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ENVIRONMENTAL IMPACT ASSESSMENT OF WATER QUALITY ISSUES CAUSED BY THE GRANITE QUARRYING AND STONE PROCESSING INDUSTRY IN RAMANAGARA DISTRICT, KARNATAKA STATE, INDIA

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Abstract

The granite quarrying and stone processing businesses will be significantly impacted by the geology, soil, and water environment of the research region. Numerous factors affecting society, the environment, and people's health and quality of life are brought about by the granite industry. This investigation's foundation was created by the primary and secondary sources that were used. The persons who are most vulnerable to air, dust, water, and noise pollution—including vibrations from rock blasting—are those who live nearby and work in quarries. Evaluating potential environmental implications of water quality from various granite quarries and stone processing companies in the Ramanagara district was the aim of the study. For analysis, water samples were gathered from industrial regions, residential neighborhoods close to communities, and quarry sites. We have taken eight (08) groundwater samples and twelve (12) surface water samples from diverse locations in order to evaluate the water quality. Water samples from the surface and groundwater were collected using two-liter plastic containers. Samples from surface and groundwater were divided, and samples were placed in polyethylene carbons for chemical analysis. Water samples were acidified with one milliliter of HNO_3 in order to look for metals. In the research region, specific physical, chemical, and heavy metal elements have been analyzed to evaluate the quality of surface and groundwater. In order to compute the Water Quality Index (WQI), twenty four significant factors pertaining to the physicochemical characteristics of surface water and twenty significant factors for groundwater were taken into consideration (Parameters for water quality: Colour, Odour, Turbidity, pH, Electrical Conductivity, Total Dissolved Solids, Total Hardness as $CaCO_3$, Total Alkalinity as $CaCO_3$, Cl, SO_4, F, NO_3, NH_3, PO_4, Na, K, Ca, Mg, Fe, Total Suspended Solids, Dissolved Oxygen as O_2, Chemical Oxygen Demand as O_2, Bio-Chemical Oxygen Demand at 27°C for 3 days, Total Coliforms). The results demonstrated that the mean concentrations of suspended and physicochemical parameters are within the criteria set by the Karnataka State Pollution Control Board (KSPCB) and the World Health Organization (WHO). According to Indian Standards and Specifications for Drinking Water, IS 10500, 2012, and IS 2296, 1982, all surface water and groundwater characteristics are within permissible limits. Most of the heavy metal concentrations in the research area samples are well within the detection limits. Surface and groundwater quality baselines are established for the region. Furthermore, the results indicated that the degree of pollution caused by quarrying activities is correlated with the distance from the source. To lessen the detrimental effects of quarrying activities, compliance monitoring visits to quarry sites should be conducted on a monthly or quarterly basis. This research has demonstrated the necessity of providing quarry workers with training and information regarding the environmental effects of their activity. Owners of quarries, locals, and the government should all work together to routinely check the operations of the quarries to guarantee complete adherence to accepted norms. Academic researchers, educational institutions, government and business agencies, and society at large will find value in this research data.

Keywords: Quarrying, Water Pollution, Water Quality, Granite Industry.

1. INTRODUCTION

The process of extracting rich minerals from the earth's top crust is known as quarrying. Excessive granite quarrying caused by human need and want has led to serious environmental and water quality issues that the globe is currently dealing with (Ako et al., 2015). Many natural resources, such as the biosphere, noise, dust, air, water, and land, are harmed by the mining, quarrying, and stone-processing industries (Sreekala et al., 2023; Ukpong, 2012). Over the past four or five centuries, we have overused natural resources without considering the effects on the environment, water quality, and human health (Melodi, 2017). As result, we are currently dealing with serious environmental issues like natural hazards like flooding, extreme cold, rising temperatures, seasonal variation, heavy rain, rising sea levels, forest fires, landslides, etc. (Singh et al., 2010; Idris et al., 2014). Additional issues include building collapses or cracks nearby, soil erosion, sedimentation, loss of agricultural land, decreased agricultural productivity, formation of unproductive wastelands, changes in topography, loss of vegetation, accidents involving machinery and workers in the quarry, uneven socio-economic development in the quarry's vicinity, illegal stone extraction and transportation, socio-political conflicts, and serious health risks for the local community and society as a whole (Ming'ate et al., 2016; Mwangi, 2014).

The granite business needs to take environmental issues seriously if it is to develop and prosper sustainably. To improve people's socioeconomic status and standard of living, it is crucial to take the environment and overall development into account simultaneously, recognizing their mutual dependence (Oyinloye et al., 2015). The act of quarrying is the extraction of natural resources, which are essentially all forms of rock that are found above or below the surface, without endangering the ecology in the vicinity (Rathore, 2020; Roja, 2022). Granitic rocks, as well as other types of rocks like migmatite, anorthosite, gneiss, granite, granodiorite, monzonite, syenite, gabbro, dolerite, diorite, norite, porphyritic granite, marble, limestone, sandstone, slate, etc., are used in the stone processing and quarrying industries (Bhat et al., 1991; Swamy, 1998). The most popular technique for obtaining natural resources is open-pit, or open-cast, quarrying. According to Saha et al. (2011) and Peter et al. (2018) the most harmful impacts of human activity are those that permanently harm the environment, the natural world, people's socioeconomic status in society, and the purity of the water. According to Sayara (2016); Singh et al. (2010); Singhal, (2018); Salem, (2021), and others, some of these adverse

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environmental effects include topographical shifts, land degradation, air pollution, noise, altered water quality from drilling and blasting, ground vibration, soil erosion, health problems, biodiversity, dying native species, and socioeconomic repercussions. This is taking place because negligent mineral mining is posing serious environmental risks. Businesses that mine granite and process stone are under pressure from the abuse of natural resources brought on by human demand and necessity, which is worsening environmental degradation (Vandana et al., 2020; Emmanuel, 2018).

Granite quarrying has become environmentally hazardous due to overuse and the growing demand for both finished and unfinished granite commodities in many industries, especially the construction industry (Fugiel et al., 2017; Oyinloye et al., 2015). The formation of artificial ponds in open pits; small-scale isolated artificial relief changes; irregularly shaped depressions; soil erosion and sedimentation; instability of waste materials or quarry dump yards; potential destruction of fluvial terraces; depression of piezometric surface; altered groundwater infiltration and flow direction changes; potential formation of periodically flooded areas that eroded the landscape and soil; permanent destruction of agricultural areas; potential changes to farming practices; and changes to the pedological characteristics of soil were the main environmental effects of quarries (Sayara et al., 2016; Tiba 2017; Ukpong, 2012; Abhishek Pandey, 2018).

In general, water quality indices generate a numerical rating system for a body of water using data from many water quality parameters (Ashton et al., 2001). Therefore, efforts should be undertaken at each stage of quarrying activities to repair the degraded environment to finally allow the reuse of these sites and resources. The primary reason for the devastation of the surrounding landscapes in areas utilized for quarrying is the issues with handling waste rock material in dust and dump yards. Geographic information system (GIS) software tools and remote sensing (RS) are the most widely used and reliable modern technologies for monitoring, managing, and making decisions regarding natural resources and ecosystems (Balakrishnan et al., 2011; Chebud et al., 2012; Dinakar et al., 2008). This study aims to evaluate the environmental impact of the granite quarrying, sand mining, stone crushing, and stone processing enterprises operating in the research region. Additionally, it provides beneficial mitigating techniques to protect the environment going forward, particularly in water quality management. The main objectives of this research are to assess the possible environmental effects of granite quarrying in the Ramanagara district, with a focus on ambient water quality; look into the connection between this activity and health problems; and assess how this activity affects the socioeconomic status of individuals and the community as a whole.

2. STUDY AREA

On August 23, 2007, the former Bengaluru Rural District—which included the taluks of Ramanagara, Channapatna, Kanakapura, and Magadi—was divided into the Ramanagara district. It has a north-south travel range of 102.25 kilometers and an east-west travel range of 62.08 kilometers (Bhat et al., 1994; Swamy, 1998). Within the district's 3516 km^2 geographical area, there are 823 settlements. Approximately 17.21%

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of the district's total area, or 699.46 km^2, is covered by forest. The Indian city of Ramanagara is located in the state of Karnataka. The town of Ramanagara, which is situated around fifty miles southwest of Bangalore, serves as the district capital.

The Ramanagara district is located between latitudes 12.720N and 77.270E. The most notable low and high-elevation locations in the district, at 289 and 1196 meters above mean sea level, respectively, are shown by contour lines. It is, on average, 742.50 meters above sea level, as seen in Figure 1. Bangalore Urban District borders the district to the northeast, Bangalore Rural and Tumakuru districts to the north, and Mandya District to the west. The state of Tamil Nadu is located to the south and southeast of the districts of Chamarajanagar.

During the research period, temperatures at the quarrying site recorded highs of 33°C and lows of 19°C. The average temperature in the quarry zone was discovered to be 26°C. The average relative humidity varied from 34% to 63% throughout the trial. The Ramanagara District experiences an average of 931.58 mm of rain every year. The bulk of winds are north-easterly during the winter monsoon and south-westerly during the summer monsoon. The quarry zones had monthly wind speeds ranging from 4.9 m/s to 5.6 m/s throughout the three-month experiment. Daily records for temperature, relative humidity, air pressure, solar radiation, precipitation, wind speed, and wind direction are all included in the AERMET data. To prepare meteorological data for use as an input in the AERMOD model, AERMET reformats it (Neshuku, 2012). The industries that extract and process stones won't change the environment. The study area's location map is displayed in Figure 1.

