure and spatial-temporal variations of urban and suburban aerosols in Helsinki - Finland. Atmospheric Environment - ATMOS ENVIRON. 39. 1655-1668. 10.1016/j.atmosenv.2004.11.031.

Iavazzo P, Ducci D, Adamo P, Trifuoggi M, Migliozzi A, Boni M (2012) Impact of past mining activity on the quality of water and soil in the High Moulouya Valley (Morocco). Water Air Soil Poll 223:573–589. doi:10.1007/s11270-011-0883-9.

Ibrahim, T. Z. (2007). Towards a Sustainable Quarry Industry in Malaysia: Some Issues and Challenges in Malaysia. [Online] Available at: htt://www.opendor.com (September 28, 2012).

IEG (The Independent Evaluation Group) of Journal (2008) Environmental Sustainability

Ilyas, M. &Rasheed, F. (2010).Health and environment related issues in stone crushing in Pakistan. Paper submitted on 10th Round Regional Research Competition of South Asia Network of economic Research Institute (Sanei).

ILO-IPEC, (2007). The world of child labour: An historical and regional survey.

India Ministry of Agriculture and Co-operation (1972) Handbook of hydrology. Soil Conservation Dept, New Delhi.

Indian minerals yearbook (2021), Indian Bureau of Mines, Nagpur

Ingold, C.T. (1971). Fungal Spores: Their Liberation and Dispersal. Clarendon Press: Oxford, UK.

Iqbal, M., Shafiq, M., Zaidi, S., Athar, M., (2015). Effect of automobile pollution on chlorophyll content of roadside urban trees. GJESM 1 (4), 283–296. https://doi.org/ 10.7508/gjesm.2015.04.003.

ISID (2012) Institute for Studies in Industrial Development Annual Report **2012**-13

Islam M. R. A (2016) "Study on the TDS Level of Drinking Mineral Water in Bangladesh. American Journal of Applied Chemistry 2016, 4(5), 164. doi: 10.11648/j.ajac.20160405.11 [CrossRef] [Google Scholar]

Islam, M.S.; Saha, S.C.; Sauret, E.; Gemci, T.; Yang, I.A.; Gu, Y.T. (2017) Ultrafine particle transport and deposition in a large scale 17-generation lung model. J. Biomech. **2017**, 64, 16–25. [**Google Scholar**] [**CrossRef**][**Green Version**].

J. Torano, S. Torno, I. Diego, M. Menendez, and M. Gent, (2009) Dust emission calculations in open pit storage piles protected by means of barriers, CFD and experimental tests, Environ. Fluid Mech. 9 (2009), pp. 493–507.

Jain CK, Bandyopadhyay A, Bhadra AA (2010) Assessment of groundwater quality for drinking purpose, District Nainital Uttarakhand, India. Environ Monit Assess 166:663–676.

Jain R, Cui Z, Domen J. (2016) Environmental impact of mining and mineral processing: management, monitoring, and auditing strategies. Oxford: Butterworth-Heinemann; 2016.

Jain R, Cui Z, Domen J.(2016) Environmental impacts of mining. In: Jain R, Cui Z, Domen J, editors. Environmental impact of mining and mineral processing: management, monitoring, and auditing strategies. Amsterdam: Elsevier; 2016. p. 53–157.

Jain S, Khare M (2008) Urban air quality in mega cities: a case study of Delhi City using vulnerability analysis. Environ Monit Assess 136: 257–265. https://doi.org/ 10.1007 /s10661-00 7 -9681- 7.

Jain S, Khare M (2010) Adaptive neuro-fuzzy modelling for prediction of ambient CO concentration at urban intersections and roadways. Air Qual Atmos Health 3:203–212. https://doi.org/10.1007/s11869- 010-0073-8.

Jamwal, Karan & Slathia, Deepika. (2019). Geospatial mapping and drinking water quality status of fluoride endemic hilly District Doda (J&K), India. Journal of Applied and Natural Science. 11. 410-423. 10.31018/jans.v11i2.2066.

Jankowski J, Acworth RI (1997) Impact of debris-flow deposits on hydrogeochemical processes and the development of dryland salinity in the Yass River catchment. New South Wales, Australia. Hydrogeol J 5:71–88.

Jaszczur, M., Teneta, J., Styszko, K., et al., (2019). The field experiments and model of the natural dust deposition effects on photovoltaic module efficiency. Environ. Sci. Pollut. Res. Int. 26 (9), 8402–8417. https://doi.org/10.1007/s11356-018-1970-x.

Jeong, C.-H., Evans, G.J., Hopke, P.K., Chalupa, D., Utell, M.J., (2006). Influence of atmospheric dispersion and new particle formation events on ambient particle number concentration in Rochester, United States, and Toronto, Canada. Journal of the Air & Waste Management Association (Air & Waste Management Association) 56 (4), 431–443.

Jha AK, Singh JS (1991) Spoil characteristic and vegetation development on an age series of mine spoils in a dry tropical environment. Vegetation 97:63–76

Jhariya, D. and Choraisia, K. (2010) Khanij utpadan ka jal sansadhan aivam jal sanrakshan par prabhav. Bhu - Jal Sanvardhan aivam Jal sansadhano ka sanrakshan.

Jhariya, Dalchand & Khan, Rubia & Thakur, G.S.. (2016). Impact of Mining Activity on Water Resource : An Overview study.

Jim, C., Chen, W.Y. (2008). Assessing the ecosystem service of air pollutant removal by urban trees in Guangzhou (China). Journal of Environmental Management, 88: 665-676.

John W. Doran, Michael R. Zeiss, (2000) Soil health and sustainability: managing the biotic component of soil quality, Applied Soil Ecology,Volume 15, Issue 1,2000, Pages 3-11, ISSN 0929-1393, https://doi.org/10.1016/S0929-1393(00)00067-6

Jomaa, I., Auda, Y., Abi Saleh, B., Hamze. M. and Safi, S.(2008). Landscape spatial dynamics over 38 years under nat-ural and anthropogenic pressures in Mount Lebanon. Land-scape and Urban Planning 87, 67–75.

Jones, T., Blackmore, P., Leach, M., Matt, B.K., Sexton, K., Richards, R., (2002). Characterisation of airborne particles collected within and proximal to an opencast coalmine: South Wales. UK Environmental Monitoring and Assessment 75, 293–312.

Joshi, A.U., Gorania, P., Limaye, M.A. et al. (2022) Geo heritage Values of the Champaner-Pavagadh Archaeological Park, UNESCO World Heritage Site, Gujarat, Western India. Geoheritage **14**, 88 (2022). https://doi.org/10.1007/s12371-022-00720-w.

Joshi, P.C., Swami, A., (2007). Physiological responses of some tree species under roadside automobile pollution stress around city of Haridwar, India. Environmentalist 27, 365–374. https://doi.org/10.1007/s10669-007-9049-0.

Joshi, P.C., Swami, A., (2007). Physiological responses of some tree species under roadside automobile pollution stress around city of Haridwar, India. Environmentalist 27, 365–374. https://doi.org/10.1007/s10669-007-9049-0.

Jung MC.(2008) Heavy Metal Concentrations in Soils and Factors Affecting Metal Uptake by Plants in the Vicinity of a Korean Cu-W Mine. Sensors (Basel). 2008 Apr 4;8(4):2413-2423. doi: 10.3390/s8042413. PMID: 27879826; PMCID: PMC3673422.

Jyothi, S.J., and Jaya, D. (2010). Evaluation of air pollution tolerance index of selected plant species along roadsides in Thiruvananthapuram, Kerala. Journal of Environmental Biology, 31: 379–386.

Kalu IE, Ogbonna NJ (2019) Investigation of environmental effect of stone quarrying activities on soil and water in Akpoha and Ishiagu communities of Ebonyi state Nigeria. International Journal of Construction Management. https://doi.org/10.1080/15623599.2019.16014115.

Kambhoj N & Kambhoj V (2019) Water quality assessment using overall index of pollution in riverbed-mining area of Ganga-River Haridwar, India, Water Science, 33:1, 65-74, DOI: 10.1080/11104929.2019.1626631.

Kan H, Chen R, Tong S (2012) Ambient air pollution, climate change, and population health in China. Environ Int 42:10–19.

Kanu, S. Barnes W. Heller, C., Miller and J. Terium (Eds.), Environmental protection, Harrodsburg: Pennsylvanian Department of Environment. 1-30.

Karmakar, H.N., Das, K. P. (2012) Impact of Mining on Ground & Surface water. International Mine Water Association. www. IMWA.info.

Kashyap C A, Ghosh A, Singh S, Ali S, Singh H K, Chandrasekhar T, Dornadulla Chandrasekharam, (2020) Distribution, genesis and geochemical modelling of fluoride in the water of tribal area of Bijapur district, Chhattisgarh, central India, Groundwater for Sustainable Development, Volume 11, 2020,100403, ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2020.100403.

Katz BG, Coplen TB, Bullen TD, Hal Davis J (1997) Use of chemical and isotopic tracer to characterize the interactions between groundwater and surface water in mantled karst. Groundwater 35(6):1014–1028.

Kaur, S., Nieuwenhuijsen, M., Colvile, R., (2005). Personal exposure of street canyon intersection users to PM2.5, ultrafine particle counts and carbon monoxide in CentralLondon, UK. Atmos. Environ. 39 (20), 3629–3641. https://doi.org/10.1016/j.atmosenv.2005.02.046.

Keeling A, Sandlos J. (2011) Ghost towns and zombie mines: the historical dimensions of mine abandonment, reclamation, and redevelopment in the Canadian North. In: Bocking S, Martin B, editors. Ice Blink: Navigating Northern Environmental History; 2011. p. 377–420.

Keesari, T., Pant, D., Roy, A. et al. (2021) Fluoride Geochemistry and Exposure Risk Through Groundwater Sources in North-eastern Parts of Rajasthan, India. Arch Environ Contam Toxicol **80**, 294–307 (2021). https://doi.org/10.1007/s00244-020-00794-z.

Keywood, M.D., Ayers, G.P., Gras, J.L., Gillett, R.W., Cohen, D.D., (1999). Relationships between size segregated mass concentration data and ultrafine particle number concentrations in urban areas. Atmos. Environ. 33 (18), 2907–2913. https://doi.org/10.1016/S1352-310(99)00102-8.

Khan, F , Srinivasmoorthy, K , Raja, Prakash & Gopinath, Saravanan, K. Vinnarasi, F. &Cm, Babu Cheelil, Rabina. (2021). Human health risk assessment for fluoride and nitrate contamination in the groundwater: a case study from the east coast of Tamil Nadu and Puducherry, India. Environmental Earth Sciences. 80. 10.1007/s12665-021-10001-4.

