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Soil Characteristics Around Nanjangud, Mysore District India - A Case Study



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ABSTRACT

Soil characteristics around Nanjangud have been studied in detail. The rocks in this terrain are made up of hornblende-granulites, garnet-pyroxene, fuchsite quartzite and calc-silicates. The soil samples collected from the area adjacent to the distillery unit were subjected to a systematic characterization using XRD, XRF, thin section study, and positron annihilation spectroscopic test. The soil properties such as pH, electrical conductivity, and availability of Ca, Mg, N, P, K and organic carbon have been measured. It was found that the effect of industrial effluent is much faster than the effect of geological process in this area.

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KEYWORDS

Calc-silicates;
Industrial effluent;
Positron annihilation;
Soil degradation.

INTRODUCTION

Nanjangud, which belongs to Mysore district, Karnataka state, forms the northern part of Sargur high-grade terrain essentially made up of amphibolites, quartzites and a wide range of manganiferous calc-silicates. Janardhan et al. (1979, 1986, and 1994)^[1-3] have studied this area in detail and described hornblende granulites, garnet pyroxenes, fuchsite quartzite and calc-silicate rocks and correlated this

geological sequence with charnockite series. Subsequently several other workers have studied this terrain in detail and the most significant reports are from Swaminath and Ramakrishnan (1981)^[4] and Radhakrishna and Vaidyanadhan (1994)^[5]. The terrain has a rich assemblage of rare carbonate silicate minerals, feldspathoids and banded iron formation, particularly BHQs. In course of time, these rocks have undergone extensive weathering and erosion. The area under investigation has red to brownish soil,

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which is rich in quartz, feldspar, hematite and biotite as major components followed by various other mafic and calc-silicate minerals. Such a rich mineral assemblage has made this soil highly fertile. The present authors have chosen a particular region in this area with an extensive industrial activity, which in turn has degraded the soil characteristics significantly and also, reduced the fertility of the soil. The area chosen is located at a distance of 7 kms south of Nanjangud covering an area of 7-8 acres. The present authors have carried out a systematic investigation of the soil samples up to a depth of 5 feet, and dealt with the soil parameters like pH, porosity, electrical conductivity and estimation of important components like N, P, K, Ca, Mg and organic carbon. Such an investigation will yield highly useful information related to soil degradation process and the possible reasons for such a rapid degradation process or chemical activity due to the effluent action.

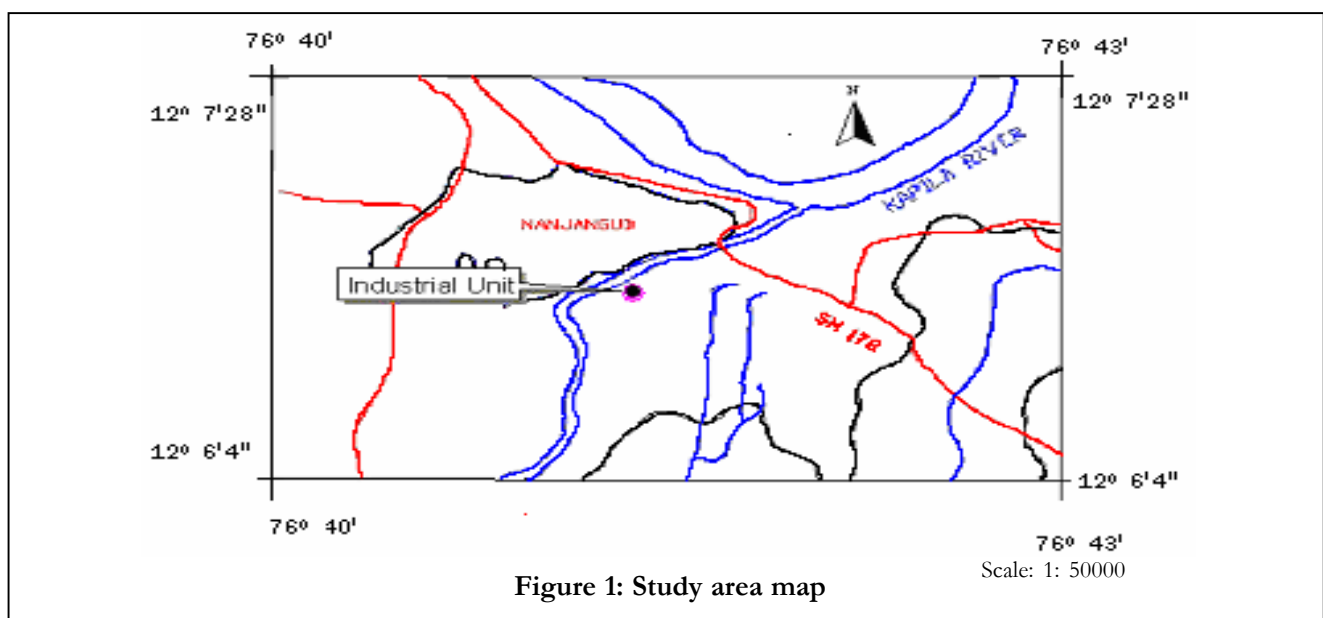
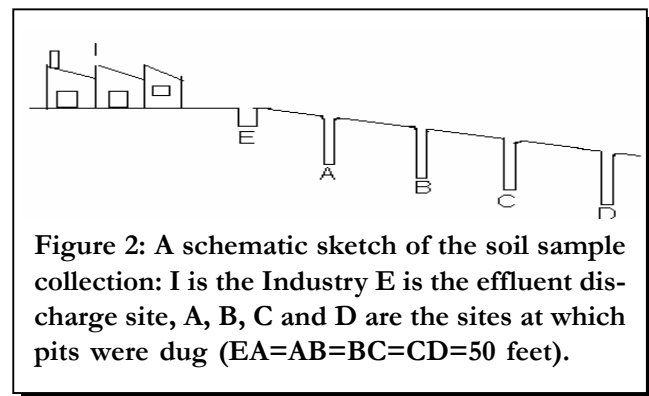
Methodology

