Asian Journal of Chemistry; Vol. 31, No. 1 (2019), 169-175

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2019.21668

Soil Quality Assessment and its Suitability for Crop Production

D. RAMA RAO[1,*], V. SIDDAIAH[1] and P.V.S. MACHIRAJU[2]

[1]Department of Chemistry, Andhra University, Visakhapatnam-530003, India
[2]Departments of Chemistry, Pragati Engineering College, Surampalem-533437, India

*Corresponding author: E-mail: chris.olive7@gmail.com

Received: 22 August 2018; *Accepted*: 17 September 2018; *Published online*: 30 November 2018; AJC-19178

Soil properties are sensitive to various changes in the management and can be employed as indicators. Pollution in soil and water is strictly related to anthropogenic activities such as industrial wastages. Soil is a vital component, medium of unconsolidated nutrients and materials, forms the life layer of plants. The physico-chemical parameters of soil determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. In view of the applications of chemical fertilizers for higher production of crops, the quality of soil decreases. Keeping in view of the rapid industrialization and hectic agricultural activities in East Godavari region of India, there is great need in analyzing the soils for physico-chemical parameters *viz.* pH, electrical conductivity, total dissolved solids, total alkalinity, CO_3^{2-}, HCO_3^-, OH^-, total hardness, Ca^{2+}, Mg^{2+}, Na^{2+}, K^+, chloride, sulphate and phosphate to assess the chemical contamination of soils. The correlation matrices for physicochemical parameters are generated to verify the internal relationship between the parameters. Further it is also proposed to estimation of the irrigation parameters *viz.*, percent sodium (Na %), sodium adsorption ratio (SAR), Kelly's ratio (KR) and magnesium hazard (MH) to verify the suitability of soils for irrigation purposes. The results revealed that the soils near sago, paper and sugar industrial areas are slightly alkaline in nature. Higher phosphate concentration indicates the discharge of agriculture runoff in to soils. These irrigation parametric values indicate that these soils suitable for irrigation purposes however higher magnesium hazard (MH) values of soil indicate the depletion of the soil quality which in turn reduce the yield of the crops in study areas.

Keywords: Soil, Parameters, Irrigation, East Godavari region.

INTRODUCTION

Soil is a general term usually denotes the unconsolidated thin, variable layer of mineral and organic material usually biologically active which covers rest of the earth land surface. Soil properties are sensitive to various changes in the management and can be employed as indicators. In India, large numbers of fertilizers are employed instead of manures as such the crop productivity increases speedily but the quality of soil support decreases. It is difficult to control the adverse effects of the chemical fertilizers to the soil, plants, animals and human being [1,2]. Analysis of soil was carried out for the studies of various parameters like pH, conductivity, TDS, organic carbon, available nitrate nitrogen, calcium and magnesium. Various devastating ecological and human disasters of the last four decades implicate industries as a major contribution to environmental degradation and pollution [3-5].

Pollution in soil and water is strictly related to anthropogenic activities such as industry, agriculture, burning of fossil fuels, mining and metallurgical processes and their corresponding waste disposal [6]. All industrial effluents and most of byproducts from industry create most serious pollution to the water bodies and soil bodies [7]. The contamination of soil is often a direct or indirect consequence of industrial activities [8]. Soil is a dynamic natural body, consisting of mineral and organic constituents, possessing definite, physico-chemical, mineralogical and biological properties, having a variable depth over the surface of the earth and provides a medium for plant growth [9].

The pH is a synthesizing factor in soil fertility due to its influence on the assimilation of soil nutrients by plants. In fact, the absorption of minerals *viz.*, as phosphorus, potassium and nitrogen by the plant becomes more difficult as pH decreases [10]. Land use further affects the physico-chemical properties of soil [11]. Poor quality of irrigation water affects both soil quality and crop production adversely [12].The function of soil is generally threatened by increasing and very often conflicting demands of a constantly growing human population and its activities (such as irrigation), as well as by land use and climate change. This leads to a number of physical and chemical degradation processes that affect the sustainable functioning of soils [13]. Soil health is a state defined by the delicate balance of various physical, chemical and biological characteristics of soil and its relationship with environment. From the crop production point of view a healthy soil may be defined as one of the produce good crops suitable for human and animal consumption and has the ability to recuperate to sustain production.

The studies of Doran and Pakill [14] suggested that the soil quality assessments could be used as a management tool or aid to help farmers select specific management practices and as a measure of sustainability. The studies further suggested that the approaches used to define and assess soil quality should be tailored for specific applications such as sustainable production, environmental quality and animal or human health.

EXPERIMENTAL

Samples: The soil samples were collected in east, west, north and south directions around the sago, paper and sugar industries by considering the industry as nucleus at a distance of 0-1 km, 2-3 km and 3-5 km and the details of sampling locations which their coordinates are presented in Table-1.

