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Research Article

In situ measurement and management of soil, air, noise and water pollution in and around the Limestone mining area of Yerraguntla, YSR kadapa, Andhra Pradesh, India for the sustainable development

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Abstract
For emerging countries, mining has been a vital factor in employment, economic development, infrastructure, and supply of essential raw materials for Nation's Gross domestic product (GDP) growth. The Limestone mine industry is serving as a viable route for economic transformation in India. Limestone exploration causes major damage to the environment at Yerraguntla industrial zone, YSR Kadapa district, Andhra Pradesh, India. The main objective of this study is to evaluate the environmental Pollution parameter that causes Air, Water, Noise, and Soil pollution in and around limestone quarries started in the early 1984. The present study estimated Air Quality Index (AQI) as 76 based on the air quality sub-index approach using four pollutants (PM10, PM2.5, SO2, NOx) for a period of 24 hrs by taking one sample per hour during the post monsoon. Water Quality Index (WQI) obtained as 303.91 from fourteen physicochemical parameters (pH, EC, fluoride, Total alkalinity etc.) measured from water samples. Soil quality was determined using four physicochemical parameters (pH, EC, WHC, Calcium and Magnesium) from the soil samples collected from ten sampling stations. The obtained pH range was (7.6 to 9.4), EC of the soil was determined as 4,140 µs/cm, the water retention capacity of the soil, ranges from (17.68 to 97.68) %, and the Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ranged from 74.5 to 272.75 mEq/L. Noise levels were determined as 76.64 dB in the mine's, 58.16 dB in the cement industry, and 52.285 dB in the mine surrounding villages. This study can help mining sector management's in developing a sustainable Environmental Management frame work to meet the world sustainable development goals (SDGs).

Keywords: Environmental parameters, Limestone mines, Society , Sustainable activities

INTRODUCTION

Increased industrialization and urbanization in developing countries like India have led to over-exploitation of limestone, which has negative impact on ecosystem of mining area (Thakur *et al*., 2022). The mining industry, directly and indirectly, employs around 1.1 billion people and provides a livelihood for approximately 5.5 billion people and the mining sector contributed ₹4.10 lakh crore to India's Gross domestic product (GDP) in Fiscal Year (FY) 2018-19 (https://mines.gov.in/). Limestone is a nonmetallic mineral composed mainly of calcium carbonate ($CaCO_3$) and, in certain circumstances, calcium and magnesium carbonate ($CaMg(CO_3)_2$). Limestone is broadly utilized as a building material and a great raw resource for the manufacture of high-quality cement (Sudhakar and Umamaheswara., 2019).

Limestone mining creates job and income prospects, as well as infrastructure and community development, commerce, and medical facilities in the area (Goswami, 2015; Thakur *et al*., 2022). However, large-scale surface limestone mining causes considerable soil erosion, biodiversity loss, and air, water, and noise pollution in the region, negatively impacting biotic communities, landscapes, and the overall ecosystem. (Bell *et al*., 2001; Chauhan *et al*., 2020; Kittipongvises, 2017; Kumar *et al*., 2020; Sarma and Kushwaha, 2015; Thakur *et al*., 2022). Limestone processing releases hazardous gases such as Sulphur dioxide (SO_2), Nitrogen Oxide (NO), Carbon dioxide (CO_2), and dust, as well as high levels of noise and vibrations, all of which harm the environment (Ganapathi and Phukan, 2020; Mondal, *et al*., 2013; Sudhakar and Reddy, 2022).

The objectives of this study included: To map active limestone mines using high-resolution Google Earth satellite images, b)To pinpoint the position of environmental parameter monitoring systems using Google Earth imagery, c) To compute the Air Quality Index (AQI), Water Quality Index (WQI), Noise levels, and Soil Pollution and compare them to standard index categories, d) To describe industry Sustainable Development and Corporate Social Responsibility actions in order to accomplish the Sustainable Development Goals (SDGs). The objectives depict the current environmental scenario of the mining area based on the projected mining activities, which helps to develop an eco-friendly mining plan to ensure the mining industry's long-term viability.

MATERIALS AND METHODS

Study area

The Yerraguntla is an industrial region (Fig.1) in the YSR Kadapa district, Andhra Pradesh, India (Sudarshan Reddy *et al*., 2020). It is situated between the latitudes 14^o 38'0" N and the longitude 78^o 32'0" E. Yerraguntla is also well-known for its stones, which are used for house flooring and construction (Sumithra *et al*., 2013). The proposed study involved a Niduzuvvi captive Limestone mine of The India Cements Limited (ICL) is located between $14^0$37'49" N to $14^0$39'20" N and $78^0$29'23" E to $78^0$31'14" E (Niduzuvvi Limestone Mine, 2020). The India Cements Limited (ICL) captive mine, Coromandel Limestone, is located close to the mine lease area from 14°38'51" N to 14°40'31" N and 78°27'55" E to 78°29'40" E (Coromandel Limestone Mine, 2019). The Zuari Cement Limestone Mine, which is located between $14^0$36'10"N to $14^0$38'30" N and $78^0$31'24" N to $78^0$33'30"E, is a captive mine of Zuari Cement Limited (ZCL) and is next to the mine lease area (Zuari Limestone Mine, 2019). The Bharati Cement Limestone Mine, which is located at 14°34'02"N to 14°36'28" N and 78°33'35"E to 78°36'51"E and is next to the mine lease area, is a captive mine of Bharathi Cement Corporation Private Limited (BCCPL) (Bharathi Cement Corporation Private Limited, 2017) The region's tropical climate manifests itself in hot and humid summers, as well as moderate monsoon and winter seasons. The hottest month is May, while the coldest month is December. The months of December, January, and February are supposed to have a pleasant climate (Sudhakar and Reddy, 2022).

Cement grade captive limestone mines

The mines used a fully mechanized opencast mining approach (Table 1), which included deep drilling and blasting, loading the broken material with heavy machineries such as hydraulic excavators and tippers, and conveying the limestone to the cement plant's crusher. Almost all cement plants in the study area produce Ordinary Portland Cement (OPC), Portland Pozzolana

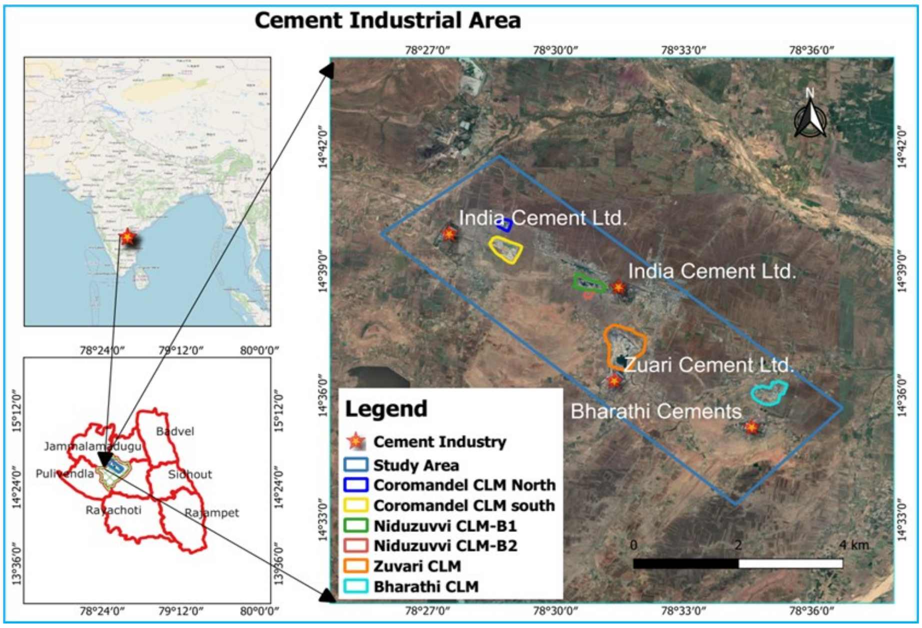


Fig. 1. *Study area location map with geo-coordinates*

Table 1. Details of cement-grade limestone mines.