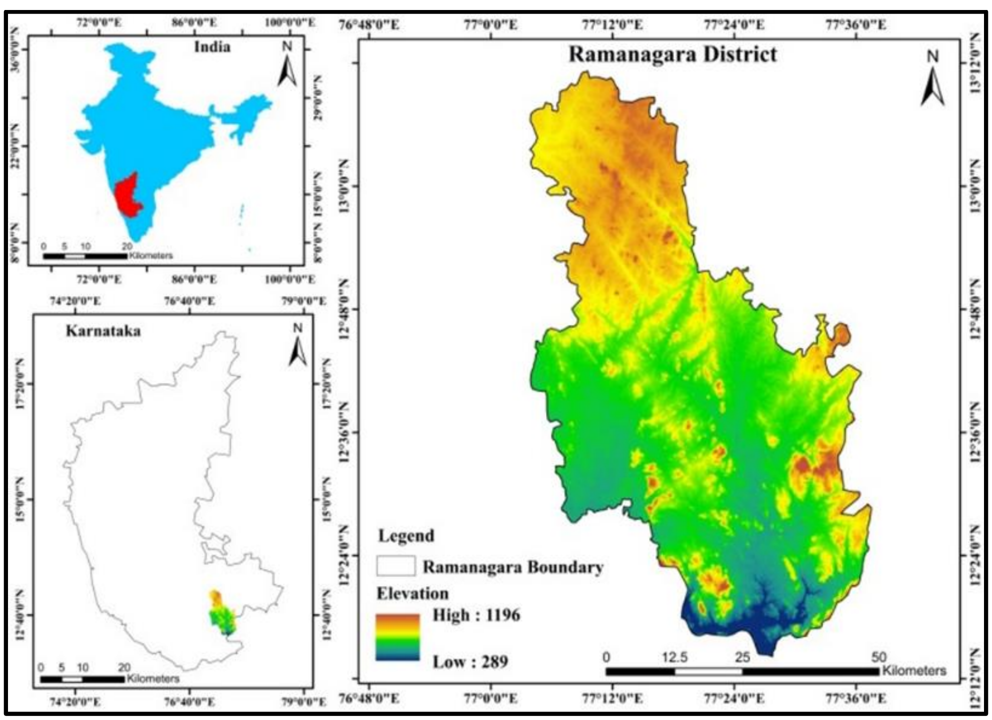

Fig 1: Study area with elevation information

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3. MATERIALS

Toposheet numbers such as D43R4_57G4, D43R8_57G8, D43X1_57H1, D43X2_57H2, D43X3_57H3, D43X5_57H5, D43X6_57H6, D43X7_57H7, D43X8_57H8, D43X9_57H9, D43X10_57H10, and D43X11_57H11 are provided by the Indian Government's Survey of India (SOI). These toposheet numbers were used in this study to extract the morphological areas. The DEM Cartosat-1 and LISS satellite imagery are used by the ISRO Bhuvan website to give elevation and land use/cover data. Fieldwork, a few government technical papers, the Karnataka State Pollution Control Board and Groundwater Directorate, the Karnataka Groundwater Authority, and the Indian Open Government Data (OGD) portal were the sources of the meteorological and ambient water quality data sets. The Department of Mines and Geology (DMG) and the Ramanagara district mineral survey report were two of the government agencies from which the reports and statistics regarding quarrying were gathered. Table 1 displays these data sets.

Table 1: Data sets used for the research work

Data name	Resolution	Website
DEM	10m	Indian Geo platform(Bhuvan)
LISS 3	30m	Indian Geo platform(Bhuvan)
Landsat 8	30m	USGS
Toposheets	1:50000	SOI(survey of India)
Rainfall and temperature	0.5*0.5 km	IMD(India meteorological department)
Quarry and rocks	-	DMG(department of Mines and Geology
Water quality	-	Open governmental data (OGD) platform, India, WHO standard report, Indian standard reports
Water quality	-	Karnataka State Pollution Control Board
Water quality and resources	-	Groundwater Directorate and Karnataka Groundwater Authority

4. METHODOLOGY

4.1 Collection of data with different sources

The foundation of this investigation was primary and secondary sources. Field research, mapping, questionnaires, interviews, market and field surveys, and laboratory tests are examples of primary sources. Books, journals, reports—both published and unpublished—and official government documents are examples of secondary sources. The effects of pollution on the local flora and wildlife, crops, ambient water and air quality, and surrounding environment were evaluated using field surveys and general observations. This study only examines the Ramanagara district of the state of Karnataka, India, which is renowned for having a large quantity of forest cover, biodiversity, water resources, and granite deposits. The sample households were established by creating a

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sample of the dwellings at the randomly chosen quarry sites using a methodical and unbiased selection process. Just a hundred or so nearby towns or homes that are impacted by quarrying operations, both directly and indirectly, made up the sample. Data from the families was gathered via standardized questionnaires and field research.

A research study report was created utilizing baseline data gathered at numerous places throughout one season (January 2024–March 2024) for the investigation in the Ramanagara district areas. Table 2 displays the information. The potential harm brought about by the stone-processing and quarrying sectors was evaluated using these numbers. They provide advice on the appropriate course of action for the industry and the quarry site, as well as government agencies, management tools, and mitigation techniques. The results of the analysis report and study summary were carefully taken into account for this research endeavor. **Table 2** lists the data collection sources.

Table 2: Parameter taken from different sources

Sl. No.	Attribute	Parameter	Source of Data
1	Climatology and Meteorology	Wind speed, Wind direction, Dry bulb temperature, Wet bulb temperature, Relative humidity, Rainfall, Solar radiation, Cloud cover and Environmental Lapse.	Field research, collecting data from a variety of locations, including industrial, residential, and quarry sites.
2	Geology, Rock and Soil	Geological history	Field research, primary and secondary sources, satellite photos, topographical maps, etc.
4	Surface Water Quality and Groundwater quality	Colour, Odour, Turbidity, pH at 25°C, Electrical Conductivity, Total Dissolved Solids, Total Hardness and Alkalinity $CaCO_3$, Cl, SO_4, F, NO_3, NH_3, PO_4, Na, K, Ca, Mg, Fe, Mn, Phenol, Cu, Hg, Cd, Se, As, CN, Pb, Zn, Cr, Ni, Al, Total Suspended Solids, Anionic Surfactants as MBAS, Mineral oil, PCB, PAH, O_2, Chemical Oxygen Demand, Bio-Chemical Oxygen Demand at 27°C for 3 days, Oil and Grease, Total Coliforms. E. Coli.	Primary data, mapping, field research Monitored Data (20 locations)

4.2 Choosing sites for sampling within the research area.

The study area topography, climate data, surface and groundwater resources, ponds and lakes, rivers, reservoirs, and canals, the concentration of quarry sites, residential and industrial areas, human settlements, health status, resource availability, accessibility of the monitoring site, representativeness of the region for establishing baseline status, and representativeness concerning likely impact areas were all taken into consideration when choosing the monitoring sites for water quality. **Table 3** provides a list of the research area's sample collection locations and procedures for a range of environmental settings.

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Table 3: Location and sample Collection from different environmental settings

Location Code	Sample code	Locations	Latitude	Longitude	Distance (km) from Ramanagara town	Azimuth Directions	Environmental setting
QL 1	GW 1	Doddamudawadi quarry site	12°37'38.08" N	77°22'47.27" E	15.74	SE	Commercial
QL 2	GW 2	Yadamaranahalli quarry site	12°24'54.09"N	77°22'56.53"E	35.54	S	Commercial
QL 3	GW 3	Hanakadaburu, kodihalli hobali quarry site	12°24'17.24"N	77°32'50.28"E	45.4	SE	Commercial
QL 4	GW 4	Hanakadaburu, kodihalli hobali quarry site	12°23'49.59"N	77°32'39.51"E	46.58	SE	Commercial
QL 5	GW 5	Achalu quarry site	12°27'55.43"N	77°21'18.06"E	30.37	S	Commercial
QLV 6	GW 6	Hanakadaburu village	12°24'1.12"N	77°32'51.18"E	46.5	SE	Residential
QLV 7	GW 7	Kodahalli village	12°25'9.41"N	77°18'34.70"E	33.66	SW	Residential
QLV 8	GW 8	Achalu village	12°28'30.11"N	77°21'47.08" E	28.55	S	Residential
QLV 9	GW 9	Harohalli village	12°40'53.59"N	77°28'26.33"E	21.3	SE	Residential
QLV 10	GW 10	Bidadi village	12°47'56.48"N	77°23'9.77"E	15.67	NE	Residential
QLIN 11	GW 11	Harohalli Industrial area	12°41'0.05"N	77°26'43.60"E	18.27	SE	Industrial
QLIN 12	GW 12	Bidadi industrial area	12°47'54.84"N	77°23'0.33"E	14.51	NE	Industrial
WB 1	SW 13	Yadamaranahalli lake	12°25'7.19"N	77°22'27.20"E	34.99	S	Water body
WB 2	SW 14	Arishina lake	12°24'19.11"N	77°23'4.22"E	36.89	S	Water body
WB 3	SW 15	Harohalli Kere/lake	12°40'36.76"N	77°28'10.48"E	21.64	SE	Water body
WR 4	SW 16	Arkavathi River	12°21'4.19"N	77°26'53.59"E	43.44	SE	River
WR 5	SW 17	Vrishabhavathi River	12°47'24.88"N	77°26'12.60"E	18.72	E	River
WRR 6	SW 18	Suvarnamukhi Reservoir	12°42'20.90"N	77°27'33.82"E	19.87	SE	Reservoir
WRR 7	SW 19	Bairamangala Reservoir	12°45'37.45"N	77°25'24.79"E	16.26	E	Reservoir
WRC 8	SW 20	Bairamangala Lake	12°45'34.42"N	77°24'26.82"E	14.22	E	Lake

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4.3 Method of water sample collection

By selecting representative surface and groundwater sampling sites at random within a radial distance of 10 to 20 km from the quarry site, a baseline status of the water environment has been developed. The CPCB's recommendations for monitoring the water quality by conducting a thorough survey of the quarrying regions and the adjacent residential and industrial areas led to this conclusion. The test protocols used to look at the water quality parameters are shown in Tables 4.

Table 4: Methods of analyzing data for ambient surface water and groundwater quality parameter analysis (NAAQS)

Methods of analyzing data for ambient surface water and groundwater quality parameter analysis (NAAQS)						
Surface water quality parameters					Groundwater quality parameters	
Sl. No	Parameters	Unit	Test method	Tolerance Limits For Inland Surface Waters, (IS: 2296-1982) CLASS – C	Test Method	Tolerance Limits for groundwater as per IS 10500 : 2012
1	Colour	Hazen	IS 3025 Part 4	300	IS 3025:1983 Part 4	5
2	Odour	-	IS 3025 Part 8	Not Specified	IS 3025:1984 Part 5	Agreeable
3	Turbidity	NTU	IS: 3025 Part 10-1984 (Reaff: 2017)	1	IS : 3025 Part 10-1984 (Reaff:2017)	1
4	pH at 25°C	-	IS: 3025 Part 11- 1983 (Reaff:2017)	6.5 – 8.5	IS : 3025 Part 11- 1983 (Reaff:2017)	6.5-8.5
5	Electrical Conductivity,	µS/cm	IS: 3025 Part 10-1984 (Reaff: 2012)	Not Specified	IS : 3025 Part 14- 1984 (Reaff: 2019)	Not Specified
6	Total Dissolved Solids	mg/l	IS: 3025 Part 16-1984 (Reaff: 2017)	1500	IS : 3025 Part 16-1984 (Reaff:2017)	500
7	Total Hardness as CaCO3	mg/l	IS: 3025 Part 21-2009 (Reaff: 2019)	Not Specified	IS : 3025 Part 21-2009 (Reaff:2019)	200
8	Total Alkalinity as CaCO3	mg/l	IS: 3025 Part 23- 1986 (Reaff:2019)	Not Specified	IS : 3025 Part 23-1986 (Reaff:2019)	200