Polythene containers were employed for sampling and preserved for analysis by following the standard procedures [15]. The samples were analyzed for physico-chemical parameters which include pH , electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), Ca^{2+} and Mg^{2+}, Na^+, K^+, chloride, sulphate and phosphate. pH determined by pH meter (Global-DPH 505, India-Model) and conductivity measured by the digital conductivity meter (Global-DCM-900-Model). Total dissolved solids are determined from the relation TDS = electrical conductivity (EC) × 0.64. Chloride, total alkalinity (TA) and total hardness (TH) were estimated by titrimetry. Fluoride, sulphate, nitrate and phosphate by spectrophotometer (Model-167, Systronics), Na^+ and K^+ by flame photometer (Model-125, Systronics). The irrigation parameters sodium sdsorption ratio (SAR) [16], residual sodium carbonate (RSC) [17] are determined for the soils. Percent sodium (Na%) [18], Kelly's ratio (KR) [19] and magnesium hazard (MH) [20] are determined by the following relation:

$$\text{Per cent sodium (meq/L)} = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

$$\text{Sodium adsorption ratio (meq/L)} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

$$\text{Residual } Na_2CO_3 \text{ (meq/L)} = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

$$\text{Kelly's ratio} = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$$

$$\text{Magnesium hazard} = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100$$

Characterization of soil: The representative soil samples are prepared collected and labelled with code from SG-1 to SG-12, P-1 to P-12, and S-1 to S-12 from the identified study area and the waters are characterized for physico-chemical parameters.

RESULTS AND DISCUSSION

The soil samples are prepared and labelled with code from SG-1 to SG-12 for sago industry, P-1 to P-12 for paper industry and S-1 to S-12 for sugar industry are characterized for physico-chemical parameters *viz*., pH, EC, TDS, TA, CO_3^{2-}, HCO^{3-}, OH, TH, Ca^{2+}, Mg^{2+}, Mg^{2+}, Na^+, K^+, chloride, sulphate and phosphate. The analytical data are presented in Tables 2 and 3. The correlation matrices are generated and presented in Tables 4-6 in order to find the relationship between the physico-chemical parameters and their internal relationship.

pH: pH of soils near by sago industrial area ranges from 7.3 -8.5, pH of soils near by paper industrial area ranges from 7.1-8.3 and pH of soils near by sugar industrial area ranges from 7.6-8.5 the pH levels are within the permissible limit and indicates the soil health.

Electrical conductivity: Electrical conductivity (EC) levels of soils within the permissible limit of 4000 µmhos/cm and hence these soils exibhited non-saline nature. Electrical condu-

TABLE-1
DETAILS OF COORDINATES OF SAMPLING LOCATIONS

Sample code	Distance	GPS-Coordinates of Sago Industry		Sample code	GPS-Coordinates of Paper Industry		Sample code	GPS-Coordinates of Paper Industry	
		Latitude	Longitude		Latitude	Longitude		Latitude	Longitude
SG-1	E (0-1km)	N-170 01'842"	E-820 08'937"	P-1	E-81°58'051"	N-16°51'450"	S-1	N-17°02'517"	E-82°10'025"
SG_2	E (2-3km)	N-170 01'390"	E-820 08'645"	P-2	E-81°58'205"	N-16°51'194"	S-2	N-17°02'558"	E-82°10'270"
SG-3	E (3-5km)	N-170 01'972"	E-820 09'248"	P-3	E-81°58'387"	N-16°51'321"	S-3	N-17°02'934"	E-82°10'737"
SG-4	W (0-1km)	N-170 02'140"	E-820 09'034"	P-4	E-81°56'630"	N-16°51'795"	S-4	N-17°02'682"	E-82°09'901"
SG-5	W (2-3km)	N-170 02'152"	E-820 09'038"	P-5	E-81°56'314"	N-16°51'658"	S-5	N-17°02'958"	E-82°09'201"
SG-6	W (3-5km)	N-170 02'152"	E-820 09'038"	P-6	E-81°55'934"	N-16°51'729"	S-6	N-17°02'658"	E-82°10'154"
SG-7	N (0-1km)	N-170 01'951"	E-820 09'134"	P-7	E-81°57'055"	N-16°51'919"	S-7	N-17°02'682"	E-82°09'975"
SG-8	N (2-3km)	N-170 02'312"	E-820 09'614"	P-8	E-81°57'065"	N-16°52'021"	S-8	N-17°02'812"	E-82°10'209"
SG-9	N (3-5km)	N-170 02'536"	E-820 10'047"	P-9	E-81°57'386"	N-16°52'216"	S-9	N-17°03'052"	E-82°10'469"
SG-10	S (0-1km)	N-170 01'831"	E-820 08'845"	P-10	E-81°55'634"	N-16°51'649"	S-10	N-17°02'321"	E-82°09'606"
SG-11	S (2-3km)	N-170 01'460"	E-820 08'367"	P-11	E-81°55'029"	N-16°51'567"	S-11	N-17°01'917"	E-82°09'086"
SG-12	S (3-5km)	N-160 57'933"	E-820 12'814"	P-12	E-81°57'442"	N-16°51'401"	S-12	N-17°01'839"	E-82°08'933"

