



IMPACT OF STONE QUARRY MINING ON ENVIRONMENT: A CASE OF KHURDA DISTRICT, ODISHA

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Abstract

The improvement from the sector in the form of improved investment are being reached at great environmental, health and social cost to the people recording series of public outcry against the quarrying companies. The numerous impacts produced by these operations are both size and locations dependent. The Khordha region is facing the brunt of extensive stone mining and due to unrestricted mining activities, several hills in the region are now completely broken down and the change in the landscape could also impact the local biodiversity. The main objective of the study is to analyse the landuse/landcover dynamic of the study area due to Stone quarry mining and assessment of air pollution of the study area. The hypothesis of the study are stone crushing dust have negative effect on the community surrounded quarry sites. Firstly, elevation data sourced from the SRTM (Shuttle Radar Topography Mission) and TanDEM-X datasets, Optical satellite imagery, drawn from Landsat, Sentinel, and Google Earth, provides a comprehensive view of the quarry and its surroundings. Moreover, air pollution data from MODIS and Sentinel 5p satellites add another layer to the study. Lastly, the GLAD (Global Land Analysis and Discovery) dataset offers information on land use and land cover (LULC), crucial for understanding the broader environmental impact of the stone quarry.

Key words: LULC, SRTM, Google Earth, MODIS, GLAD

Introduction

To achieve rapid economic development, many countries resort to various activities to exploit natural resources. One of such activities is quarry mining. In the last decade, environmental and health

concerns have expanded prominence throughout the world. Several international protocols have been recognized by the global community to deal with the emerging environmental and health issues. Mining activities have lots of environmental and health impacts. This has originated from the methods of operation by the quarrying companies and its properties spread on the natural environment as well as the people in the quarry located area. The health cost of mining operations sometimes out weights the benefits increased (1, 3). The improvement from the sector in the form of improved investment are being reached at great environmental, health and social cost to the people recording series of public outcry against the quarrying companies. Residents are the major victims of the adverse impacts of quarrying operations. The numerous impacts produced by these operations are both size and locations dependent (6, 7). Many of specific impacts are on the nearest communities in the form of properties on air, earth surface, land degradation, deterioration of ground water, erosion of soil, noise and percussions from rock blasting, generation of dust, smoke and fumes, production of noxious gases and ground vibration. Suspended particulate matter is quite outstanding among all pollutants originating from quarrying operations (4, 5). These environmental impacts will becomes as a major threat to the residents of the quarrying sectors with several health diseases. Stone has been a very popular building material in India for hundreds of years due to its availability in huge quantities and its remarkable quality (2). India produces more than 27% of the total stone produced throughout the world. The dark side of this stone industry is the unjustifiable practices used in quarrying and the huge amounts of waste generated every year. These wastes are dumped unsafely, eventually affecting the local environment and health of the quarry workers and nearby local residents (8, 9). During extraction and processing, around 50-70 % of the extracted stone is wasted in the form of waste slurry and scrap stone. Slurry is basically stone dust mixed with water, which is produced from the wet cutting of stone. Slurry and stone dust have very small sizes which can lead to air pollution due to the presence of particulate matter. Long-term exposure to stone dust leads to silicosis and pneumoconiosis which are associated with breathlessness, chronic bronchitis, recurrent chest illness and heart failure. Other complications include tuberculosis, microbial infections, and chronic silicosis (8, 9).

Apart from land degradation, other negative impacts of quarrying includes swamp formation, deterioration of ground water, erosion

of soil, noise and percussions from rock blasting, generation of dust, smoke and fumes, production of noxious gases and ground vibration. Suspended particulate matter is quite outstanding among all pollutants emanating from quarrying operations. Solid materials in the form of smoke, dust and also vapour generated during quarrying operations are usually suspended over a long period in the air. Moreover, particulate matter in the air are capable of being transported from the point of generation to areas far removed. Once particles of varying chemical compositions are inhaled, they lodge in human lungs, thereby causing lung damages and respiratory problems (10).

Study Area

The National Highway 16 (NH 16) is a major National Highway in India that runs along east coast of West Bengal, Odisha, Andhra Pradesh, and Tamil Nadu. It was previously known as National Highway 5. The northern terminal starts at Dankuni National Highway 19 near Kolkata and the southern terminal is at Chennai, Tamil Nadu. It is a part of the Golden Quadrilateral project to connect India's major cities. NH 16 has a total length of 1,764 km (1,096 mi) and passes through the states of West Bengal, Odisha, Andhra Pradesh and Tamil Nadu. The NH 16 is the major highway in Odisha and the study area is 5 Km.