The study area from which the soil samples were collected is shown in figure 1, which falls in the toposheet No.57 D/12. The figure 2 shows the scheme of soil sample collection in such a way that the industrial effluent has a direct contact with the soil. Also the soil samples were collected from different depths. For this purpose a pit of about two feet wide, five feet long and five feet length was dug

(Soil Survey Manual, U.S.D.A, 1951)^[6]. Soil samples were collected at a regular interval of fifty feet away from the effluent, and depth wise up to 5 feet depth at a regular interval of 1 foot. The samples are designated for convenience as E (for sample collected at the vicinity of the effluent) A, B, C, and D (for samples collected at a regular interval of fifty feet away from the effluent). It means that from the effluent and soil intersection point we have covered a distance of two hundred feet. The soil samples collected were dried gradually by keeping them in a clean place free from contaminants like gases or dust particles.

Characterization

The soil samples were subjected to characterization using various analytical techniques like, pH determination, measurement of electrical conductivity

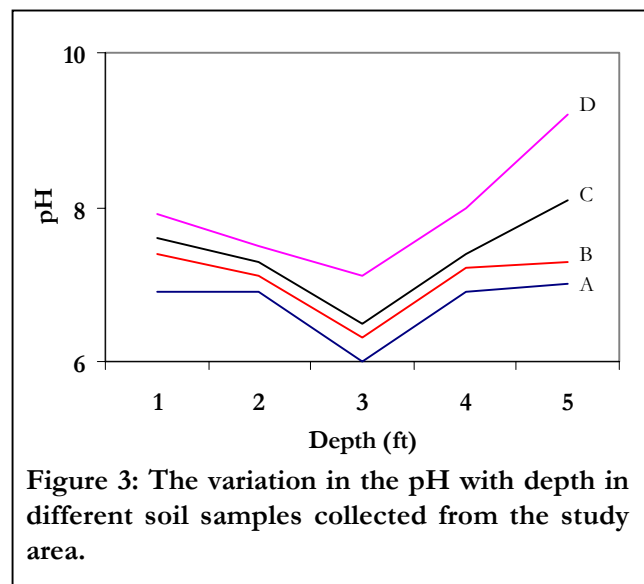


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ity, positron annihilation test, X- ray powder diffraction (to identify the mineral phases), X-ray fluorescence (to determine mineral composition). The estimation of Ca, Mg, N, P, K and organic carbon was carried out using volumetric analysis.

pH

pH test was mainly carried out to know the acidic or basic nature of the soil. pH was measured using a pH meter of Salvin Process Instruments Co. SP 3079B, India. pH meter was standardized using a standard buffer solution before each measurement.



