Indian Journal of Ecology (2022) 49(2): 440-445
DOI: https://doi.org/10.55362/IJE/2022/3543

Manuscript Number: 3543
NAAS Rating: 5.79

Integrative Study of Coastal Land-Based Pollution and Effects: Focus on Soil Properties

D.A. Kiran and H.K. Ramaraju

Department of Civil Engineering, Dayananda Sagar College of Engineering
Bangalore-560 078, India
E-mail: dakiran07@gmail.com

Abstract: The discharge and dumping of untreated domestic and industrial wastes into estuaries, rivers, and nearshore waters are the principal sources of coastal pollution in the current study area. Ten soil samples were collected near the industry pollutant exit point near the seashore and towards Mangalore city and were undergo chemical and physical analysis. Also, both distilled water and seawater were used to determine the strength characteristics of the samples. SEM, XRD and EDS were used to determine the surface morphology, chemical compositions of samples. From the results, it was found that most of the samples collected were more or less not met the sufficient range for the agricultural activities. When soil samples undergo Compaction and UCS tests in the presence of seawater and distilled water, MDD and UCS values were decreased in the presence of seawater. From the SEM study, the majority of samples have crystalline texture. Carbon, Oxygen, Aluminium, Silicon, Iron and Mercury were major elements abundantly found in the collected soil samples when it undergoes EDS Analysis. From the XRD analysis, it was known that Quartz, illite, kaolinite, orthoclase, mica, halloysite are the major mineral compounds found in the collected soil samples.

Keywords: Compaction, Industrial waste, Coastal pollution, Soil properties, Mangaluru, Micronutrients, Seawater

Urbanization, industrialization, and a variety of agricultural activities all release significant amounts of pollutants into the surrounding aquatic ecosystems, including estuaries, rivers, oceans, seashores, and coastal wetlands. In the last few decades, with these activities, heavy metal contamination which is caused by industrial and domestic wastewater emissions, sewage irrigation, vehicle exhaust, and overuse of pesticides and fertilizers, has become more serious in many countries (Wu et al 2016). Many factors influence the accumulation of heavy metals in the soil's surface layer, including parent rock, soil properties, human activities, agricultural processes and industrial production (Khalaf and Khuder 2021). Some are essential micronutrients for plants and animals, making them important for human health and food production. All trace elements, however, become potentially toxic at high concentrations. Man-made trace metal input into the natural environment thus poses a number of ecological and health issues. A wide range of industrial activities generate wastes and contaminants that end up in the soil via direct disposal, spills, leaks, atmospheric deposition from air, and other means (Nadal et al 2009). Anthropogenic activities, in addition to natural weathering, are regarded as substantial source to increasing trace metal concentrations in soils (Devkota 2000, Singh 2004). Because soil pollution is the starting point for pollutant transportation to plants, animals, and even the atmosphere, many researchers confirmed that trace heavy metal pollution of surface soils as a result of intensive and extensive industrialization and urbanization has become a serious concern in many developing countries.

The Baikampady industrial region in Mangaluru has been suffering from environmental degradation for almost a decade. Industrial wastes from this area are routed into the coastal water, while municipal wastes from Mangalore are disposed of in a nullah adjacent to the Gurupura River, which flows into the coastal sea off Mangalore. Such releases could pollute the water, causing serious ecosystem changes, including the decrease of fisheries resources (Kiran 2020). Rivers that travel through varied land-use activities are exposed to a variety of contaminants, ranging in strength from point to non-point sources (Samanta et al 2005). Some of the problems reported in and around the Mangalore coastal area are disposal of untreated or partially treated industrial and domestic wastes on the water bodies, crude oil contamination of the soil, oil leakages in the underground soils, coastal erosion etc.