E-East, W-West, N-North, S-South

ctivity values of soils near sago industrial araea ranges from 37.1-494 µmhos/cm while EC of soils near paper industrial araea ranges from 425-1598 µmhos/cm and EC of soils near sugar industrial araea ranges from 23.74-953 µmhos/cm.The EC values of soils are at lower levels indicates the absence of saline nature.

Total dissolved solids: Total dissolved solids values of soils near by sago industry area ranges from 23.744-316 mg/L, TDS values of soils near by paper industry area ranges from 47.872-1022.72 mg/L and TDS values of soils near by sugar industry area ranges from 12.608-609.92 mg/L.

TABLE-2
PHYSICO-CHEMICAL CHARACTERISTICS OF SOILS

Sample code	pH			EC (µmhos/cm)			TDS (mg/L)		
	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar
1	8.2	7.8	8.0	318	889	136	203.52	568.96	87.04
2	8.0	7.2	7.9	183	723	150	117.12	462.72	96.90
3	8.2	7.5	8.2	137	934	174	87.68	597.76	111.36
4	8.5	8.1	8.5	326	74.8	241	208.64	47.872	154.24
5	8.3	7.3	8.5	318	1166	240	203.52	746.24	153.60
6	8.3	7.2	7.8	197	425	953	126.08	272.00	609.92
7	8.0	7.4	8.2	168	717	196	107.52	458.88	125.44
8	7.7	7.5	8.0	37.1	609	218	23.744	389.76	139.52
9	7.3	7.1	8.2	461	1580	158	295.04	1011.20	101.12
10	8.5	8.3	7.9	494	1598	19.7	316.16	1022.72	12.608
11	7.9	7.2	7.6	285	855	48.5	182.40	547.20	31.04
12	8.3	7.7	7.7	238	1090	738	152.32	697.60	472.32
Sample code	**TA (mg/L)**			**HCO_3^- (mg/L)**			**CO_3^{2-} (mg/L)**		
	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar
1	20	10	20	20	10	20	BDL	BDL	BDL
2	20	30	20	20	30	20	BDL	BDL	BDL
3	30	20	30	30	20	30	BDL	BDL	BDL
4	20	30	30	20	30	30	BDL	BDL	BDL
5	30	20	20	30	20	20	BDL	BDL	BDL
6	40	20	50	40	20	50	BDL	BDL	BDL
7	20	10	20	20	10	20	BDL	BDL	BDL
8	10	40	20	10	40	20	BDL	BDL	BDL
9	20	30	30	20	30	30	BDL	BDL	BDL
10	20	10	30	20	10	30	BDL	BDL	BDL
11	30	20	30	30	20	30	BDL	BDL	BDL
12	20	10	40	20	10	40	BDL	BDL	BDL
Sample code	**OH^- (mg/L)**			**TH (mg/L)**			**Ca-H (mg/L)**		
	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar
1	BDL	BDL	BDL	370	370	190	20	280	50
2	BDL	BDL	BDL	140	140	210	20	90	20
3	BDL	BDL	BDL	280	280	260	20	240	30
4	BDL	BDL	BDL	470	470	260	30	330	10
5	BDL	BDL	BDL	210	210	200	20	160	20
6	BDL	BDL	BDL	150	150	150	30	120	30
7	BDL	BDL	BDL	230	230	380	30	180	20
8	BDL	BDL	BDL	180	180	350	10	140	20
9	BDL	BDL	BDL	170	170	260	20	110	10
10	BDL	BDL	BDL	390	390	260	10	250	10
11	BDL	BDL	BDL	180	180	290	30	110	10
12	BDL	BDL	BDL	110	110	210	20	70	20
Sample code	**Mg-H (mg/L)**			**Ca^{2+} (mg/L)**			**Mg^{2+} (mg/L)**		
	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar
1	210	90	140	8	112	20	51.24	21.96	34.16
2	160	50	190	8	36	8	39.04	12.2	46.36
3	250	40	230	8	96	12	61.0	9.76	56.12
4	290	140	250	12	132	4	70.76	34.16	61.0
5	170	50	180	8	64	8	41.48	12.2	43.92
6	420	30	120	12	48	12	102.48	7.32	29.28
7	300	50	360	12	72	8	73.2	12.2	87.84
8	430	40	330	4	56	8	104.92	9.76	80.52
9	330	60	250	8	44	4	80.52	14.64	61.0
10	160	140	250	4	100	4	39.04	34.16	61.0
11	120	70	280	12	44	4	29.28	17.08	68.32
12	50	40	190	8	28	8	12.2	9.76	46.36