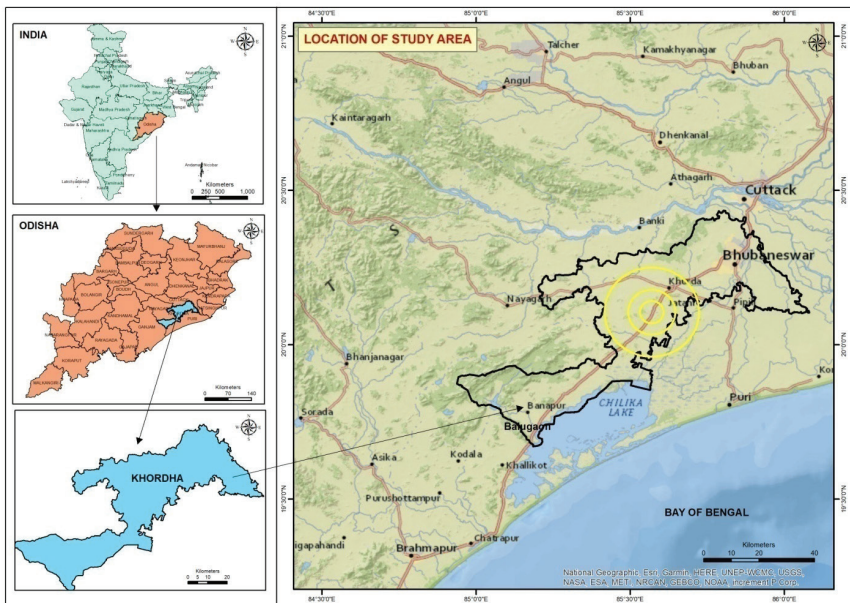


Fig. 1: Location Map of Study Area

buffer of NH 16 from Khordha to Balugaon. The Study area is situated within the $19^{\circ}44'51.37''\text{N}$ to $20^{\circ}11'10.75''\text{N}$ latitude and $85^{\circ}12'23.96''\text{E}$ to $85^{\circ}38'40.37''\text{E}$ longitude. Both Khordha and Balugaon is the major town of the Khordha district but the NH 16 is also crossing some portions of the Nayagarh District. Balugaon is a major economic centre of Khordha district because of its prawn and fish business.

The Khordha region is facing the brunt of extensive stone mining and due to unrestricted mining activities, several hills in the region are now completely broken down and the change in the landscape could also impact the local biodiversity. The area has undergone might have a serious impact on land and water sources, air quality and the health of people living in the nearby area. The degradation of hillocks and mountains due to the stone mining activities are directly linked to reduction of water quality in nearby water bodies and also interferes with the course of natural drainage systems (12, 13).

Objective

The main objectives of the study are:

1. To analyse the landuse/landcover dynamic of the study area due to Stone quarry mining.
2. Assessment of air pollution of the study area.

Material and Method

The study on a stone quarry encompasses various data parameters crucial for understanding the environmental dynamics associated with quarry operations. Firstly, elevation data sourced from the SRTM (Shuttle Radar Topography Mission) and TanDEM-X datasets offer insights into the terrain characteristics, with SRTM data spanning from 2000 and TanDEM-X data from 2015, both at a resolution of 30 meters. Optical satellite imagery, drawn from Landsat, Sentinel, and Google Earth, provides a comprehensive view of the quarry and its surroundings. Landsat imagery, covering the period from 2000 to 2023 at a 30-meter resolution, offers long-term observations, while Sentinel data from 2017 to 2023, at a higher 10-meter resolution, provides detailed recent information. Google Earth's historical imagery supplements these datasets with high-resolution views dating back to 2011(11).

Moreover, air pollution data from MODIS and Sentinel 5p satellites add another layer to the study. MODIS data spanning from 2000 to 2023 and Sentinel 5p data from 2018 to 2023, both at a resolution of 1

kilometer, enable tracking of aerosol concentrations, nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and carbon monoxide (CO) levels, providing insights into air quality dynamics influenced by quarry activities. Lastly, the GLAD (Global Land Analysis and Discovery) dataset offers information on land use and land cover (LULC), crucial for understanding the broader environmental impact of the stone quarry. Available for 2000 and 2020 at a 30-meter resolution, this dataset facilitates the assessment of LULC changes over time, aiding in the comprehensive evaluation of the quarry's environmental footprint and its surrounding areas (14, 15).

Table 1: Showing summary of datasets used in the study

<i>Sl No</i>	<i>Parameter</i>	<i>Dataset</i>	<i>Variable</i>	<i>Period</i>	<i>Resolution</i>
1	Elevation	SRTM	NASADEM 30	2000	30m
		TanDEM-X	GLO-30	2015	30m
2	Optical Satellite	Landsat	Landsat 5, 8, 9	2000-2023	30m
		Sentinel	Sentinel 2b	2017-2023	10m
		Google Earth	Historical	2011-2023	High
3	Air Pollution	MODIS	Aerosol	2000-2023	1km
		Sentinel 5p	Aerosol, NO ₂ , SO ₂ , CO	2018-2023	1km
4	LULC	GLAD	Global LULC-30	2000, 2020	30m

Spatial Change Analysis

Spatial changes from 2000 to 2024 have been analyzed utilizing remote sensing data, including elevation models from SRTM and TanDEM-X datasets. Landsat imagery spanning from 2000 to 2023, along with Sentinel data from 2017 to 2023, has provided detailed information on land cover changes at varying resolutions. Change detection techniques, such as image differencing and classification algorithms, have been employed to identify and quantify spatial alterations within the study area. Google Earth historical satellite data has been utilized to analyze spatial changes due to its high resolution and easy availability.