A standard reference and the sample were maintained at the ambient temperature.

Electrical conductivity

The electrical conductivity measurement was done to test the soluble ions using a conductivity meter (Make: Salvin Process Instruments C., Model SP 1000A, India). About 10 mg of the dry sample was taken and 100 ml of the distilled water was added to it to prepare a solution. The instrument was calibrated using 0.01 N KCl solution kept at different conductivity range (1468- 2000 α Siemens) at room temperature.

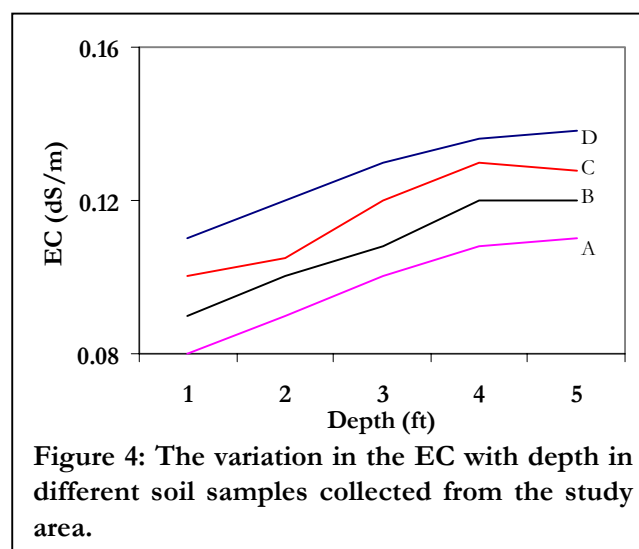


TABLE 1: List of the chemicals used in the present work

Sr. No.	Chemical Reagents	Grade	Manufacturer
1	Zinc Sulphate	Laboratory reagent	Loba chemicals, India
2	EDTA	Laboratory reagent	RANBAXY, India
3	Buffer pH = 10		
4	Potassium Hydroxide	Analytical reagent	RANBAXY, India
5	Sodium Hydroxide	Analytical reagent	RANBAXY, India
6	Zinc Granules	Analytical reagent	GLAXO Laboratories, India
7	Ammonium acetate	Laboratory reagent	RANKEM, India
8	Potassium dichromate	Laboratory reagent	RANBAXY, India
9	Sodium fluoride	Laboratory reagent	Qualigens fine chemicals, India
10	Ferrous ammonium sulphate	Laboratory reagent	RANBAXY, India
11	Sulphuric acid	Laboratory reagent	RANBAXY, India
12	Perchloric acid	Laboratory reagent	RANBAXY, India
13	Phosphoric acid	Laboratory reagent	RANKEM, India
14	Nitric acid	Laboratory reagent	S.d.Fine- chem ltd, India
15	Boric acid	Analytical reagent	SRL PVT.Ltd, India

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Volumetric analysis

Estimation of calcium and magnesium

The estimation of Ca and Mg in the soil samples collected was carried out using the volumetric method (Baruah and Barthakur, 1997)^[7]. The chemicals used were 0.01 N zinc sulphate, EDTA, Buffer pH-10 and 4N KOH solution. The indicators used were Eriochrome Black T, and Pattern Reader indicator. Then the estimation of Ca and Mg was done using the following equation:

$$Ca = [0.0004 * A \text{ ml} * 10^6] / 10 \quad (1)$$

$$Mg = [0.00024 * (B-A) \text{ ml} * 10^6] / 10 \quad (2)$$

Where A is the volume of EDTA used for the estimation of Ca and (B-A) is the volume of EDTA used for the estimation of Mg.

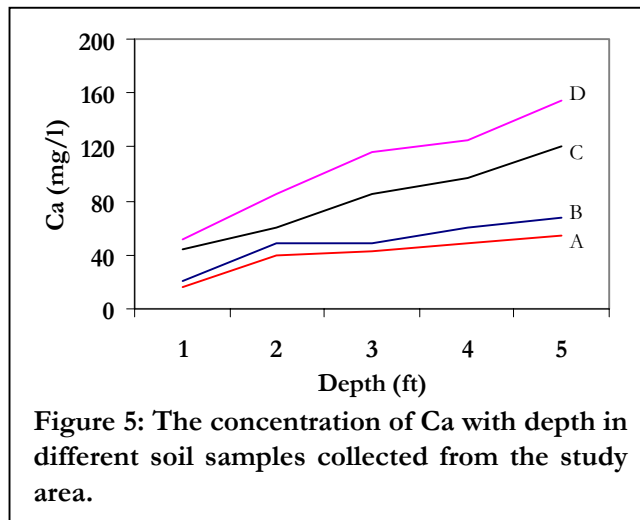


Figure 5: The concentration of Ca with depth in different soil samples collected from the study area.

