Impacts of Stone Quarrying on Physico-Chemical Properties of Soil

Abstract

A large number of activities in operation of stone quarrying cause environmental degradation including dust pollution. These quarries are usually located in clusters in remote locations of mineral rich areas where living standards is lower and understanding of people towards environmental impact is also poor. These quarrying activities results in disturbance of land surface, altering drainage pattern and land use, besides the pollution problems, which may lead to the environmental problem of water, air, noise, solid waste pollution and dust pollution. Consequently want of suitable solutions to the problem were very much high on demand for eco-friendly quarrying.

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Introduction

Dhar (1993) has mentioned that, due to lack of proper planning and negligence regulations and appreciable amount of environmental degradation and ecological damage to water, air, noise and soil occur.

Mining and quarrying are essentially destructive development activities, where ecology suffers at the altar of economy. Unfortunately, in most region of the earth, the underground geological resources are superimposed by biological resources. This is particular evident in India. Hence mining operations quarrying necessarily involves deforestation, habitat destruction, biodiversity erosion and destruction of ores and minerals also lead to widespread environmental pollution (Sinha et al., 2000).

Mishra and Bhubaneswar (2008) reported that phenomenal growth of construction activity in the country to meet the modern day requirements of civilization has tremendously boosted the demand for building materials. Meeting the domestic commitments as well as fulfilling the export demands has forced the stone quarrying industry to quickly readjust for proven quality, maximum production and profitability. However, along with the accrued benefits, the industry is facing severe crisis due to constraints such as quarrying in proximity of habitation, critical structures etc. there by endangering them through various quarry activities. Main issues are noise pollution, water pollution, air pollution and dust pollution.

Material and Methods

For soil sampling, composites of four corners and one centre of a grid by quartering method were used to prepare one sample at each location for control sites well as different quarrying sites. Soil samples were studied for various parameters including, pH, **SAR**, organic matter, WHC, electrical conductivity, total alkalinity, total hardness, TDS, chlorides, magnesium, sodium, calcium and texture.

pH

pH of soil is the measure of the hydrogen ion activity and depends on relative amounts of the absorbed hydrogen and metallic ions. Accurate result of the pH of water was determined by pH meter.

Sodium Absorption Ratio (SAR):

Sodium Absorption Ratio can be calculated to determine the alkali hazard due to use of irrigation of water rather than its soluble sodium percentage.

$$S.A.R. = Na^{+} / \frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}$$

Organic Matter

The organic matter present in the soil is digested with excess of potassium dichromate and sulphuric acid and the residual unutilized dichromate is than titrated with ferrous ammonium sulphate. Percentage organic matter can be calculated by this formula.

$$\%c = \frac{3.951}{g}\left(1 - \frac{T}{S}\right)$$

%Organic matter =% C x 1.724

Where, g = weight of sample in gm

S = ml ferrous solution with blank titration
T = ml ferrous solution with sample titration
C = carbon (elementary)

The factor 3.951 is based on the assumption the carbon is only 75% of the organic matter. The factor 1.724 is based on the assumption the carbon is only 58% of the organic matter.

Water Holding Capacity (WHC)

Water holding capacity of the soil is measured as the amount of water taken up by unit weight of dry soil when immersed in water under standardized conditions.

$$\text{WHC (\%)} = \frac{(W2-W1)-(W1-W0)}{(W1-W0)} \times 100$$

Where, WO = weight of empty box
W1 = Weight of box with dried soil
W2 = Weight of box with water saturated soil

Electrical Conductivity

It is the ability of a substance to conduct the electric current. It is measured with the help of a conductivity meter having a conductance cell containing electrodes of platinum coated with carbon.

Conductivity=observed conductance × cell constant × temperature factor at 25 ˚C

Total Alkalinity

Alkalinity can be determine by the direct titration of the soil solution with a strong acid HCl or H2SO4 using methyl orange and phenolphthalein as indicators. All the reagents needed for determination of total alkalinity similar to water alkalinity.

$$\text{Total Alkalinity, mg/ 100 g} = \frac{(\text{ml} \times \text{N})\text{of HCl} \times 500}{\text{ml of soil solution}}$$

Total Hardness

Hardness is mainly caused by calcium and magnesium ions present in water. Permanent hardness is caused mainly by sulphates and chlorides of same metals. Hardness is determined by the use of **EDTA** method.