Land Use/Land Cover Change Assessment

Assessment of land use/land cover changes from 2000 to 2021 has involved analyzing GLAD dataset information. By comparing land cover classifications between 2000 and 2021, shifts in land use patterns, such as conversions between forested areas and quarry zones, have

been identified. This analysis has provided insights into the evolving landscape dynamics influenced by stone quarry activities, aiding in understanding the environmental impact over time.

Air Pollution Evaluation

The assessment of air pollution, including aerosol, NO₂, and SO₂ concentrations, has been conducted using MODIS and Sentinel 5p satellite data from 2000 to 2023 and 2018 to 2023, respectively. By analyzing spatial and temporal variations in pollutant levels around the quarry area, we aimed to understand the air quality dynamics influenced by quarry operations. Statistical analysis and visualization techniques have been employed to interpret the pollution trends and their potential impacts on the surrounding environment. (16, 18)

Integration of Data and Reporting

Integration of spatial, land cover, and air pollution analyses has provided a comprehensive understanding of the environmental dynamics associated with stone quarry activities. Findings have been synthesized into detailed reports, supported by visualizations and statistical summaries. These reports have served to communicate the research outcomes effectively to stakeholders, policymakers, and the scientific community, facilitating informed decision-making regarding quarry management and environmental conservation efforts.

All these analysis are done zone wise, created by buffer analysis from the median centre of stone quarries at distances of 4 km, 8 km, and 16 km. These buffer zones help in studying the spatial impact of quarry activities at varying distances from the source, providing insights into the extent of environmental changes and pollution dispersion.

Result and Discussion

Fig. 2 showing the satellite imagery of the study area of the year 2000, visually the some hillocks have vegetation and some are barren but not identified any quarry activities. The satellite imagery of the study area of the year 2011 visually identified that the stone mining activities have started. The hillocks reflectance has changed green colour to white due to stone and small ponds have generated near the mining area. The satellite imagery of the study area of the year 2024 visually interpreted that the area has been totally changed into stone mining area and the surrounding biodiversity affected due to many crushers are established for processing of the stone. The reflectances of the leaves are also as

same as stone due to layer of dust on the leaves which produces from the crushers. Many small ponds have generated in that area (17).