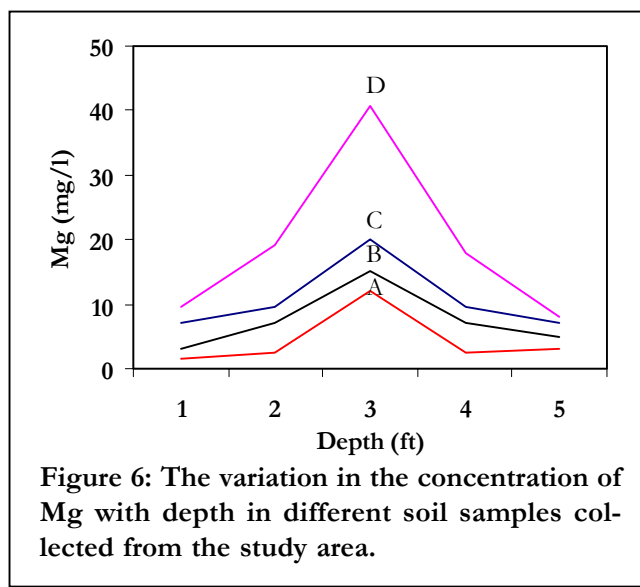


Figure 6: The variation in the concentration of Mg with depth in different soil samples collected from the study area.

Estimation of available nitrogen

The nitrogen content in the soil samples was estimated by Kjeldhal method (Baruah and Barthakur, 1997)^[7]. The reagents used for the estimation were catalytic mixture of sulphuric acid, sodium hydroxide solution, zinc granules, boric acid cum indicator solution and hydrochloric acid. Then the available nitrogen present in the samples was calculated as follows:

$$\text{Available Nitrogen} = \{[A-B] * 280\} / \text{Volume of sample} \quad (3)$$

Where A is the volume of 0.02 N sulphuric acid required for titrating the sample and B is the volume of 0.02 N sulphuric acid required for blank titration.

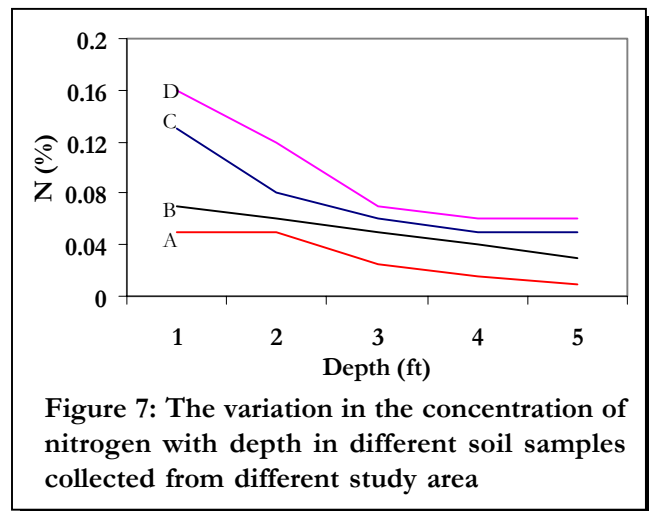


Figure 7: The variation in the concentration of nitrogen with depth in different soil samples collected from different study area

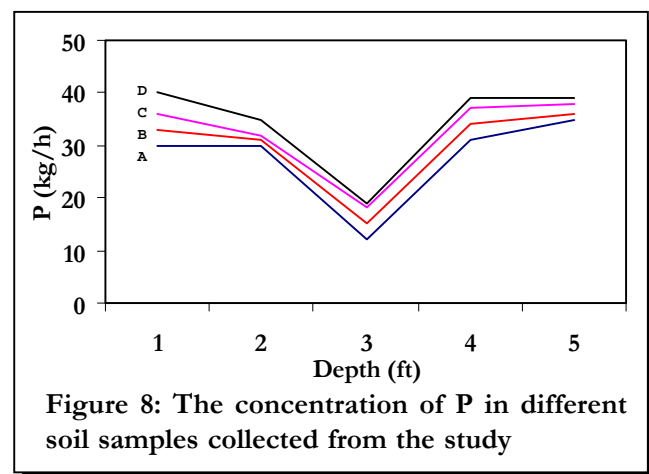


Figure 8: The concentration of P in different soil samples collected from the study