	Coromandel Mine	**Niduzuvvi Mine**	**Zuari cement mine**	**Bharati cements Mine**
Cement Industry	: ICL at Chilamkur	: ICL at *Yerraguntla*	: ZCL at *Yerraguntla*	: BCCPL at Nallalingayapalli
Established Year	: 1982	:1979	: 1984	: 2006
Mine lease area	: 602.137Ha	:335.06Ha	: 656.68Ha	: 632.28Ha
Active Mining Area	: 112.37Ha	: 66.17Ha	: 241.0Ha	: 67.56Ha
Limestone Production	: 2 to 5.5MTPA	:1.0MTPA	: 7.0MTPA	: 5.0 MTPA
Cement grade	: OPC & PPC	:OPC & PPC	:OPC 43&53,	: OPC 43& 53, PPC
Cement production	: 1.485MTPA	:1.38 MTPA	:4.6 MTPA	: 5 MTPA
Lease period ends (Year)	: 2031	: 2034	:2041	: 2038
Reserves/ Resources	: 276.06 MT	:82.98 MT	:178.856MT	: 330.186MT

Cement (PPC), Portland Slag Cement (PSC), and PRIMO Concrete cement. (Sudhakar and Reddy, 2022). Fig.2 depicts an operational satellite view of captive limestone mines and cement factories.

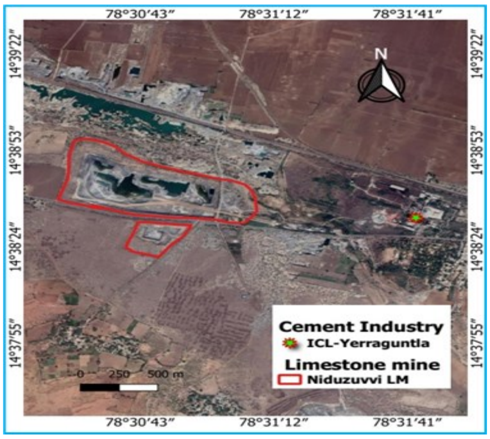
Mining process

Limestone is mined using a fully mechanized opencast method (https://ibm.gov.in/). Fig.3 shows mining and processing flow diagrams.

First, the black topsoil is scooped using excavators and dumpers, resulting in soil erosion and vegetation loss. During dry weather conditions, ammonium nitrate and fuel oil (ANFO) and priming cartridges with delay Nonel detonators are used for blasting, and excavators are employed to extract limestone materials. The main environmental impact at this level is noise pollution.

After excavation, the limestone is transported by dumpers to the crusher plant and, in the event of polluted limestone, to the screening facility. In this stage, raised dust particles pollute the air.

A. Coromandel limestone mine



B. Niduzuvvi limestone mine.

C. Zuari cement limestone mine

D. *Bharati cements limestone Mine*

Fig. 2. *Captive cement grade Limestone mine satellite view*

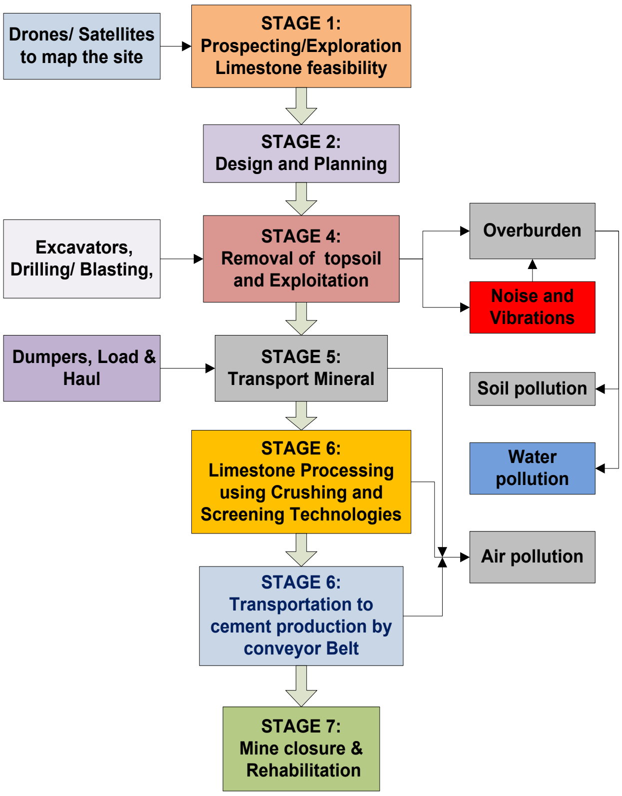


Fig. 3. *Limestone quarrying operations flow diagram*

The crushed limestone will be conveyed via a covered conveyor belt to the Interlinked Cement Plant.

During the mine closure and rehabilitation process, the physical, chemical, and biological quality of land is restored to a level acceptable to all stakeholders.

Local impact of limestone mining

The environmental, economic, and social implications (Fig. 4) of limestone mining operations have been envisaged during the last 37 years (1984 to 2022) (Worlanyo and Jiangfeng, 2021). Some of the negative consequences revealed that loss of vegetation cover and land degradation by the dumping of overburdens/ spoils and lime waste material, mass destruction of water bodies due to dumps encroachment , loss of biodiversity, land-use changes, increased social vices and conflicts, food insecurity, high cost of living, and air pollution during limestone transportation and processing.The positive impacts include that mining is a source of revenue and employment for many people in the area (Wang *et al*., 2018; Ganapathi and Hukan, 2020).

Environmental impact caused by limestone extraction

The surrounding environment has been degraded as a result of limestone mining and open dumping of lime waste in the vicinity. Environmental degradation include land degradation caused by the dumping of overburdens/spoils and lime waste material, encroachment of wate dump into the nearby vegetation patches and water bodies, diversion and disappearance of small natural stream routes, formation of infertile waste land, and changes in landscape topography(Gultom *et al*., 2018). The significant environmental impacts in the study area are land degradation, air pollution, noise pollution, water pollution, vibration issues, and worker health and safety.