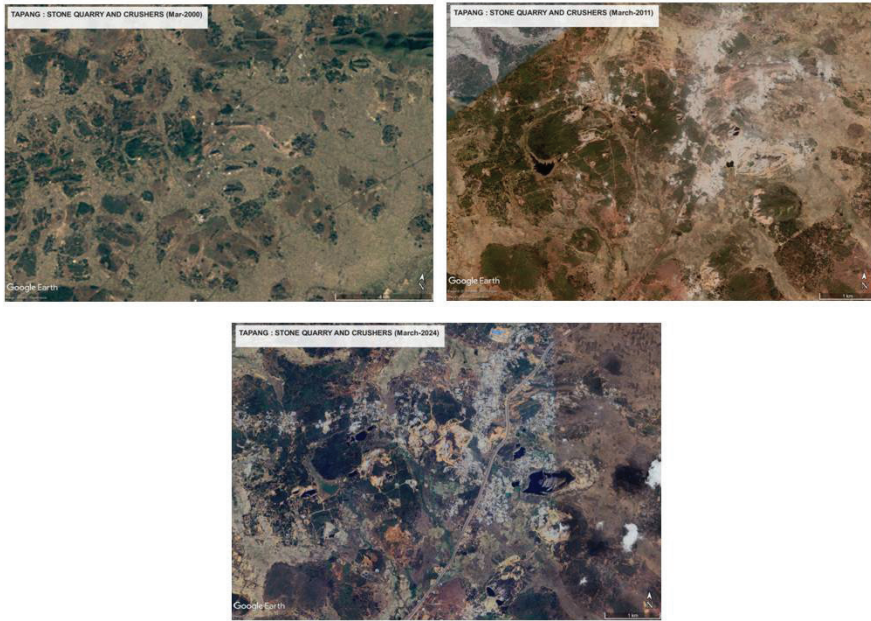


Fig. 2: The Time series satellite imageries of the year 2000, 2011 and 2024

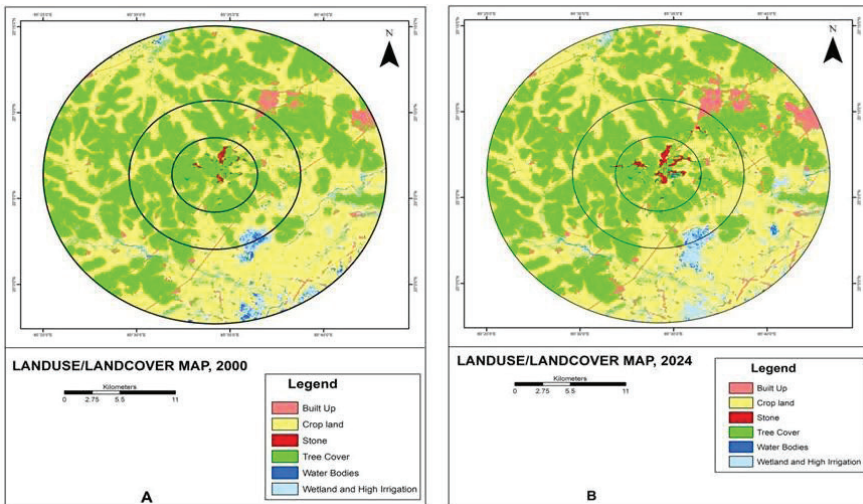


Fig. 3: The Landuse/Landcover Map of the year 2000 (A) and 2024 (B)

The Fig. 3 and Table 2 showing the Landuse/Landcover (LULC) map of the study area which showing the different buffer zone area

statistics which represent the LULC dynamic of the study area during the 24 years. The area table showing the tree clad area is decreasing during the 24 years in all Zone 1, 2 and 3. The wetland and highly irrigated land decreasing during these 24 years in the Zone 1 and 2 but increasing in the Zone 3. The Water bodies are increasing in the Zone 1 and 2 but decreasing in Zone 3 due to stone extraction, the area became water body during the time period. The Crop land also decreasing in the Zone 1, 2 and 3. But the Built up land is increasing in the Zone 1, 2 and 3 Zone. The all stone quarries are existing under the Zone 1 and 2 and during the 24 years are increasing drastically. Overall maximum stone quarries are existing in Zone 1 and the table showing during 24 years the stone quarry area increased approximately double than the previous year. In Zone 3, there is no stone quarry area neither in the year 2000 nor in the year 2024.

The Table 3 shows the LULC statistics of the 16 Km. buffer area and all the categories of LULC type are very dynamic which found from the temporal data. The Crop land is decreasing from 48.07% to 46.4 % of the total area and built up area is increasing 4.65% to 6.98% respectively. The stone quarry area is also increasing 0.31% to 0.58% of the total area. During the 24 years, the increasing of stone quarry creates the growth of crushers in that area. Due to crusher, the area totally polluted and the local community faces many health issues. Maximum Quarries are established both side of the National Highway 16, most of the quarries and crushers are established within 50 m. distance from the National Highway.

Table 2: Area statistics of the Zone wise LULC of the year 2000 and 2024

LU/LC Type	Zone 1 (Area in Sq. Km.)		Zone 2 (Area in Sq. Km.)		Zone 3 (Area in Sq. Km.)	
	2000	2024	2000	2024	2000	2024
Tree Clad Area	32.6	30.03	75.78	75.24	234.25	225.24
Wetland and High Irrigation Area	0.16	0.02	3.78	3.15	29.4	35.09
Water Bodies	0.13	0.66	1.23	1.62	6.4	5.07
Cropland	14.38	14.11	66.66	64.75	311.86	300.34
Builtup Area	1.35	1.99	5.73	7.99	30.94	47.1
Stone Quarry	2.45	4.26	0.12	0.53	NA	NA

Table 3: Area statistics of the LULC of the year 2000 and 2024

LU/LC Type	% of Area (2000)	% of Area (2024)
Tree Clad Area	41.92	40.44
Wetland and High Irrigation	4.08	4.68
Water Bodies	0.95	0.9
Crop land	48.07	46.4
Built up Area	4.65	6.98
Stone Quarry	0.31	0.58