Estimation of phosphorous

Nitric acid and perchloric acid were used in the estimation of phosphorous content. The amount of phosphorous present in the soil samples was calculated using the equation

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$$PO_4 = [Pd * V] / [100 * X] \quad (4)$$

Where Pd is the amount of PO_4 indigested, V is the volume of the solution and X is the weight of air dried soil used for the estimation of phosphorous.

Estimation of potassium

The Flame Photometer 128 and FPM compressor 126, Systronics Co.India, was used for estimating potassium (Baruah and Barthakur, 1997)^[7]. The reagents used were ethyl alcohol, ammonium acetate and standard KOH solution. The air pressure was maintained at 15 lbs using the filter of 769 nm. The extract of the soil sample was observed under flame photometer and potassium content in the soil sample was calculated using the equation:

$$K = [Y * V] / [W * 100] \quad (5)$$

Where K is the potassium content of the soil extract, V is the total volume of soil extract and W is the weight of the soil taken for extraction.

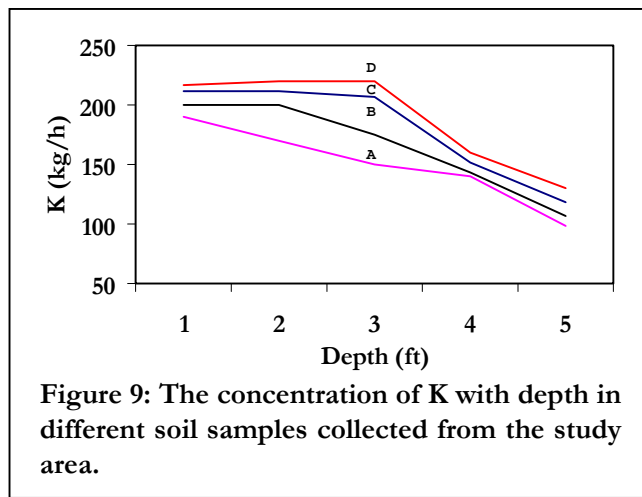


Figure 9: The concentration of K with depth in different soil samples collected from the study area.

Estimation of organic carbon

The estimation of organic carbon present in the soil samples was carried out by the volumetric method (Baruah and Barthakur, 1997)^[7]. The reagents used for the estimation of organic carbon in the soil samples were potassium dichromate, phosphoric acid, sulphuric acid, sodium fluoride, biphenyl amine indicator and ferrous ammonium sulphate solution. The presence of organic carbon was calculated using the equation:

$$O.C = 6.791 / [X * 1724 \{1 - (V_1/V_2)\} * 10] \quad (6)$$

Where X is the weight of soil sample taker, V_1 is

the volume of titrates used against the sample, and V_2 is the volume of titrates used against the distilled water for the blank.

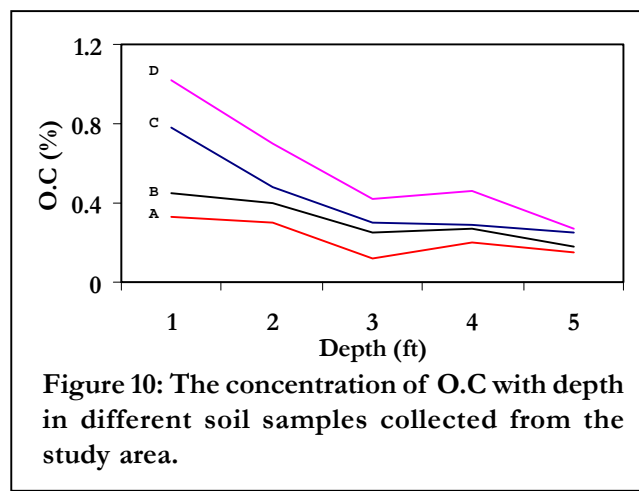


Figure 10: The concentration of O.C with depth in different soil samples collected from the study area.