Various studies conducted so far in the Indian coastal environment indicate that discharges from industrial and domestic outfalls have degraded the coastal environments of Mumbai and Gujarat on the west coast and Pondicherry on the east coast (Zingde and Govindan 2000). Industrial pollution continues to be a major source of pollution in the environment. Numerous studies have already shown that locations in close proximity to industrial activity have considerable air, soil, and water contamination (De Bartomeo et al 2004, Landja et al 2004, Miro et al 2004). As a result, heavy metals in such heavily polluted soils may have detrimental health consequences (Huang et al 2019; Barbieri et al 2014). The current study was undertaken to examine the chemical and physical properties of soil from an industry pollutant exit point near the seashore and towards Mangalore city, also, the impacts of seawater and distilled water on the strength characteristics of soil were investigated.

MATERIAL AND METHODS

Mangaluru is located at 12.87°N 74.88°E in the Dakshina Kannada district of Karnataka. It has an average elevation of 22 m (72 ft) above mean sea level. Mangaluru coast is a belt of about 22 Kms with Arabian Sea in the West and the Western Ghats in the East. The area is characterized by tropical monsoon climate. The major industries located in and around Mangalore are: Mangalore Chemicals and Fertilizers Ltd. (MCF), Kudremukh Iron Ore Company Ltd. (KIOCL), Mangalore Refinery and Petrochemicals Ltd. (MRPL), Badische Anilin und Soda Fabrik (BASF), Indian Oil Corporation Limited (IOCL).

The soil is predominantly lateritic and alluvial in nature, with significant iron and aluminium content. The soil texture ranges from fine to coarse. The soil in valleys and intermediate slopes is rich in loam, whereas it is coarser on the top slopes. Silty and loamy soils are mainly found along river banks and in valley plains, and are of transported origin. They have a high infiltration capacity and are fertile, making them ideal for agriculture. Mangalore receives 4,242.5 millimeters of rain each year (167 inches). On average, the humidity level is at 78%.During the summer, the relative humidity is extremely high, approaching saturation levels. Mangalore has a tropical climate, with average temperatures ranging from 27 degrees Celsius (81 degrees Fahrenheit) to 34 degrees Celsius (93 degrees Fahrenheit) between the summer and winter months. The city's landscape is flat up to 30 kilometers (18.64 miles) inside the coast, and then abruptly turns to undulating hilly terrain in the Western Ghats to the east. Within the city, there are four hilly zones with natural valleys. Ten soil samples were collected near the industry pollutant exit point near the sea shore and towards the Mangalore city using standard sampling methods (Table 1).

For chemical analysis of soils, soil samples were taken at a depth of 10-30cm and collected individually in polythene bags according to conventional protocols (Srinivasamurthy 2010). The soil samples were air dried, crushed, and sieved through a 2mm sieve for analysis. Moisture content (MC), specific gravity (SG), atterberg limits, permeability test, grain sieve analysis, compaction test, unconfined compressive strength (UCS) tests were conducted. Scanning Electron Microscopy (SEM), X-ray powder Diffraction (XRD) and Energy Dispersive X-ray Spectroscopy (EDS) tests were conducted to know its morphology, elemental analysis/chemical characterization and mineralogical composition respectively. SEM-EDS are operated at 20 kV and images were taken at magnification levels up to 500-5000 times, Carbon tape was used to attach the powder samples to a holder. A thin layer of gold was also applied to the samples to provide an electrically conductive surface. Analysis of soil samples were done by adopting standard methods (Jackson 1958, Lindsay 1978) (Table 2).

RESULTS AND DISCUSSION

Chemical properties of soil: The pH of the soil varied from 4.4 to 6.9, most of the samples were acidic in nature with an average of 5.51 which is not suitable for agricultural activities

Table 1. Details of the soil sampling

Sampling code	Sampling locations	Geographical position	
		Latitude	Longitude
S1	Near MRPL, Thokur	12º 57 ' 51.6"N	74º 50 ' 10.9"E
S2	Near Adani Wilmar Ltd	12º 57 ' 10.1"N	74º 50 ' 10.9"E
S3	Near TOIL	12º56 ' 48.0"N	74º 50' 12.7"E
S4	Chitrapura	12º57'16.1"N	74º48'13.7"E
S5	Near NMPT	12º 56 ' 23.0"N	74º 48 ' 33.7"E
S6	Near IOCL	12º54 ' 54.9"N	74º 49 ' 00.1"E
S7	Near Kulur Junction	12º55'23.43"N	74º49'46.03"E
S8	Near BP Petroleum	12º54'51.82"N	74º50'3.28"E
S9	Along Edapally Pavel Highway	12º54'21.67"N	74º50'20.65"E
S10	Near KSRTC	12º53'53.64"N	74º50'40.43"E