Khater, C., Martin, A. and Ma illet, J. (2003). Spontaneousvegetation dynamics and restoration prospects for limestonequarries in Lebanon. Applied Vegetation Science 2, 199–204.

Khyaliya, R.K., Kabeer, K.I.S.A., Vyas, A.K., (2017). Evaluation of strength and durability of lean mortar mixes containing marble waste. Construct. Build. Mater. 147, 598–607. https://doi.org/10.1016/j.conbuildmat.2017.04.199.

Knobblock EA, Pettersson Ö. (2010) Restructuring and risk-reduction in mining: employment implications for northern Sweden. Fenn Int J Geogr. 2010;188:61–75.

Knuckles, T. L., Stapleton, P. A., Minarchick, V. C., Esch, L., McCawley, M., Hendryx, M., & Nurkiewicz, T. R. (2013). Air pollution particulate matter collected from an Appalachian mountaintop mining site induces microvascular dysfunction. *Microcirculation, 20*(2), 158-169.

Kondolf GM (1994) Geomorphic and environmental effects of instream gravel mining. Landsc Urban Plan 28:225–243. doi:10.1016/0169-2046(94)90010-8.

Kori E, Mathada H (2012) An assessment of environmental impacts of sand and gravel mining in Nzhelele Valley, Limpopo Province, South Africa. In: Proceeding of the third international conference on biology, environment and chemistry, pp 137–141.

Kumar A, Adak P, Gurian PL, Lockwood JR (2010) Arsenic exposure in US public and domestic drinking water supplies: a comparative risk assessment. J Eposure Sci Environ Epidemiol 20(3):245–254. https ://doi.org/10.1038/jes.2009.24.

Kumar Pawan. (2013) The mining activity and its impact on plant biodiversity: A case study at Bhiwani Open Cast mining zones-Haryana, India. Asian journal of Plant Sciences and Research. 2013; 3(6):78-83.

Kumar S, Lata S, Yadav J, Yadav JP (2016) Relationship between water, urine and serum fluoride and fluorosis in school children of Jhajjar District, Haryana, India. *Appl Water Sci* **7,** 3377–3384. https://doi.org/10.1007/s13201-016-0492-2.

Kumar SK, Rammohan V, Sahayam JD, Jeevananadam M (2009) Assessment of groundwater quality and hydrogeochemistry of Manimuktha river basin, Tamil Nadu, India. Environ Monit Assess 159:341–351.

Kumar, Balwant & Singh, Umesh Kumar & Mukherjee, Indrani. (2017) Hydrogeological Influence on the Transport and Fate of Contaminants in the Groundwater, India. JSM Biology (2017). 2. 1-11.

Kumar, C.S.S., Kumar, P., Deshpande, V.P., Badrinath, S.D., (1994). In: Khuntia, G.S., (Ed.), Fugitive dust emission estimation and validation of air quality model in bauxite mines, Proceedings of International Conference on Environmental Issues in Minerals and Energy Industry, IME Publications, New Delhi, India, pp. 77–81.

Kumar, M. and Nandini, N. (2013). Identification and Evaluation of Air Pollution Tolerance Index of Selected Avenue Tree Species of Urban Bangalore, India. International Journal of Emerging Technology and Computer Application Science, 13: 388-390.

Kumar, P., Fennell, P.S., Hayhurst, A.N. et al. (2009) Street Versus Rooftop Level Concentrations of Fine Particles in a Cambridge Street Canyon. Boundary-Layer Meteorol **131**, 3–18 (2009). https://doi.org/10.1007/s10546-008-9300-3.

Kumar, P.,Wiedensohler, A., Birmili,W., Quincey, P., Hallquist,M., (2016). Ultrafine Particles Pollution and Measurements. Compr. Anal. Chem. 73, 369–390. https://doi.org/ 10.1016/bs.coac.2016.04.004.

Kumar, Prashant & Ketzel, Matthias & Vardoulakis, Sotiris & Pirjola, Liisa & Britter, Rex. (2011). Dynamics and dispersion modeling of nanoparticles from road traffic in the urban atmospheric environment – A review. Journal of Aerosol Science. 42. 580-603. 10.1016/j.jaerosci.2011.06.001.

Kumar, S., Gupta, R.C., Shrivastava, S., (2017a). Long term studies on the utilisation of quartz sandstone wastes in cement concrete. J. Clean. Prod. 143, 634–642. https://doi.org/10.1016/j.jclepro.2016.12.062.

Kumar, S., Gupta, R.C., Shrivastava, S., Csetenyi, L.J., (2017b). Sulfuric acid resistance of quartz sandstone aggregate concrete. J. Mater. Civ. Eng. 29, 1–12. https://doi.org/ 10.1061/(ASCE)MT.1943-5533.0001870.

Kumar, S., Skariah Thomas, B., Gupta, V., Basu, P., Shrivastava, S., (2018). Sandstone wastes as aggregate and its usefulness in cement concrete – a comprehensive review. Renew. Sustain. Energy Rev. 81, 1147–1153. https://doi.org/10.1016/j. rser.2017.08.044.

Kumar, S., Venkatesh, A. S., Singh, R., Udayabhanu, G. & Saha, D. (2019) Geochemical Signatures and isotopic systematics constraining dynamics of fluoride in groundwater across Jamui district, Indo-Gangetic alluvial plains, India. (2019) Chemosphere. 205, 493–505.

Kurihara, N. &Wada, O. (2004). Silicosis and smoking strongly increase lung cancer risk in silica-exposed workers.Journal of Industrial Health 2004. 42(3): 303-314.

Kurth LM, Kolker A, Engle M, et al. (2015) Atmospheric particulate matter in proximity to mountaintop coal mines: sources and potential environmental and human health impacts. Environ Geochem Health. 2015;37(3):529- 544.

Kurth ML, McCawley M, Hendryx M, Lusk S (2014) Atmospheric particulate matter size distribution and concentration in West Virginia coal mining and non-mining areas. J Exposure Sci Environ Epidemiol 24:405–411.

Lad R. J., Samant J. S. (2013) Environmental impact of bauxite mining in the Western Ghats in south Maharashtra, India, International Journal of Recent Scientific Research, Vol. 4, Issue 8, 1275-1281 pp.

Lameed G, Ayodele A (2010) Effect of quarrying activity on biodiversity: case study of Ogbere site, Ogun State Nigeria. Afr J Environ Sci Technol 4(11):740–750.

Langer WH (2001) Potential environmental impact of quarrying stone in karst A literature Review UK Department of the Interior and US Geological Survey http://geologyCr.usgs.gov/pub/ofrs/OFR-01- 0484.

Langer, W.H., Drew, L.J. & Sachs, J.S. (2004).Aggregates and the environment**.** American Geological Institute (US Geological Survey) 4220 King Street, Alexandria, VA 112302; ISBN 0-922152-71-3.

Laskar N, Singh U, Kumar R, Meena S K, (2022) "Spring water quality and assessment of associated health risks around the urban Tuirial landfill site in Aizawl, Mizoram, India", Groundwater for Sustainable Development, Volume 17, 2022, 100726, ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2022.100726.

Last, J.M. (1998**).** Public Health and Human Ecology, (2ndEdition) pp153-200.McGraw-Hill Medical Publishing Prentice – Hall Int. Edition, Canada.

Lechner, A.; McIntyre, N.;Witt, K.; Raymond, C.; Arnold, S.; Scott, M.; Rifkin,W. (2017) Challenges of integrated modelling in mining regions to address social, environmental and economic impacts. Environ. Model. Softw. **2017**, 93, 268–281. [CrossRef].

Lee JK, Kim DY, Park SH, Woo SY, Nie H, Kim SH. (2022) Particulate Matter (PM) Adsorption and Leaf Characteristics of Ornamental Sweet Potato (Ipomoea batatas L.) Cultivars and Two Common Indoor Plants (Hedera helix L. and Epipremnum aureum Lindl. & Andre). Horticulturae. 2022; 8(1):26. . https://doi.org/10.3390/horticulturae8010026.

Leon, L.G., Bengtsson, M., Evertsson, C.M., (2018). Analysis of the concentration in rare metal ores during compression crushing. Miner. Eng. 120, 7–18. https://doi.org/ 10.1016/j.mineng.2018.01.041.

Lesley R. (2011).Chronic obstructive pulmonary disease and occupational exposure to silica.Reviews on Environmental Health, 22(4), 255-272.

Levei E, Senila M, Miclean M, Abraham B, Roman C, Stefanescu L, Moldovan OT (2011) Influence of Rosia Poieni and Rosia Montana mining areas on the water quality of the Aries River. Environ Eng Manag J 10:23–29.

Levy S, Hillis S, Warren J, Broffitt B, Mahbubul Islam A, Wefel J, Kanellis M (2002) Primary tooth fluorosis and fluoride intake during the first year of life. *Community Dent Oral Epidemiol.* 30(4):286-95. doi: 10.1034/j.1600-0528.2002.00053.x

Li A, Chen C, Chen J, Lei P. (2021) Environmental investigation of pollutants in coal mine operation and waste dump area monitored in Ordos Region, China. RSC Adv. 2021 Mar 10;11(17):10340-10352. doi: 10.1039/d0ra10586d. PMID: 35423509; PMCID: PMC8695702.

Li P, He S, He X, Tian R (2018a) Seasonal hydrochemical characterization and groundwater quality delineation based on matter element extension analysis in a paper wastewater irrigation area, northwest China. Expo Health 10(4):241–258. https ://doi.org/10.1007/s1240 3-017-0258-6.

Li P, He X, Guo W (2019a) Spatial groundwater quality and potential health risks due to nitrate ingestion through drinking water: a case study in Yan'an city on the loess plateau of northwest China. Hum Ecol Risk Assess 25(1–2):11–31. https ://doi.org/10.1080/10807 039.2018.15536 12.

Li P, He X, Li Y, Xiang G (2019b) Occurrence and health implication of fluoride in groundwater of loess aquifer in the Chinese Loess Plateau: a case study of Tongchuan, Northwest China. Expo Health 11(2):95–107. https ://doi.org/10.1007/s1240 3-018-0278-x.

Li P, Qian H, Wu J, Chen J, Zhang Y, Zhang H (2014a) Occurrence and hydrogeochemistry of fluoride in shallow alluvial aquifer of Weihe River, China. Environ Earth Sci 71(7):3133–3145. https :// doi.org/10.1007/s1266 5-013-2691-6.