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9	Chloride as Cl	mg/l	IS: 3025 Part 32-1988 (Reaff: 2019)	600	IS : 3025 Part 32-1988 (Reaff: 2019)	250
10	Sulphate as SO4	mg/l	APHA 23rd EDN-4500- SO42- E	400	APHA 23rd EDN -4500- SO42- E	200
11	Fluoride as F	mg/l	APHA23rd EDN-4500-F, B&D	1.5	APHA 23rd EDN -4500- F B&D	1
12	Nitrate as NO3	mg/l	APHA23rd EDN-4500-NO3- B	50	APHA 23rd EDN -4500- NO3- B	45
13	Ammonia as NH3	mg/l	APHA 23rd EDN -4500- NH3 B&C	Not Specified	-	
14	Phosphate as PO4	mg/l	IS: 3025 Part 31-1988 (Reaff:2019)	Not specified	-	
15	Sodium as Na	mg/l	IS: 3025 Part 45-1993(Reaff:2019)	Not Specified	IS : 3025 Part 45-1993 (Reaff:2019)	Not Specified
16	Potassium as K	mg/l	IS: 3025 Part 45-1993 (Reaff:2019)	Not Specified	IS : 3025 Part 45-1993 (Reaff:2019)	Not Specified
17	Calcium as Ca	mg/l	IS: 3025 Part 40-1991 (Reaff:2019)	Not Specified	IS : 3025 Part 40-1991(Reaff:2019)	75
18	Magnesium as Mg	mg/l	APHA 23rd EDN 3500 Mg B	Not Specified	APHA 23rd EDN Mg B	30
19	Iron as Fe	mg/l	APHA 23rd EDN -3111 B	Not Specified	APHA 23rd EDN -3111 B	1
20	Total Suspended Solids	mg/l	IS: 3025 Part 17-1984 (Reaff: 2019)	Not Specified	IS : 3025 Part 17-1984 (Reaff:2017)	Not Specified
21	Dissolved Oxygen as O_2	mg/l	IS:3025:Part-38:1989 (Reaff:2019)	4	-	
22	Chemical Oxygen Demand as O_2	mg/l	IS:3025:Part-58:2006 (Reaff:2019)	Not Specified	-	
23	Bio-Chemical Oxygen Demand at 27°C for 3 days	mg/l	IS:3025:Part-44:1993 (Reaff:2019)	3	-	
24	Total Coliforms	MPN/100ml	IS: 1622 -1981(Reaff-2014)	Not Specified	IS 1622 (1981) (Reaff – 2014)	Absent/ 100ml

Surface and groundwater samples were separated and put in polyethylene carbons for chemical analysis. One milliliter of HNO_3 was used to acidify water samples to detect the presence of metals. Specific physical, chemical, and heavy metal constituents have been examined to assess the quality of the groundwater and surface water in the research region.

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4.4 Techniques used in the analysis of water samples:

Groundwater and surface water are the primary supplies for drinking water and domestic requirements in nearly all of the communities surrounding the research region. The quality of the surface and groundwater that is obtained is affected by a variety of factors, such as pathogenic microorganisms, organic materials, soil, and air pollution, the dumping of waste from residences and commercial buildings, and the use of pesticides and fertilizers in agriculture.

Several villages around the granite quarry and crusher site had a total of twelve (12) groundwater and eight (08) surface water monitoring points (physical, chemical, and biological parameters) selected for assessment in light of the subsurface water consumption of the villages and settlements in the study region.

The results for surface and groundwater are compared to the drinking water legal and acceptable requirements as outlined in IS 10500, 2012, and IS 2296, 1982. The sample parameters, analytical techniques, and standards (NAAQS) used to monitor the quality of ambient surface water and groundwater is listed in **Tables 4**.

Table 5 demonstrates how the frequency and monitoring approaches were applied during the sample and analysis processes. For this research endeavor, the analytical report and the synopsis of the water quality study's findings were carefully taken into account.

Table 5: The frequency and monitoring Techniques

Attributes	Sampling		Measurement Method	Remarks
	Network	Frequency		
Meteorology				
Wind speed, Wind direction, Dry bulb temperature, Wet bulb temperature, Relative humidity, Rainfall, Solar radiation, Cloud cover and Environmental Laps	Selected locations	Continuous for 3 Months	Weather monitors with the database	As per Meteorological department standard. Field survey, Primary data
Water				
Parameters for water quality: Colour, Odour, Temperature, pH, Conductivity, Turbidity, TDS, Total Hardness, Total Alkalinity, Cl, SO_4, F,NO_3, NH_3, Na, K, Ca, Mg, Fe, Phenolic, compounds, Mn, Cu, Hg, Cd, As, CN, Pb, Zn, Cr, Ni, Se, Al, As, Pb, Zn, COD, BOD, DO, Total Coliform, Faecal Coliform etc.	Set of grab groundwater and surface water samples. Selected locations	Once in season	Samples for water quality collected and analyzed as per IS: 2488 (Part 1-5) methods for sampling and testing of Industrial Effluents Standard. Methods for the examination of water by American Public Health Association.	IS:10500:2012 (GW); IS: (SW) IS: 2296, 1982, Field survey, Primary data

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5. RESULTS AND DISCUSSION

5.1 The granite quarry's geological context within the research area: Geology of the district of Ramanagara:

According to Bhat et al., (1994); Syed Abrar et al. (2000 & 2005) and Swamy (1998), the rocks of the district are derived from the following groups: The Sargur group, the Charnockite group, the Peninsular Gneissic Complex (PGC), the Closepet granite, and the basic and more recent intrusives. Charnockite is the representative of the Charnockite group. The Sargur group includes lenses found in gneisses as well as microscopic bands of banded magnetite seen in migmatite, amphibolite, and quartzite. The PGC is located east and west of the Closepet granite and is composed of granites, gneisses, and migmatite (Simha et al., 2015; Venkatesha et al., 2015). Local sources have reported that PGC is being converted into charcoal in the district. The intrusive bodies containing the Closepet granite are located within the gneisses and have a Near-N-S trend. They are 50 km long and 15-20 km wide.

The granite of Closepet has a variety of compositions, some of which include enclaves of gneisses, quartzite, amphibolites, and migmatite. The most frequent intrusives are gabbro, pyroxenite, gabbro, and infrequently norite. According to Paranthaman et al. (1995), dolerite is the most prevalent of the fundamental dikes. The district's NNW-SSE lineaments are divided into three primary sections. The length of these lineaments varies from 45 to 70 kilometers. The interpretation of this data points to the crossing of the Closepet granites by a deep-seated fault going NNW-SSE.

In the areas covered by quarry leases, the main land uses are plan land, hills, vegetation, different types of rock formations, and soil cover or overburden. The location of the granite quarry, the type and amount of deposit formation, the quality of the materials, their lack of natural imperfections, etc. all affect the geological setting of the granite quarry region. The majority of the leased areas have thin patches of dirt covering them that are between 0.5 and 10 meter thick. Pebbles are particularly abundant in low-lying, loose soils. There are deposits of rock that are both above and below the surface. Most of the hill's eastern, western, and north-western portions are covered in brownish-red soil capping at the base of the quarry lease area.

The dirt in the middle of the ridge is only found in the crevices between the stones, and its average thickness is less than 0.5 meters. The research region's established stratigraphic succession is provided below, based on observations and fieldwork. **Table 6** shows the rock types and lithostratigraphy of the Ramanagara District. In Kanakapura, Ramanagara, Channapatna, and Magadi Taluk, sand mining as well as defined and unspecified minor mineral licenses were carried out alongside taluk-specific quarrying activities for dimension stone, construction stone, brick earth, crushers, and stone cutting facilities in this district.

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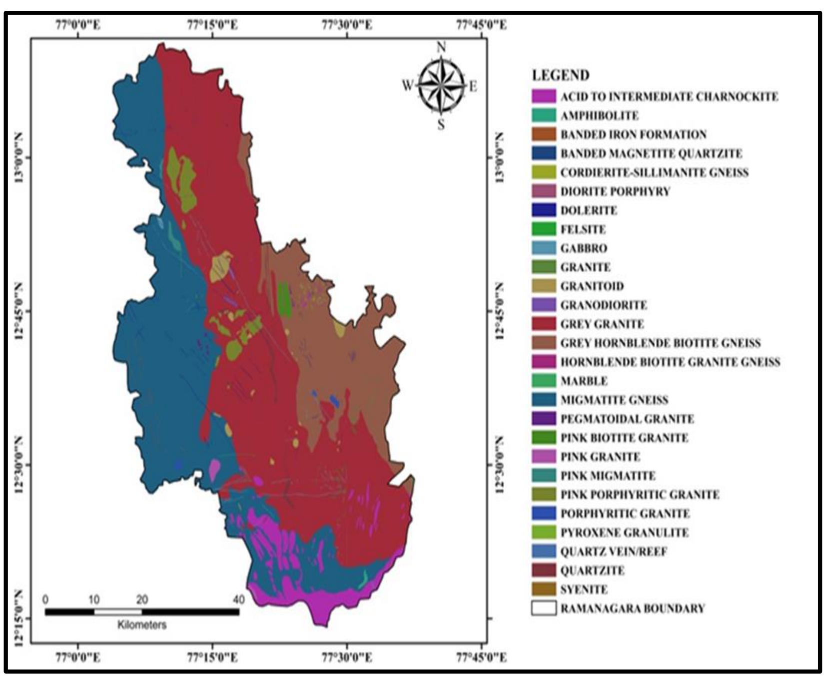
Table 6: Lithostratigraphy and rock types available in Ramanagara District.

- Soil Clover –	
I. **Younger intrusive** (More recent invasion)	Extremely potassic rocks; dolerite/gabber/diorite/norite dykes; felsite/felsite porphyry dykes; coarse-grained pink/grey porphyritic granite.
II. **Closepet granite (2400–2100 Ma)**	Pink/grey porphyritic granite with coarse grain; pink granites (less mafic); grey granites; pink hornblende granite; pink equigranular/porphyrite migmatites.
III. **Peninsular Gneissic Complex (3000 Ma)**	Grey migmatites, biotite gneiss, leucogneiss and homophonous gneiss, charnockite and migmatite.
IV. **Sargur group (> 3000 Ma)**	Garnet-sillimanite gneiss, quartzite (fuchsite and BMQ), meta-ultramafites, amphibolites (both massive and schistose), and banded magnetite quartzite.
----Not visible is the base. ----	

In comparison to other districts, it also has more crushing plants per square mile, and forty to fifty years ago; it was home to multiple granite quarries and crushing companies. Noise, dust, water, and other pollutants from quarrying and stone-cutting activities pollute the environment. Because of the dust emissions from the crushing and quarrying processes, the associated radioactivity varies depending on the surrounding environment. The study area is located in Seismic Zone IV, also referred to as the high damage risk zone. Seismic Zone III is defined as having a very high potential for earthquake shocks of 5 or 6. The lithology and size of the Ramanagara district are shown in Figure 2. The two primary lithologies in this region are migmatite gneiss and gray granite. The area is between 1552 and 1080 km^2. The percentage of rocks covered in the Ramanagara district is shown in Table 7.