Sample code	Na^+ (mg/L)			K^+ (mg/L)			Chloride (mg/L)		
	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar
1	18.95	4.94	9.65	7.06	17.63	15.83	170.16	70	248.15
2	12.64	4.94	3.41	5.52	22.8	10.3	46.085	126	319.05
3	5.74	3.52	7.7	6.12	15.56	6.75	38.995	142	212.7
4	29.9	10.72	3.39	13.62	20.19	10.87	31.905	20	850.8
5	45.93	2.96	10.1	18.88	2.08	8.39	148.89	74	1169.9
6	12.76	2.66	3.05	5.85	9.63	3.86	42.54	50	531.75
7	5.82	4.77	4.02	12.16	2.5	11.55	141.8	20	1878.9
8	1.99	6.37	13.94	4.63	19.04	18.82	38.995	60	319.05
9	7.84	4.28	12.88	8.61	4.29	8.18	138.26	110	283.6
10	23.9	5.51	1.51	10.68	3.16	3.22	42.54	20	283.6
11	27.86	8.11	2.4	11.01	8.23	4.74	194.98	69	283.6
12	10.01	19.54	18.84	13.42	7.87	21.23	99.26	70	1205.3
Sample code	Sulphate (mg/L)			Phosphate (mg/L)			Nitrate (mg/L)		
	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar
1	BDL	368	247	29.3	26.2	19.4	10.795	2.058	18.74
2	BDL	122	192	4.9	42	26.9	12.03	5.753	1.93
3	354	3	166	9	47.5	8.5	5.74	8.279	8.61
4	187	20	84	19.6	43.2	25.1	1.134	5.088	2.69
5	BDL	76	298	43.5	22.8	10.2	4.847	3.660	10.63
6	BDL	49	330	5.7	25.9	49.6	3.271	8.788	20.26
7	BDL	193	264	4.6	10.3	135.2	4.94	4.021	5.83
8	323	158	19	13.8	62.8	9.8	2.847	7.642	11.17
9	95	97	87	5.1	4.0	25.1	1.994	5.589	4.28
10	BDL	141	213	4.9	18.3	12.8	2.184	6.279	2.53
11	15	127	418	92.5	32.5	21.1	7.921	9.544	3.16
12	BDL	134	152	48.3	14.3	190.9	2.421	5.113	4.44

*BDL = Below detectable limit

TABLE-3
IRRIGATION PARAMETERS OF SOILS

Sample code	% Na (meq/L)			SAR (meq/L)			RSC (meq/L)			Kelly's ratio (KR)			MH		
	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar	Sago	Paper	Sugar
1	14.97	2.68	9.21	0.55	0.11	0.31	BDL	BDL	BDL	0.18	0.03	0.11	91.11	23.9	73.2
2	13.04	6.01	3.28	0.41	0.18	0.10	BDL	BDL	BDL	0.16	0.08	0.04	88.65	35.2	90.3
3	4.389	2.5	5.98	0.15	0.09	0.21	BDL	BDL	BDL	0.05	0.03	0.07	92.42	14.0	88.2
4	16.44	4.52	2.68	0.73	0.22	0.09	BDL	BDL	BDL	0.21	0.05	0.03	90.42	29.3	96.1
5	32.22	2.95	9.61	1.46	0.09	0.31	BDL	BDL	BDL	0.54	0.03	0.11	89.24	23.4	89.8
6	5.838	3.45	4.18	0.26	0.09	0.11	BDL	BDL	BDL	0.06	0.04	0.05	93.18	19.6	79.6
7	3.605	4.28	2.21	0.14	0.14	0.09	BDL	BDL	BDL	0.04	0.05	0.02	90.71	21.3	94.6
8	0.983	6.37	7.64	0.04	0.21	0.33	BDL	BDL	BDL	0.01	0.08	0.09	97.67	21.8	94.2
9	4.605	5.07	9.57	0.18	0.14	0.35	BDL	BDL	BDL	0.05	0.06	0.11	94.15	34.7	96.1
10	22.42	2.97	1.26	0.81	0.12	0.04	BDL	BDL	BDL	0.31	0.03	0.01	93.98	35.3	96.1
11	27.31	8.54	1.77	1	0.26	0.06	BDL	BDL	BDL	0.41	0.1	0.02	79.61	38.3	96.5
12	20.2	26.3	10.8	0.52	0.81	0.57	BDL	BDL	BDL	0.32	0.39	0.20	70.93	35.8	90.3