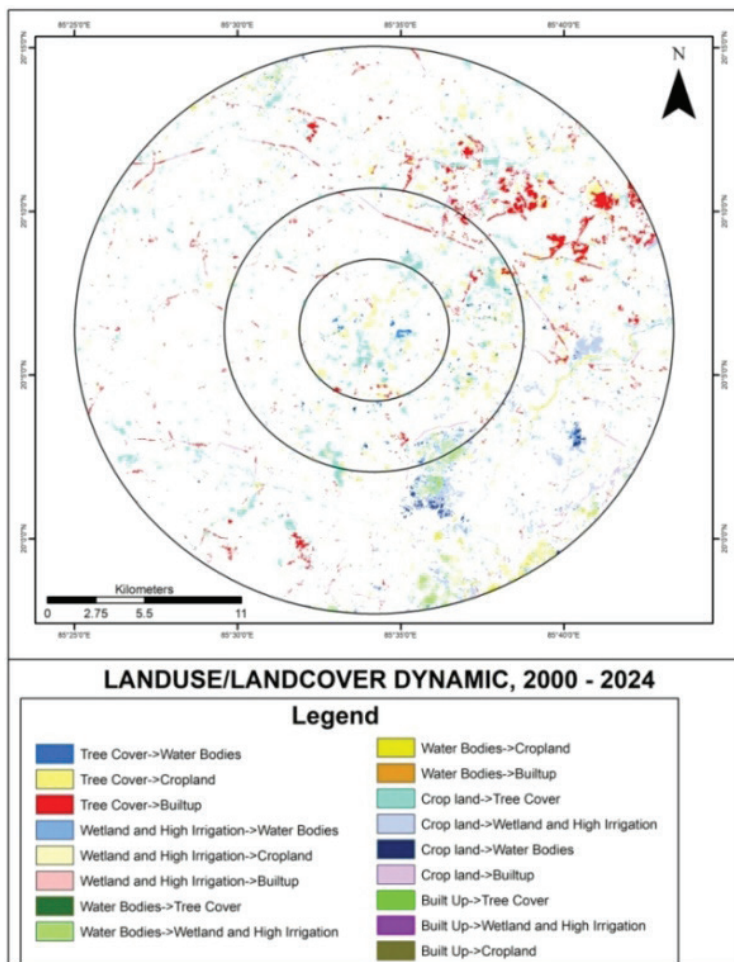


Fig. 4: The Landuse/Landcover Dynamic during the year 2000 and 2024

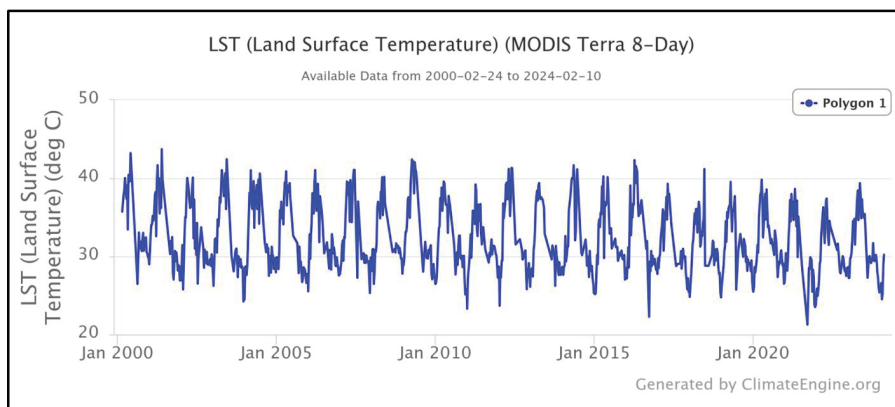


Fig. 5: Land Surface Temperature (LST) during the year 2000-2022

The temperature at which the Earth's surface feels hot to the touch at a particular place is known as the land surface temperature, or LST. It has a significant role in biology and climate, having an impact on organisms and ecosystems both locally and globally. Land-surface processes and the greenhouse effect are also well-represented by LST. The Land Surface Temperature (LST) showing in the Fig. 5 that the temperature is decreasing of the study area and the reason behind of the decreasing temperature is the increasing pond due to stone quarry. In the summer season also the pond have sufficient water which reduces the temperature of that area. The Fig. 5 shows the LST value during the year 2000 to 2022, the value is 35^o to 40^o C.

The amount of light lost through the atmosphere as a result of particles is measured by the aerosol optical depth, or AOD. Aerosol optical thickness (AOD), which combines absorption and scattering, is the vertical optical thickness of aerosols. One important metric for evaluating air pollution is AOD. It also aids in the forecasting of aviation, visibility, and air quality by meteorologists and other professionals. Climate scientists also track and forecast climate change using AOD data. Tiny liquid and solid particles suspended in the atmosphere are known as aerosols. Aerosols include things like wind-blown dust, sea salts, volcanic ash, smoke from wildfires, and factory pollution. Aerosols have the ability to either warm or cool the surface depending on their size, type, and placement.

The amount that dust and haze obstruct the sun's beam is measured by the aerosol optical depth. Put differently, dust, smoke, and pollution are examples of atmospheric particles that can block sunlight by either

scattering or absorbing light. The amount of direct sunlight that these aerosol particles block from reaching the ground is shown by the AOD. The Fig. 6 depicts that, during the year 2000 to 2022, the growth of AOD is from 0.34 to 0.78 in Zone 1, 0.36 to 0.77 in Zone 2 and 0.37 to 0.75 in Zone 3. Also during the 2018 and 2021 it was 1 in Zone 1 and 0.98 in Zone 2 and 3, particularly in the pre-monsoon period it is rising. The analysis shows that the aerosol distribution has increased during the year 2011 to 2022. The stone crushers are increasing during this period of 2011 to 2022 than the period 2000 – 2010 which affect community health.