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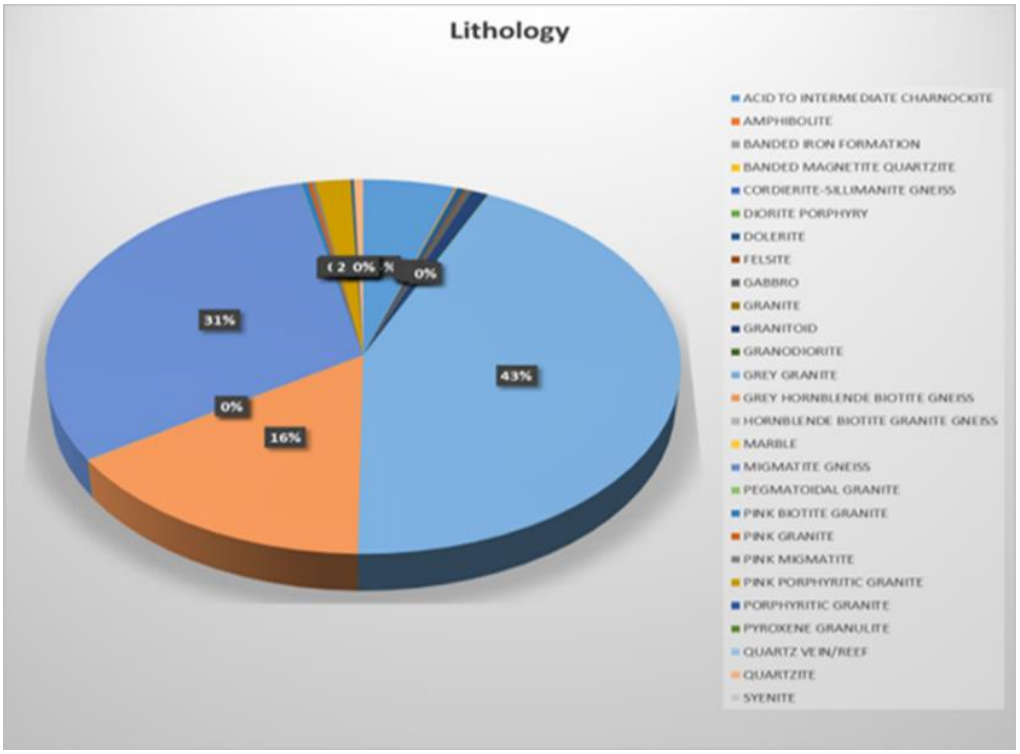

Fig 2: Lithology and its percentage of rocks covered in Ramanagara district

Table 7: Total area is covered by rocks in Ramanagara district

Sl. No	Lithologic Units	Area in sq. Km	Sl. No	Lithologic Units	Area in sq. Km
1	Acid to intermediate charnockite	173.60	15	Hornblende biotite granite gneiss	0.69
2	Amphibolite	3.12	16	Marble	0.59
3	Banded iron formation	4.24	17	Migmatite gneiss	1080.64
4	Banded magnetite quartzite	1.20	18	Pegmatoidal granite	3.37
5	Cordierite-sillimanite gneiss	0.30	19	Pink biotite granite	12.03
6	Diorite porphyry	0.96	20	Pink granite	8.07
7	Dolerite	12.40	21	Pink migmatite	6.92
8	Felsite	3.26	22	Pink porphyritic granite	66.46
9	Gabbro	12.82	23	Porphyritic granite	4.66
10	Granite	0.54	24	Pyroxene granulite	2.00
11	Granitoid	29.36	25	Quartz vein/reef	0.23
12	Granodiorite	3.23	26	Quartzite	16.19
13	Grey granite	1522.90	27	Syenite	0.57
14	Grey hornblende biotite gneiss	545.83			
Total areas in Sq. Km 3516.21					

5.2 The type's soil and its percentage of area covered in Ramanagara district:

While dirt is necessary for air and dust pollution, it is typically not used in the quarrying process or other related activities. Red, sandy soil covers slightly over 60% of the

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Ramanagara district (Hema et al., 2012). The remaining soil is reddish-brown and loamy. Because of the combined influences of parent material, climate, biosphere, topography, relief, stage, age, maturity, and time of rock weathering conversion, rainfall, solar radiation, and management (enhancement and degradation/erosion), geology and soil are strongly associated in pedogenic systems. The taluks of Channapatna, Kanakapura, Magadi, and Ramanagara are the primary areas with red sandy soil because of their diverse topographies (Hema et al., 2013). All the types of soil are listed in **Table 8** and **Figure 3.**

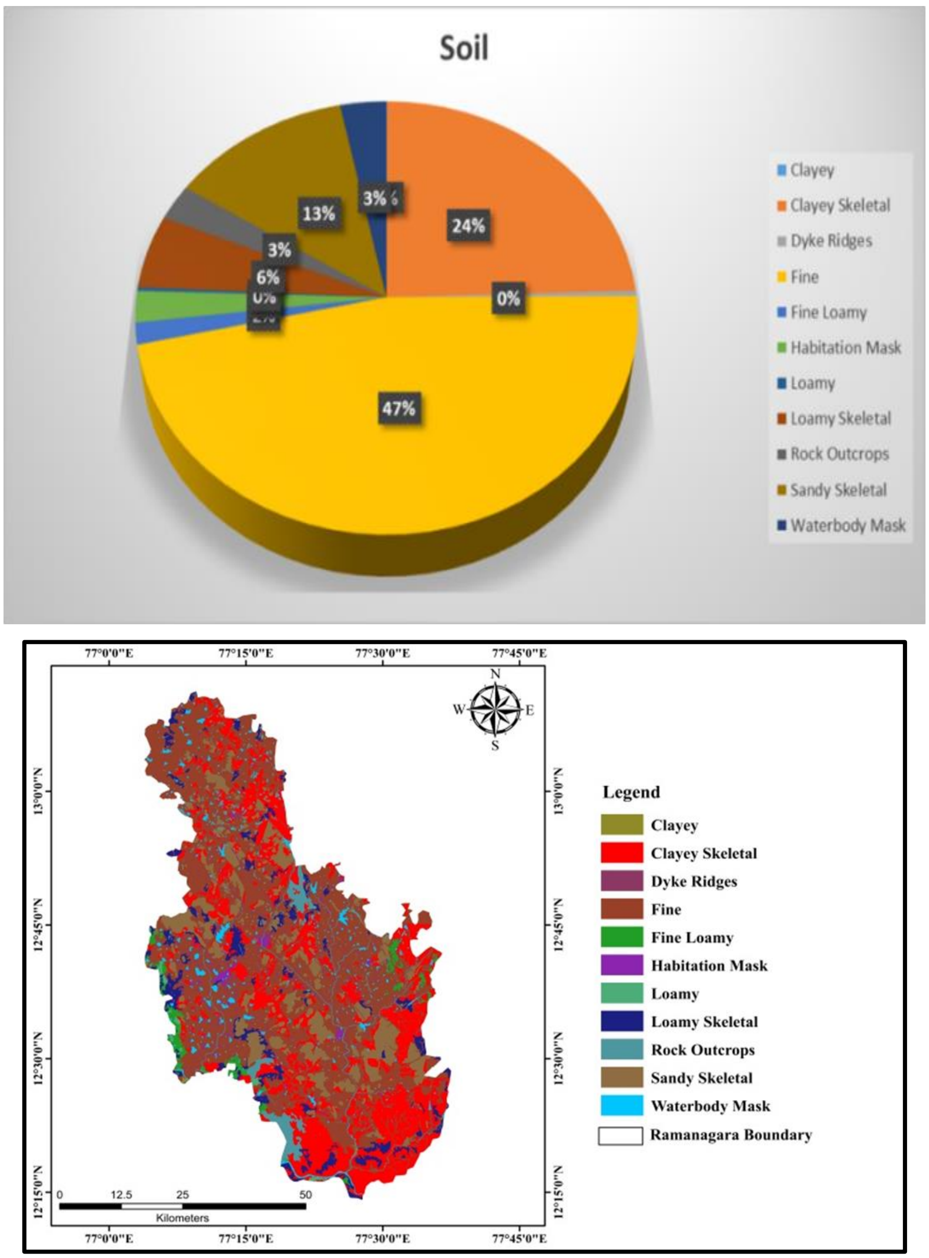

Fig 3: Conditions of the soil and its percentage in the study area:

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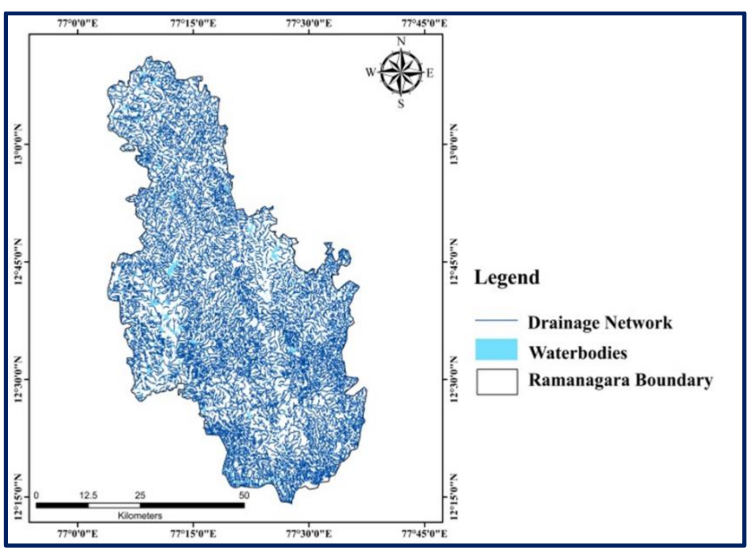
Table 8: Total area is covered by different types of soil in Ramanagara district

Soil Texture	Area in Sq. Km
Clayey	2.38
Clayey Skeletal	859.70
Dyke Ridges	17.09
Fine	1634.47
Fine Loamy	54.79
Habitation Mask	81.91
Loamy	12.23
Loamy Skeletal	192.06
Rock Outcrops	98.34
Sandy Skeletal	445.70
Water body Mask	117.54
Total Area	**3516.21**

5.3 A brief account of water bodies, surface, and groundwater potential in Ramanagara district:

At deeper depths, groundwater is found in semi-confined to restricted circumstances in fractured formations. Groundwater is found in the study area in weathered and jointed zones of gneisses, granites, charnockite, Closepet granite, and alluvium along river courses in unconfined or water table conditions. The majority of the district is made up of weathering that is between five and ten meters thick; the remaining portion is thicker than ten meters. The unconfined aquifer system is managed by shallow bore wells and excavated wells. In this zone, a depth of 25 mbgl is achieved. The aquifer's storage capacity dictates the yields in each location (Ganesha et al., 2017). The Kanva Reservoir Project and the Byramangala Reservoir Project are the two medium-irrigation projects. There are three other irrigation projects in addition to these two medium-sized ones. They are the Manchanabele Reservoir Project and the Iggalur Anecut Project. Situated on the Vrishabhavathi River, a tributary of the Arkavathi River, the Byramangala Reservoir Project spans a command area of 1949 hectares in Bidadi Hobli, Ramanagara taluk.