*BDL = Below detectable limit

TABLE-4
CORRELATION MATRIX OF SOILS NEAR SAGO INDUSTRIAL AREA

	pH	EC (μmhos/cm)	TDS (mg/L)	TA (mg/L)	TH (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)
pH	1										
EC (μmhos/cm)	0.096	1									
TDS (mg/L)	0.096	1	1								
TA (mg/L)	0.303	0.038	0.038	1							
TH (mg/L)	0.513	0.402	0.402	-0.175	1						
Na^+ (mg/L)	0.474	0.495	0.495	0.320	0.352	1					
K^+ (mg/L)	0.366	0.405	0.405	0.106	0.158	0.727	1				
Chloride (mg/L)	-0.324	0.276	0.276	0.097	-0.178	0.299	0.385	1			
Sulphate (mg/L)	-0.193	-0.453	-0.453	-0.245	0.182	-0.376	-0.375	-0.490	1		
Phosphate (mg/L)	0.040	0.068	0.068	0.214	-0.179	0.485	0.429	0.630	-0.247	1	
Nitrate (mg/L)	-0.069	-0.214	-0.214	0.071	-0.129	0.032	-0.310	0.334	-0.271	0.194	1

TABLE-5
CORRELATION MATRIX OF SOILS NEAR PAPER INDUSTRIAL AREA

	pH	EC (μmhos/cm)	TDS (mg/L)	TA (mg/L)	TH (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)
pH	1										
EC (μmhos/cm)	0.002	1									
TDS (mg/L)	0.002	1	1								
TA (mg/L)	-0.317	-0.330	-0.330	1							
TH (mg/L)	0.799	-0.151	-0.151	-0.161	1						
Na^+ (mg/L)	0.345	-0.082	-0.082	-0.168	-0.086	1					
K^+ (mg/L)	0.113	-0.619	-0.619	0.520	0.194	0.062	1				
Chloride (mg/L)	-0.543	0.250	0.250	0.286	-0.430	-0.194	0.295	1			
Sulphate (mg/L)	0.155	0.163	0.163	-0.388	0.097	0.012	0.039	-0.190	1		
Phosphate (mg/L)	0.073	-0.573	-0.573	0.621	0.131	-0.079	0.790	0.199	-0.205	1	
Nitrate (mg/L)	-0.285	-0.145	-0.145	0.337	-0.319	-0.074	0.073	0.180	-0.555	0.399	1

TABLE-6
CORRELATION MATRIX OF SOILS NEAR SUGAR INDUSTRIAL AREA

	pH	EC (μmhos/cm)	TDS (mg/L)	TA (mg/L)	TH (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)
pH	1										
EC (μmhos/cm)	-0.270	1									
TDS (mg/L)	-0.270	1.000	1								
TA (mg/L)	-0.410	0.780	0.779	1							
TH (mg/L)	0.135	-0.497	-0.498	-0.464	1						
Na^+ (mg/L)	0.009	0.260	0.260	-0.018	-0.040	1					
K^+ (mg/L)	-0.034	0.172	0.172	-0.257	0.152	0.756	1				
Chloride (mg/L)	0.314	0.265	0.265	-0.073	0.268	0.106	0.278	1			
Sulphate (mg/L)	-0.355	0.086	0.086	0.173	-0.267	-0.498	-0.519	0.121	1		
Phosphate (mg/L)	-0.277	0.523	0.523	0.299	0.092	0.371	0.497	0.713	0.020	1	
Nitrate (mg/L)	-0.031	0.460	0.459	0.191	-0.419	0.124	0.073	-0.117	0.224	-0.145	1

Total alkalinity: Total alkalinity of soils near by sago industrial area ranges from 20-40 mg/L. These values are within the permissible limit. Total alkalinity (TA) of soils near by paper industrial area ranges from 10 to 40 mg/L and total alkalinity of soils near by sugar industrial area ranges from 20-40 mg/L. Total alkalinity levels are within the permissible limit indicating the non-alkaline nature of soils.

Total hardness: Total hardness values of soils near by sago industrial area ranges from 70-450 mg/L. In sample SG-3, SG-6, SG-7, SG-8 and SG-9, total hardness crossed the permissible limit indicating the presence of excess Ca^{2+} and Mg^{2+} ion in the solids. Total hardness value of soils near paper industrial area ranges from 110-470 mg/L. Total hardness exceeded the permissible limit in sample P-1, P-4 and P-10 while total hardness of soils near sugar industry area range from 150 to 380 mg/L. Total hardness is found higher in sample S-7 and S-8 indicating the hardness nature of soils while in other soil samples it is below the permissible limit.Total hardness of majority of soils near sago, paper and sugar industry area are within the permissible limit indicating the non-encrustive nature of soils

Ca^{2+}: Ca^{2+} concentration of soils near by sago industrial area ranges from 4 to 12 mg/L, Ca^{2+} concentration of soils near by paper industrial area ranges from 36 to 112 mg/L and Ca^{2+} concentration of soils near by sugar industrial area ranges from 4-20 mg/L. Cacium concentration in soils near sago, paper and sugar areas are within the permissible limit of International Agriculture Standards (10 to 30 mg/L) [20] while the soils near paper industrial area exeeded the permissible limit.