Li P, Wu J, Qian H, Zhang Y, Yang N, Jing L, Yu P (2016a) Hydrogeochemical characterization of groundwater in and around a wastewater irrigated forest in the southeastern edge of the Tengger Desert, Northwest China. Expo Health 8(3):331–348. https :// doi.org/10.1007/s1240 3-016-0193-y.

Li, L.G., Huang, Z.H., Tan, Y.P., Kwan, A.K.H., Chen, H.Y., (2019). Recycling of marble dust as paste replacement for improving strength, microstructure and eco-friendliness of mortar. J. Clean. Prod. 210, 55–65. https://doi.org/10.1016/j. jclepro.2018.10.332.

Li, P., Wu, J. (2019) Drinking Water Quality and Public Health. Expo Health **11**, 73–79 (2019). https://doi.org/10.1007/s12403-019-00299-8.

Liang S, Nie ZW, Zhao M, Niu YJ, Xin KT, Cui XS (2017) Sodium fluoride exposure exerts toxic effects on porcine oocyte maturation. *Sci Rep* 7**,** 17082. https://doi.org/10.1038/s41598-017-17357-3

Liu, Y., Ding, H., (2008). Variation in air pollution tolerance index of plants near a steel factory: implications for landscape-plant species selection for industrial areas. WSEAS Trans. Environ. Develop. 4 (1), 24–32.

Liu, Y., Wang, P., Gojenko, B., Yu, J., Wei, L., Luo, D., & Xiao, T. (2021). A review of water pollution arising from agriculture and mining activities in Central Asia: Facts, causes and effects. *Environmental Pollution*, *291*, 118209.

Loayza N, Rigolini J. (2016) The local impact of mining on poverty and inequality: evidence from the commodity boom in Peru. World Dev. 2016;84:219–34.

Lowndes I.S., S.A. Silvester, S.W. Kingman and D.M. Hargreaves, (2008) The application of an improved multi-scale computational modelling techniques to predict fugitive dust dispersion and deposition within and from surface mining operations, Proceedings of the 12th U.S./North American Mine Ventilation Symposium, K.G. Wallace ed., Reno, NV, ISBN 978-0-615-20009-5, 2008, pp. 359–366.

Lloyd, J. W., & Heathcote, J. A. A. (1985). Natural inorganic hydrochemistry in relation to ground water.

MacDonald AM, Bonsor HC, Ahmed KM et al (2016) Groundwater quality and depletion in the Indo-Gangetic basin mapped from iShin situ observations. Nat Geosci. https ://doi.org/10.1038/ngeo2 791.

Machin J, Navas A (2000) Soil pH changes induced by contamination by magnesium oxides dust. Land Degrad Dev 11(1):37–50.

Madhavan, P., (2005). Budhpura ‘ Ground Zero ’ Sandstone Quarrying in India.’ Indian committee of Netherlands.

Mahar A, Wang P, Ali A, Awasthi MK, Lahori AH, Wang Q, Li RH, Zhang ZQ. (2016) Challenges and opportunities in the phytoremediation of heavy metals contaminated soils: a review. Ecotoxicol Environ Saf. 2016; 126:111–21.

Mahajan, 1934. Annual Report of Hyderabad State, 3, Indian Council of Agricultural Research, New Delhi

Mahvi AH, Ghanbarian M, Ghanbarian M, Khosravi A, Ghanbarian M (2012) Determination of fluoride concentration powdered milk in Iran 2010. Br J Nutr 107(7):1077–1079. https ://doi.org/10.1017/ S0007 11451 10039 41.

Mallick J, Singh CK, AlmesferMK, Kumar A, Khan R, Islam S, Rahman A (2018) Hydrogeochemical assessment of groundwater quality in Asser Region. Water 10. https://doi.org/10.3390/w.10121847.

Mamatha, P., & Rao, S. M. (2010). Geochemistry of fluoride rich groundwater in Kolar and Tumkur Districts of Karnataka. *Environmental Earth Sciences*, *61*, 131-142.

Manwar VD, Mandal BB, Pal AK. (2016) Environmental propagation of noise in mines and nearby villages: A study through noise mapping. Noise Health. 2016 Jul-Aug; 18(83):185-93. doi: 10.4103/1463-1741.189246. PMID: 27569406; PMCID: PMC5187660.

Marconi, A., Cattani, G., Cusano, M., Ferdinandi, M., Inglessis, M., Viviano, G., Forastiere, F., (2007). Two-years of fine and ultrafine particles measurements in Rome, Italy. J. Toxic. Environ. Health A 70 (3–4), 213–221. https://doi.org/10.1080/15287390600883174.

Margitai, Z., Simon, E., Fábián, I., Braun, M., (2017). Inorganic chemical composition of dust deposited on oleander (Nerium oleander) leaves. Air Qual. Atmos. Health 10 (3), 339–347. https://doi.org/10.1007/s11869-016-0416-1.

Marrugo-Negrete JL, Urango-Cardenas ID, Núñez SMB, Díez S (2014) Atmospheric deposition of heavy metals in the mining area of the San Jorge River basin, Colombia. Air Qual Atmos Health 7:577– 588.

Martínez-Ruiz C, Fernández-Santos B, Putwain PD, Fernández-Gómez MJ (2007) Natural and man-induced revegetation on mining wastes: changes in the floristic composition during early succession. Ecol Eng 30(3):286–294. https ://doi.org/10.1016/j.ecoleng.2007.01.014.

Maskooni EK, Naser-Rad M, Berndtsson R, Nakagawa K (2020) Use of heavy metals content and modified water quality to assess groundwater quality in a semi-arid area. Water 12:1–22.

Matheson, F.J. (1966).Geology of the Kajiado Area.Report No. 70, Published by the Ministry of Natural Resources and Wildlife, Geological Survey of Kenya.

Matthess, G. (1982) The Properties of Groundwater. Department of Environmental Science, John Wiley and Sons Inc., New York, 406 p.

Mayo AL, Loucks MD (1995) Solute and isotopic geochemistry and groundwater flow in the Central Wasatch Range, Utah. J Hydrol 172(1–4):31–59.

McDonald, J.C., McDonald, A.D., Hughes, J.M., Rando, R.J. &Weill,H. (2005).Mortality from lung and kidney diseases in cohort of North American industrial sand workers.Annals of Occupational Hygiene:49(5) 367-373.

McIntyre, N.; Bulovic, N.; Cane, I.; McKenna, P. (2016) A multi-disciplinary approach to understanding the impacts of mines on traditional uses of water in Northern Mongolia. Sci. Total Environ. **2016**, 557–558, 404–414. [CrossRef] [PubMed].

Meenalbal, T., Akil, K., (2000). Ambient air quality at selected sites in Coimbatore city. Indian Journal of Environmental Protection 20, 49–53.

Mehta, S. P. (2002) The Indian Mining Sector: Effects on the Environment and FDI Inflows. Conference on foreign Direct Investment and the Environment.

Melaku E (2007) Impact assessment and restoration of quarry site in urban environment: the case of Augusta quarry. Addis Ababa University, Addis Ababa Ming'ate FLM.

Mencio A, Mas-Pla J, Otero N, Regas O, Boy-Roura M, Puig R, Bach J, Domenech C, Zamorano M, Brusi D, Folch A (2016) Nitrate pollution of groundwater; all right, but nothing else? Sci Total Environ 539:241–251. https ://doi.org/10.1016/j.scito tenv.2015.08.151.

Mengeshe, Y.A.& Bekele, A. (1998). Relative chronic effects of occupational dust on respiratory indices and health of workers in three Ethiopian factories.American Journal of Industrial Medicine 1998 34:373-80.

Meybeck M (1987) Global chemical weathering of surficial rocks estimated from river dissolved loads. Am J Sci 287:401–428.

Mineo Consortium (2000) Review of potential environment and social impacts of mining.www.brgm.fr/mineo.

Mines and Geology department Government of Haryana., (2020) http://minesharyana.gov.in/en

Mitchell CJ, O'Neill K. The Sherriff Creek Wildlife Sanctuary: further evidence of mine-site repurposing and economic transition in northern Ontario. Extr Ind Soc. 2017;4:24–35.

Mohabansi N, Tekade P, Bawankar S (2011) Physico-chemical Parameters of Textile Mill Effluent Hinganghat, Dist. Wardha (M.S.). Curr World Environ 6(1):165–168. https ://doi.org/10.12944 / CWE.6.1.24.

Mölders, N., (1998). Landscape changes over a region in East Germany and their impact upon the processes of its atmospheric water-cycle. Meteorology and Atmospheric Physics, 68(1–2), 79–98.

Molnár, V.É., Tóthmérész, B., Szabó, S., Simon, E., (2018). Urban tree leaves' chlorophyll-a content as a proxy of urbanization. Air Qual. Atmos. Health 11 (6), 665–671. https:// doi.org/10.1007/s11869-018-0573-5.

Mondal, S., Bandayopahyay, J. and Chakarvarty, D. (2014) Scientific Investigation of the Environmental Impact of Mines Using Geospatial Tecniques over a small part of

Keonjhar Dstrict of Orissa. International Journal of Scientific and Research Publication.v.4.pp.1-8.

Monjezi M, Shahriar K, Dehghani H, Namin FS (2009) Environmental impact assessment of open pit mining in Iran. Environ Geol 58(1):205–216.

Morawska, Lidia & Ristovski, Zoran & Jayaratne, Rohan & Keogh, Diane & Ling, Xuan. (2008). Ambient nano and ultrafine particles from motor vehicle emissions: Characteristics, ambient processing and implications on human exposure. Atmospheric Environment. 42. 10.1016/j.atmosenv.2008.07.050.

Moshammer, H., Hochgatterer, K., Haluza, D., (2014). Occupational exposure to mineral dust. Effects of on lung function in a nine-year study. Occup. Environ. Med. 71, A62.

Mridha D, Priyadarshni P, Bhaskar K, Gaurav A, De A, Das A, Joardar M, Nilanjana Roy Chowdhury, Tarit Roychowdhury, (2021) "Fluoride exposure and its potential health risk assessment in drinking water and staple food in the population from fluoride endemic regions of Bihar, India," Groundwater for Sustainable Development, Volume 13, 2021, 100558, ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2021.100558.

MSHA (Mine Safety and Health administration) (2013). Effect of blasting on air quality Arlington, VA:US Depratmnet of Labour . http://www.msha.gov/illness _prevention/healthtopics/blasting.htm. Accessed 31 October 2013.

Mukate S, Bhoominathan S & Solanky V (2022) Assessment of human health risk arising due to fluoride and nitrate in groundwater: a case study of Bhokardan tehsil of Maharashtra, Human and Ecological Risk Assessment: An International Journal, 28:5-6, 594-620, DOI: 10.1080/10807039.2022.2081837.