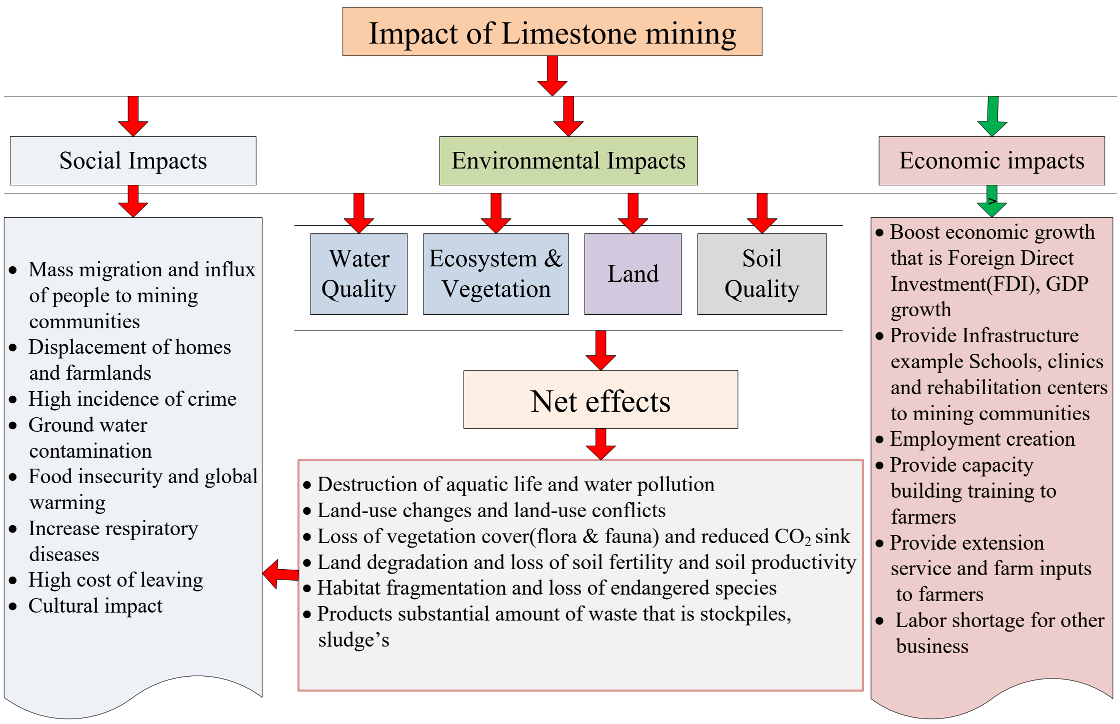


Fig. 4. *General impacts of limestone mining*

A. Limestone dump near India cement plant B. *Agriculture(Jowar) land near the mining area*

C. Development of fine dust during transport *D. Trees were affected by the mine dust*

Fig. 5. *Land degradation area*

Land degradation

The main causes of land degradation in the Yerraguntla industrial zone were the cement industry's production of calcite and soapstone, limestone grinding for the cement industry (Firozjaei et al., 2021; Soni and Nema, 2021), and random dumping of solid waste (Fig. 5) generated. Removing plants and trees in preparation for mineral exploration caused major land degradation, which significantly influenced regional ecosystems. The overlay is a bed of black cotton topsoil excavated to extract minerals. After mineral extraction, the overburdened materials are periodically deposited on open ground and used for afforestation and pit backfilling (Worldwide, 2010; Ganapathi & Phukan, 2020). Long-term disposal of limestone mixed waste material has been reported to deteriorate the quality of the soil and alter soil characteristics (Lamare and Singh 2016).

Air pollution

Air pollution in the Limestone mining area is fugitive dust distribution (Fig. 6) due to various operations like drilling, blasting, loading, transportation, unloading,

Table 2. AQI color coding, six levels, and possible health consequences

AQI Category (Range)	Color	Possible Health Consequences
Good (0 – 50)	Green	Impacts are minimal
Satisfactory (51 – 100)	yellow	People with delicate lungs may experience minor breathing difficulties.
Moderately polluted (101– 200)	Orange	People suffering from lungs, asthma, and heart illness may experience difficulty breathing.
Poor (201 – 300)	Red	Most people experience breathing difficulty after extended exposure.
Very Poor (301 – 400)	Purple	Respiratory illness on prolonged exposure
Severe (401 – 500)	Maroon	Affects healthy persons as well as those suffering from exciting disorders.

crushing plant, and so on. suspended particulate matter (PM) is the principal air pollutant in opencast mechanized mining. Gaseous pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), and carbon monoxide (CO) are released by Heavy Earth Moving Machinery (HEMM) such as dumpers and excavators (Lamare and Singh 2016; Soni and Nema, 2021).

Importance of the Air Quality Index

The Air Quality Index (AQI) is a tool for effectively (https://app.cpcbccr.com) presenting air quality status to consumers and decision-makers. It converts complex data on multiple pollutants' air quality into a single value. Table 2 shows each of the six AQI categories, color, and potential health effects. Each of these categories was decided (Tables 2 and 3) by the National Ambient Air Monitoring (NAAM) Program and Central Pollution Control Board (CPCB) in New Delhi (CPCB, 2014; Sharma et al., 2003) based on ambient concentration values of air pollutants.

Water pollution

Limestone Mine water drainage, mineral exposed water leakage or flow to the surface of the neighboring aquifer system and surface water body, water from spoil heaps and mine-pit water rebound (Fig. 7), and wastewater containing oil and grease from the workshop are the main sources of water pollution (Coromandel Limestone Mine, 2019). Furthermore, mining can lower the water table, and mine-pit water can pour out into the underlying aquifer, contaminating groundwater. (Yenugu et al., 2020; Soni and Nema, 2021). According to the BIS (1986) specifications, Table 4 shows the WQI and the related water quality rating. In the research region, groundwater can be found 60 meters below ground level. The region is arid, with an average annual rainfall of 700mm/year (Niduzuvvi Limestone mine, 2019).

Noise pollution and ground vibrations

Apart from dust, noise is the most common and recurring environmental stress in mining sites. There are three types of noise sources in a limestone mining environment: stationary, mobile, and impulsive sources. Heavy Land-moving machinery (HLMM), drill bits, dumpers, and material handling are some of the most common noise sources, with noise levels ranging from 90 to 115 dB (Niduzuvvi Limestone mine, 2019). In a limestone mine, vibrations caused by HLMM, machinery, and mine blasting are also noticeable and substantial (Nguyen *et al*., 2020).

Noise pollution is harmful because it disrupts spoken communication, neurotic irritation, hearing impairment, and physical strain (Mandal *et al*., 2022). Table 5 shows the noise levels and preventive measures recommended by India's Directorate General of Mines Safety (DGMS) (Soni and Nema, 2021).