Powder X- ray diffraction analysis

The representative dry soil samples were powdered in an agate mortar and the X- ray diffraction patterns were recorded using Bruker AXS X-ray diffractometer system D8 ADVANCE. The X-rays used were from the copper target with λ -1.5404 Å using a nickel filter. The powder X- ray diffraction patterns were indexed and the d- spacing of all the peaks were identified and compared with the JCPDS files.

X- ray fluorescence analysis

The X- ray fluorescence (XRF) analysis was carried out for the representative soil samples from the study area using the XRF X' UNIQUE (PHILIPS) instrument. The XRF analysis shows the presence of major, minor and trace elements present in the soil samples.

TABLE 2: XRF data of the soil sample

Composition	Wt %	Composition	Wt %
SiO ₂	65.95	Al ₂ O ₃	12.84
Fe ₂ O ₃	7.62	TiO ₂	1.01
CaO	2.67	MgO	1.9
Na ₂ O	1.66	MnO	0.14
K ₂ O	1.11	P ₂ O ₅	0.05
Cr ₂ O ₃	0.02	NiO	0.01
BaO	0.03	LOI	4.71

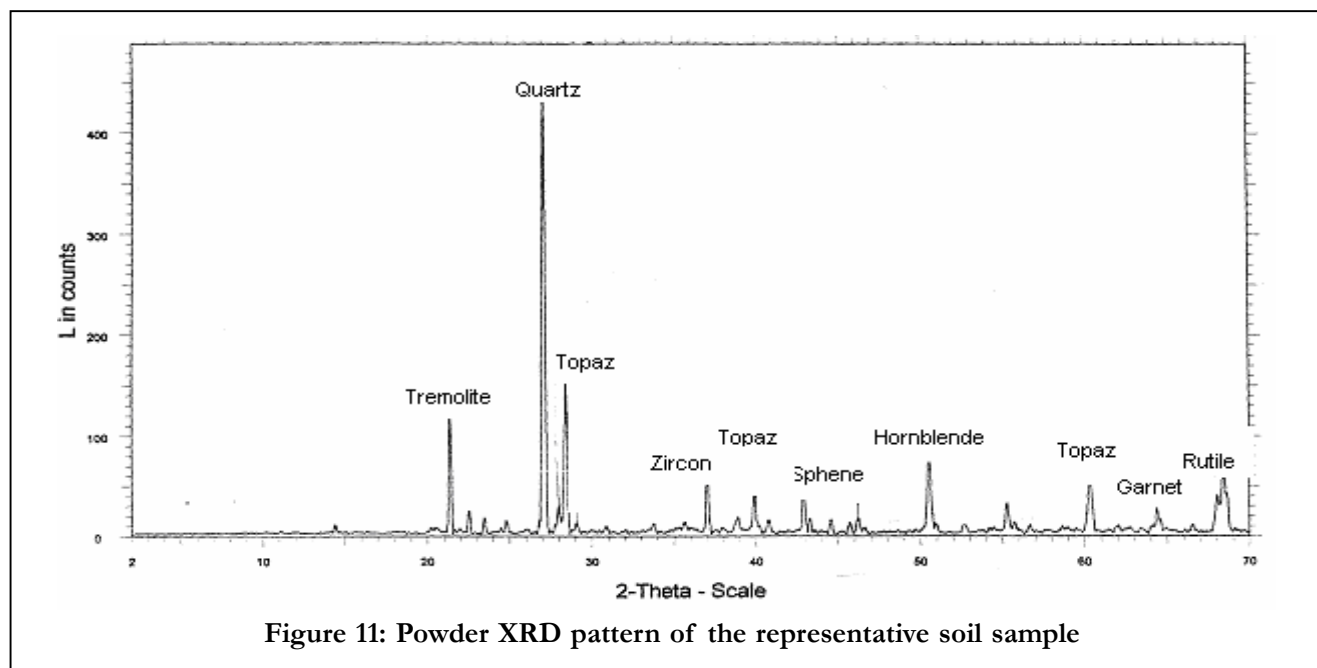


Figure 11: Powder XRD pattern of the representative soil sample

Positron annihilation life time study

It is one of the sophisticated analytical techniques developed recently for material characterization. Positron annihilation study has been carried out using an indigenously developed instrument for representative soil samples to understand the micro-porosity of the soil collected from a depth of 3 feet. In the positron annihilation lifetime spectrometer the $10 \mu\text{Ci } ^{22}\text{Na}$ source is sandwiched between two identical pellets of the soil sample. The positron annihilation lifetime spectra are measured with a slow – fast coincidence assembly. The detectors are BaF_2