Mukherjee, A., Agrawal, M., (2015). Pollution response score of tree species in relation to ambient air quality in an urban area. Bull. Environ. Contam. Toxicol. 96 (2), 197–202. https://doi.org/10.1007/s00128-015-1679-1.

Mulopo, J., (2015). Continuous pilot scale assessment of the alkaline barium calcium desalination process for acid mine drainage treatment. J. Environ. Chem. Eng. 2, 1295e1302.

Muralidhara Reddy B., Sunitha V., (2020) "Geochemical and health risk assessment of fluoride and nitrate toxicity in semi-arid region of Anantapur District, South India", Environmental Chemistry and Ecotoxicology, Volume 2, 2020, Pages 150-161, ISSN 2590-1826, https://doi.org/10.1016/j.enceco.2020.09.002.

Nadgórska-Socha, A., Kandziora-Ciupa, M., Trzęsicki, M., Barczyk, G., (2017). Air pollution tolerance index and heavy metal bioaccumulation in selected plant species from urban biotopes. Chemosphere 183, 471–482. https://doi.org/10.1016/j.chemosphere.2017.05.128.

Nagaraju, A., Sunil Kumar, K. & Thejaswi, (2014) A. Assessment of groundwater quality for irrigation: a case study from Bandalamottu lead mining area, Guntur District, Andhra Pradesh, South India. Appl Water Sci **4**, 385–396 (2014). https://doi.org/10.1007/s13201-014-0154-1.

Naidoo R, Seixas N, Robins T (2006) Estimation of respirable dust exposure among coal miners in South Africa. J Occup Environ Hyg 3:293–300.

Nakazawa K, Nagafuchi O, Kawakami T, Inoue T, Yokota K, Serikawa Y, Cyio B, Elvince R. (2016) Human health risk assessment of mercury vapour around artisanal small-scale gold mining area, Palu city, Central Sulawesi, Indonesia. Ecotoxicol Environ Saf. 2016; 124:155–62.

Narsimha A, Sudarshan V (2016) Contamination of fluoride in groundwater and its effect on human health: a case study in hard rock aquifers of siddipet, Telangana state, India. *Water Sci* **7,** 2501–2512. https://doi.org/10.1007/s13201-016-0441-0

NEERI (2002) National environment engineering research institute annual report published on 2002 at CSIR NEERI.

NIOSH, (2002) National Institute of Occupational Safety and Health Hazard (NIOSH) Review (2002).Health effects of occupational exposure to respirable crystalline silica.DHHS 2002 – 129: 23.

Navarro, M.C. & Perez, Carmen & Martínez-Sánchez, M.J. & Vidal, Josefa & Tovar, P.J. & Bech, Jaume. (2008). Abandoned mine sites as a source of contamination by heavy metals: A case study in a semi-arid zone. Journal of Geochemical Exploration. 96. 183-193. 10.1016/j.gexplo.2007.04.011.

Nemery, B.; Behr, J.; Bourke, S.; et. al: (2001) “Interstitial lung disease induced by exogenous agents: Factors governing Susceptibility.” Eur Respi Journal, **2001**, 18(suppl-32):30-42.

Noor, M.J., Sultana, S., Fatima, S., Ahmad, M., Zafar, M., Sarfraz, M., and Ashraf, M.A. (2017). Retraction note to: estimation of anticipated performance index and air pollution tolerance index and of vegetation around the marble industrial areas of Potwar region: bio indicators of plant pollution response. Environmental Geochemistry and Health, 39(3):705-705.

Nuccio M (2016). Pollution of waters and soils by contaminants of magmatic origin. *Rend. Fis. Acc. Lincei* 27**,** 21–28 https://doi.org/10.1007/s12210-015-0474-6

Nwibo, A.N., Ugwuja, E.I., Nwambeke, N.O., Emelumadi, O.F. &Ogbonnaya, L.U. (2012). Pulmonary problems among quarry workers of crushing stone industrial site at Umuoghara, Ebonyi state, Nigeria.The International Journal of Occupational and Environmental Medicine 2012; 3: 178-185.

Obiri-Nyarko F, Grajales-Mesa SJ, Malina G.(2014) An overview of permeable reactive barriers for in situ sustainable groundwater remediation. Chemosphere. 2014;111:243–59.

Odell, S.D., Bebbington, A., Frey, K.E., (2018). Mining and climate change: a review and framework for analysis. Extr. Ind. Soc. 5, 201–214. https://doi.org/10.1016/j. exis.2017.12.004.

OEHHA, Office of Environmental Health Hazard Assessment (OEHHA), (2005).Adoption of chronic exposure levels for respirable crystalline silica.http://www.oehha.ca.gov/air/chronic rels/silicafinal html.

Ogunkunle, C.O., Suleiman, L.B., Oyedeji, S., Awotoye, O.O., Fatoba, P.O., (2015). Assessing the air pollution tolerance index and anticipated performance index of some tree species for biomonitoring environmental health. Agroforest. Syst. 89, 447–454. https://doi.org/10.1007/s10457-014-9781-7.

Oguntoke, O., Abaoba,A.&Gbadebo, A. (2009).Impact of granite quarrying on the health of workers and nearby residents in Abeokuta, Ogun state, Nigeria.Ethiopian Journal of Environmental Studies 2(1), 2009.

Oişte AM (2014) Groundwater quality assessment in urban environment. Int J Environ Sci Technol 11(7):2095–2102. https ://doi. org/10.1007/s1376 2-013-0477-8.

Okafor, F. O. (1988). Palm kernel shell as a lightweight aggregate for concrete. *Cement and Concrete Research*, *18*(6), 901-910. https://doi.org/10.1016/0008-8846(88)90026-9

Olivero, J.; Solano, B (1998) Mercury in environmental samples from a waterbody contaminated by gold mining in Colombia, South America. Sci. Total Environ. **1998**, 217, 83–89. [CrossRef]

Olusegun O., A. Adeniyi, and G.T. Adeola,(2009) Impact of Granite Quarrying on the Health of Workers and Nearby Residents in Abeokuta Ogun State, Nigeria, Ethiop. J. Environ. Stud. Manage. 2(1) (2009), pp. 1–11.

Omosanya, K.O. and Ajibade O.M., (2011). Environmental Impact of Quarrying on Otere village, Odeda, Southwestern Nigeria.Ozean Journal of Applied Sciences 4(1), 75-82.

Organiscak J.A. and W.R. Reed, (2004) Characteristics of fugitive dust generated from unpaved mine haulage roads, Int. J. Surf. Min. Reclam. Environ. 18(4) (2004), pp. 236–252. Pollution 126, 171–191.

Ozcan O, Musaoglu N, Seker DZ (2012) Environmental impact analysis of quarrying activities established on and near a river bed by using remotely sensed data. Fresenius Environ Bull 21(11):3147–3153.

Ozcelik, M(2016) Environmental pollution and its effect on water sources from marble quarries in western turkey. Environmental Earth Sciences 75(796).

Paatero, P., (2005) “Estimating time series of aerosol particle number concentrations in the five HEAPSS cities on the basis of measured air pollution and meteorological variables”, <i>Atmospheric Environment</i>, vol. 39, no. 12, pp. 2261–2273, 2005. doi:10.1016/j.atmosenv.2004.12.036.

Pal S, Mandal I (2017) Impacts of stone mining and crushing on stream characters and vegetation health of dwarka river basin of Jharkhand and West Bengal, Eastern India. J Environ Geogr 10(1–2):11–21. https://doi.org/10.1515/jengeo-2017-0002.

Pamei, M., Naresh, G., Dutta, D. et al. (2020) Accessibility of safe drinking water in greater Dimapur area of Nagaland and related health hazards: an analytical study. Int J Energy Water Res **4**, 245–255 (2020). https://doi.org/10.1007/s42108-020-00074-5.

Pandey, Arvind & Shekhar, Shashank & Nathawat, Mahendra. (2012). Evaluation of Fluoride Contamination in Groundwater Sources in Palamu District, Jharkhand, India. Journal of Applied Sciences. 12. 882-887. 10.3923/jas.2012.882.887s.

Pandey, B., Agrawal, M., & Singh, S. (2014). Coal mining activities change plant community structure due to air pollution and soil degradation. *Ecotoxicology*, *23*, 1474-1483.

Papantonopoulos, G., Taxiarchou, M., (2005). A study on best available techniques for the management of stone wastes. Indica 1–6.

Paramesha D, Naik Ushamalini, Somashekar R. K. (2007) Noise Pollution in Stone Quarrying Industry – A Case Study in Bangalore District, Karnataka. Indian Journal of Industrial Pollution Control. 2007; 23(1):43-48.

Pathak, R.K., Tomar, C., Neelumalviya, M.S., (2015). Phytomonitoring of atmospheric pollution in road side perennial trees of Indore city (M.P.) India. IJAET 7 (6), 1727–1734.

Pathak, V., Tripathi, B.D., Mishra, V.K., (2011). Evaluation of Anticipated Performance Index of some tree species for green belt development to mitigate traffic generated noise. Urban For. Urban Gree. 10 (1), 61–66. https://doi.org/10.1016/j.ufug.2010. 06.008.

Patolia, P., & Sinha, A. (2017). Fluoride contamination in Gharbar Village of Dhanbad District, Jharkhand, India: source identification and management. *Arabian Journal of Geosciences*, *10*, 1-10.

Patton, A.P., Perkins, J., Zamore, W., Levy, J.I., Brugge, D., Durant, J.L., (2014). Spatial and temporal differences in traffic-related air pollution in three urban neighborhoods near an interstate highway. Atmos. Environ. 99, 309–321. https://doi.org/10.1016/j. atmosenv.2014.09.072.

Peng, X., Lu, G., (1995). Physical modelling of natural wind and its guide in a large open pit. Journal of Wind Engineering and Industrial Aerodynamics 54/55, 473–481.

Prajapati, S.K., and Tripathi, B.D. (2008). Anticipated performance Index of some tree species considered for green belt development in and around an urban area: a case study of Varanasi city, Indian Journal of Environmental Management, 88:1343-1349.

Prasad B, Bose JM (2001) Evaluation of heavy metal pollution index for surface and spring water near a limestone mining area of the lower Himalayas. Envi Geol 41:183–188.

Podgorski JE, Labhasetwar P, Saha D, Berg M. (2018) Prediction Modeling and Mapping of Groundwater Fluoride Contamination throughout India. Environ Sci Technol. 2018 Sep 4;52(17):9889-9898. doi: 10.1021/acs.est.8b01679. Epub 2018 Aug 14. PMID: 30052029.