Mg^{2+}: Magnesium ion concentration of soils near sago industrial area ranges from 12.20 to 104.92 mg/L, Mg^{2+} ion concentration of soils near paper industrial area ranges from 7.32 to 34.16 mg/L and Mg^{2+} ion concentration of soils near sugar industrial area ranges from 29.98 to 87.84 mg/L. Magnisium concentration in soils near sago, paper and sugar industrial areas exceeded the permissible limit of International Agriculture Standards (5-10 mg/L)

Na^+: Sodium ion concentration of soils near by sago industrial area ranges from 1.99 to 29.9, while Na^+ ion concentration of soils nearby paper industrial area ranges from 2.66 to 19.54. Similarly, Na^+ ion concentration of soils nearby sugar industrial area ranges from 4.63 to 18.88. The sodium ions concentration levels near Sago, paper and sugar industrial areas are within the permissible limit of WHO standards.

K^+: The potassium ion concentration of soils near sago industry and sugar industry areas ranges from 1.99 to 45.93 and 1.26 to 10.8 mg/L, respectively thus the values are within the permissible limit while the K^+ concentration of soils near paper industry area ranges from 3.52 to 19.54 mg/L.

Chloride: Chloride ion concentration of soils near by sago industrial area ranges from 31.905 to 46.085 mg/L and the values are within the permissible limit. Chloride ion concentration of soils near by paper industrial area ranges from 20 to 142 mg/L, however chloride ion concentration of soils near by sugar industrial area ranges from 212.7 to 1878.9 mg/L. The chloride levels in soils near sago and paper industry are within the permissible limit (250 mg/L). While the majority of soils near sugar industry exceeded the discharge of effluent in to soils.

Sulphate: Sulphate ion concentration of soil samples near by sago industrial area range from 31.905 to 194.98 mg/L. Two samples (SG-3 and SG-8) crossed the permissible limit indicating the discharge of industrial effluent into water sources in these particular locations. Sulphate ion concentration of soils near by paper industry area ranges from 3.0 to 368 mg/L indicate the non-discharge of effluent into the soil. Sulphate levels range of sugar industry area 19 to 418 mg/L. Higher values of sulphate are observed in soil samples S-5, S-6, S-7 and S-11 indicating the discharge of industrial effluent into soils in those study area locations. Sulphate ion concentration in majority of soils near sago and paper industrial areas are within the permissible limit (250 mg/L). While in majority soil samples near sugar industry exceeded the permissible limit indicates the discharge of effluent into soils.

Phosphate: Phosphate conentration of soils near by sago industry ranges from 4.9 to 92.5 mg/L. Concentration of phosphate in samples SG-1, SG-3, SG-4, SG-5, SG-6, SG-8, SG-9, SG-11 and SG-12 crossed the permissible limit indicating the discharge of agricultural runoff into the soils. Phosphate ion concentration of soils near paper industry ranges from 4 to 62.8 mg/L. All the levels exceeded the permissible limit of agriculture runoff standards indicating the discharge of agriculture runoff in to soil samples in the study area locations.

Phosphate ion concentration of soils near sugar industry ranges from 9.8 to 190.9 mg/L. All the levels exceeded the permissible limit of agriculture runoff standards indicating the discharge of agriculture runoff into soil samples in the study areas. Phosphate ion concentration in majority soils near sago, paper and sugar industrial areas crossed the permissible limit (5 mg/L) indicates the discharge of agriculture runoff into the soils.

Nitrate: Nitrate ion concentration of soil samples near paper industry is about 3.18 mg/L, while its concentration ranges from 2.05 to 9.544 mg/L. Nitrate levels of soils near sugar industry ranges from 53 to 20.26 mg/L, all the levels are at lower side. Nitrate ion concentration in soils near sago, paper and sugar industrial areas are within the permissible limit (45 mg/L) indicating the non-discharge of nitrogenous agriculture runoff into the soils. Nitrate values are within the permissible limit and hence can cause no concern.

Sodium percent (Na%): Sodium percent in soils of sago industry ranges from 0.983 to 27.31 mg/L. Percent sodium of soils near paper industry ranges from 2.50 to 26.3 mg while near sugar industry ranges form 1.26 to 9.57 mg/L and these values are within the permissible limit (60 mg/L) of irrigation standards indicating the suitability of soils for irrigation purposes.