Health hazards

Fine dust particles of the size range of 0.5 to 5 µm are injurious to the health of the miners. Dust motes are inhaled through the nose, travel through the respiratory

Table 3. AQI categories and health breakpoints for the eight pollutants

	Concentration range (C_{min}– C_{max}) of pollutant							
AQI categories (I_{min}– I_{max})	**PM_{10}** (µg/m^3)	**$PM_{2.5}$** (µg/m^3)	**NO_2** (µg/m^3)	**O_3** (mg/m^3)	**CO** (µg/m^3)	**SO_2** (µg/m^3)	**NH_3** (µg/m^3)	**P_b** (µg/m^3)
Standard values	**100** (24 hrs)	**60** (24 hrs)	**80** (24 hrs)	**100** (8 hrs)	**2.0** (8hrs)	**80** (24 hrs)	**400** (24 hrs)	**1.0** (24 hrs)
0 - 50	0 - 50	0 - 30	0 - 40	0 - 50	0 - 1.0	0 - 40	0 - 200	0 - 0.5
51-100	51 - 100	31 - 60	41- 80	51 - 100	1.1 - 2.0	41 - 80	201 - 400	0.5 - 1.0
101- 200	101- 250	61- 90	8 -180	101- 168	2.1 - 10	81- 380	401- 800	1.1- 2.0
201 - 300	251- 350	91- 120	181- 280	169 - 208	10 - 17	381- 800	801- 1.2k	2.1 - 3.0
301 - 400	351- 430	121- 250	281- 400	209 - 748	17 - 34	801- 1.6k	1.2k - 1.8k	3.1-3.5
401-500	430+	250+	400+	748+	34+	1.6k+	1.8k+	3.5+

Note: k=10^3

Table 4. Water Quality Index-Particulate Matter

WQI Range	Category of water	Possible usages
0 – 50	Excellent	Drinking, Irrigation & Industrial
50 – 100	Good	Irrigation & industrial, Domestic
100 – 200	Poor	Irrigation
200 – 300	Very poor	For all purposes, use is restricted.
>300	Severe	Before use, proper treatment is essential.

Source: https://pcb.ap.gov.in

A. Explosion of dust at the mine *B. Air pollution at Zuari cement plant premises*

Fig. 6. *Showing air pollution in the mine and cement plant premises.*

A. View of mine-pit benches *B. Stormwater accumulation at mine-pit*

C. Groundwater impact *D. Water inundation in mine tailings*

Fig. 7. *Water pollution due to limestone mines*

Table 5. Indian standards for noise levels in mines

S. No.	Noise level(dB)	Protective measures
1	< 85	Very little risk to unprotected ears
2	90 – 115	The danger of hearing destruction and deafness
3	115 – 130	Without ear protection, the worker will not be allowed to enter.
4	130 – 140	Person protective equipment is a must
5	> 140	No workers shall be allowed to enter

Source:https://cpcb.nic.in/

tract, and end up in the lungs and chest cavity (Kurnia *et al*., 2014). Hearing defects may be caused due to exposure to excess Noise and Vibration (above 90 dB) during work in the long run. The disease is called Noise -Induced Hearing Loss (NIHL) which does not initially affect the normal speech range. It affects the high frequency (above 4kZHz) at first and gradually shifts to the speech frequency. The person gradually becomes deaf; irritable, talks in a loud voice; develop sleeplessness and high blood pressure. Air pollution irritates the respiratory systems of the people staying nearby. Many people, particularly the children suffer from allergies, asthma, respiratory infection, and bronchitis (Coromandel Limestone Mine, 2019).

RESULTS AND DISCUSSION

Evaluation ofe environmental impacts

The mining sector is actively monitoring environmental parameters under recommendations set forth by the Andhra Pradesh Pollution Control Board (APPCB), the (IBM) Indian Bureau of Mines, and the Ministry of Environment and Forest (MoEF). Through field visits or from space, an Environmental Impact Assessment (EIA) identifies, anticipates, and assesses environmental impacts (Fig. 8) such as soil, air, water, noise pollution, and ground vibration; biological environment; and socio-economic elements. Stakeholders establish an Environmental Management Plan (EMP) based on the EIA to mitigate the impacts (Soni and Nema, 2021).

Soil quality evaluation

Soil quality is defined as "the capacity of a specific kind of soil to function with its surroundings, sustain plant and animal productivity, maintain or enhance soil, water, and air quality and support human health and habitation"(Thakur *et al*., 2022). Hence, In terms of ecosystem function and effective reclamation, soil quality is one of the most important aspects of recovering the ecosystem (Mfondoum *et al*., 2016).

An electronic pH meter was used to determine the pH values of soil samples(S_1-S_9) taken from a depth of 10 to 20 cm at Nine locations (Fig. 9) in and around mining area, including reclaimed land, virgin land, beside factories, and near dust dumps. The pH range found in soils varies from 7.6 to 9.4 (Table 6), which shows alkaline type on the pH scale, as well as soil samples, showed sandy loam in texture with a sand percentage of 35%.silt and clay 65%, Average fertility, and Chloride (Cl) in the soil samples were found 0.20meq/100gm.

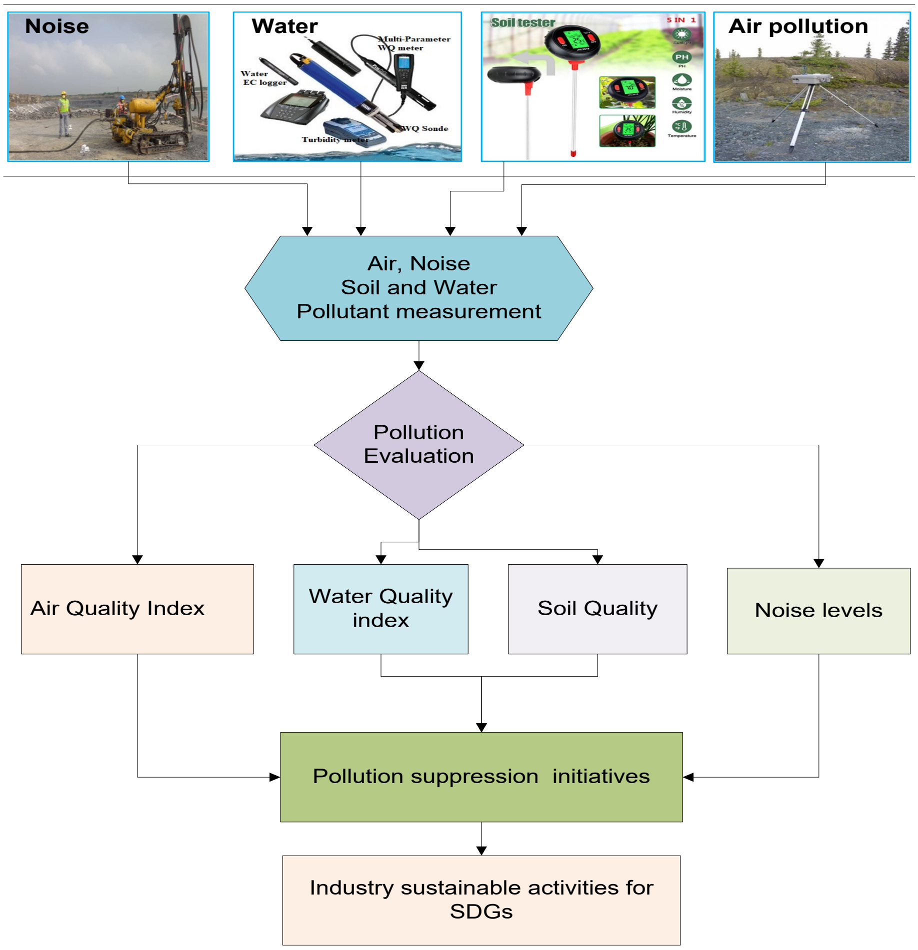


Fig. 8. *Environmental impact analysis*

Mathematically pH is represented in Equation (1)

$$pH = -log[H^+]$$ Eq.1

Where $[H^+]$ denotes the molar hydrogen ion concentration.