which helps to calibrate the spectrometer and to shift the spectrum to desired region in the multi-channel analyzer. The output pulses from TAC whose amplitudes are proportional to the time gap between emissions of the 1.276 MeV start gamma ray and the subsequent 0.511 MeV annihilation stop gamma ray pulses are recorded in a PC based multi-channel analyzer. The resolving time (FWHM) is 230 ps. For each positron annihilation spectra, nearly 10^5 coincidence counts are recorded. The measured spectra are analyzed using PATFIT-88 program with necessary source corrections and following the variance of fit.

TABLE 3: Positron annihilation life time data

τ_2 (n sec)	I_2 (%)	τ_3 (n sec)	I_3 (%)	Average size of the pores v_f (A^3)	Relative fraction of pores (au)
0.30 ± 0.004	62.9 ± 0.6	0.890 ± 0.027	6.5 ± 0.48	13.2 ± 0.7	13.2 ± 0.7

scintillators (25 mm in diameter and length) optically coupled to the photomultiplier tubes (PMT, XP2020Q) with DC200 silicon fluid. Two PMT are used as start channel and stop channel with the energy selections of 300 KeV to 550 KeV and 700 to 1320 KeV respectively. The operating voltage has been set to +2100 volts. To eliminate the effect of time walk, the PMT pulses are processed through constant fraction differential discriminator (CFDD) one in each channel. The pulses from CFDD are connected to TAC (time to amplitude converter),

Mineralogical studies

The thin section study was carried out for the representative soil samples collected from different depths. Leitz, Germany, Petrological microscope was used for such a purpose to study the mineral composition of the soil samples.

RESULTS AND DISCUSSION

The soil samples collected from the study area show the following characteristics: The pH of the

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representative soil samples varies from 6 to 9.2 depending on the depth and its proximity to the effluent. At the surface the highest pH is 7.9 and goes on decreasing as the distance from the source of the discharge increases and as the depth increases the pH of the soil goes on decreasing up to certain depth (at about 3 ft) and starts increasing as depth increase. The presence of calc-silicate and alkali rich feldspar indicates pH of 9.2 with depth as they are unaltered and also less affected by the effluent. Whereas the organic rich acidic effluent discharged directly into the ground shows a decrease in pH values up to 6. The pH values of various samples collected from different levels are shown graphically in figure 3.

The electrical conductivity of the soil increases as depth increases. This indicates the presence of alkali rich elements at depth, contributing to the higher conductivity, which states that the soil has undergone degradation due to the interaction with the industrial effluent. As per the results the conductivity of the soil sample varies from low to medium. The least value is found at the depth of 1 to 2 ft. At this depth the root hairs of the crops make use of water and nutrients for their growth. The less alkali soil is poor in physical condition, which leads the root to suffer from poor aeration. The variation in the electrical conductivity of the soil samples is depicted in the figure 4.

The calcium and magnesium are responsible to maintain the salinity of the soil. The calcium content in these soils is relatively high as it contains calc-silicate minerals in surplus amount. The highest amount of Ca recorded for the soil was at the direct proximity of the effluent. Usually at the surface the Ca content is less compared to different depth. This is because the Ca ions must have been washed away due to weathering and erosion. The variation in the Ca concentration with depth in the soil samples is graphically shown in the figure 5. The Mg content has been recorded as 47.4 mg/l at the vicinity of the effluent but as the depth increases the Mg content increases up to 3 ft and there onwards it decreases. As the distance from the source of the effluent discharge increases the Mg content decreases figure 6.