(Table 3). EC of soil samples varied from 0.05 ds/m to 3.26 ds/m with an average value of 0.48 ds/m. EC of all the soil samples was within 1 dS/m except sample no.2.

Macronutrients in Soils

Organic carbon (OC): All the soil samples were in the low range as their OC content below 0.5 % except sample 2. OC content in the soils is important parameter from the fertility and physical properties points of view. Continuous cultivation, removal of agricultural wastes without return, and the effects of water and wind erosion, which preferentially remove the soil colloids, including the humidified organic fractions, can all be attributed for the low OC.OC of the soil samples ranges between 0.06 to 1.16% with an average OC of 0.312 %. Konthoujam 2(021) observed that, soil organic carbonwas higher at the surface soil (0-10 cm) than the deeper layers (10-20 cm and 20-30 cm).

Table 2. Soil testing methods

Test parameter	Methods
SG	IS 2720 (part 3/section 2)
Sieve analysis	IS 2720 (part 4) - 1985
Atterberg limits	IS 2720 (part 5) - 1985
Permeability	IS 2720 (part 17) - 1986
Compaction	IS 2720 (part 7) – 1980
UCS	IS 2720 (part 10) - 1991

Available phosphorus (P_2O_5): This varied from 5 to 160 kg/acre with an average of 30.8 kg/acre. Most of the samples were fall under low to medium value category as per the soil rating chart.

Available potassium (K_2O): K_2O ranged from 12 to 382 kg/acre with a mean value of 86.7 kg/acre. Most of the samples were fall under the low range category.

Available calcium (Ca) and magnesium (Mg): Ca is absorbed by plants as Ca^{2+} and its concentration ranges from 0.2 to 1 %. Ca^{2+} is generally considered to be an immobile element in the plant. Similarly, Mg is absorbed as Mg^{2+} and its concentration in crops varies between 0.1 to 0.4%. Mg is involved in a number of physiological and biochemical functions. Ca varies from 115.3 mg/kg to 2756 mg/kg with an average value of 563.03 mg/kg and highest value was found in the sample no. 2 in both the cases

Available sulphur (S): Sulfur deficiency is more frequent in sandy soils with little organic matter (less than 2%) and

Table 3. Chemical analysis of the samples

Code	pH	EC at 25°C	OC	P_2O_5	K_2O	Ca
Adequate range	6.3-8.3	0.01-1.0	0.75	10-25	61-120	>301
S1	5.6	0.67	0.49	6	101	779.2
S2	4.5	3.26	1.16	7	382	2756
S3	4.4	0.27	0.06	160	59	148.2
S4	6.9	0.05	0.11	26	12	157.0
S5	6.5	0.15	0.06	40	13	281.7
S6	4.8	0.13	0.06	5	72	219.7
S7	4.8	0.06	0.09	5	20	115.3
S8	5.4	0.05	0.37	9	40	396.5
S9	6.1	0.10	0.09	30	110	433.1
S10	6.1	0.06	0.63	20	58	343.6

Code	Mg	S	Zn	Fe	Cu	Mn	B
	>120.01	>10.01	>1	>4.51	>0.21	>2.01	>0.51
S1	148.4	62.44	0.30	15.45	0.58	3.58	0.46
S2	910.5	1928	2.57	118.7	1.25	49.60	3.05
S3	21.72	39.59	2.15	27.90	0.38	2.25	0.47
S4	18.35	0.57	28.04	8.18	0.13	0.19	0.08
S5	14.0	12.64	0.35	32.57	0.40	3.57	0.21
S6	29.74	9.01	10.39	13.80	0.21	2.93	0.38
S7	51.88	10.29	0.14	2.62	0.09	3.73	0.10
S8	70.52	24.77	0.09	5.81	0.31	1.88	0.27
S9	69.93	2.67	2.05	10.80	0.40	0.54	0.10
S10	25.75	6.08	5.1	8.04	0.24	0.26	0.07

during periods of heavy rainfall. S in the soil samples varied from 0.57 to 1928 mg/kg with an average value of 209.606 mg/kg.