Podgomy P, McLaren L (2015) Public perception and scientific evidence for perceived harms/risks of community water fluoridation: an examination of online comments pertaining to fluoridation cessation in Calgary in 2011. *Can. J. of Public Health.* 19: 106(6): e413-25. doi: 10.17269/cjph.106.5031.

Pumure, I., Renton, J. J., & Smart, R. B. (2010). Ultrasonic extraction of arsenic and selenium from rocks associated with mountaintop removal/valley fills coal mining: Estimation of bioaccessible concentrations. Chemosphere, 78, 1295–1300.

Qiu H, Yu ITS, Wang X, Tian L, Tse LA, Wong TW.(2013) Season and humidity dependence of the effects of air pollution on COPD hospitalizations in Hong Kong. Atmosph Environ. 2013;76: 74-80.

Rai, P.K. (2013). Environmental magnetic studies of particulates with special reference to bio magnetic monitoring using roadside plant leaves. Atmospheric Environment, 72:113-129.

Rai, P.K., Panda, L.L.S., (2014). Dust capturing potential and air pollution tolerance index (APTI) of some road side tree vegetation in Aizawl, Mizoram, India: an Indo-Burma hot spot region. Air Qual. Atmos. Health 7 (1), 93–101. https://doi.org/10.1007/ s11869-013-0217-8.

Raja, V., Neelakantan, M.A. (2021) Evaluation of groundwater quality with health risk assessment of fluoride and nitrate in Virudhunagar district, Tamil Nadu, India. Arab J Geosci **14**, 52 (2021). https://doi.org/10.1007/s12517-020-06385-5.

Ramana T.V. (2011) Management of stone crushing industry and its impact on Employees and environment "a case study". International journal of Research in Commerce, Economics and Management. 2011; 1 (3):154-157.

Rana S, Ganguly R, Gupta AK (2018) Indexingmethod for assessment of pollution of leachate from non-engineered landfill sites and its effect on groundwater quality. Environmental Monitoring and Assessment 190(46). https://doi.org/10.1007/s/0661-017-6147.

Rankama, K. and Sahama, Th.G. (1950) Geochemistry. University of Chicago Press, Chicago, 912 p.

Rapant, Stanislav & Cvečková, Veronika & Krčmová, Katarina & Sedláková, Darina & Stehlikova, Beata. (2017). Impact of Calcium and Magnesium in Groundwater and Drinking Water on the Health of Inhabitants of the Slovak Republic. International Journal of Environmental Research and Public Health. 14. 278. 10.3390/ijerph14030278.

Rawat NS. (1982) A study of physicochemical characteristics of respirable dust in an Indian coal mine. Sci Total Environ. 1982 Apr;23:47-54. doi: 10.1016/0048-9697(82)90120-6. PMID: 7100908.

Rawat, J.S., Banerjee, S.P. (1996). Urban forestry for improvement of environment. Journal of Energy Environment Monitoring, 12 (2): 109–116.

Reddy, G.S., Ruj, B., (2003). Ambient air quality status in Raniganj–Asansolarea, India. Environmental Monitoring and Assessment 189, 153–163.

Regmi, G., Indraratna, B., Nghiem, L.D., (2009). Long-term performance of a permeable reactive barrier in acid sulphate soil terrain. Water, Air, & Soil Pollut. Focus 9 (5e6), 409e419.

Reche, C., Querol, X., Alastuey, A., Viana, M., Pey, J., Moreno, T., ... & Quincey, P. (2011). New considerations for PM, Black Carbon and particle number concentration for air quality monitoring across different European cities. *Atmospheric Chemistry and Physics*, *11*(13), 6207-6227.

Richter P, Pecharova E (2013) Effects of mining activities on river water quality. Pol J Environ Stud 22:1269–1276.

Rodell M, Velicogna I, Famiglietti JS (2009) Satellite-based estimatesof groundwater depletion in India. Nature 460(7258):999–1002.

Rodrıguez, S., Van Dingenen, R., Putaud, J.P., Dell'Acqua, A., Pey, J., Querol, X., Gemelli, V., (2007). A study on the relationship between mass concentrations, chemistry and number size distribution of urban fine aerosols in Milan, Barcelona and London. Atmos. Chem. Phys. 7 (9), 2217–2232.

Roperto, F., Troncone, A. & Galati, P. (1995).Extra-pulmonary silicosis in two water buffaloes.Journal of Comparative Pathology, Volume 112 (1), 97-1-3.

Roșca O. M., Dippong T, Monica M, Mihali M., Mihalescu L., Hoaghia M.-A., et al. (2020) Impact of anthropogenic activities on water quality parameters of glacial lakes from Rodnei mountains, Romania. Environmental Research, 2020, 182, 109136, doi: 10.1016/j.envres.2020.109136 [PubMed] [CrossRef] [Google Scholar]

Rose AW, Cravotta A (1998) Geochemistry of coalmine drainage. Coalmine drainage prediction and pollution prevention In T. roofs using the UFORE model. Urban Ecosystem, 11: 409–422.

Rosner, D. & Markowitz, G. (2006).Deadly Dust: Silicosis and the on-going struggle to protect workers' health. University of Michigan Press, 2006 2ndEdition.

Saha DC, Padhy PK (2011) Effect of stone crushing industry on Shorea robusta and Madhuca indica foliage in Lalpahari forest. Atmos Pollut Res 2:463–476.

Sahoo, S. S., Umlong, J. M., Bharti, S. K., Naik, J. K., & Pal, T. (2022). Petrogenesis and geochemistry of fayalite and fluorite-bearing granite from the Assam Meghalaya Gneissic Complex, West Khasi Hills, Meghalaya, India: their implication towards Rodinia Supercontinent amalgamation. Current Science (00113891), 122(10).

Sahu S, Gogoi U, N.C. Nayak,(2021) "Groundwater solute chemistry, hydrogeochemical processes and fluoride contamination in phreatic aquifer of Odisha, India", Geoscience Frontiers, Volume 12, Issue 3, 2021, 101093, ISSN 1674-9871, https://doi.org/10.1016/j.gsf.2020.10.001.

Sahu, P., Kisku, G.C., Singh, P.K. et al. (2018) Multivariate statistical interpretation on seasonal variations of fluoride-contaminated groundwater quality of Lalganj Tehsil, Raebareli District (UP), India. Environ Earth Sci **77**, 484. https://doi.org/10.1007/s12665-018-7658-1.

Salifu M, Yidana SM, Osae S, Armah YS (2013) The influence of the unsaturated zone on the high fluoride contents in groundwater in the Middle Voltaian Aquifers—the Gushegu District, Northern Region of Ghana. J Hydrogeol Hydrol Eng 2:2.

Sami K (1992) recharge mechanisms and geochemical processes in semi-arid sedimentary basin, Eastern Cape, South Africa. J Hydrol 139:27–48.

Sarkar, F. (2022) Assessment of Environmental Impacts of Different Mine Unit Operations on Mine Workers and the Workplaces: A Field-Based Investigation. J. Inst. Eng. India Ser. D (2022). https://doi.org/10.1007/s40033-022-00432-z.

Sarupria, M., Manjare, S.D. & Girap, M. (2019) Environmental impact assessment studies for mining area in Goa, India, using the new approach. Environ Monit Assess **191**, 18 (2019). https://doi.org/10.1007/s10661-018-7135-z.

Saviour M N, (2012). Environmental Impacts of Soil and Mining: A Review. International Journal of Science, Environment and Technology, Vol.1, No. 3, 125-134.

Sedam, A.C., Eberts, S.M., and Bair, E.S., (1988), Ground-water levels, water quality, and potential effects of toxic-substance spills or cessation of quarry dewatering near a municipal ground-water supply, southern Franklin County, Ohio: U.S. Geological Survey Water-Resources Investigations report 88-4138, 93 p.

Segura-Salazar, J., Tavares, L.M., (2018). Sustainability in the minerals industry: Seeking a consensus on its meaning. Sustainability (Switzerland) 10. https://doi.org/10.3390/ su10051429.

Selvam S, Jesuraja K, Venkatramanan S, Chung SY, Roy PD, Muthukumar P, Kumar M, (2020) “Imprints of pandemic lockdown on subsurface water quality in the coastal industrial city of Tuticorin, South India: A revival perspective”, Science of The Total Environment, Volume 738, 2020, 139848, ISSN 0048-9697 ,https://doi.org/ 10.1016/j.scitotenv. 2020.13984.

Smedley, P. L., W. M. Edmunds, and K. B. Pelig-Ba. (1996) "Mobility of arsenic in groundwater in the Obuasi gold-mining area of Ghana: some implications for human health." *Geological Society, London, Special Publications* 113.1 :163-181

Senthilkumar, M., Mohapatra, B., Gnanasundar, D. et al. (2021) Identifying fluoride endemic areas and exposure pathways for assessment of non-carcinogenic human health risk associated with groundwater fluoride for Gujarat state, India. Environ Sci Pollut Res **28**, 50188–50203 (2021). https://doi.org/10.1007/s11356-021-14156-2.

Shaban, A., El-Baz, F., & Khawlie, M., (2007). The relation between water-wells productivity and lineaments morphometry: selected zones from Lebanon. Hydrology Research, 38(2), 187–201.

Shaji, E., Gómez-Alday, J., Hussein, S. et al. (2018) Salinization and Deterioration of Groundwater Quality by Nitrate and Fluoride in the Chittur Block, Palakkad, Kerala. J Geol Soc India **92**, 337–345 (2018). https://doi.org/10.1007/s12594-018-1017-4.

Shannigrahi, A.S., and Agrawal, K.M. (1996). An overview on optimal greenbelt development for industrial project. Indian Journal of Environmental Protection, 17 (4): 253–261.

Shannigrahi, A.S., Fukushima, T., and Sharma, R.C. (2004). Anticipated air pollution tolerance of some plant species considered for green belt development in and around an industrial/urban area in India: an overview, International Journal of Environmental Studies, 61 (2): 125–137.

Sharma, Piyush & Singh, Mitasha & Dinesh, Kumar & Grover, Ashoo & Bhardwaj, Ashok. (2017). Effect of fluoride exposure through drinking water on the oral health status and intelligence profile of school children of district Una, Himachal Pradesh: an interim analysis. jemds. 5. 10.14260/jemds/2016/1694.

Sheoran V, Sheoran A, Poonia P (2010) Soil reclamation of abandoned mine land by revegetation: a review. Int J Soil Sediment Water 3(2):13.

Shi, Y., Feng, X., Wei, F., Jiang, W., (2000). Three-dimensional non-hydrostatic numerical simulation for the PBL of an open-pit mine. Boundary-Layer Meteorology 94, 197–224.