Calcium and magnesium form a complex of wine red color with Eriochrome Black T at pH of 10.0 = 0.1. The EDTA has got a stronger affinity towards Ca^{2+} and Mg^{2+} and therefore by addition of EDTA, the former complex is broken down and a new complex of blue color is formed.

$$\text{Hardness as mg/L } CaCO_3 = \frac{\text{ml of EDTA used} \times 1000}{\text{ml of sample}}$$

Total Dissolved Solids (TDS)

Total Dissolved Solids are determined as the residue left after evaporation of the filtered sample.

$$\text{TDS (mg/L)} = \frac{A-B \times 1000 \times 1000}{V}$$

Where, A = Final weight of the dish in gram
B = Initial weight of the dish in gram
V = Volume of sample taken in ml

Salinity (Water soluble solids as Chlorides)

Most of the chlorides in the soils are soluble in the water and determined directly in soil solution. The most common method is titrimetric, involving direct titration of the soil solution with Ag NO3 using K2CrO4 as an indicator.

$$\text{\% Chlorides} = \frac{(\text{mlXN})\text{of AgN}O_3\text{X } 35.5}{\text{ml of soil solution X 2}}$$

To convert the value in mg/100 g, multiply the values in % by 1000.

Calcium and Magnesium

Calcium and magnesium present in soil can be removed by leaching the soil with ammonium acetate solution.

$$\text{Calcium mg/100gm} = \frac{\text{Ax } 400.8\text{xV } 1}{\text{VxSx } 10000}$$

$$\text{Magnesium mg/100gm} = \frac{(B-A)\text{x}400.8\text{xV } 1}{\text{Vx } 1.645\text{xWx } 10000}$$

Where A = volume of EDTA (ml) used for calcium determination
B = volume of EDTA (ml) used for calcium and magnesium determination
V = total volume of soil extract prepared
V1 = volume of soil extract titrated (ml)
S = weight of soil taken

Sodium

Use the remaining ammonium acetate leachate of soil after calcium and magnesium determination for sodium.

$$\text{Sodium (mg/gm)} = \frac{\text{A x V}}{\text{Wx } 10000}$$

Where A = sodium content of soil extract mg/l
V = total volume of soil extract (ml)
W = weight of air-dry soil-sediment (g)

Soil Texture

Soil texture refers to the relative proportion of various groups of the individual's soil particles. Soil is classified into number of textural classes depending upon their particles size distribution. Texture can be evaluated accurately in the lab by mechanical analysis. According to the international system the range of the particle sizes in the soil is as under:

1. Coarse Sand = 0.2 mm – 2.2 mm
2. Fine Sand = 0.02mm - 0.2 mm
3. Silt = .002 mm - 0.02 mm
4. Clay = $<$ .002 mm

Observation

The study was conducted at four study areas in stone quarrying sites around Ajmer. These quarrying sites are situated in Bubani village, Srinagar village, Sedariya village and Dhola Bhata village.

In order to assess the impact of quarrying activities on soil quality, the study has been carried out on four samples in the study areas. The result of physico-chemical analysis of soil samples of control sites (residential area) near of (Bubani – R1, Srinagar – R2, Sedariya – R3 and Dhola Bhata – R4) and quarrying sites (Bubani – S1, Srinagar – S2, Sedariya – S3 and Dhola Bhata – S4) are represented in the table no. 01 and 02.

Result and Discussion

Soil samples were studied for various parameters including, pH, SAR, organic matter, WHC, electrical conductivity, total alkalinity, total hardness, TDS, chlorides, magnesium, sodium, calcium and texture.

The chemical nature of soil was determined by its pH. The degree of acidity or alkalinity of soil is of particular importance in the influencing the activities and relative abundance of the different groups of soil organisms. The pH of soil was determined by a number of factors including the concentration of salts and carbondioxide in the soil solution and exchangeable cations present. pH affects the chemical properties of soil by altering the soil solubility. Many substances are more soluble in acidic condition and may be leached out resulting in nutrient deficiencies (yadav, 1996).pH in the soil of study sites (S1, S2, S3 & S4) vary from 7.57 to 8.38. Maximum pH was observed in quarrying site (S3) during the study period 2013 and minimum pH in study site (S2) during study period 2011. Alkaline pH helps in the absorption of minerals (Panday et al., 2003). During experimental condition the pH of soil of control sites (R1, R2, R3 &R4) was observed 7.36 to 7.97. This variation indicated that the pH of the soli of quarrying sites was higher than that of control sites due to higher concentration of carbonates and bicarbonates of calcium and magnesium.