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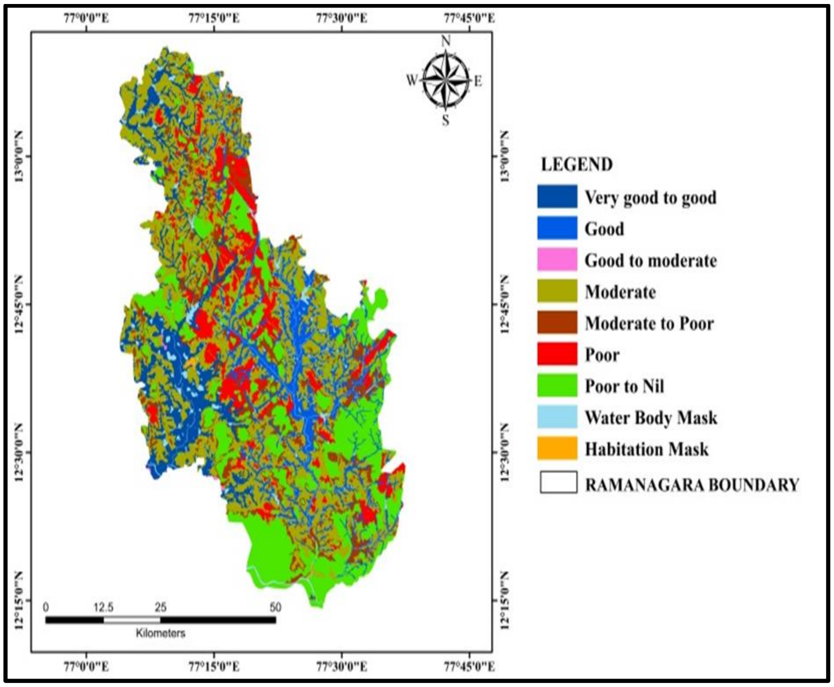

Fig 4: Maps indicate the drainage, water body and groundwater prospect in Ramanagara district

The Arkavathi Reservoir Project, which is presently under development, has planned command areas of 4380, 3846, and 4957 hectares, in that order (Hema et al., 2012; Venkatesha et al., 2015). The Kanva Reservoir Project, which is located in Channapatna Taluk on the Kanva River, covers a command area of 2076 hectares. Thus, the current medium-irrigation projects have produced 4025 hectares of irrigation potential. **Figure 4** shows the groundwater prospects, drainage system, and water body in the Ramanagara district. The whole area of Ramanagara district's groundwater potential is shown in **Table 9.** The percentage of the land covered by the groundwater potential zone is shown in **Figure 4 and 5.**

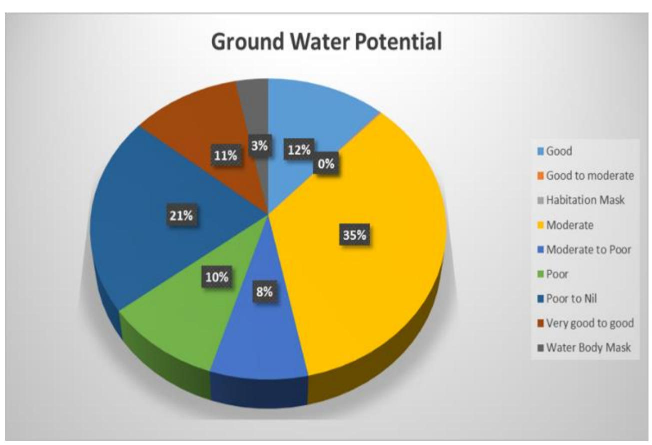

Fig 5: Indicated the percentage of area covered the groundwater potential zones...

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Table 9: Total area is covered by different of groundwater prospect in Ramanagara district

Groundwater prospect	Area in Sq. km
Good	418.78
Good to moderate	3.75
Habitation Mask	4.82
Moderate	1215.88
Moderate to Poor	286.30
Poor	340.31
Poor to Nil	747.79
Very good to good	384.04
Water Body Mask	114.54
Total Area in Sq. km	**3516.21**

5.4 The Ramanagara district's granite quarrying operation techniques:

It is commonly known that surface water and groundwater regimes are impacted by granite quarrying and stone processing activities. The geography and drainage system in the region can have a big influence on how bad the pollution is. The primary sources of liquid effluent in opencast mining include de-watering of quarry water, leachate runoff from waste dumps, and spilled water from dust extraction and suppression systems. The primary factors influencing the composition of the quarry water are the mineralization process and the characteristics of the host rock (Hema et al. 2013, Ganesha et al. 2017).

In the Ramanagara district region, opencast extraction and processing methods are used for the majority of stone quarrying, stone cutting, and stone processing operations. During open-cast quarrying, substantial overburdens like organic plant cover and topsoil must be removed to reach the mineral reserves. Granite is extracted via open-cast quarrying for decorative or dimension stone. This entails several procedures, such as clearing the area, moving, cutting, and splitting the rough blocks; dressing the rough blocks; bench formation; excavation; primary and secondary drilling, blasting, and splitting; loading waste or well-dressed materials; transportation; processing raw materials; quality control; shifting; managing stockyards; and recycling waste materials as brick materials (Rajan Babu et al., 2000, 2002, & 2003; Gbeve, 2013; Eshiwani, 2014). Stone quarrying, sand mining, and stone crusher construction are subject to additional operational limitations (Akanwa et al. 2016). The negative impact these behaviours have on the ecology has been demonstrated.

Quarrying operations are divided into several stages, each of which affects the environment. Prospecting and deposit exploration, the construction and preparation of quarries, the use of materials from the quarries, and the processing of the minerals gathered at the various installations to produce goods that could be sold are typical tasks associated with these phases (Chandrashekar et al., 1985 & 1992; Jayaram et al., 1996). The following Ramanagara district areas are leased by the government for quarrying as of 2022–2023, **Table 10**, even though open-cast quarrying activities carry significantly more environmental dangers.

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Table 10: The following are examples of quarrying activities in the Ramanagara district areas leased by the government as on 2022 - 2023

Sl. No	Taluk	Building Stone	Ornamental or dimension stone	Brick Earth	Crusher Units	M-Sand Units
1	Ramanagara	38	02	-	29	08
2	Kanakapura	25	52	-	03	02
3	Magadi	19	04	02	10	02
4	Channapatna	-	02	-	-	-
	Total	82	60	02	42	12

Quarry rock ranks third and fourth globally in terms of both volume and value of non-fuel mineral commodities. But the quarry's operations damage the surrounding area and those who live or work thereby degrading the state of the land and increasing noise, air, and water pollution (Gupta 2003; Luis M. O. Sousa, 2007). The results demonstrate that the dust created during the process is carried by the atmosphere, ends up in the water bodies by contaminating them, and travels great distances to reach people in the vicinity of the quarrying and crusher sites (Afeni T. Busuyi, 2008; Ajibade et al., 2022). Depending on the quarry's capacity, the following equipment (minimum) is employed each shift to assist with the semi-mechanized quarry operation: The equipment required to run a quarry varies depending on production capacity, as **Table 11** illustrates.

Table 11: The list of machinery required for quarry operation depends on the capacity of production

Sl. No.	Type	No's.	Size/ capacity	Make	Motive Power
01	Compressor	02	440 cfm	Atlas Copco	Diesel/Electricity/DG
02	Jack Hammer	10	33mm dia.	Atlas Copco	-
03	Hydraulic Rock Breaker/Excavator	02	1.2 cu.m	SANY – SY210C-9	Diesel
04	Tipper	02	20 tons	TATA	Diesel
05	Water tanker	01	5000 liter	Mahindra	Diesel
06	Tractor	01	04 tons	Mahindra	Diesel
07	JCB	01		JCB	Diesel
08	Diamond Wire saw machine	02	40 and 60 hp.	-	Electricity
09	Quarry core drilling machine		-	-	Diesel/Electricity/DG
10	Diesel Generator	01	02	Cummins 320 KVA and 26 KVA	Diesel/Electricity
11	Accessories	-	All size drilling rods and other machine spare parts	-	-

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5.5 Water pollution impacts the environment:

The granite quarrying and stone processing industries have an impact on surface and subsurface environmental components that determine the quality of surface and groundwater. A decrease in the overall amount and quality of water, along with a drop in the water table, are the primary consequences of quarrying operations (C1 Peter et al., 2018). They can be filled with pumped-out quarry water to make room for the creation of stored water bodies. This provides an excellent recharge facility and ensures that the appropriate amount of water is supplied by the National Water Policy. When it is possible to halt some bodies of water, grouting can be employed. Sedimentation can be tracked by stabilizing dumps and utilizing additional engineering solutions (Venkatesha et al., 2015).

The following are the main reasons why granite quarrying, stone processing, and stone cutting processes contaminate water: a decrease in groundwater accessibility; a limited effect on water level due to poor aquifer conditions; a decline in the quality of the surface or groundwater in the receiving body; alterations to the hydraulic system; contamination of watercourses from fuel and material storage area spills; runoff from vehicles and access roads carrying oil and suspended particles. Domestic wastewater from the quarries; wastewater from cooling machines; and the quarries' discharge water. The topsoil is compacted by heavy equipment and automobiles, which may alter how surface water drains. According to several studies (Bud et al., 2007), the amount and kind of water entering the underground regime have a significant impact on the quality of subsurface water.

To determine the area's baseline water quality, samples of the water have been gathered. The physical and chemical properties of the water were examined using the techniques outlined in IS and "Standard Procedures for the Examination of Water and Wastewater (American Public Health Association)". After grab samples were collected, the physical, chemical, and biological properties of the water were examined. The area's water quality is generally well within statutory limits, according to research on the water's current quality and results that are presented separately.

There are no permanent water features or courses in the permit area. Situated higher on a hillside is the quarry. In the vicinity of the quarry, the groundwater table is 20 meters below the surface. Because charnockite is an inert material, it does not affect groundwater. Groundwater is the primary source of water for domestic and drinking purposes in nearly all of the communities surrounding the research region.