Micronutrients in soils: Plants need very small quantities of micronutrients the so-called trace or minor elements for their nutrition among them are zinc (Zn), Iron (Fe), manganese (Mn), copper (Cu) and boron (B).

Zinc (Zn): Zinc in the soil samples varied from 0.09 mg/kg to 28.04 mg/kg with an average of 5.118 mg/kg. It is possible that such high levels of zinc may be exerting some toxic effect on the root zone or they may be responsible for creating nutrient imbalance.

Iron (Fe): In all drained red and lateritic soils, iron poisoning is ubiquitous. Under reducing conditions, the washings from adjacent upland lateritic and plinthites, deposits at low lands, and valley bottoms, cause toxicity. The values range between 2.62 mg/kg to 118.7 mg/kg with an average of 24.387 mg/kg.

Manganese (Mn): Mn in soils occurs as various oxides and hydroxides coated on soil particles, deposited in cracks and veins and mixed with Fe oxides and other soil constituents. Mn in the soils varied from 0.19 mg/kg to 49.60 mg/kg.

Copper (Cu): Cu concentration in soils ranged from 0.09 mg/kg to 1.25 mg/kg and averaged about 0.399 mg/kg. The amount of copper available to plants in the soil is determined by the pH of the soil. In the alkaline range, it is lower, while in the acid range, it is higher.

Boron (B): It was ranged between 0.07 mg/kg to 3.05 mg/kg and averaged about 0.519 mg/kg. It is possible that high levels of Zn, Cu, Mn, and Cu may be exerting some toxic effect on the root zone or may be responsible for creating nutrient imbalance.

Physical properties of soil: Specific gravity varied from 2.56 to 2.74. The liquid limit varied from 23 to 58. The plastic limit ranged between 19 to 43. Permeability varies from 0.15 to 2.41 m/d (Table 4). From the sieve analysis, most of the samples were SW and SC (Table 5). Figure 1 shows the grain size distribution of soil samples.

Compaction: For the most of the samples, the optimum moisture content has increased in the seawater treated soil

Table 4. Physical properties of the soil samples

Sample No.	Specific gravity	Permeability constant, K (m/d)	Liquid limit	Plastic limit	Plasticity index
S1	2.60	0.45	51	35	16
S2	2.74	0.36	42	25	17
S3	2.66	0.31	28	21	7
S4	2.63	2.18	25	20	5
S5	2.68	2.41	23	19	4
S6	2.56	1.82	26	22	4
S7	2.69	0.33	58	43	15
S8	2.62	0.22	38	24	14
S9	2.63	0.15	41	25	16
S10	2.59	0.20	48	35	13

Table 5. Classification of the soils

Sample code	Soil classification			IS Soil classification
	Gravels (%)	Sand (%)	Silt and clay (%)	
S1	22	52	26	SC
S2	3.6	37.68	58.72	OL
S3	17	66	17	SM
S4	1	89.20	9.8	SW
S5	4.4	88.31	7.5	SW
S6	3.2	92	4.8	SW
S7	23.9	62	14.1	SC
S8	14.6	58	27.4	SC
S9	6	28.8	65.20	CL
S10	20	59	21	SC