Electrical conductivity (EC) changes with soil depth, rainfall pattern, permeability, soil suspension dilution, and other factors. In general, the EC of healthy soil is less than 1 μS/cm, indicating that it is good for plants. The EC of the soil was determined to be 4,140 μs/cm (Table 6) in stone crushed areas in the current study (Sumithra *et al*., 2013).

The water holding capacity (WHC) of soil is a measure of numerous physical qualities. A good water retention capacity indicates that the soil is in good physical condition. The use of sewage water for agriculture increases the capacity to hold water (Sumithra *et al*., 2013). The water retention capacity of soil ranges from 17.68 % to 97.68 % (Table 6).

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) are essential elements for plant life, and their levels were determined using the Ethylenediaminetetraacetic acid (EDTA) filtration method, which yielded results ranging from 74.5 to 272.75 milliequivalents per litre (mEq/L).

Quality of air interpretation using INDIA-AQI

The impact of the limestone mining on ambient air quality is monitored by installing ambient air quality (AAQ) monitoring stations(A_1-A_{10}) at ten locations (Fig.10) in the mine premises (core zone) and adjacent areas (buffer zone) using pre-calibrated respirable dust and fine dust samplers (Dutta *et al*., 2021; Oberai *et al*.,2022). The air quality data is collected season-wise on 24 hrs basis and computed the Air Quality Index (AQI) from criteria parameters (Equations 2 and 3), namely, particulate matter-10 μm (PM10), & PM2.5, gaseous pollutants (NOx, SO_2 CO). The Segmented linearity is represented by Equations (2) and (3).

$$I_{si} = \left(\frac{(C_{obs}-C_{min})*(I_{max}-I_{min})}{(C_{max}-C_{min})}\right) + I_{min}$$ Eq.2

$$AQI = Max\,(I_{si1},\ I_{si2},\ I_{si3}\ \dots\dots\dots I_{sni})$$ Eq.3

Where

I_{si} = Sub-index value of the observed pollutant

C_{obs} = Observed pollutant concentration

C_{min} = The concentration breakpoint that is $\leq C_{obs}$

C_{max} = The concentration breakpoint that is $\geq C_{obs}$

I_{min} = Minimum AQI value corresponding to C_{min}

I_{max} = Maximum AQI value corresponding to $\leq C_{max}$

The probable ground level concentration of PM at the mine's border is less than 5μg/m3. Carbon monoxide concentrations were found to be less than 1ppm at all locations (1 hour).

As shown in Tables 7 and 8, the PM10, PM2.5 Sulphur Dioxide, and Nitrogen oxide readings are well under the

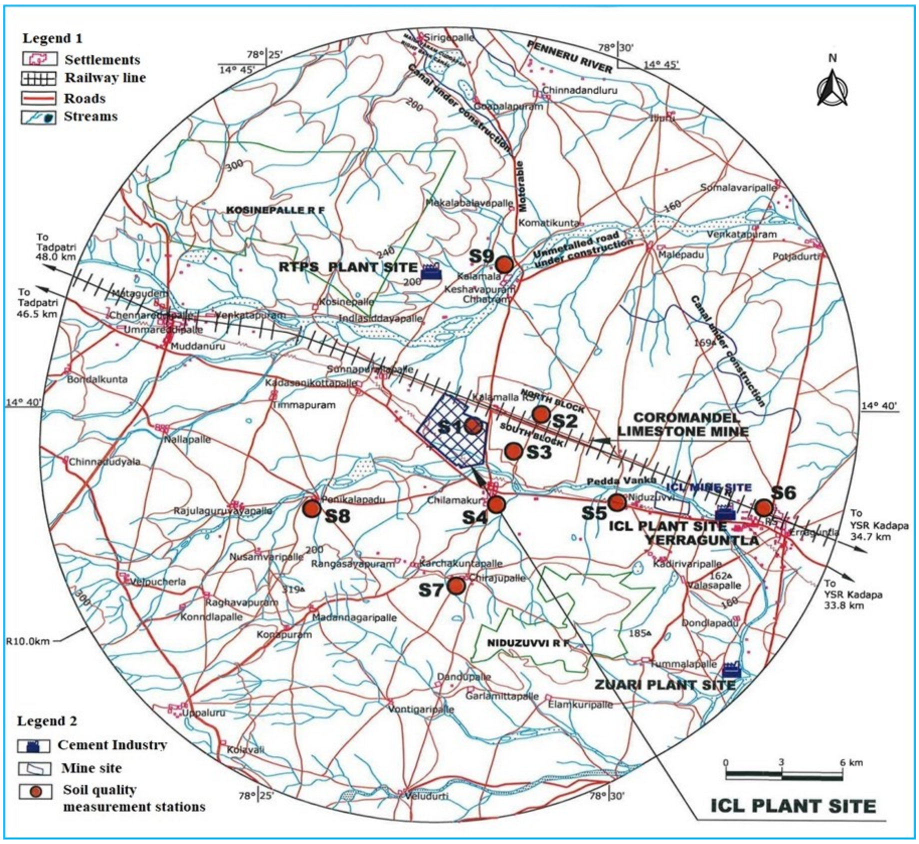


Fig. 9. *Soil quality measurement stations satellite view*

Table 6. Physical properties of soil samples

Soil parameter	Minimum	Maximum
pH	7.66	9.45
EC (μs/cm)	103.7	4140
WHC(%)	17.68	17.68
Calcium and Magnesium (mEq/L)	74.5	272.75

specified limits of 100 and 80 μg/m^3, respectively and moderate AQI.

Ambient noise and vibrations

A blasting vibration recorder (EXP 3850) and a sensor (CDJ-1) were used to monitor blast-induced vibrations. Cap-sensitive explosives (class-2) are employed as a booster, and ammonium nitrate fuel oil (ANFO) is used in a 20:80 ratio for blasting.

A Optimus Red Sound Level Meters(CR162A) were used to measure instantaneous noise quality at chosen eight locations(N_1–N_8) such as schools, hospitals, bus stops, and residential areas in and around the mine sites (Fig.11) of Yerraguntla, Chilamkur, and Kalamalla for 24 hours (T). Table 9 shows the locations of noise quality monitoring stations as well as the recorded noise levels. Equation 4 is used to calculate the equivalent noise level, which is as follows.

$$L_{eq} = 10log_{10}\left[\sum_{i=1}^{n}\left\{\left((10)^{\frac{L_i}{10}}\right) * t_i\right\}\right] \quad \text{Eq. 4}$$

Where n = The total number of samples taken (24)

L_i = The noise levels in dB of the i^{th} sample

$t_i = \frac{t}{T} = \frac{1}{24}$ = fraction of total sample time of the i^{th} sample

t = Sampling time of i^{th} sample (1hr)

T = Total sampling time (24hrs)

The average equivalent noise levels were recorded in the mine as 76.64 dB, in the cement site as 58.16 dB, and in the villages found 52.285 dB.