The quality of the obtained groundwater may be affected by several factors, including organic materials, pathogenic microorganisms, water and air pollution, waste disposal (both commercial and personal), pathogenic microorganisms, and the use of pesticides and fertilizers in agriculture. The businesses that mine granite and process stone won't have a major effect on groundwater quality. The amount of rainwater that overflows from the pits and landfills will be controlled by the garland-lined streams. Along the toe of the dump slopes, a retaining wall will be constructed to regulate the amount of silt that enters

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the lake. Only clean water will be allowed through diversion channels after the salinity of the quarry runoff water has been evaluated and treated as needed. Construction stone quarrying is generally not expected to cause significant water contamination, in contrast to other types of quarrying activities (Bwapwa, 2018; Charou et al., 2010; Cosgrove et al., 2015). As precautionary measures, rainwater entering the quarry pit, rainwater flowing over the material, and installing appropriate garland drains around the whole active quarry area will all be carried out. To minimize soil erosion and enable the downstream fields to be utilized for agricultural and related uses, rainwater collected in the work area will be collected and suitably drained out downstream using guide drains. Quarry water will be used for both wetting and automated block cutting. There will be channelization and safety precautions for the dump runoff. Quarry water will help with dust reduction, green belt expansion, and wet drilling. There are plans to channel the dump runoff and take safety precautions (Cullis et al., 2018; García et al., 2016).

5.6 Surface water contamination:

The only streaks in the river that are visible are those brought on by pollution from homes, businesses, and—surprisingly—radiation. The growth of unplanned and uncontrolled businesses involved in stone quarrying and processing in the area has caused devastating environmental deterioration. Due to inappropriate quarrying methods, rock and soil that are extracted during the quarrying process, known as overburden and quarry waste, have been carelessly deposited. The exposed dirt seeps into the river during monsoons, causing the reservoirs and dams to become silted and increasing the number of suspended particles and rock debris in the water (Gaur et al., 2013). The quarrying of various building materials, such as granite, basalt, quartzite, dolerite, sandstone, limestone, dolomite, gravel, and even sand, has resulted in the creation of vast tracts of wasteland in the river basin. Mineral waste, both active and inactive, and suspended particles can be found in quarries. Deposits of oil and slugs on the riverbed limit fish mobility by preventing the growth of moss and fungi, which are vital sources of food for fish. A sizable fraction of sweet water fish also die during the spawning season (Venkataraman, 2012; Ekpa et al., 2022). Health issues, including skin diseases, allergies, cholera, fever, cough, malaria, headaches, physical disabilities, TB, and heart-related issues, are said to plague villages near Ramanagara. Additionally, there has been a decline in male fertility. Unfortunately, people have not yet actively participated in river conservation despite the chance to act responsibly and learn from successful social movements in other river basins (Ajah et al., 2018; Ajibade et al., 2022; Halwenge 2015).

5.7 Groundwater contamination:

Surface and underground quarrying operations as well as the stone processing industry may have a direct or indirect impact on the quantity, quality, and usability of groundwater supplies. The type of mining activity, the geological substrata, and the redistribution of surface and subsurface minerals will be the main factors affecting groundwater supplies (Kantharaja et al., 2012; Elangbam et al., 2013). Waters alter and mobilize components such as salts, metals, trace elements, and/or organic molecules through their interaction with disturbed geologic rocks. The groundwater quality may be impacted by the dissolved

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materials once they are released and seep into deep aquifers (Shankar et al., 2008; Tamma Rao et al., 2011, 2012 & 2013; Sharma et al., 2008; Anantha, 2013; Karthikeyan et al., 2010). In addition to problems with naturally occurring contaminants, quarrying operations may result in groundwater pollution from leaking underground storage tanks, improper solvent and lubricant disposal, contaminant spills, and other sources. Particularly in granite field locations, many materials such as PM, silt, chemicals, rock fragments, dust, oil and lubricants, copper, fluorides, iron, zinc, and others affect groundwater. In the granite quarrying areas of the Ramanagara district, chemicals have contaminated the groundwater (Srinivasamoorthy et al., 2008; Prasanna et al., 2011).

5.8 Measure of water quality (WQI):

In the first phase, water quality measures that had a significant impact in the regions were selected to provide an overview of the water quality. pH, E.C., HCO_3, Cl, SO_4, Ca, Mg, Na, K, and SAR were among these parameters. In the second phase, each parameter's quality rating, or sub-index (qi), is determined using the following expression: The Water Quality Index (WQI) is created using the weighted arithmetic index approach. The water quality classifications and types based on milligrams per liter (WQI) readings for each sample were constructed using the following expression to create the quality rating scale for each parameter, qi (Venkatesha et al., (2015); Qureshimatva et al., 2015). Si, the World Health Organization standard for each chemical parameter in milligrams per liter, is based on standards from the World Health Organization (2002) and is calculated by multiplying the value by 100.

Water quality factors were ranked according to their importance to the level of drinkable water quality (Wi). First, the SI is determined for each parameter to calculate the final WQI step. The SI values are added to determine each sample's water quality index. Sli = Wi = Qi

By combining the quality rating (Qi) and unit weight (Wi) linearly as Sli, the overall Water Quality Index (WQI) was determined: WQI = , Sli.

Where SIi is the ith parameter's sub-index. If n is the number of parameters, then Qi is the rating based on the concentration of each parameter.

Water Quality Classification Based on WQI Value:

Unit, Suggested Organizations, and Drinking Water Guidelines. I <50 Excellent; II 50-100 Good Water; III 100-200 Poor Water; IV 200-300 Very Poor Water; V > 300 Class WQI Value Water Quality Status It is inappropriate for humans to drink water.

5.9 Analysis of the ambient water quality in the research area:

5.9.1 Surface water quality assessment:

The selection of quarry sites was found to be less affected by geological factors such as structural elements, strata's strike and dip, underlying and overlying lithology, and landslide issues after holding pond samples were analyzed. Several water-holding ponds in the Ramanagara district areas are linked to check dams and the storm water drainage

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system, according to the field investigation. Springs that emerge downstream from villages near quarries may become contaminated; a hydrogeological study indicates that this could be because the protective cover was removed. As a result of this removal, contaminants, and animal feces were carried into the area by surface drainage from the neighboring communities. This demonstrated that quarry catchments provided the heaviest stone debris to river flows when compared to other catchments (Karmakar et al., 2012). Large proportions of waste components in quarry resources may be the source of the trend. These pollution factors were then used to compute the amounts of each pollutant that the quarry catchments contributed to the river flows (Purandara et al., 2012).

According to the report, there is substantial stone mining taking place in the river beds and flood plains of reservoirs, nallahs, and rivers by the granite quarrying, stone processing, and stone crushing firms in the region. As a result, there have been notable changes and diversions of the water bodies in numerous places. Inundation and flooding of agricultural fields during the rainy season have become commonplace. Another factor affecting the area's diminishing water quality is careless stone quarrying from riverbeds. Water contains a considerable number of suspended and dissolved particles. The solid components, which originate from the erosion runoff process, are present in stream water as silt or other materials.

Surface water samples were collected from eight (08) locations, including the settlements, lakes, rivers, reservoirs, and crusher units that surround the granite quarrying zones. The locals use water for washing big cars, taking showers, and doing laundry. That being said, there are numerous causes of water pollution. The rainy season had higher total solid concentrations than the dry season. This came about as a result of the quarries adding to the river's total solids through runoff. The total solid values at each sampling site were found to be below the WHO threshold of 30 mg/liter. Throughout the study period, the quality of surface water has been evaluated. The allowable and acceptable water quality standards for drinking water, as outlined in IS 2296, 1982, are compared to the surface water results.

5.9.2 Groundwater quality assessment:

Groundwater is the primary supply for drinking and domestic requirements in nearly all of the communities close to the study region. The quality of groundwater obtained is influenced by various factors, such as pathogenic bacteria, organic materials, soil and air pollution, organic waste disposal, and the use of pesticides and fertilizers in agriculture. Twelve groundwater monitoring locations were selected for assessment in various communities surrounding the quarry sites, taking into account the subsurface water usage of the study area's settlements and villages. The allowed and acceptable water quality standards for drinking water, as outlined in IS 10500, 2012, are compared to the groundwater results. **Figure 6** provides a map indicating the locations of the surface and groundwater monitoring stations.

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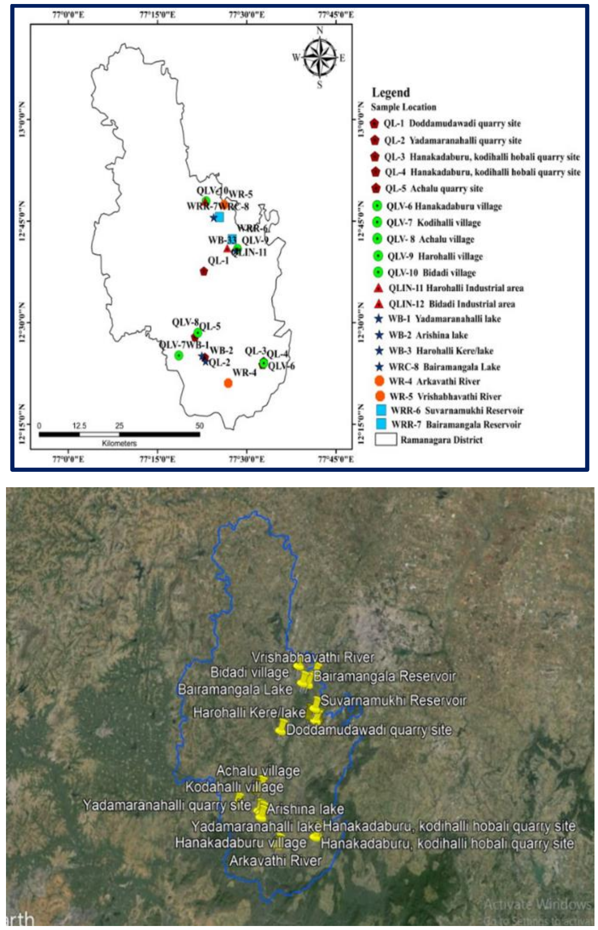

Fig 6: Locations for monitoring ambient water quality (SW) and (GW)

5.9.3 Results of Ambient Water Quality Analyses:

The standard methodology is applied to the study of the physico-chemical properties of water within ten to twenty kilometers of a reservoir, river, or nallah. Results from eight surface water and twelve groundwater assessments showed that the water quality parameters met both WHO and BIS guidelines for acceptable levels of water quality. This suggests that it's safe to use and drink the water in your home. It has also been discovered that there are no aquatic plants or animals in any of the water bodies that surround these units. In addition, unplanned stone quarrying operations in the riverbeds have reduced the amount of drinking water available to locals and wildlife, especially those who live downstream and close to the quarrying sites. These activities have interfered with surface and groundwater flow and natural water recharge. In addition, there are several deserted dig sites close by that border the reservoir, the nallah, and the river. The test results that are enclosed pertain to the ambient water quality in the vicinity of the quarry. For every location, the observed data were utilized in their calculation. The findings of the ambient water quality tests for surface and groundwater are summarized in **Tables 12 and 13.**

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Table 12: Study area location surface water monitoring and analysing results.