Sodium Absorption Ratio (SAR) in the soil of study sites (S1, S2, S3 & S4) was found varied from 1.52% to 6.47. Maximum SAR was observed in Sedariya quarrying site (S3) and minimum SAR in Srinagar quarrying site (S2). During experimental conditions SAR in soil of control sites (R1, R2, R3 &R4) vary from 4.76 to 9.08. This variation showed that the SAR was lower in quarrying sites than that of control sites due to lower concentration of sodium, calcium and magnesium ions in quarrying sites but these were found within the desirable limits (Mukherjee et al.,2005).

Organic Matter

Humus contain chemicals such as proteins, amino acids, purines, pyrimidines, sugar, fats, alcohol and waxes are found in more quantity in natural soil (Trivedi and Goel, 1986). Organic matter in the soil of study sites (S1, S2, S3& S4) was found varied from 1.58% to 4.93%. Maximum organic matter was observed in Sedariya quarrying site (S3) and minimum in Srinagar quarrying site (S2). During experimental conditions the organic matter of soil of control sites (R1, R2, R3 &R4) vary from 4.91% to 8.06%.This variation showed that the organic matter was lower in quarrying sites than that of control sites due to quarrying activities.

Water holding capacity (WHC) of the soil refers to amount of maximum water which can be held in the saturated soils. WHC in the soil of study sites (S1, S2, S3 & S4) was found varied from 37.3% to49.7%. Maximum WHC (58.7%) was observed in Sedariya quarrying site (S3) and minimum WHC (48.6%) in Srinagar quarrying site (S2). During experimental conditions WHC in soil of control sites (R1, R2, R3 &R4) vary from 57.3% to 69.6%. This variation showed that the WHC was lower in quarrying sites than that of control sites due to different quarrying activities. Moisture content in the soil at any time depends upon WHC of soil (Warhate et al. 2007).

Electrical Conductivity signifies the measure of TDS in the soil (Jain et. al., 2006). Conductivity is a measure of the current carrying capacity, gives a clear idea of soil salts present in soil. It is conventionally determined in 1:5Soil Suspension. Conductivity of soil water rises with the addition of soluble salts present in soil at particular temperature (Murali et al., 2004). When present in the soil dissociate into their respective cations and anions. These cations and anions impart electric conductivity by carrying current (Gupta et al., 1998). In the study sites (S1, S2, S3 & S4) the electrical conductivity of the soil varied from 348.5µmho/cm to 443.3µmho/cm. Maximum conductivity was observed in Sedariya quarrying site(S3)and minimum in Srinagar quarrying site(S2). During experimental conditions the conductivity of soil of control sites (R1, R2, R3 &R4) various from 271.5µmho/cm to 324.5µmho/cm. This variation indicated that the E.C. of study sites was higher than that of control sites due to addition of quarrying dust which resulted in higher level of ions like potassium, calcium, magnesium, carbonates, bicarbonates, chlorides in the soil which also contribute to the salinity of the soil. Soil is classified as saline if the electrical conductivity of the soil exceeds (400 µmho/cm) according to ISI standard.

Alkalinity in the soil of study sites (S1, S2, S3 & S4) varied from 157.50ppm to 225.75ppm. Maximum alkalinity) was observed in Sedariya quarrying site (S3) and minimum in Srinagar quarrying site (S2). During experimental conditions the alkalinity of soil of control sites (R1, R2, R3 &R4) vary from 140.5ppm to 191.75ppm. This variation indicated that the alkalinity of the soil of quarrying sites was higher than that of control sites due to higher concentration of carbonates and bicarbonates of calcium. Higher alkalinity hampers the growth of the plants (Jain et al., 2006).

Total hardness in the soil of study sites (S1, S2, S3 & S4) was found varied from 153.25 ppm to 283.25ppm. Maximum total hardness was observed in Sedariya quarrying site (S3) and minimum in Srinagar quarrying site (S2). During experimental conditions the alkalinity of soil of control sites (R1, R2, R3 &R4) vary from 143.5ppm to 236.5ppm. Chlorides in the soil study sites (S1, S2, S3 & S4) was found varied from 98.0 ppm to 233.3ppm. Maximum chloride was observed in Sedariya quarrying site (S3) and minimum in Srinagar quarrying site (S2). During experimental conditions the alkalinity of soil of control sites (R1, R2, R3 &R4) vary from 94.75ppm to 176.50ppm. This variation indicated that the total hardness and chlorides were higher in quarrying sites than that of control sites due to higher concentration of calcium chloride and magnesium chloride (Druzina, 1983).