Water quality

The water quality index (WQI) is a measure of the chemical, physical, and biological properties of water. During the post-monsoon season, Ground watter(GW) samples were collected in 2 liters water bottles from 8 villages existing bore/hand pump and surface water (SW) collected from 4 locations in and around the mine sites (Fig.12), and various ionic and non-ionic parameters (Saikrishna *et al*., 2020) such as the potential of hydrogen (pH), Conductivity(EC), measured using waterproof EC/TDS conductivity meter, PHeP pocket pH tester respectively, Total dissolved solids (TDS), (0.64×EC μS/cm), TH (Total hardness), Total alkalinity (TA), Calcium (Ca^{2+}), Magnesium (Mg^{2+}) , Potassium (K^+), Sodium (Na^+), Chloride (Cl^-), Bromide (Br^-), Nitrate (NO_3^-), Sulphate (SO_4^{2+}) were determined by Titrimetry, An ion-selective electrode (Orion 4 star ion meter, Model: pH/ISE) was used to measure fluoride (F^-) (Suvarna *et al*., 2020). Turbidity of river water is measured using an LP200 turbidity meter it is within the permissible limit that is less than 5NTU in all the seasons. Water categorization was determined by comparing the examined data to World Health Organization (WHO) and Indian criteria (WHO, 2011; IS, 2012).

Analytical procedures

The Water Quality Index (WQI) was calculated using mean values of fourteen parameters (Table 10) computed from collected water samples. WQI was calculated in this study in five stages using the weighted arithmetic index method (Divahar *et al*., 2020; Suvarna *et al*., 2020; Saikrishna *et al*., 2020; Said & Khan, 2021; Sunitha & Reddy,2022). The 1st step is “assigning weight (w_i)” to each of the fourteen parameters for drinking water purposes(Equation 5) (Table 11). The 2nd step is the “relative weight (W_i) calculation” using Equations (6). The 3rd step is the “quality rating (Qi)” calculation using Equation (7). The 4th step is sub Index (SI_i) determination for each of the chemical parameters

Table 7. AAQ parameters were monitored during June and September 2019.

	Sampling location							
	Core zone				Buffer zone			
Pollutant	PM_{10} 24 hrs	$PM_{2.5}$ 24 hrs	SO2 24 hrs	NO_X 24 hrs	PM_{10} 24 hrs	$PM_{2.5}$ 24 hrs	SO2 24 hrs	NO_X 24 hrs
June	69.75	24.75	12.3	15.8	72	27.25	12.2	13.5
September	65.75	24.25	18.5	20.2	74.25	29.25	16.4	19.4

*units: mg /m^3 unless mentioned otherwise

Table 8. Calculation AQI for September month core zone

Parameter (mg/m^3, 24 hrs)	C_{obs}	I_{min}	I_{max}	C_{min}	C_{max}	I_{si}	AQI Max(Isi)
PM_{10}	65.75	50	100	50	100	56	76 (Moderate)
$PM_{2.5}$	24.25	0	50	0	30	76	
SO_2	18.5	0	50	0	30	26	
NO_x	20.2	0	50	0	40	19	

*Note that C_{min} & I_{min} are the rounded down values

(Equation 8).In the 5[th] step computed WQI using Equation (9).

$$w_i = \frac{k}{s_i}$$ Eq. 5

Where

$$k = \frac{1}{\Sigma^1/_{S_i}}$$

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$ Eq.6

$$Q_i = \left(\frac{C_i}{S_i}\right) * 100$$ Eq.7

$$SI_i = W_i * Q_i$$ Eq.8

$$WQI = \sum SI_i$$ Eq.9

Where

W_i = Relative weight

w_i = Weight of each parameter

n = Number of parameters

C_i = Concentration of parameter in a water sample

S_i = WHO standard value of the parameter.

SI_i = Subindex of each parameter.

Q_i = quality rating parameter

The calculated WQI value is 303.91, indicating that the groundwater from this location is unfit for drinking.

The findings revealed that the soil was abundant in the elements calcium and magnesium, alkaline in character, and had a higher quantity of soluble salts. The measured WQI value indicated that the groundwater in this area was not safe to drink.The AQI result implies minor breathing discomfort and associated health problems for those who are sensitive to dust. Because of the high noise levels in cement plants and mines, those who spend a lot of time there may suffer noise-induced hearing loss (NIHL).

Limestone mine sustainability initiatives

To maximize limestone production while reducing the effect on the nearby physical, chemical, and biological surroundings, the tall flora in and around the mining lease region was grown by the industry managers. The topsoil formed as a result of limestone mining was used for green belt development (Sudhakar and Reddy, 2022). Rainwater was collected using deep sump development, and the same water is used on a regular basis for dust suppression at the mine face and haulage roadways, processing in the cement plant, and replenishing the underlying aquifer (Soni and Nema, 2021). The mined-out area will be converted into a reservoir at the end of the mining operation.

The effluent generated from the workshop was passed through an oil separator and sand filter constructed at the workshop of the mine. Treated wastewater was

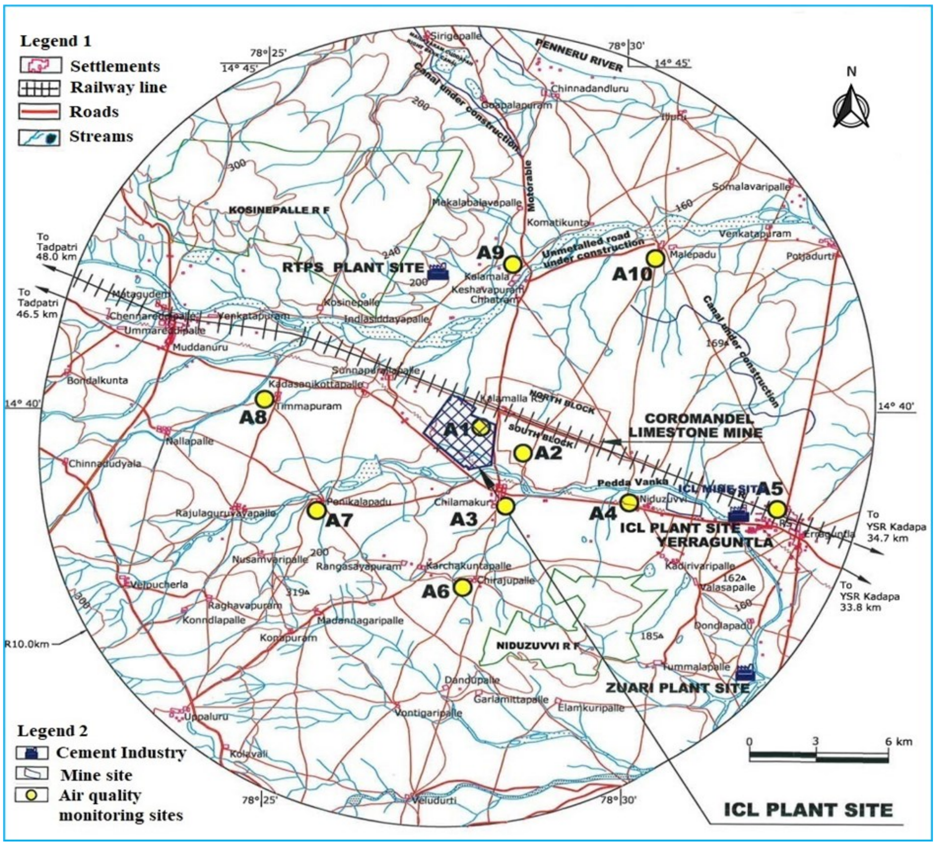


Fig. 10. *Ambient air quality monitoring stations satellite view*

Table 9. Spot noise quality measuring stations and values

Category	Location	Day time noise level (dB), (L_i)	Nighttime Noise level (dB), (L_i)
Commercial	Near ZPHS School Yerraguntla	53.10	42.1
Residential	Niduzuvvi	53.70	42.2
	Chilamkur	55.09	42.2
	kalamalla	47.25	42.2
	Timmapuram	54.06	41.2
Machinery	Excavator	81.2	-
	Dumper	73.6	-
	Dozer	74.8	-
	Loader	75.2	-
	Drill machine	78.4	-
Industry	ICL plant	58.16	-