Surface water monitoring and analysing results										
Sl. No	**Parameters**	**Unit**	**SW 13**	**SW 14**	**SW 15**	**SW 16**	**SW 17**	**SW 18**	**SW 19**	**SW 20**
1	Colour	Hazen	<1	10	1	4	11	1	10	7
2	Odour	-	NOO	NOO	NOO	NOO	NOO	NOO	NOO	NOO
3	Turbidity	NTU	1	4	1.8	12.8	10.7	6.1	4.7	5.3
4	pH at 25°C	-	7.58	7.63	7.63	6.6	7.1	7.1	7.79	7.5
5	Electrical Conductivity	µS/cm	284	396	264	1389	879	1254	680	267
6	Total Dissolved Solids	mg/l	157	225	148	963	635	714	994	91
7	Total Hardness as CaCO3	mg/l	58	102	48	311.9	193.6	271.9	274.6	84.7
8	Total Alkalinity as CaCO3	mg/l	66	90	53	181.9	128.4	138.4	91.5	77.4
9	Chloride as Cl	mg/l	45	66	47	173.7	104.6	215.9	133.9	72.9
10	Sulphate as SO4	mg/l	7	10	8	66.4	43.7	81.5	51.8	29.8
11	Fluoride as F	mg/l	0.1	0.11	0.1	0.61	0.54	0.42	0.67	0.55
12	Nitrate as NO3	mg/l	0.1	0.11	1	2.2	3.9	4.5	4.9	2.7
13	Ammonia as NH3	mg/l	0.11	0.13	0.15	0.12	0.16	0.15	0.13	0.09
14	Phosphate as PO4	mg/l	0.16	0.11	0.11	0.11	0.11	0.12	0.09	0.16
15	Sodium as Na	mg/l	35	36	36	101.23	89.54	131.7	197.6	56.49
16	Potassium as K	mg/l	1.4	1.3	1.3	9.4	7.9	13.9	11.1	5.5
17	Calcium as Ca	mg/l	21	16	16	31.8	23.7	59.3	49.2	11.6
18	Magnesium as Mg	mg/l	6	2	2	21.9	19.1	36.9	33.7	8.3
19	Iron as Fe	mg/l	0.05	0.24	0.05	0.19	0.17	0.19	0.08	0.21
20	Total Suspended Solids	mg/l	2	5.8	3	71	39	12	7	42
21	Dissolved Oxygen as O2	mg/l	6.9	6.2	6.7	6.8	7.2	5.9	5.3	6.9
22	Chemical Oxygen Demand as O2	mg/l	8	20	10	21.9	22.4	13.7	16.6	17.9
23	Bio-Chemical Oxygen Demand at 27°C for 3 days	mg/l	<2	2.2	<2	11.54	12.4	4.9	5.4	7.9
24	Total Coliforms	MPN/100 ml	40	320	17	23	87	83	380	35
Every sample analyzed for surface water falls below IS 2296:1962. Standard like Manganese as Mn - BDL (<0.01) mg/l; Phenolic compounds as Phenol - BDL (<0.001) mg/l; Copper as Cu - BLQ (LOQ 0.01) mg/l; Mercury as Hg - BDL (<0.001) mg/l; Cadmium as Cd - BLQ(LOQ 0.001) mg/l; Selenium as Se - BDL (<0.01) mg/l; Total Arsenic as As - BLQ (LOQ 0.005) mg/l; Cyanide as CN - BLQ(LOQ 0.01) mg/l; Lead as Pb - BDL(<0.01) mg/l; Zinc as Zn - BDL (<0.01) mg/l; Total Chromium as Cr - BLQ(LOQ 0.01) mg/l; Aluminum as Al - BDL(<0.03) mg/l; Boron as B - BLQ(LOQ 0.1) mg/l; Nickel as Ni - BLQ(LOQ 0.01) mg/l; Anionic Surfactants as MBAS - BDL(<0.025) mg/l; Mineral oil - BDL(<0.5) mg/l; Poly Chlorinated Biphenyl's (PCB's) - BDL (<0.0001) mg/l.										
Note: NOO - No odour observed, BDL - Below detection level, BLQ – Below Limit of Quantification; LOQ – Limit Of Quantification										

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Table 13: Study area location groundwater monitoring and analysing results

Ground water monitoring and analyzing results														
Sl. No	**Parameters**	**Unit**	**GW 1**	**GW 2**	**GW 3**	**GW 4**	**GW 5**	**GW 6**	**GW 7**	**GW 8**	**GW 9**	**GW 10**	**GW 11**	**GW 12**
1	Colour	Hazen	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2	Odour	-	NOO	NOO	NOO	NOO	NOO	NOO	NOO	NOO	NOO	NOO	NOO	NOO
3	pH at 25°C	-	7.14	7.24	6.91	7.11	7.2	7.8	6.7	7.8	6.3	6.8	7.2	6.9
4	Electrical Conductivity	µS/cm	498	642	814	387	861	748	813	1014	583	692	857	738
5	Turbidity	NTU	0.65	0.72	0.68	0.54	0.69	0.73	0.63	0.78	0.64	0.72	0.66	0.72
6	Total Dissolved Solids	mg/l	278	359	466	218	417	527	385	424	380	387	436	374
7	Total Suspended Solids	mg/l	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
8	Total Hardness as CaCO3	mg/l	106	156	168	90	83	98	79	71	138	87	118	134
9	Total Alkalinity as CaCO3	mg/l	118.2	142.5	152.4	82.6	77.2	83.3	64.3	52.8	68.5	72.2	127.8	136.7
10	Chloride as Cl	mg/l	81.5	103.4	144.5	78.3	188.7	233.8	207.9	211.4	167.3	159.6	142.3	176.4
11	Sulphate as SO_4	mg/l	14.3	21.5	44.3	11.6	68.5	63.7	78.2	64.4	81.3	35.5	69.8	72.4
12	Fluoride as F	mg/l	0.26	0.31	0.17	0.21	0.8	0.34	0.49	0.75	0.63	0.37	0.32	0.48
13	Nitrate as NO3	mg/l	3.7	6.2	13.1	2	8.1	5.1	4.8	5.7	8.3	7.2	7.8	6.3
14	Sodium as Na	mg/l	61.4	76.2	83.4	45.6	94.2	83.4	88.7	49.5	67.3	74.8	84.6	72.6
15	Potassium as K	mg/l	2.6	3.1	1.8	2.1	8.5	7.4	6.7	7.2	5.3	4.2	7.3	7.9
16	Calcium as Ca	mg/l	34.7	47.3	56.8	31.3	21.4	33.2	29.7	15.9	17.4	23.6	28.4	32.8
17	Magnesium as Mg	mg/l	5.1	9.3	7.2	3.9	14.9	15.7	11.8	10.5	6.8	8.3	10.9	12.7
18	Iron as Fe	mg/l	0.1	0.11	0.14	0.12	0.16	0.13	0.17	0.14	0.18	0.14	0.15	0.12
19	Total Coliforms	MPN/100 ml	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
20	E coli	MPN/100 ml	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Every sample analyzed for groundwater falls below IS 10500 (2012). Standard like Manganese as Mn - BDL (<0.01) mg/l; Phenolic compounds as Phenol - BDL (<0.001) mg/l; Copper as Cu - BLQ (LOQ 0.01) mg/l; Mercury as Hg - BDL (<0.001) mg/l; Cadmium as Cd - BLQ(LOQ 0.001) mg/l; Selenium as Se - BDL (<0.01) mg/l; Total Arsenic as As - BLQ (LOQ 0.005) mg/l; Cyanide as CN - BLQ(LOQ 0.01) mg/l; Lead as Pb - BDL(<0.01) mg/l; Zinc as Zn - BDL (<0.01) mg/l; Total Chromium as Cr - BLQ(LOQ 0.01) mg/l; Aluminum as Al - BDL(<0.03) mg/l; Boron as B - BLQ(LOQ 0.1) mg/l; Nickel as Ni - BLQ(LOQ 0.01) mg/l; Anionic Surfactants as MBAS - BDL(<0.025) mg/l; Mineral oil - BDL(<0.5) mg/l; Poly Chlorinated Biphenyl's (PCB's) - BDL (<0.0001) mg/l.														
(Note: NOO - No Odour Observed, BDL - Below detection level, BLQ – Below Limit of Quantification; LOQ – Limit Of Quantification; NR – No Relaxation)														

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6. DISCUSSION

Concerns regarding the effects of granite quarrying and stone processing on water supplies were raised by a field survey conducted in the Ramanagara area. Quarrying is known to decrease the water table and occasionally even cause significant watercourses to be diverted away from the quarry site. The majority of the rivers, streams, and other bodies of water have dried up or have become chemically poisoned. According to field observations, quarry dust has impacted the majority of the community's major streams and rivers. The rivers around the quarries are no longer home to fisheries due to contamination; therefore, fishing is not done there. A startling 85% of survey participants indicated that chemical contamination of streams and groundwater by quarries and stone processing facilities is a major issue for the water resources in the research area. Moreover, 15% of respondents indicated that they were hesitant to respond to the question due to the financial benefits they received from quarry owners. Furthermore, the outcomes showed that water pumped from the quarry field had an effect on the stream water in the Ramanagara district. Because the streams are overflowing with quarry debris during the wet season, drinking water pollution from run-off from quarries is a major concern. The speakers went on to add that runoff from quarries had been the source of stream pollution for several years.

Tin concentrations in surface waters are frequently high because leaching results in mineralization in stream sediments. One of the main risk factors for the emergence of many other diseases, including water-transmitted diseases, is the downstream area used by the nearby population. The study also showed how increasing sediment loads in streams and water courses result in more saline water, a consequence of quarry operations, which seriously degrade water quality. In the Ramanagara district, 85% of the sample population agreed with this statement. Additionally, because of chemical contamination, the people no longer consume the crops along the streams. Despite the lack of research to verify the accuracy of the water pollution content, the responses from the sample population appear credible. The great majority of people living in the Ramanagara district agreed that they no longer get their drinking water from streams. Residents who rely on streams and other bodies of water may become ill from waterborne illnesses such as malaria, typhoid, and diarrhoea, especially in areas with limited access to other water sources. According to the research, drinking water quality and quantity have decreased since 76% of the community's quarry operations impede natural water recharge. The inhabitants are forced to utilize the tainted water for household purposes, even if it is in streams.

6.1 Observations:

The lease area does not contain any permanent bodies of water. Surface-water ecosystems will not be significantly affected by this. There are no known sources that could poison the water or air. While groundwater can be found in unconfined or water table conditions in weathered and jointed zones of gneisses, granites, charnockite, closepet granite, and alluvium along river courses, it is found in semi-confined to restricted

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conditions in fractured formations at higher depths. In most areas of the district, the weathering is between 5 and 10 m thick; in some areas, it is more than 10 m thick.

The parameters for water quality observation and results:

The level of pollution in both surface and groundwater was assessed using the following parameters: pH, electric conductivity, total dissolved solids, total alkalinity, chlorides, total hardness, dissolved oxygen, fluoride, calcium, iron, magnesium, sulfate, and nitrate. This spike in values could be caused by an algal bloom or an improper sewage discharge into surface water sources. The local water quality is much below the standards set by law. The physicochemical characteristics of the groundwater and surface water in the research region are compared to the reference values of the standards (IS 10500, 2012, and IS 2296, 1982, Indian Standards/Specifications for Drinking Water).