The role of calcium in soil is unique among all the chemical elements. Calcium in the soil of study sites was found vary from 67.50 ppm to 165.75 ppm. Maximum value of calcium was observed in study site (S3) and minimum in study site (S2). During experimental condition calcium in the soil of control sites (R1, R2, R3 &R4) was observed from 81.0 ppm to 176.75 ppm. Magnesium in the soil of study sites (S1, S2, S3 & S4) was found vary from5.50 ppm to 20.25 ppm. Maximum value of magnesium was observed in study site (S3) and minimum in study site (S2). During experimental condition magnesium in the soil of control sites (R1, R2, R3 &R4) was observed vary from 13.5 ppm to 26.5ppm. Sodium in the soil was found vary from 97.5 ppm to 130.3 ppm in the study sites (S1, S2, S3 & S4). Maximum value of Sodium was observed in study site (S3) and minimum in study site (S2). During experimental condition sodium in the soil of control sites (R1, R2, R3 &R4) was observed vary from101.75 ppm to 136.25 ppm. This variation indicated that calcium, magnesium and sodium in soil study sites was lower than that of control sites. Lower percentage of calcium, magnesium and sodium carbonates can be correlated with the dust fall in the study area (Druzina, 1983).

Relative proportion of the soil particles of various sizes is an important physical parameter which determines texture of soil. Larger particles help in providing the physical support to the plants while smaller size particles determine the water holding capacity. Diameters determine the WHC and nutrient availability of soil. Soil is classified into number of texture classes depending upon their particle size distribution (Pandit and Pandeya, 2002). Texture of soil in the quarrying sites (S1to S4) and control sites (R1toR4) was observed as coarse sand, fine sand, silt and clay. Maximum coarse sand 49.9% was found in study site (S2), Fine sand 23.6% in study site (S1), Silt 18.4% in study site (S3) and Clay 11.3% was found in study site (S3) and minimum coarse sand 46.3% was observed in study site (S3), Fine sand 24% in study site (S3), Silt 17.2% in study site (S2) and Clay 10.1% was found in study site (S2). Whereas minimum coarse sand 10.5% was found in control site (R2), Fine sand 17.6% in site (R2), Silt 22.4% in site (R2) and Clay 45.9% found in site (R3) and maximum coarse sand 11.7% was observed in control site (R3), Fine sand 18.8% in site (R3), Silt 23.6% in site (R3) and Clay 49.5% was found in site (R2).These variation may be due to different quarrying activities.

Conclusion

Tables revealed that there were significant variations in the above parameters in the study sites (S1, S2, S3 & S4) and control sites (R1, R2, R3 &R4). It was reported that the quarrying dust reduces the porosity and permeability of the top soil tremendously and in due course of time it results in water logging problems at the surface thereby not allowing the water to percolate down due to which the ground water level has adversely been affected and it has gone down to deeper levels. The fine quarrying dust reduces the fertility of the soil by increasing its alkalinity.

Present study indicates that quarrying dust generates during processing adversely affects the soil quality. The result shows that the quarrying sites have higher conductivity, total alkalinity and total hardness and lower value of organic matter, TDS, SAR, pH, chlorides, sodium, calcium and magnesium than that of control sites making it unfertile hence the adverse effects of quarrying on the physical and chemical properties of soil were clearly noted. These adverse changes due to quarrying activities will contribute to eco-degradation in central Aravali region.

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Table: (01) Soil Analysis of Control Site for Average Seasonal Variation During Study Period: – 2011 to 2013