used for plantation and dust control. The wastewater released by the residential front would be processed in a septic system before being disposed of in a soak pit (Niduzuvvi Limestone Mine, 2020).

In addition to the greenbelt built along the mine area's boundary to reduce the impact of noise from mining operations on the surrounding environment, a down the hole initiating system is used for noise pollution management. Nonel detonators are used to reduce ground vibrations and fly rock. Employees who operate drill machines, dumpers, excavators, and crushers must wear earplugs or earmuffs. All of the equipment/ machines employed had optimal noise levels in the operator's cabins of less than 90 dB, according to Occupational Safety and Health Administration (OSHA) rules. The noise produced is reduced by lubricating the machinery and equipment; blasting is done only during the day and not on cloudy days (Coromandel Limestone Mine, 2019).

Limestone mine officials had also taken the following

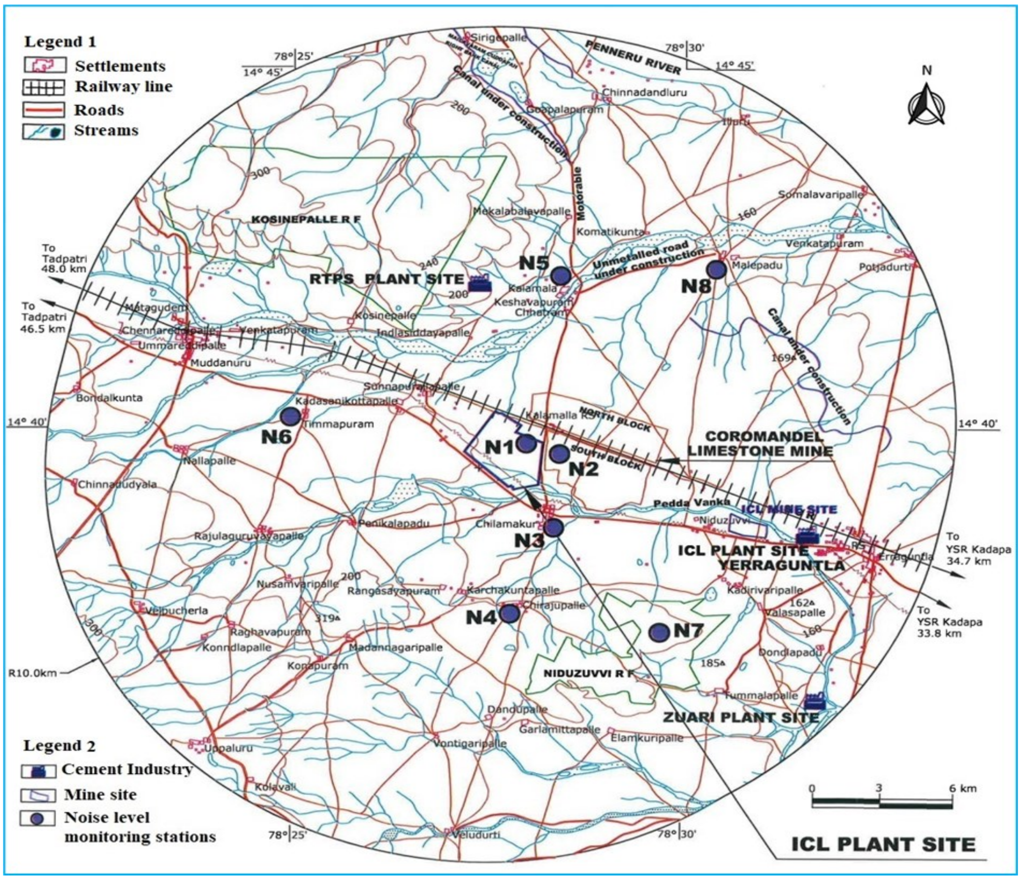


Fig. 11. *Noise level monitoring stations satellite view*

steps to reduce air pollution. Wet drilling for dust control, near drilling and loading facilities, sprinkling water on the blasted muck pile. Baghouse system for cleaning raw mill/kiln flue gas, Electrostatic Precipitators (ESP) for dust control, Bag filter systems in combination with ventilation systems to control fugitive dust created in material handling areas, Nitrogen oxides are controlled by using a low NOx burner (Niduzuvvi Limestone mine, 2020; Zuari Limestone Mine, 2019; Bharathi Cement Corporation pvt Ltd., 2017).

Industry programs to meet Sustainable development goals (SDGs)

Every country in the world is working to achieve the following 17 Sustainable Development Goals (SDGs): (1) No Poverty, (2) Zero Hunger, (3) Good Health and Well-being, (4) Quality Education, (5) Gender Equality, (6) Clean Water and Sanitation, (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation and Infrastructure, (10) Reduced Inequality, (11) Sustainable Cities and Communities, (12) Responsible Consumption and Production, (13) Climate Action, (14) Life Below Water, (15) Life On Land, (16) Peace, Justice, and Strong Institutions, (17) Partnerships for the Goals (https://sdgs.un.org/goals). Under the Corporate Social Responsibility (CRS) policy, the cement and limestone mining industries have undertaken the following activities to meet the SDGs and ensure the long-term viability of the industries.

Promotion of education programs (SDGs – 4, 8 and 17)

Support for local government village schools through the donation of books, educational equipment, and furniture on a need-basis, as well as merit scholarships to Engineering and Medical students for financial assistance. providing quality education to employees' children and adjacent village children through the Zuari cement DAV public school.