Shrestha RK, Lal R (2008) Land use impacts on physical properties of 28 years old reclaimed mine soils in Ohio. Plant Soil 306(1):249–260. https ://doi.org/10.1007/s1110 4-008-9578-4.

Shrestha, R.K., Lal, R., (2011). Changes in physical and chemical properties of soil after surface mining and reclamation. Geoderma 161, 168–176. https://doi.org/10.1016/ j.geoderma.2010.12.015.

Sills, E., Pattnayak, K. S., Saha, S., Yang, C. J., Sahu, P. and Singha, A. (2006) Mine over matter? Health, wealth and forests in a mining area of Orissa. Government of Orissa,. Action Planning Workshop on Growth and Environment in Orissa, Bhubaneswar.India.

Silvester S.A., I.S. Lowndes, and D.M. Hargreaves, (2009), A computational study of particulate emissions from an open pit quarry under neutral atmospheric conditions, Atmos. Environ. 43 pp. 6415–6424.

Simon, E., Braun, M., Vidic, A., Bogyó, D., Fábián, I., Tóthmérész, B., (2011). Air pollution assessment based on elemental concentration of leaves tissue and foliage dust along an urbanization gradient in Vienna. Environ. Pollut. 159 (5), 1229–1233. https://doi. org/10.1016/j.envpol.2011.01.034.

Simon, E., Harangi, S., Baranyai, E., Fábián, I., Tóthmérész, B., (2016). Influence of past industry and urbanization on elemental concentrations in deposited dust and tree leaves. Urban For. Urban Gree. 20, 12–19. https://doi.org/10.1016/j.ufug.2016.07. 017.

Singh AK, Mahato MK, Neogi B, Tewary BK, Sinha A (2012) Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India. Environ Earth Sci 65:49–65.

Singh, S. K., Rao, D. N., Agrawal, M., Pandey, J., & Naryan, D. (1991). Air pollution tolerance index of plants. *Journal of Environmental Management*, *32*(1), 45-55.

Singh, A.N., Srinivas, M. And Naik, B.N. (2015). Forecasting the impact of surface mining on surrounding cloud computing. Journal of Computer Sciences and Applications.

Singh, G., Rishi, M.S., Herojeet, R. et al. (2020) Evaluation of groundwater quality and human health risks from fluoride and nitrate in semi-arid region of northern India. Environ Geochem Health **42**, 1833–1862 (2020). https://doi.org/10.1007/s10653-019-00449-6.

Singh, K.P., Malik, A. & Sinha, S. Persistent (2007) Organochlorine Pesticide Residues in Soil and Surface Water of Northern Indo-Gangetic Alluvial Plains. Environ Monit Assess **125**, 147–155 (2007). https://doi.org/10.1007/s10661-006-9247-0.

Singh, R.S., Tripathi, N. and Pal, D. (2012). Indian mining induced human-wildlife conflict and mitigation measures. International Conference "Biodiversity Asia", 7-10 August, 2012, IISC, Bangalore, India.

Singh, U. K., Ramanathan, A. L., & Subramanian, V. (2018). Groundwater chemistry and human health risk assessment in the mining region of East Singhbhum, Jharkhand, India. *Chemosphere*, *204*, 501-513.

Singhal, A., Goel, S., (2020). Impact of sandstone quarrying on the health of quarry workers and local residents in Keru , Jodhpur , India. In: Sengupta, D., Dubey, B.K., Goel, S. (Eds.), Treatment and Disposal of Solid and Hazardous Wastes. Springer International Publishing, pp. 103–126.

Singhal, N., Singhal, S., Sharma, M., Singh J Agarwal, S., & Arora, S. (2018). Environmental implications of rice and wheat stubble burning in north-western states of India. In *Advances in Health and Environment Safety: Select Proceedings of HSFEA 2016* (pp. 47-55). Springer Singapore.

Sinha RK, Pandey DK, Sinha AK (2000) Mining and the environment: a case study from Bijolia quarrying site in Rajasthan. India. Environ 20(3):195– 203. https ://doi.org/1 0.1023/A:10067 95529 201.

Sinha, S., Banerjee, S.P., (1994). A method for estimating fugitive particulate emission from haul roads in opencast coal mines and mitigative measures. In: Banerjee, S.P., (Ed.), Proceedings of Second National Seminar on Minerals and Ecology, Oxford and IBH, Dhanbad, India, pp. 217–227.

Sinha, S., Banerjee, S.P., (1997). Characterisation of haul road in Indian open cast iron ore mine. Atmospheric Environment 31, 2809–2814.

Sivacoumar, R., Jayabalou, R., Swarnalathan, S. & Balakrishnan, (2006).Particulatematter from stone crushing industry.Size distribution and health effects.JournalofEnvironmental Engineering.132(3), 405-414.

Sivrikaya, O., Kiyildi, K.R., Karaca, Z., (2014). Recycling waste from natural stone processing plants to stabilise clayey soil. Environ. Earth Sci. 71, 4397–4407. https:// doi.org/10.1007/s12665-013-2833-x.

Sobolewski, A.: (1998), J. of Mining Environmental Management, July, pp. 21.

Soni, D.K., Agarwal, A., (1997). Characterisation of dust emission in coal mining activities—case study. Indian Journal of Environmental Protection 17, 80–814.

Soutar, C.A., Robertson, A., Miller, B.G.&Searle, A. (2000).Epidemiological evidence on the carcinogenicity of silica: factors in scientific judgment**.**Annals of Epidemiology 2000; 44: 3-14.

Souza, A.J., Pinheiro, B.C.A., Holanda, J.N.F., (2010). Recycling of gneiss rock waste in the manufacture of vitrified floor tiles. J. Environ. Manag. 91, 685–689. https://doi.org/ 10.1016/j.jenvman.2009.09.032.

Spigner, B.C., (1978), Land surface collapse and ground-water problems in the Jamestown area, Berkley County, South Carolina: South Carolina Water Resources Commission Open-File Report 78-1, 99 p.

Steen land, K. & Greenland, S. (2000).Monte Carlo sensitivity analysis and Bayesian analysis of smoking as an unmeasured confounder in a study of silica and lung cancer. American Journal of Epidemiology 2004; 160: pp 384-392.

Steen land, K. (2001). One agent many diseases: Exposure-response data and comparative risks of different outcomes following silica exposure. American Journal of Industrial Medicine, 48(1) 16-23.

Steffen, O. (1997): Planning of open pit mines on a risk basis. Journal-South African Institute of Mining And Metallurgy, 97, 47-56.

Subba Rao, N., Marghade, D., Dinakar, A., Chandana, I.,Sunitha, B., Ravindra, B., & Balaji, T. (2017). Geochemical characteristics and controlling factors of chemical composition of groundwater in a part of Guntur district, Andhra Pradesh, India. *Environmental earth sciences*, *76*, 1-22.

Su F, Wu J, He S (2019) Set pair analysis-Markov chain model for groundwater quality assessment and prediction: a case study of Xi’an City, China. Hum Ecol Risk Assess 25(1–2):158–175. https ://doi.org/10.1080/10807 039.2019.15688 60.

Subramani T, Elango L, Damodarasamy SR (2005) Groundwater quality and its suitability for drinking and agricultural use Chithar River Basin, Tamil Nadu, India. Environ Geol 47:1099–1110.

Subramanian V (1987) Environmental geochemistry of Indian River basins-a review. J Geol Soc Ind 29:205–220.

Sulistijorini, Mas'ud, Z.A., Nasrullah, N., Bey, A., Tjitrosemito, S., (2008). Tolerance levels of roadside trees to air pollutants based on relative growth rate and air pollution tolerance index. HAYATI J. Biosci. 15 (3), 123–129. https://doi.org/10.4308/hjb.15. 3.123.

Sumi, L. and Thomsen, S. (2001) Mining in Remote Areas, Issues and Impacts. MinindWatch Canada/ Mines Alerte.

Susheela & Kumar, A & Bhatnagar, M & Bahudur, Rashmi. (1993). Prevalence of endemic fluorosis with gastro-intestinal manifestations in people living in some North-Indian villages. Fluoride - Quarterly Reports. 26. 10.13141/RG.2.2.26997.17122.

T.E. Gill, T.M. Zobeck, J.E. Stout, J.M. Gregory, (1999) Fugitive dust generation in the laboratory, in: Wind Erosion: An International Symposium, US Department of Agriculture’s Wind Erosion Research, USA, 1999.

Tanee, F.B.G., Albert, E., (2013). Air pollution tolerance indices of plants growing around Umuebulu Gas Flare Station in Rivers State, Nigeria. Afr. J. Environ. Sci. Technol. 7 (1), 1–8. https://doi.org/10.5897/AJEST12.075.

Tartakovsky D., D.M. Broday, and E. Stern, (2013) Evaluation of AERMOD and CALPUFF for predicting ambient concentrations of total suspended particulate matter (TSP) emissions from a quarry in complex terrain, Environ. Pollut. 179 (2013), pp. 138–145.

Thapa R, Gupta S, Kaur H, Baski R,(2019)“Assessment of groundwater quality scenario in respect of fluoride and nitrate contamination in and around Gharbar village, Jharkhand, India”,HydroResearch, Volume 2, 2019, Pages 60-68, ISSN 2589-7578, https://doi.org/10.1016/j.hydres.2019.09.002.

The Sustainable Development Working Group (SDWG) (2011) of the Arctic Council. Circumpolar Information Guide on Mining for Indigenous Peoples and Northern Communities. 2011.

Tian R, Wu J (2019) Groundwater quality appraisal by improved set pair analysis with game theory weightage and health risk estimation of contaminants for Xuecha drinking water source in a loess area in northwest China. Hum Ecol Risk Assess 25(1–2):176–190. https ://doi.org/10.1080/10807 039.2019.15730 35.

Tian, Y.Z., Shi, G.L., Han, B., Wu, J.H., Zhou, X.Y., Zhou, L.D., et al., (2015). Using an improved Source Directional Apportionmentmethod to quantify the PM2.5 source contributions from various directions in a megacity in China. Chemosphere 119, 750–756.

Tiwary, R. K. and Dhar, B. B.: (1994), International J. of Surface Mining, Reclamation and Environment **8**, 111.

Tiwary, R. K., Dhar, B. B. and Jamal, A.: (1997), 'Acid Mine Drainage Occurrences and Its Control in Indian Coal Mines', in Dhar and Bhaumik (eds.), Proceedings of the 27th International Conference of Safety in Mines Research Institute, New Delhi, India, February 1997, pp. 1253–1259.