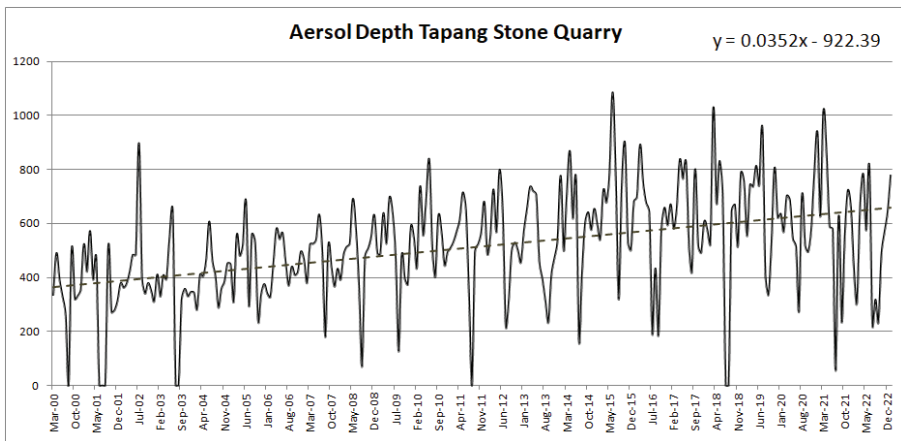


Fig. 6: Aerosol Depth during the year 2000-2022

The poisonous, colourless, and odourless gas known as carbon monoxide (CO) has a lethal potential. It is created when fuels containing carbon, such as charcoal, wood, kerosene, natural gas, gasoline, or oil, burn partially, leaving the fuel with insufficient oxygen. Some sources of incomplete combustion include vehicle exhausts. Furnaces that burn fuel, Power plants that burn coal, Space heaters, stoves, lanterns, grills, fireplaces, and gas ranges are among the items that use fuel. When CO accumulates indoors, breathing it in either humans or animals can be deadly.

Headache, dizziness, weakness, upset stomach, vomiting, chest discomfort, confusion, shortness of breath, blurred vision, and drowsiness are some of the signs and symptoms of carbon monoxide poisoning.

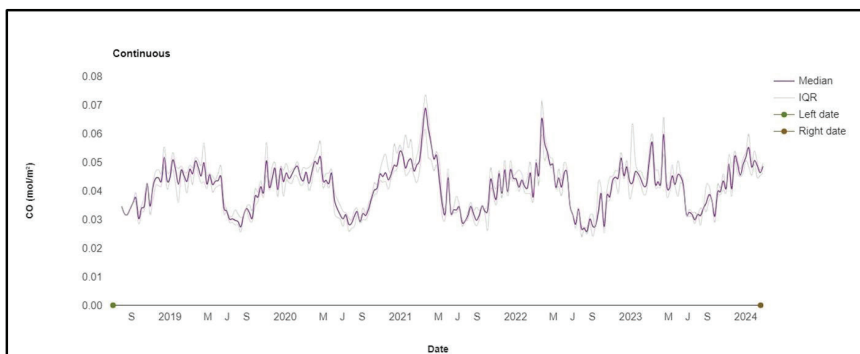


Fig. 7: Carbon Monoxide (CO) during the year 2000-2024

The Fig. 7 showing the Carbon monoxide (CO) distribution during the year 2000 and 2024 and during summer season the CO is higher than other season during this above time period due to pre-monsoon and dry period. During the study period the maximum CO value is 0.07 in the year 2021.

Parts per million by volume, or PPMv, is the unit of measurement used to describe the concentrations of air pollutants. It is the proportion of the dry gas partial pressure to the water vapor partial pressure. The conventional definition for gases is PPMv, which is equivalent to ppm. When ppm is used to describe a gas in literature on air pollution, it always refers to parts per million by volume or by mole. For an ideal gas, these are the same, and for the majority of gases that are relevant to air pollution, they are almost the same at 1 atm. When talking about the amount of carbon dioxide in the atmosphere, PPMv is frequently used. The Fig. 8 indicating that the value is increasing trend during the study period.