Skill development and self-employment programs (SDGs – 1, 2 and 8)

The Limestone and Cement industries have launched a self-employment scheme called 'Prazna' to support the locals around its production sites by fostering skill enhancement activities for rural youth and enabling them to sustain themselves and their families. Under Prazna skill development program tailoring, candle-making skill

Table 10. Statistical parameters for water quality (WQ) measurement

WQ parameters	pH	EC	TDS	TH	Ca	Mg	K	Na	Cl	Br	NO_3	SO_4	TA	F
Mean	7.7	4984	2398	505	85.6	102	24.6	227.5	475	1.25	82	374	637	1.52
Maximum	8.3	15.8k	7.7k	1.6k	344	305	90	560	1.8k	4.34	752	1.2k	1.3k	5.81
Minimum	7.1	1.38k	660	100	24	2.92	0.26	22.32	68.0	0.04	2.29	45.2	292.4	0.49

*Note: Except for pH, EC in µs/cm, and k=10^3, all parameters are stated in mg/L

Table 11. Water quality index parameters

Parameter	Weight (w_i)	Relative weight (W_i)	S_i	C_i	Q_i	SI_i	WQI
pH	3	0.0612	8	7.52	94	5.755	303.91
EC	4	0.0816	1500	5620	374.66	30.585	
Magnesium	3	0.0612	50	106.92	213.84	13.092	
Sulphate	5	0.1025	250	586.21	234.48	23.926	
Sodium	3	0.0612	200	251.11	125.55	7.686	
TDS	2	0.0408	600	2600	433.33	17.687	
Potassium	3	0.0612	12	75.004	625.03	38.267	
Chloride	3	0.0612	200	405.01	202.50	12.398	
Fluoride	5	0.1025	1.5	1.09	72.66	7.415	
Nitrate	5	0.1020	10	66.4	664	67.755	
Bromide	4	0.0816	0.5	0.54	108	8.816	
TH	2	0.0408	500	520	104	4.245	
Total alkalinity	4	0.0816	100	732	732	59.755	
Calcium	3	0.0612	75	80	106.66	6.530	
	$\sum w_i$ =49	$\sum W_i =$ 1				$\sum SI_i =$ 303.91	

*Note: Except for pH, EC in µs/cm, and k=10^3, all parameters are stated in mg/L training conducted for women. motor winding and maintenance, consumer appliance repairs, and computer skills for adolescents.

Health and medical support (SDG – 3)

Mega health check-ups & consultation camps are regularly being organized for employees and the nearby villages. In the mega health camp, various multi-Specialty doctors from well-known Hospitals in Hyderabad have provided their services to the villagers in the areas of Ophthalmology-Eye Camps, Orthopedic and Heart Speciality. The free general health check-up, consultations & free medicines services are provided through this camp.

Rural development and village infrastructure (SDGs – 6 and 11)

Construction of village internal cement concrete/gravel roads, community hall, rural electrification assistance, provision of public bathrooms, drainage facilities, dust bins, and so forth. Providing drinking water to people via water tankers or create permanent water resources such as hand ump, bore wells, Reverse Osmosis (RO) plants, and pipelines.

Conclusion

The present work reports the level of environmental factors, in and around the Limestone mining area of Yerraguntla zone,YSR Kadapa, Andhra Pradesh. In this study area, it was found that, the soil was rich in elements like Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ranges from 74.5 to 272.75 mEq/L. The pH of the soil samples was determined as alkaline ranges from (7.6 to 9.4). Near the Limestone crushing area, electrical conductivity was observed to be high (4140 µs/cm), since, the soil content is of more soluble salts. The assessed WQI value was 303.91, that showed the groundwater in this location was not safe to drink. The AQI value found as 76 was in the satisfactory range, indicating minor breathing discomfort to dust-sensitive people and related health issues. Noise levels were determined as 76.64 dB in the mine, 58.16 dB at the cement industry, and 52.285 dB around mining areas (Chilamkuru, Kalamalla, Timmapuram and Niduzuvvi villages). These values were within the permissible limit of 90 dB, but it was revealed that long-term exposure of the people in these area may suffer from Noise -Induced Hearing Loss (NIHL). A well-crafted eco-

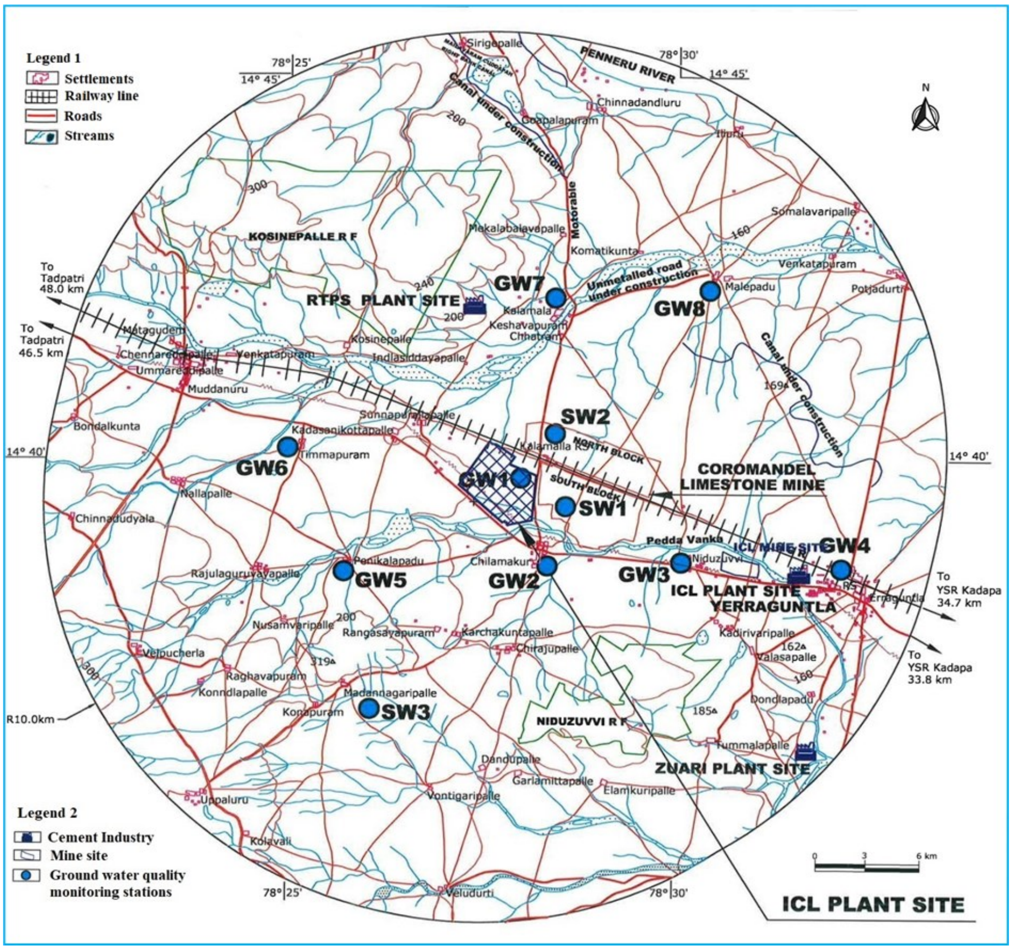


Fig.12. *Groundwater quality monitoring stations satellite view*

friendly mine management plan should aid in limiting the environmental effects of mining. The best practices promote sustainable limestone mining. In the future work, Environmental Impact Assessment (EIA) has to significantly improve the viewing, mobility, inquiry, and even map-making capabilities of the research area through the use of cost-efficient and high-precision spatial techniques such as Remote Sensing & Geographical Information Systems (RS&GIS), and Machine learning methods. However, gaining access to the most recent and reliable geospatial data and interpretations is one of the most significant challenge.

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Conflict of interest

The authors declare that they have no conflict of interest.

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