Tiwary, R.K., (2001) "Environmental Impact of Coal Mining on Water Regime and its Management." Water, Air and Soil Pollution, 132 (1-2), 2001, pp 185-199. Transactions of Environmental Development, 4: 24-32.

Toraño, J., Torno, S., Diego, I., Menendez, M., & Gent, M. (2009). Dust emission calculations in open storage piles protected by means of barriers, CFD and experimental tests. *Environmental Fluid Mechanics*, *9*, 493-507.

Triantafyllou, A.G., Kassomenos, P.A., (2002). Aspects of atmospheric flow and dispersion of air pollutants in a mountainous basin. The Science of the Total Environment 297, 85–103.

Tripathi, N. Singh, R.S. and Nathanail, C.P. (2014). Mine spoil acts as a sink of Carbon dioxide in Indian Dry Tropical Environment. Science of the Total Environment, Elsevier, 468-469, 1162-1171.

Tripathi, N., Singh, R.S. and Hills, C.D. (2016). Reclamation of Mine-impacted Land for Ecosystem Recovery. Wiley Blackwell publishers, UK, ISBN: 9781119057901.

Tuch, T.M., Brand, P., Wichmann, H.E., Heyder, J., (1997). Variation of particle number and mass concentration in various size ranges of ambient aerosols in Eastern Germany. Atmos. Environ. 31 (24), 4193–4197. https://doi.org/10.1016/S1352-2310(97)00260-4.

Tugrul Tunc, E., (2019) Recycling of marble waste: a review based on strength of concrete containing marble waste. J. Environ. Manag. 231, 86–97. https://doi.org/10.1016/j. jenvman.2018.10.034.

Tugrul Tunc, E., Esat Alyamac, K., (2019) A preliminary estimation method of Los Angeles abrasion value of concrete aggregates. Construct. Build. Mater. 222, 437–446. https://doi.org/10.1016/j.conbuildmat.2019.06.176.

Ugbogu, O.C., Ohakwe, J. &Foltescu, V. (2009). Occurrence of respiratory and skin problems among manual stone-quarrying workers.African Journal of Respiratory Medicine, March, 2009 pp 23-26.

Ulm,K.,Waschulzik, B., Ehnes, H., Guldner, K., Thomasson, B., Schwebig, A. & Nub, H. (1998). Silica dust and lung cancer in the German stone quarrying and ceramic industries: results of a case-control study. International Journal of Respiratory Medicine, 54(4), April 1999.

UNEP (1997) Industry and environment, mining and sustainable development; 1997. Available:http://www.uneptie.org/vol20no4. html.

UNEP (2002). EIA Training Resource Manual. Topic 13 Social Impact Assessment.

United Nations, (2015). Population 2030, demographic challenges and opportunities for sustainable development planning. NewYork: Department of Economic and Social Affairs.

United States Environmental Protection Agency. (2018) Edition of the Drinking Water Standards and Health Advisories Tables (EPA 822-F-18-001). US EPA, Washington D.C., USA, 2018; pp. 9–19. [Google Scholar]

USEPA (1973). Compilation of Air Pollutant Immission Factors, 2nd edn. Research Triangle Park, NC: Office of Air Quality Planning and Standards.

USEPA, AP42, Fifth Edition, (2004) Volume I Chapter 11: Mineral Products Industry. 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing, Mineral Products Industry, 8/04, 2004 ,pp.5-7. (October2015) .http:// www.epa.gov/ttn/ chief/ap42 / ch11 /final / c11s1902 pdf .

USGS (2019), Mineral commodity services https://doi.org/10. 3133/70202434

Vailshery, L.S., Jaganmohan, M., and Nagendra H. (2013). Effect of street trees on microclimate and air pollution in a tropical city. Urban Forestry & Urban Greening, 12: 408-415.

Velis M, Conti KI, Biermann F (2017) Groundwater and human development: synergies and trade-offs within the context of the sustainable development goals. Sustain Sci 12(6):1007–1017. https ://doi. org/10.1007/s1162 5-017-0490-9

Vida, S., Pintos, J., Parent, M.E., Lavoue, J.& Siemiatycki, J. (2001). Occupational exposure to silica and lung cancer: Pooled Analysis of Two-Case Control Studies in Montreal, Canada: Cancer Epidemiology Biomarkers Preview; Volume 19 Issue 6; pp1602-1611© 2010 AACR.

Viswanathan, G.R., 1935, Annual Report Madras. Indian Council of AgriculturalResearch, New Delhi. (Quoted from Indian Institute of Science, 33A, 1, 1951).

Vijay Kumar V, Swathy S, Radhika R, Fasi Khan M.A and Chakradhar B (2019) " Green Belt Requirement for New and Expansion Projects for Obtaining Environmental Clearance in India" International Journal of Applied Environmental Sciences ISSN 0973-6077 Volume 14, Number 5 (2019), pp. 475-487.

Wang, L., Ji, B., Hu, Y., Liu, R., & Sun, W. (2017). A review on in situ phytoremediation of tailings. *Chemosphere*, *184*, 594-600. https://doi.org/10.1016/j.chemosphere.2017.06.025

Wang, F., Ketzel, M., Ellermann, T., Wahlin, P., Jensen, S.S., Fang, D., Massling, A., (2010). Particle number, particle mass and NOx emission factors at a highway and an urban street in Copenhagen. Atmos. Chem. Phys. 10, 2745–2764.

Wang, L., Zhang, J. L. & Liu, L.M. (2010). Diversification of Rural Livelihood Strategies and its Effect on Local Landscape Restoration in the Semiarid Hilly Area of the Loess Plateau, China. [Online] Available at: www.wileyonlinelibrary.com (September 28, 2012).

Wang, Q., Shi, J., Chen, G. and Xue, L. (2002). Environ-mental effects induced by human activities in arid Shiyang river basin, Gansu province, northwest China. Environmental Geology 43 (1-2), 219-227.

Wang, Y., Hopke, P.K., Chalupa, D.C., Utell, M.J., (2011). Long-term study of urban ultrafine particles and other pollutants. Atmos. Environ. 45 (40), 7672–7680. https:// doi.org/10.1016/j.atmosenv.2010.08.022.

Wang, X., Gao, H.O., (2011). Exposure to fine particle mass and number concentrations in urban transportation environments of New York City. Transp. Res. Part D: Transp.Environ. 16 (5), 384–391. https://doi.org/10.1016/j.trd.2011.03.001.

Wantzen, K. M., & Mol, J. H. (2013). Soil erosion from agriculture and mining: a threat to tropical stream ecosystems. *Agriculture*, *3*(4), 660-683.

Wei Z., Simin L., Fengbing T. (2013) Characterization of Urban Runoff Pollution between Dissolved and Particulate Phases. The Scientific World Journal 2013, 2013, 1–6. doi: 10.1155/2013/964737 [PMC free article] [PubMed] [CrossRef] [Google Scholar].

Wheater CP, Cullen WR (1997) The flora and invertebrate fauna of abandoned limestone quarries in Derbyshire, United Kingdom. Restorat Ecol 5(1):77–84. https ://doi.org/10.1046 /j.1526-100X.1997.09708 .x.

Wheeler, A.J., Williams, I., Beaumont, R.A., Manilton, R.S., (2000). Characterisation of particulatematter sampled during a study of children’s personal exposure to air borne particulate matter in a UK urban environment. Environmental Monitoring and Assessment 65, 69–77.

WHO (1970) - World Health Organization. Guidelines for drinking water quality, World Health Organization,.

WHO (2004) - World Health Organization. Guidelines for drinking water quality, World Health Organization, Third Edition, Vol. 1, Geneva.

WHO, (2006). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: global update 2005: summary of risk assessment. World Health Organization (WHO) https://apps.who.int/iris/handle/10665/69477.

William H. Langer, (2001). Potential Environmental Impacts of Quarrying Stone in Karst— A Literature Review.

Wilson, W.E., and H.H. Suh, (1997). Fine and coarse particles: concentration relationships relevant to epidemiologic studies. Journal of the Air&WasteManagementAssociation47, 1238-1249.

Wolf, K., Cyrys, J., Harcinikova, T., Gu, J., Kusch, T., Hampel, R., Peters, A., (2017). Land use regression modeling of ultrafine particles, ozone, nitrogen oxides and markers of particulate matter pollution in Augsburg, Germany. Sci. Total Environ. 579, 1531–1540. https://doi.org/10.1016/j.scitotenv.2016.11.160.

World Bank (2001). Attacking Poverty: World Development Report, 2000, World Bank, Washington D.C.

World Bank. (2017). Annual report. www. Worldbank.org/annual report.

World Health Organization. Guidelines for Drinking-Water Quality: (2017) Fourth Edition Incorporating the First Addendum. WHO, Geneva, Switzerland, 2017; pp. 7, 219–230, 423. [Google Scholar]

Worldwide Environmental Law Alliance. (2010) Guidebook for evaluating mining project EIAs. Eugene: Environmental Law Alliance Worldwide; 2010.

Wu Q, Xing LT, He Ye C, Liu YZ (2011) The influences of coal mining on the large karst springs in North China. Environ Earth Sci 64:1513–1523.

Xue, Y.G., Teng, D.B., Li, S.C. and Su, M.X. (2010). "Studyon Environmental-Geological Problem and Ecosystem Re-Establishment Countermeasures about Quarry and DamagedMountain in Peri-Urban, "4th International Conference on Bi-oinformatics and Biomedical Engineering (iCBBE 2010) 4,pp.3717 - 3721, 18-20 June 2010, China.

Yarahmadi, R., Bagherpour, R., and Khademian, A. (2014): Safety risk assessment of Iran's dimension stone quarries (Exploited by diamond wire cutting method). Safety Sci-ence, 63, 146-150.

Yavuz Çelik, M., Sabah, E., (2008). Geological and technical characterisation of Iscehisar (Afyon-Turkey) marble deposits and the impact of marble waste on environmental pollution. J. Environ. Manag. 87, 106–116. https://doi.org/10.1016/j. jenvman.2007.01.004.

Yesilnacar MI, Kadiragagil Z (2013) Effects of acid mine drainage on groundwater quality: a case study from an open-pit copper mine in eastern Turkey. Bull Eng Geol Environ 72:485–493. doi:10. 1007/s10064-013-0512-5.

Younger PL, Wolkersdorfer C (2004) Mining impacts on the fresh water environment: technical and managerial guidelines for catchment scale management. Mine Water Environ 23(Suppl.1):s2–s80.

Younger, P.L. (1997) The longevity of minewater pollution: A basis for decision-making. Sci. Total Environ. **1997**, 194–195, 457–466. [CrossRef].