Sodium adsorption ratio (SAR): SAR of soils near sago industry area ranges from 0.04 to 1.46 meq/L while near paper industry area, it ranges from 1.89 meq/L. The SAR of soils near sugar industry area ranges from 0.04 to 0.057 mg/L and all these levels are within the permissible limit (26 mg/L) of irrigation standards indicating the suitability of soils for irrigation purposes.

Residual sodium carbonate (RSC): Residual sodium carbonate (RSC) values of soils near sago, paper and sugar industrial nareas are observed at below detectable limit.

Kelly's ratio (KR): Kelly's ratio values of soils near sago industry area range from 0.01 to 0.54 meq/L while in paper industry area it ranges from 0.03 to 0.1 meq/L. Kelly's ratio values of soils near sugar industry are ranges from 0.01 to 0.11 meq/L within the permissible limit (1.0). All these values indicate the suitability of soils for irrigation purposes.

Magnesium hazard (MH): Magnesium hazard values of soils near sago industry area ranges from 63.07 to 97.67 meq/L its value near paper industry ranges from 19.6 to 38.3 meq/L. Magnesium hazardous of soils near sugar industry ranges from 73.2 to 96.5 meq/L and crossed the permissible limit (50) of irrigation standards indicating the magnesium hazardousness of soils in the study area. Higher magnesium hazard values depletes the soil qualities which in turn reduce the crop yield.

Correlation between physico-chemical parameters

Soils near sago industrial areas: pH moderately corre-lated with total hardness, electrical conductance is strongly corelated with TDS, Na^+ is moderately corelated with K^+, and chloride is also moderately corelated with phosphate. Strong corelation of electrical conductance with TDS indicated that electrical conductance values are more due to the presence of discharged soluble solids into soils.

Soils near paper industrial area: pH is strongly correlated with total hardness, total hardness is strongly corelated with TDS, total alkalinity is strongly correlated with K^+ while K^+ is strongly correlated with phosphate. Strong correlation of pH with total hardness indicates that the pH is related and its values will be contributed due to the presence of Ca^{2+} and Mg^{2+} ion concentrations in soils.

Strong correlation of electrical conductance with TDS indicates that the higher electrical conductance values are due to the presence of soluble solide contents in soils. Strong corelation of K^+ with phosphate indicate the impacts of potasium and phosphatic fertilizers on soil quality.

Soils near sugar industrial area: Electrical conductance is strongly correlated with TDS and moderates correlated with total alkalinity and phosphate. Total dissolved solids has moderate correlation with total alkalinity and phosphate while Na^+ moderately correlated with K^+. Also the chloride is in moderately correlated with phosphate. Strong correlation of EC with TDS indicates the higher EC values due to the presence of soluble solids available in soils.

Conclusion

The pH values of soils near sago industrial area indicated slight alkaline nature of soils. Lower EC values and TDS indicate the non-saline nature of soil and absence of solid matter in the soils. Higher hardness in few soil samples indicates the presence of calcium and magnesium ions. Lower sodium, potassium and chloride ion concentrations also indicate the non-saline nature of soils. Higher values of sulphate in few soils confirm the discharge of industrial effluent into soils. Higher concentrations of phosphate in majority of soils indicate the discharge of agricultural runoff from the surrounding agricultural activities. Higher concentration of magnesium indicate magnesium hazard of soils and thereby decrease the soil quality and hence the yield of the crops in the study areas will be minimized. pH values of soils near paper industry indicates slight alkaline nature of soils, however the EC values are higher only in 4 samples indicating the saline nature of soils. Total dissolved solids is the major parameters which exceeded the permissible limits indicating the presence of solid matter in the soils. Ca^{2+} and Mg^{2+} ion concentrations indicate the presence of minerals. Lower values of nitrate indicate lower concentration of nitrate, while higher concentration of phosphate indicates the discharge of agriculture run-off containing phosphate fertilizers in to the soils in the study area. pH values of soils near sugar industry indicate slight alkaline nature of soils. Lower EC values and TDS indicate the non saline nature of soil and non-presence of solid matter in the soils. Total alkalinity values are within the permissible limit. Total hardness in only two soil samples crossed the permissible limits. Calcium ion concentrations are lower, while magnesium ion concentrations are higher in soils which can cause an indication of magnesium hazard of soils in majority soils in study area locations. Sodium ion concentrations are within the permissible limit, however, sodium, potassium ion levels is higher in sample locations S-12. Higher chloride concentrations revealed the corrosive nature of soils. The nitrate levels are within the permissible limit while phosphate levels crossed the permissible limits indicating discharge of agricultural run-off in to the soils. Higher sulphate levels in four sampling locations ensure the permissible limit and confirmed the discharge of industrial effluent in to the soil samples in the study area locations. The correlation matrices of physico-chemical properties of soils near sago, paper and sugar industries also revealed that there is a strong relation between EC and TDS which significantly indicates that the soils are rich in soluble soild content and there by the quality of soils may be depleted and in turn the crop yields may be reduced in the study areas.