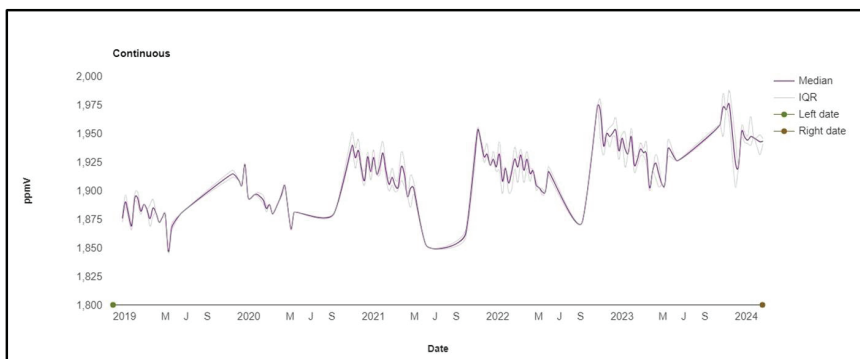


Fig. 8: PPMv during the year 2000-2024

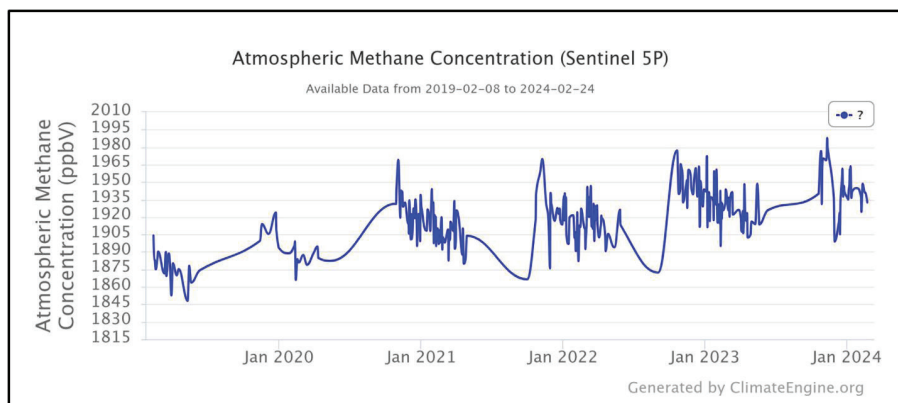


Fig. 9: Atmospheric Methane Concentration during the year 2000-2024

The Fig. 9 showing the the air pollution increasing towards 2024 and the community surrounding study area affects with many diseases related with pollution. The methane gas found in Earth's atmosphere is known as atmospheric methane. It is a greenhouse gas (GHG) and a hydrocarbon that influences temperature and the Earth's climate system. Methane content in the atmosphere is more than 2.5 times higher than pre-industrial levels, and it accounts for around 30% of the increase in global temperatures since the Industrial Revolution. Methane is released by both naturally occurring and man-made sources. Forty percent of emissions come from natural sources, the greatest of which are wetlands. The remaining 60% are anthropogenic emissions, which are caused by human activity. The breakdown of landfill waste, the burning of fossil fuels, and agriculture are the main human-caused methane emission sources. The Fig. showing that the increasing trend during the study period from 1920 in the year 2020 but it is more than 1980 in the year 2024. The Fig. no 9 showing the Atmospheric methane concentration in the study area which is increasing during the period 2000-2024. Due to the powder produces from the stone crushers which affect the ozone layer and the layer of powder also concentrated on the leaves of plants.

One of a class of gases known as nitrogen oxides, or NO_x, nitrogen dioxide (NO₂) is a gaseous air pollutant that is made up of nitrogen and oxygen. Burning fossil fuels at high temperatures, such as coal, oil, natural gas (methane gas), or diesel, produces nitrogen dioxide. Reddish-brown and aromatic, nitrogen dioxide (NO₂) belongs to the nitrogen oxide (NO_x) chemical family. At room temperature, it is a gas composed of one nitrogen atom and two oxygen atoms. Burning

fossil fuels at high temperatures, such as coal, oil, diesel, or natural gas, releases NO_2 , a highly reactive gas, into the atmosphere. The emissions from power plants, automobiles, trucks, buses, and off-road machinery also contribute to its production. Burning fuels like wood or gas indoors can produce NO_2 . One of the six air pollutants for which there are national rules limiting the amount in outdoor air is NO_2 . In addition to causing harm and irritation, it is a contributing factor to particle pollution and the chemical reactions that produce ozone.

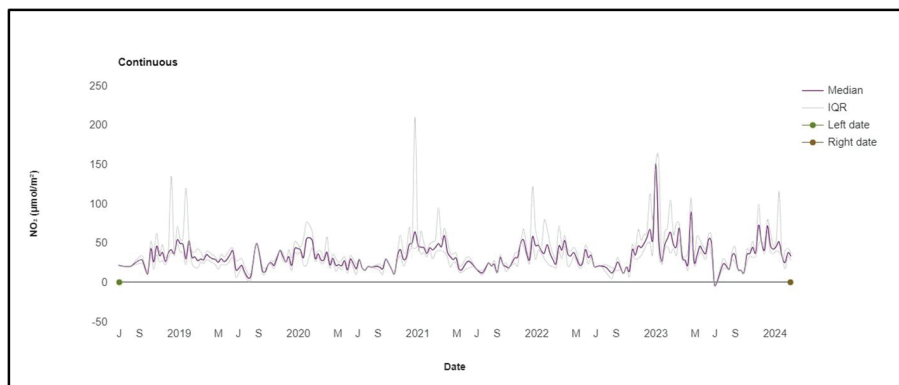


Fig. 10: Nitrogen Dioxide (NO_2) during the year 2000-2024

The Fig. no 10 showing the Nitrogen Dioxide (NO_2) concentration in the study area during the year 2000-2024. The Fig. showing that during the year 2023-24, the NO_2 has increased due to the crushers are using diesel for the processing the stones to different sizes and for different purposes. The Fig. showing that the maximum value was more than 150 in the year 2023 during the total study period.