S. No.	Parameters	Summer season (March, April, May)				Rainy season (June, July, August)				Post rainy season (Sept., Oct., Nov.)				Winter season (Dec., Jan., Feb.)			
		R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
1	pH	7.59	7.37	7.63	7.50	7.80	7.66	7.97	7.73	7.64	7.42	7.68	7.55	7.70	7.48	7.74	7.61
2	SAR	6.36	4.59	9.41	5.12	6.66	4.99	9.74	5.44	6.46	4.69	9.53	5.33	6.56	4.78	7.65	5.26
3	O.M. %	6.43	4.75	8.43	5.54	6.86	5.08	8.79	5.97	6.54	4.86	7.47	5.65	8.65	4.97	7.58	6.76
4	W.H.C.%	58.70	50.50	62.80	54.60	72.87	64.80	77.10	68.87	62.80	54.60	66.87	58.70	67.87	59.70	71.83	63.80
5	E.C.(μmho/cm)	305	263	317	273	323	281	335	302	310	268	322	278	316	274	328	284
6	Total Alkalinity	174	132	184	163	192	149	203	181	179	137	189	168	185	143	195	174
7	Total Hardness	206	126	227	175	224	96	245	194	211	131	232	177	217	137	238	187
8	TDS	668	535	679	616	686	443	697	634	673	540	684	621	679	546	690	627
9	Chlorides	163	141	169	146	180	159	187	164	168	147	174	151	173	152	180	157
10	Magnesium	17	9	21	13	26	18	30	22	20	12	24	16	23	15	27	19
11	Sodium	100	88	119	94	132	120	151	126	110	99	130	106	121	104	141	116
12	Calcium	128	66	169	97	160	98	183	129	139	77	170	108	150	87	178	128
13	Course sand %	10.7	9.9	11.1	10.3	11.9	11.1	12.3	11.5	11.5	10.3	11.5	10.7	11.1	10.7	11.9	11.1
14	Fine sand %	17.8	17.0	18.2	17.4	19.0	18.2	19.4	18.6	18.2	17.4	18.6	17.8	18.6	17.8	19.0	18.2
15	Silt %	22.6	21.0	23.0	22.2	23.8	22.2	24.2	23.4	23.0	21.4	23.4	22.6	23.4	21.8	23.8	23.0
16	Clay %	46.5	48.9	45.3	47.7	47.7	50.1	46.5	48.9	46.9	49.3	45.7	48.1	47.3	49.7	46.1	48.5

Table:(02) Soil Analysis of Quarrying Site For Average Seasonal Variation During Study Period:2011-2013

S. No.	Parameters	Summer season (March, April, May)				Rainy season (June, July, August)				Post rainy season (Sept., Oct., Nov.)				Winter season (Dec., Jan., Feb.)			
		S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
1	pH	7.53	7.36	7.54	7.43	8.16	7.96	8.28	8.08	7.67	7.46	7.75	7.54	7.74	7.55	7.86	7.67
2	SAR	3.14	1.41	6.23	1.95	3.45	1.78	6.53	2.24	3.28	1.53	6.33	2.07	3.39	1.64	6.43	2.10
3	O.M. %	3.21	1.52	5.20	2.33	3.63	1.85	5.56	2.74	3.32	1.64	4.30	2.50	3.43	1.74	4.43	2.59
4	W.H.C.%	38.60	30.40	42.70	41.17	52.87	44.63	57.87	48.80	42.70	36.17	46.80	38.93	47.80	39.60	51.87	44.03
5	E.C.	383.3	355.3	404.0	368.0	413.7	388.3	428.3	400.3	393.3	367.7	414.3	378.3	404.7	378.0	424.7	385.3
6	Total Alkalinity	183.3	161.3	190.3	171.3	211.7	193.3	220.7	202.3	190.7	172.3	200.0	181.3	201.7	183.3	207.7	192.7
7	Total Hardness	214.7	173.0	236.0	190.3	247.0	205.0	268.0	226.0	226.0	184.0	247.0	204.7	236.7	195.0	258.0	215.7
8	TDS	412.7	271.0	415.0	353.0	428.7	303.0	447.0	385.0	407.7	282.0	426.0	364.0	418.7	293.3	436.7	392.7
9	Chlorides	132.3	98.0	202.3	116.0	164.7	133.7	234.7	145.0	143.3	109.0	213.3	126.7	154.3	120.0	224.3	134.7
10	Magnesium	13	5	17	9	16	8	21	12	14	6	18	10	15	7	19	11
11	Sodium	66.3	52.0	83.0	65.0	95.3	84.3	115.0	89.7	74.0	63.0	90.7	74.7	85.0	74.0	101.7	83.0
12	Calcium	96.7	66.7	121.3	76.3	134.0	101.7	152.3	110.3	111.0	78.7	130.0	87.3	123.3	91.0	140.0	102.7
13	Course sand %	46.9	49.3	45.7	48.1	48.1	50.5	46.9	49.3	47.3	49.7	46.1	48.5	47.7	50.1	46.5	48.9
14	Fine sand %	23.0	22.2	23.4	22.6	24.2	23.4	24.6	23.8	23.4	22.6	23.8	23.0	23.8	23.0	24.2	23.4
15	Silt %	17.4	16.6	17.8	17.0	18.6	17.8	19.0	18.2	17.8	17.0	18.2	17.4	18.2	17.4	18.6	17.8
16	Clay %	10.3	9.5	10.7	9.9	11.5	10.7	11.9	11.1	10.7	9.9	11.1	10.3	11.1	10.3	11.5	10.7