The following is a study overview of the surface water quality (SW) and groundwater quality (GW) analysis reports for the research locations, which included minimum and maximum observations for each parameter: colour - <1 to 11 hazen and <1 hazen; odour – no odour observed in SW and GW; turbidity – 1 to 12.8 NTU and 0.54 to 0.78 NTU; pH at 25°C – 6.6 to 7.79 and 6.3 to 7.8; electrical conductivity – 264 to 1389 µS/cm and 387 to 1014 µS/cm; total dissolved solids – 91 to 994 mg/l and 218 to 527 mg/l; total hardness as $CaCO_3$ – 48 to 311.9 mg/l and 71 to 168 mg/l; total alkalinity as $CaCO_3$ - 53 to 181.9 mg/l and 77.2 to 152.4 mg/l; chloride as Cl – 45 to 215.9 mg/l and 78.3 to 233.8 mg/l; sulphate as SO_4 – 7 to 81.5 mg/l and 11.6 to 78.2 mg/l; fluoride as F - 0.1 to 0.67 mg/l and 0.26 to 0.75 mg/l; nitrate as NO_3 - 0.1 to 4.9 mg/l and 2 to 8.3 mg/l; ammonia as NH_3 - 0.09 to 0.16 mg/l (SW); phosphate as PO_4 - 0.09 to 0.16 mg/l (SW); sodium as Na – 35 to 197.6 mg/l and 45.6 to 88.7 mg/l; potassium as K - 1.3 to 13.9 mg/l and 1.8 to 8.5 mg/l; calcium as Ca – 16 to 59.3 mg/l and 15.9 to 56.8 mg/l; magnesium as Mg – 2 to 36.9 mg/l and 5.1 to 15.7 mg/l ; iron as Fe - 0.05 to 0.21 mg/l and 0.1 to 0.18 mg/l; total suspended solids – 2 to 71 mg/l and <2 mg/l; dissolved oxygen as O_2 - 5.3 to 7.2 mg/l (SW); chemical oxygen demand as O_2 – 8 to 22.4 mg/l (SW); bio-chemical oxygen demand at 27°C for 3 days - <2 to 12.4 mg/l (SW); total coliforms – 17 to 380 MPN/100 ml and <2 MPN/100 ml; E. coli: <2 MPN/100 ml (GW).

6.2 Impact of quarrying activities on the water environment and human health:

Water contamination is one of the main issues that quarries and the stone-cutting business have with the water environment. For example, when quarry dust dissolves in water, it can contaminate the body of water and alter its chemical composition. Moreover, these activities disrupt recharge processes and may lower the amount and quality of drinking water available to wildlife and nearby communities by interfering with the regular flow of surface water and groundwater (Yogendra et al., 2008). Streams in the vicinity that are not within the quarrying area may get silt from mine drainage. The surface water stream could become contaminated if home wastewater is discharged into it. Even if dirt and stones contaminate the water, they won't alter the groundwater table because they don't contain any dangerous materials. Quarrying operations have negatively impacted the quantity and quality of surface and subsurface waterways. The precipitation of dust

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particles generated by the crushing and quarrying machines, or the surface runoff of contaminated water from the quarrying sites, impairs the physicochemical properties of water. As per several studies (Azadeh Taghinia Hejabi et al., 2011), the groundwater quality could be impacted by contaminated water. Furthermore, explosive waste from rock quarries hurts groundwater. The water cycle has been impacted by surface characteristics altered by topsoil removal and rubbish disposal. Along with the quality of the soil, these changes have also had an impact on the amount and direction of water flowing at the surface (Anantha, 2013).

Poor sanitation and contaminated water can cause the spread of diseases like typhoid, polio, cholera, dysentery, and diarrhoea. In addition, habitats and biodiversity are disappearing. Both residents and employees are impacted by the different challenges and issues associated with stone quarrying. Among these problems are emissions and the creation of dust, water, and air. (Srinivasamoorthy et al., 2008; Kelly 1998; Drake et al., 2001; Gibson et al., 2003; Radhey Shyam et al., 2012; Peter et al., 2018) ionizing radiation emissions, land degradation and abandonment, loss of biodiversity, and ecosystems. The study's conclusions show how much dust is produced throughout the many stages of the quarrying process, including loading, drilling, stone crushing and blasting, and product transportation. The larger dust particles settle close to one another, while the thinner ones disperse widely around neighboring plants and bodies of water, depending on the direction and speed of the wind. Its size determines how much particulate matter (PM) is emitted, how long it floats in the atmosphere, and how much of it does so (Ogbonna et al., 2018 & 2020; Ojeaga et al., 2023). Based on their aerodynamic diameter, the sizes are divided into $PM_{2.5}$ (equal to or less than 2.5 micrometers) and PM_{10} (equivalent to or fewer than 10 micrometers) particles. These diameters fall below the range of 50–70 µm in diameter found in human hair. Dispersed particulate matter can cause several issues, depending on its size. For example, dust covers on plant surfaces can reduce light, which is needed for photosynthesis; it can also cause visual issues near quarries and crushers; particles can cause respiratory illnesses in animals; and it can cause ocular diseases in humans and animals (Akanwa et al., 2016). It's common knowledge that employees in quarries disobey health and safety laws. People frequently forget to use safety equipment, including dust masks, helmets, and appropriately fitting clothes. As a result, they come into contact with minute dust particles. It consequently has a detrimental effect on their health. Numerous health problems, including lung infections, skin and eye infections, respiratory and pulmonary disorders, and lung collapse, can be brought on by dust exposure (Stephens et al., 2001; Balaram et al., 2013).

The Ramanagara district quarry workers found that their lack of protective gear and the dust from the quarries were the main causes of respiratory problems. Among the symptoms noted before and during the quarry operation were dyspnea, coughing, wheezing, asthma, migraines, eye and chest pain, heart issues, mental stress, throat infections, allergies, and skin conditions. The effect of quarrying on human health is investigated based on the previously mentioned facts, which include the fact that dust, water, and air are irritating, that dust affects health, and that rain-covered roofs are dirty.

The findings showed that every respondent (100%) believed that dust, noise, water, and air were major sources of irritation and health risks. Rain falling from roofs is nearly invariably contaminated by dust. Every respondent also indicated that their continuous health problems might be exacerbated by water, flooding, dust, and noise.

The detrimental effects of processing and quarrying stone are evident in the numerous illnesses and health issues that arise, especially for the populations near crushers. Topsoil and surface rock layer loss may make groundwater more susceptible to pollution. Groundwater levels are seeing an increase in total suspended solids (TSS), primarily due to improper handling of waste from the stone-cutting sector.

Mitigation and control strategies: Water is used in automated block-cutting and wetting procedures in the stone processing and quarrying industries, especially for wire sawing and polishing. Water used for cutting and polishing will be recycled using an appropriate drainage system. Quarry water will be utilized for wet drilling, dust control, and green belt growth. The dump runoff will be diverted, and safety measures will be implemented. The two most probable causes of pollution in surface water are soil erosion and runoff from landfills. Therefore, the action plan's objective is to prevent water from dripping off uncontrollably during the monsoon and quarry silt from washing away.

6.3 Water pollution control measures:

The streams bordered by garland will regulate the amount of rainfall that overflows from the dumps and pits. To keep silt out of the river, a retaining wall will be built at the base of the dump slopes. We'll check the salinity of the quarry runoff water and, if necessary, apply the proper treatment. Only paths of divergence will allow pure water to enter. To redirect surface runoff from the quarrying area to the settling pit, garland drains are being constructed. Building gully plugs and check dams in the appropriate locations to stop flow from affected regions. After soak pits, domestic sewage from the site office will be dumped into a septic tank.

The pit is used as a rainwater reservoir when the mine closes, which aids in replenishing groundwater. Routine monitoring of the groundwater and mine water in the surrounding municipalities. By building ring drains around the quarry area that are the right size and installing dumps to keep precipitation out of the active quarry sites, surface water pollution can be reduced. Rainwater collected by the area's natural slope during monsoon season is used to create greenbelts in the quarry's water-fed tank and decrease dust. The inner slopes of the dump tops are there to control water flow and stop erosion washouts. The slopes of the populated regions and the tops of the landfills will be covered in vegetation, such as grass, shrubs, mulch, and other plants, to stop erosion.

The unstable open-pit benches at the quarry will be covered with material to stop debris from washing off the dumps and sliding off the benches. At the top of the dumps, fences with the appropriate-sized buds will also be constructed. This will lessen the chance that the rainwater from the quarry will clog the channels and drains that convey it; they are designed to capture any suspended items that may be in the water through the use of settling pits and baffles. Next, the selected grass and shrub species will be planted to

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stabilize the slopes that have been identified. Testing will be conducted regularly to determine whether any undesirable materials are present in the quarry water.

If any materials are found to be present more than the CPCB-mandated limits, the proper action will be taken. The analysis has suggested a revised alignment that is suitable for the area's upstream drainage slope to provide simple water entry into the diversion channel and ultimate water discharge into the original stream. The volume of surface runoff won't drop. Domestic sewage from the canteen and restrooms will be emptied into septic tanks while neighboring bore wells and open wells will undergo routine testing for water quality and level.

6.4 Surface Water Pollution Control Measures:

Rainwater is gathered by the area's natural slope during the monsoon season and delivered into the mine's water-fed tank, where it is utilized to reduce dust and promote the establishment of greenbelts.

The dump tops will include inner slopes to regulate water flow and stop erosion washouts. Garland drains of the proper size will be built around mining operations and landfills to divert rainfall away from active quarry regions. Grass, plants, mulch, etc. shall be applied on the slopes and dump tops of the active regions to prevent erosion. Fencing with buds the right size will be erected at the top of the dumps and the precarious open-pit benches in the mine to stop trash from washing off of them.

This will reduce the possibility of clogged drains and water channels. To collect any potential suspended particles, mine drainage will be directed through settling pits, baffles, and water channels. Planting suitable shrubs and grass species will help level out the slopes. To make sure there are no unwanted materials present, the water from the quarry and processing plant is regularly tested. The proper action will be taken if any constituent is discovered to be present more than the CPCB-mandated limits.

6.5 Groundwater pollution control measures:

Eventually, the household sewage from the canteen and restrooms will be stored in the septic tanks. The water levels and quality in the surrounding boreholes and open wells will be monitored regularly.

7. CONCLUSIONS

Except turbidity, dissolved oxygen, and biological oxygen demand, the results of the surface water and groundwater samples were found to be within acceptable ranges when compared to the drinking water tolerance limits specified in **IS 10500:2012 and IS 2296:1962 Class C Tolerance Limits.**

There is higher than permitted turbidity, dissolved oxygen, and biological oxygen demand at the monitoring sites. This spike in values could be caused by an algal bloom or an improper sewage discharge into surface water sources.

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