The irrigation parametric values sodium percent (Na %), sodium adsorption ratio (SAR), Kelly's ratio (KR) values in respect of all soil samples are within the limit of irrigation standards indicating their suitability for irrigation purposes. In majority ground water samples magnesium hazard crossed the permissible limit of irrigation standards indicating the magnesium hazard of soils which reduce the soil quality of soil and hence the crop yields will be minimized in the locations of the study area. In majority soil samples, magnesium hazard is within the permissible limits indicating the absence of magnesium hazard of soils and hence the crop yield will be increased in the locations of the study area. Magnesium hazard values crossed the permissible limit of irrigation standards and can depleted the quality of soil and minimize the crop yield in the study areas. Hence, it is suggested that the soils can be reclaimed for improvement of quality for production of more crop yields.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

1. X. Yang and S. Fang, *Ambio*, **44**, 647 (2015); https://doi.org/10.1007/s13280-015-0639-7.
2. S. Wang, H,Y.H. Chen, Y. Tan, H. Fan and H. Ruan, *Sci. Rep.*, **6**, 20816 (2016); https://doi.org/10.1038/srep20816.
3. A. Dechezleprêtre and M. Sato, *Rev. Environ. Econ. Policy*, **11**, 183 (2017); https://doi.org/10.1093/reep/rex013.
4. F.N. Chaudhry and M.F. Malik, *J. Ecosyst. Ecography*, **7**, 225 (2017). https://doi.org/10.4172/2157-7625.1000225.
5. H.I. Abdel-Shafy and A.-B.S. Emam, *Environ. Manage. Health*, **2**, 19 (1991); https://doi.org/10.1108/EUM0000000002787.
6. V. Giuliano, F. Pagnanelli, L. Bornoroni, L. Toro and C. Abbruzzese, *J. Hazard. Mater.*, **148**, 409 (2007); https://doi.org/10.1016/j.jhazmat.2007.02.063.
7. L. Baskaran, K.S. Ganesh and A.L.A. Chidambaram, *Botany Res. Int.*, **2**, 131 (2009).
8. M.J. McLaughlin, D.R. Parker and J.M. Clarke, *Field Crops Res.*, **60**, 143 (1999); https://doi.org/10.1016/S0378-4290(98)00137-3.
9. M. Velayutham and T. Bhattacharyya, ed.: J.S.P. Yadav, and G.B. Singh, Soil Resource Management, Natural Resource Management for Agricultural Production in India, International Conference on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century (2000).
10. C. Mathieu and F. Pieltain, Physical Analysis of Aoil: Selected Methods, Lavoisier TEC & DOC, Paris, France, pp 388 (1998).
11. R.E. Masto, P.K. Chhonkar, T.J. Purakayastha, A.K. Patra and D. Singh, *Land Degrad. Dev.*, **19**, 516 (2008); https://doi.org/10.1002/ldr.857.
12. S. Bello, B.Sc. Project, Quality of Irrigation Water and Soil Characteristics of Wetlands in Sokoto Metropolis Department of Soil Science and Agricultural Engineering, Usman Dan Fodio University, Sokoto, Nigeria (2001) (Unpublished).
13. EEA/UNEP, Down to Earth: Soil Degradation and Sustainable Development in Europe-A Challenge for the 21st Century; Environmental Issue Report 16, EEA and United Nations Environment Programme Regional Office for Europe: Copenhagen (2000).
14. J.W. Doran and T.B. Parkin, eds.: J.W. Doran, D.C. Coleman, D.F. Bezdicek and B.A. Stewart, Defining and Assessing Soil Quality, In: Defining Soil Quality for a Sustainable Environment, Soil Science Society of America, Madison: Wisconsin (1994).
15. D.S. Ramteke and C. Moghe, A Mannual on Water and Wastewater Analysis, National Environmental Engineering Research Institute, Nagpur, India (1998).
16. L.A. Richards, Diagnosis and Improvement of Saline Alkali Soils, IBH Publishing Co. Ltd.: New Delhi, India, pp 98-99 (1954).
17. H.M. Raghunath, Ground Water, Wiley Eastern Ltd.: New Delhi, pp 563 (1987).
18. H. Kacmaz and M.E. Nakoman, Evaluation of Shallow Groundwater Quality for Irrigation Purposes in the Koprubasi Uranium area, Turkey, Scientific Research Project Division of Dokuz Eylul University, Turkey, pp 1-9 (2010).
19. W.P. Kelley, Alkali, Soils, their Formation, Properties and Reclamation. Reinhold Publishers: New York, USA (1951).
20. S.D. Jadhav, R.S. Sawant and A.G. Godghate, *Res. J. Agric. Forestry Sci.*, **1**, 24 (2013).