The N, P and K are the most essential components of the soil from the fertility point of view. Com-

paring the results obtained with the standards, it can be concluded that the nitrogen content in the top soil is high and as the depth increases the nitrogen content in the soil decreases. The effluent released from the industry is rich in organics and is added to the soil. As the effluent percolates through the soil, the nitrogen from the effluent is adsorbed by the top soil and gradually goes on decreasing as the depth increases as shown in the figure 7. The phosphorus and potash content of the soil are within the limits as compared to the standards. But the P content initially decreased up to 3 ft depth and then gradually increased. This is due to the leaching effect caused by the effluent. As the effluent percolates through the soil beds, it has removed the phosphorus present in the soil up to certain extent as shown in the figure 8. The potash content is confined to the top soil, whereas it decreases with increasing depth. This is due to the degradation and decomposition of potash with effluent figure 9.

The organic carbon content of a soil determines the humus formation. It decreases as the distance increases from the source of discharge as well as with increasing depth. The increase in the organic carbon at the source is due to the direct contact of effluent, which is rich in organic matter. The organic matters from the effluent are added to the topsoil and it gradually decreases with increasing depth figure 10.

The powder X-ray diffraction studies carried out on the representative soil samples clearly indicate the abundance of quartz, feldspar, biotite and hematite followed by garnet, chlorite and hornblende. This was further confirmed through thin section study. The soil samples show a kind of oolitic texture with the removal of hematite from potash feldspars and also quartz grains undergoing alteration partially. The thin section study also reveals the absence of clay minerals. The feldspars grains show perfect multiple twinning thereby indicating the absence of clay minerals because the feldspars have not undergone alteration into clay minerals. The soil has no humus content and there is no agricultural activity because of the effluent leaching and interaction. A typical powder XRD pattern of the soil sample is shown in figure 11. According to the powder XRD pattern obtained; SiO_2 is the major com-

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ponent followed by other minerals like garnet, hornblende, topaz, feldspar, tremolite and biotite.

The XRF study indicates a wide range of major and minor elements. The TABLE 2 gives the XRF data for the representative samples from 3 feet depth. The XRF data clearly depicts the abundance of calc-silicate minerals and also iron formation.

Positron lifetime spectroscopic method is well established in defect studies in materials and free volume of pores in polymeric systems. Several investigators have worked on this and significant ones are Yean (1990)^[8], Ramani and Ranganathaiah (2001)^[9] and Ranganathaiah (2003)^[10]. In this, the ortho Positron (o-P) life time (τ_3) directly provides the void space size and its intensity provides the relative concentration of the pores. In addition to this, if the positron annihilates in defects like in crystalline materials where lifetime (τ_3) is small and reflects the size of the micropores. The o-Ps formation is possible as in bigger voids only. The product of $V_f I_3$ shown in the last column of the TABLE 3 shows the relative fraction of pores in the present system. The major constituent of the soil is SiO_2 (66 %). This is the major system in which positrons undergo decay. Since the value of o-Ps lifetime (τ_3) is less than a nanosecond. From the above results it is understood that the micropores represented by τ_2 are more compared to bigger voids represented by τ_3 . Therefore, the SiO_2 in the soil is mostly crystalline in nature here, which is supported by XRD data, and the effluent discharge seems to have a greater effect on this component of the soil, otherwise SiO_2 would have been more amorphous.

CONCLUSIONS

The discharge of the effluent from the industry has changed the soil characteristics around the surrounding area. The increase of N, P, K and organic carbon more than the standards may cause succulent growth of the plant. It also causes unfavourable factor like deficiency of water, rise in temperature, insects, pests and diseases, etc. It also affects the process of photosynthesis. The decrease of salts like Ca and Mg causes abnormal of chromosomes, which are the hereditary character of crops. The decrease of these salts also leads the root to suffer from poor

aeration. To overcome this, a proper management of treatment the industrial effluent should be adopted.

The industrial effluent considered in this work is more acidic and rich in organics. On the other hand the soil originally must have been red, loose textured, highly fertile, residual soil with microscopic grains. The effect of the industrial discharge is faster than the effect of the geological process acting upon this area. The effect of effluent leaching has completely changed the standard characteristics of this soil and making it degraded, polluted and unsuitable for the agricultural activity.

SUPPLEMENTARY INFORMATION AVAILABLE STATEMENT

Following information is available as SUPPLEMENTARY INFORMATION.

- TABLE 4: ICAR standards-(Indian council of agriculture research)
- TABLE 5: Standards recommended by Department of Horticulture Government of Karnataka
- TABLE 6: Rating chart used for fertilizer recommendation
- TABLE 7: Fertility status of the residual soil (Baruah and Barthakur, 1997)

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