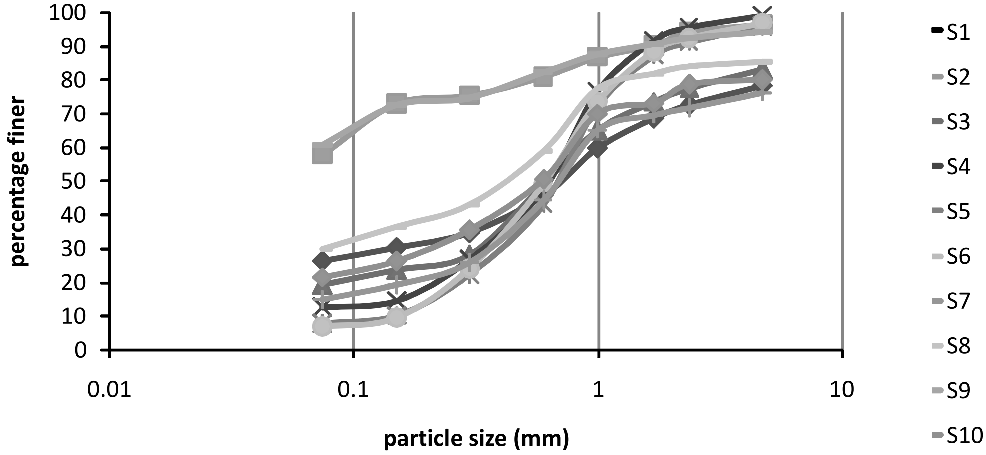

Fig. 1. Grain size distribution of soil samples

Table 6. Strength and compressibility of the soil samples in the presence of distilled water and seawater

Sample no.	MDD (g/cm^3)		OMC (%)		UCS (N/cm^2)	
	Distilled water	Seawater	Distilled water	Seawater	Distilled water	Seawater
S1	1.67	1.55	21	21.6	4.94	2.24
S2	1.44	1.41	24.7	24.2	4.93	3.1
S3	1.55	1.57	22.7	21.5	4.94	2.30
S4	1.59	1.62	22.35	21.6	4.10	2.5
S5	1.41	1.40	17.45	18.6	3.79	3.42
S6	1.62	1.49	23.5	24.2	3.83	2.06
S7	1.60	1.55	24.2	24.7	4.95	3.7
S8	1.48	1.39	20.08	22.1	4.81	2.36
S9	1.68	1.55	21.5	22.6	4.30	2.65
S10	1.52	1.42	24.12	24.8	4.45	2.3

compared to the distilled water treated soil and the maximum dry density decreased in seawater treated soil compared to the distilled water treated soil. This indicates that the situation has stabilized (Stabilized mixture has lower maximum dry density than that of unstabilized soil for a given degree of compaction). With more binders, the optimal moisture content rises.

Unconfined compression strength: UCS of the soil decreased in seawater treated soil compared to the distilled water treated soil. This can be contributed to increased size of the clay minerals (silt like behavior due to flocculation).

Material characterization of soil samples: SEM test indicate most of the samples have the crystalline texture. Average mean area of the particles was 0.6995 μm² with average minimum area of 0.0431 μm² and average maximum area of 30.25 μm². Particle sizes in the sample 4 were larger compared to the other collected samples. Similarly sample no. 8 has the smaller size particles when compared to other samples. From the EDX analysis it was concluded that, C, O, Al, Si, Fe and Hg were major elements abundantly found in the collected soil samples. XRD analysis shows that quartz, illite, kaolinite, orthoclase, mica, halloysite are the major mineral compounds found in the collected soil samples.

CONCLUSIONS

The most of the soil samples were coarse grained soils and Permeability of soils along the sea shores was high compared to the soils collected in Industrial area and towards the city center due to less silt and clay content. When soil samples undergo Compaction and UCS tests in the presence of seawater and distilled water, MDD, UCS values were decreased in the presence of seawater. Most of the samples were acidic in nature and were more or less not met the sufficient range for the agricultural activities. As a result, the anthropogenic activities occurring in and around the study area may be to blame for the chemical parameter deviations.

ACKNOWLEDGEMENTS

The authors are thankful to the Ministry of Earth Sciences, Government of India for supporting this work.

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Received 23 October, 2021; Accepted 22 March, 2022