Zaczek J, Porowski A (2017) Hydrogeological settings and origin of groundwater composition in Southern part of Gorce Mts, Kowniec Maly catchment. Ann Soc Geol Pol 87:183–197.

Zbigniew Bzowski & Andrzej Dawidowski (2002) Evaluating the Impact of Mine Groundwater on the Environment, International Journal of Surface Mining, Reclamation and Environment, 16:2, 97-104, DOI: 10.1076/ijsm.16.2.97.3396.

Zhang Q, Miao L, Wang H, Hou J, Li Y (2020) How rapid urbanization drives deteriorating groundwater quality in a provincial capital of China. Pol J Environ Stud 29(1):441–450. https://doi. org/10.15244 /pjoes /10335 9.

Zhang X, Yang L, Li Y, Li H, Wang W, Ye B. (2012) Impacts of lead/zinc mining and smelting on the environment and human health in China. Environ Monit Assess. 2012;184:2261–73.

Zhang Y, Wu J, Xu B (2018) Human health risk assessment of groundwater nitrogen pollution in Jinghui canal irrigation area of the loess region, northwest China. Environ Earth Sci 77(7):273. https://doi.org/10.1007/s1266 5-018-7456-9.

Zhang, C., W, P., Tang, C., Tao, X., Han, Z., Sun, J., Liw, H., (2013) “The study of soil acidification of paddy field influenced by acid mine drainage.” Environmental Earth Science 70(2), 2013, pp 2931-2940.

Zhen Q, Ma W, Li M, He H, Zhang X, Wang Y (2017) Reprint of “Effects of vegetation and physicochemical properties on solute transport in reclaimed soil at an opencast coal mine site on the Loess Plateau, China”. Catena 148:17–25. https://doi.org/1 0.1016/j.catena.2016.09.012.

Zia-Khan, S., Spreer, W., Pengnian, Y., Zhao, X., Othmanli, H., He, X., Müller, J., (2014). Effect of dust deposition on stomatal conductance and leaf temperature of cotton in northwest China. Water 7, 116–131. https://doi.org/10.3390/w7010116.

Zobrist, J., & Giger, W., (2013). Mining and the environment. Environmental Science and Pollution Research, 20, 7487– 7489. https://doi.org/10.1007/s11356-013-1990-5.

Zhou, G., Zhang, Q., Hu, Y., Gao, D., Wang, S., & Sun, B. (2020). Dust removal effect of negatively-pressured spraying collector for advancing support in fully mechanized coal mining face: Numerical simulation and engineering application. *Tunnelling and Underground Space Technology*, *95*, 103149.

Zyl, H.C. & Maree, J.P. & Niekerk, A.M. & Tonder, G.J. & Naidoo, C. (2001). Collection, treatment and re-use of mine water in the Olifants River Catchment. Journal- South African Institute of Mining and Metallurgy. 101. 41-46.

LIST OF PUBLICATIONS

Ambastha, S.K., Haritash, A.K. Emission of respirable dust from stone quarrying, potential health effects, and its management. *Environ Sci Pollut Res* 29, 6670–6677 (2022). https://doi.org/10.1007/s11356-021-16079-4.

Ambastha, S.K., Haritash, A.K. Prevalence and risk analysis of fluoride in groundwater around sandstone mine in Haryana, India. *Rend. Fis. Acc. Lincei* 32, 577–584 (2021). https://doi.org/10.1007/s12210-021-00997-z.

Ambastha, S., Negi, S., Singh, A., Ghunasham, M., & Haritash, A. K. (2020). Evaluation of Air Pollution Tolerance Index and Anticipated Performance Index of trees in and around the stone quarrying region of Mahendragarh, Haryana. *Indian J Air Pollut Control*, *20*(1-2), 17-27.

Curriculum vitae

Saurav Kumar Ambastha

Mobile - +91-9555941903/9709216606 Email- saurav.ambastha@gmail.com

" *Knowledgeable of principles and theories concerning resource and environmental management and climate change"*

- A seasoned Technically Savvy, Strategy-conscious, and Project-focused Environmental Professional with 9 years of exceptional Technical, Research, Academics, and Administrative abilities in Environmental Engineering and Sustainable Development.
- Working as a consultant at TGIS .
- Working part time EHS Consultant in **NSC Project Pvt.Ltd.** Construction firm which are into the construction of Highways and Airport.
- In the past I was associated with G.D.Goenka University, Gurugram as an Assistant Professor.
- Well-crafted experience of last 5.5 years in Corporate+ Academics , collaboration in Environment and Sustainable solutions.
- Deft in undertaking several Socio-Environmental projects (Environmental Issues) and also involved in Impact Assessment Auditing and suggesting changes in the assessment report to get enhanced sustainable solutions to the problem.
- Keen involvement in research of Air pollution and Ground water Modelling and Simulation.
- Communicator, adept at leading and mentoring a team towards achievement of goals with a documented track record of success in captivating and implementing technology as well as administrative decisions.
- Have done Ariel surveying of many studies and mining areas with GIS Mapping software.(Arc GIS and QGIS)

Core Skills

Mentoring / Training & Development
Waste reduction solution
GIS and Remote Sensing
Air and Water Pollution Monitoring
Energy and Environmental Impact audit
Environmental Laws
Reviewing CSR Report
calculation of Carbon footprints
Methodological and Planned orientation
Sustainable Solution of Environmental Issues.

HIGHLIGHTS & ACCOMPLISHMENTS

- **G D Goenka University**
  - Bagged 'Outstanding Performance Letter' for an Academic session.
  - Evaluation of Multiple Industrial Consultancy Projects related to Environmental impact their Issues, Majorly Quality Analysis of Air and Water.
  - Conducted many event Technical and Non-Technical and raised Fund for them(Sponsorship).
- **TATA Steel**
  - Associated with patent work and formulation of waste utilization(Waste Reduction) with ACC **cements** and **TATA steel.**

Highlights

- Have given talks related to sustainable development , Global warming and Climate change in Industries as well as academics institution.

Career Growth

Present **-**	Working as a Industrial Environmental consultant at **TGIS** from January 2020.
January 2017- Present -	Working as a EHS Consultant in **NSC Projects Pvt. Ltd**. Gurugram, Haryana
August 2014 - January 2020 -	G.D.Goenka University as Assistant Professor In Civil and Environmental Deptt.
September 2013 -August 2014-	Galgotias University as Assistant Professor In Civil and Environmental Deptt.
August 2012 -September 2013-	JSS MahaveedyaPeetha as Assistant Professor In Civil Engg. Deptt.
December 2011- June 2012 -	Acenco Constant and Management as Project Executive.
July 2010- April 2011-	TATA Steel Jamshedpur as Project Trainee

Contribution in work

- **As TGIS consultant**
- Consultancy Project on Ground water, GIS and Air pollution dispersion modelling.
- Training Industrial person and impact assessment of environment of air and water, climate change and GIS application, MODFLOW and HYSPLIT.
- Helping in Environmental Auditing and making them aware of recent amendment in Environmental laws.
- Industrial Consultancy projects and training staff and ensuring performance goals are met and set.
- Developing Industrial labs to help organisation sustain and grow programs and service.
- Study on Impact assessment of Industries.

- **As an Environmental Engineer in N.S.C Project Pvt. Ltd**
- Analysing work towards minimizing the negative effects of human activity on the environment.
- Drafting and studying environmental investigation reports.
- Analyzing and interpreting collected data regarding environmental issues.
- Supervising the overall progress of environmental programs put in place and ensuring they adhere to all applicable regulations.(Health and Safety).
- Review of quarterly and half yearly report to state pollution control board.

- **In G.D.Goenka University (Except than Teaching)**

- Industrial Sample analysis of water and Air Environment and their impact assessment and simulation studies.
- Partially involved in making and reviewing of CSR report for Welspun (A sister subsidiary of Goenka group).
- Creating budgets/ PO and track expenditures and making presentations for meetings.

- **In TATA Steel**
- Worked in legal compliances of TATA Steel and Environmental Laws.
- Waste minimisation Technique and sustainable technology.
- Water quality analysis
- Stack / Air pollution Monitoring.
- Have worked on SAP for record maintenance of Hazardous waste oil.

Trainings/Certification

Brief list of Training on

- Have done Industrial safety training for 2 weeks in TATA Steel (ISO 45001)
- Have done project on "**Effect of pollution on human health and their disorders**" From **CIMFER, Dhanbad, Jharkhand**
- Workshop on Minimisation of Industrial Pollution and Human health.
- Workshop for CSR report Preparations and calculation of carbon footprints

Short Term - Courses

- Have done Certified GIAN Course on "**Water Footprints for Urban Cities**" at Delhi Technological University.
- Have done certified course on courseera.com, (online portal) on " **The age of Sustainable Development**" by The Earth Institute Columbia University.
- Have done certified course on courseera.com, (online portal) on" **Global warming : The science and Modelling of climate change**" by Chicago University.

Research papers

1. Ambastha, S.K., Haritash, A.K. Emission of respirable dust from stone quarrying, potential health effects, and its management. *Environ Sci Pollut Res* (2021). https://doi.org/10.1007/s11356-021-16079-4.

2. Ambastha, S.K., Haritash, A.K. Prevalence and risk analysis of fluoride in groundwater around sandstone mine in Haryana, India. *Rend. Fis. Acc. Lincei* **32,** 577–584 (2021). https://doi.org/10.1007/s12210-021-00997-z.

3. Ambastha S, Negi S, Singh A, Ghunasham M, Haritash AK (2020)Evaluation of Air Pollution Tolerance Index and Anticipated Performance Index of trees in and around the stone quarrying region of Mahendragarh, Haryana. Indian J Air Pollut Control 20(1-2):17– 27.

4. Verma L, Singh P, Ambastha S. Heavy Metal Removal from Domestic Wastewater Employing Live Eichhornia Crassipes. sms [Internet]. 25Jun.2017;9(01):47-0. Available from: http://smsjournals.com/index.php/SAMRIDDHI/article/view/1064.

- **Ph.D** Pursuing on Mining impacts from Environmental Engineering Deptt., Delhi Technological University.
- **M.Tech** (2011) in Environmental Engineering (CGPA 8.55) from Birla Institute of Technology Ranchi.
- **B.Tech** (2009) in Industrial Biotechnology (CGPA 8.44) from Dr. M.G.R University Chennai.

IT SKILLS

Well versed with Windows, MS Office and Internet Applications, GIS Applications MODFLOW , HYSPLIT and SPSS.

Personal Dossier:

Date of Birth: 16th of March 1986
Language Known: English and Hindi