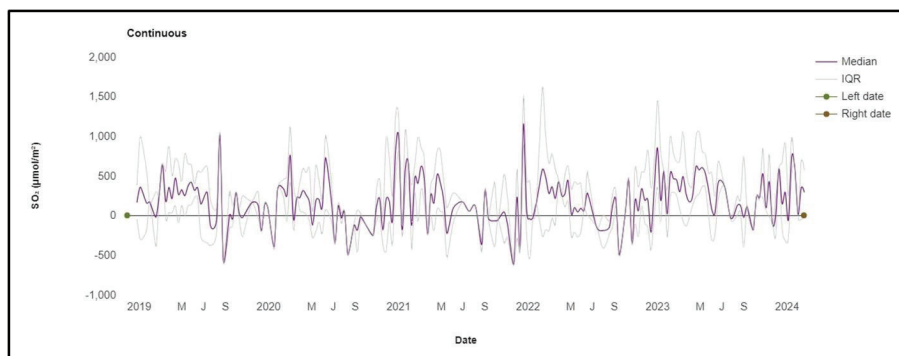


Fig. 11: Sulphur Dioxide (SO_2) during the year 2000-2024

The colourless, poisonous, and reactive gas or liquid known as sulphur dioxide (SO₂) has an overpowering, abrasive smell. It belongs to the sulphur oxide (SOX) chemical family and is composed of one sulphur and two oxygen atoms. Burning fossil fuels like coal and oil as well as smelting sulphur-containing mineral ores including iron, copper, zinc, lead, and aluminium produce sulphur dioxide. Additionally, volcanoes naturally release it. The health of humans, animals, and plants is at risk from sulphur dioxide. Corneal burns, corneal opacity, and conjunctivitis can all result from direct contact with high concentrations. Acute overexposure can cause fibrosing obliterative bronchiolitis, bronchopneumonia, and respiratory arrest in survivors. Sulphur dioxide inhalation can exacerbate lung diseases such as chronic bronchitis, emphysema, and asthma. Making sulfuric acid, sulphur trioxide, and sulphites are only a few of the numerous applications for sulphur dioxide. Bleach, disinfectant, refrigerant, and reducing agent food preservative, particularly in grape wines, fruit juices, pickled vegetables, and dried fruits.

The Fig. 11 showing the Sulphur Dioxide (SO₂) concentration in the study area during the year 2000-2024. The Fig. showing that the SO₂ has increased due to the crushers are using diesel for the processing the stones to different sizes and for different purposes which affects the human health in different types of diseases (19, 20).

Conclusion

Tapang in the illegal stone and laterite mining case before the National Green Tribunal (NGT), stated that deep water was now encircling the hillock that remained, presumably as a result of the hillock's deep stone extraction. Several miners went on to illegally drill past six meters and carved out artificially manufactured deep lakes while there was a mandate to drill only six meters below the earth. This is merely a live illustration of the illicit stone-mining activity carried out by folks in the Khurda Hills. But Hathia Mundia is not the only hilltop in Odisha that has suffered from mining-related degradation. After local protests, legal action, and official intervention, Nijigarh Tapang residents stated that mining activity in the area's major hillocks ceased, but eventually resumed in other parts of Khurda. Slowly, Khurda lost several of its mountains to stone quarry and saw increased penetration of mining-related ancillary units like stone crushing units and others which increased the quantum of dust and air pollutants in the area which was earlier filled with greenery. Even though stone mining has

ended in Tapang, new victims of the industry are emerging from the hillocks around National Highway-16, which links Tamil Nadu and Kolkata. The Khurda District Survey Report states that there are 79.5 million cubic meters of mineral reserves altogether for building stone, road metal, black stone, and white stone. Additionally, it states that since 2015–16, the district has seen an increase in tuberculosis (TB) infections annually. There were 1, 025 cases of TB overall in 2015–16, and 1, 701 cases in 2019–20. Though the cases of tuberculosis are not directly related to exposure to mining, public health experts claim that poor immunity among the workers from the economically weaker sections of the society working in such mining areas could make them more prone to develop or see increase effects of the disease. The state government has the authority to oversee mining sites and guarantee that regulations are adhered to, as stipulated by the Mines and Minerals (Development and Regulation) Act (MMDR Act). In this instance, the district administration asserted that strong steps are implemented to prevent illicit mining operations and those that deviate from established protocols.



Hatia Pahada, Tapang



Stone quarry site, Khurda



Stone quarry site, Khurda



Stone Crushers



Dust on Leaves



Stone Crushers



Crushers adjacent to NH 16



Stone Crushers

Field Photograph

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