Characterisation and Soil Pollution in Agrarian Floodplain of Ibadan Peri-Urban in South Western Nigeria

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Abstract
Ibadan metropolis in Nigeria has population of about 6millons people. There is increasing concern about lowland soils around Ibadan periurban where most of the industrial wastes transported majorly by River Ona were deposited. These soils are used for dry season farming and contribute to food security. This research was carried out to characterise and determine the vulnerability of periurban lowland soils to industrial pollution . The area was studied using 50mx50m grid. Surface samples were taken at 50m interval. Representative profile pits were dug and described using USDA method. Particle size analysis and chemical analyses including Phosphorus, Nitrogen , exchangeable Cations (Ca, Mg, Na, K,), Mn and heavy metals such as Pb. Cu, Zn, Cr, Fe, Cd determinations were carried out. The results shows that the surface soil of the flood plain was fertile with high N (0.35cmol/kg), P (51.25 cmol/kg), K (0.61 cmol/kg) with very high to toxic levels of phosphorous in the soil which range between 28.99 to 87.70 ppm. Average lead concentration was (34.30 mg/kg), Zn (171.20 mg/kg), Fe (83.97 mg/kg), Cu (19.11 mg/kg), Mn (31.10 mg/kg), Cr (0.69 mg/kg), Cd (0.3 mg/kg). The predictions from soil-plant heavy metal transfer coefficient (Pb:35-343; Cr:0.46-4.6; Zn:171-1712; Cu:19-191; Fe:83-840; Mn:31-281; Cd:0.1-10) shows that there might be toxic level in crops in the area but the high yield and health of plant from field evidence and farmers interaction indicate that the high level of P (28.99-87ppm) must have inhibited uptake of some metals such as Pb, Zn and Cu.
Keywords: Fadama, Urban waste, Heavy metals, Soil pollution, Peri-urban farming

Introduction

The need for food security especially during the dry season is majorly suppled by dry season farming on fadama. A sustainable production of vegetables to meet the demands of an ever increasing population in the country is of great concern. The need for these basic nutritional needs is always sourced for within the fertile lowland after the upland become too dry to cultivate during the dry season. Moreover farmers depend on rain fed agriculture for upland cultivation of crops. However in lowlands with associated perennial rivers surface irrigation is common to sustain production during the dry season

Industrial waste constitute the major soil pollution from urban areas.These wastes include a variety of chemical like heavy metals Lead, Cadmium etc. Recently industrial effluent and sewage sludge are being used on farm land hence, these toxic metals can be transferred and concentrated into plant tissues from the soil and these metals have changing effect on the plants (Mungur *et al*., 1995)

In Ibadan the peculiar case of river Ona that flows through the city is a peculiar case because it has impact on the surrounding Peri-urban associated Fadama. The residential and industrial wastes are usually discharge into the river. The waste that deposited on the floodplain along the river serve as source of vegetables and some arable like maize during the dry season due to haphard use of lands , fadama are under increasing pressure from various land users. (Ardo, 2004). Under these conditions, the resources base of the Fadama lands would deteriorate and Fadama farmers would experience a long term crop yield reduction and soil pollution that could jeopardize the self-reliance the country enjoys in the production of vegetables under Fadama. Consequently, profitability would reduce and the standard of living would fall. Thus, an assessment of the quality of fadama is invaluable. This is because urban and peri-urban agriculture and fadama cultivation are growing fast around all major cities in Africa with the increase of urban population and consequent rising demand. In times of drought, the importance of fadama cannot be overemphasized since it serves as the substitutes or compliment to upland crop production during dry season or when there is crop failure. Hence, fadama resources guarantee urban food security and possibility of all year round food production. Hence this research was set up to assess the impact of urban activities on soil quality of fadama associated with River Ona in Ibadan with specific objectives to characterise the soils and determine the effect of urban waste on peri-urban agriculture.

3.0 MATERIALS AND METHOD

3.1 Description of the Project Site

3.1.1 Location

The samples were collected in the valley bottom soil in Oluyole Local Government Area along Ijebu ode Road in periurban areas close to Ibadan metropolis.

3.1.2 Climate

The climate of Ibadan is dominated by the influence of two major wind currents. One from North- east is hot and very dry and other from the south west is warm and very moist. These winds current give rise to a hot dry season from December to February and a cooler rainy season in potential era transportation and precipitation at Oluyole along Ijebu-Ode-CRIN, Ibadan road. The short dry period separating the two period of peak rainfall at Ibadan is clearly shown by the period of moisture stress, when the water needed exceeds the supply.

Although only the months of December, January and February have an average rainfall, less than 254mm from the month of march. Rainfall start in the area early in March and last for about 25mm monthly total rainfall (Moor plantation, meteorological station). The average rainfall ranges from 62.85 to 196.96 mm in March. The average rainfall has risen to 131.30mm.

3.2 Land use

The land use in the area include: maize (*Zea mays*) vegetables Okra (*Abelmoscus escuents*) Tomatoes (*Lycopesium esculentus*) sweet pepper (*Capsium annum*) etc. The timing of planting operation and the number and type of crops which can be grown are influenced by one onset of the rains, the regime and duration of the wet season.

3.3. Vegetation

The project site fall in lowland rainforest. It consists of elephant grass with few bananas and plantain with few citrus trees. In clearing the land for arable farming, cutlass or machete are used. The principal food crops of the area are maize (*Zea mays*), yam (*Discorea spp*), okra (*Abelmocus esculentus*), and pepper (*Capsicum annum).*

3.4. Geology

The site is majorly combination of alluvium deposit and hill wash soils with many waste materials.

3.5. The soils

The soil is generally sandy loam and to its poorly drained has incomplete oxidation and poorly developed soil profile due to layering cause by annual flooding. The water table is generally high and therefore it could be cultivated only during the dry season and used for planting swamp rice, dry season maize, early yam and vegetables such as Amaranthus, tomatoes, okra, pepper, pumpkin and lettuce.

3.6 Field work

The land area was surveyed using grid method, River Ona was used as baseline, transect was cut across the slope perpendicular to the river. Sampling point was 50m interval, after measuring with the meter tape, then the point was augered and samples were taking out at 0-15cm. Two profile pits were dug based on the results of auger hole borings and minipits. The first was cited in the polluted areas usually flooded while the second was sited about 10m away from the flood plain for comparison. The profiles were described based on USDA standard; samples were collected from the horizons demarcated in the pits.

3.7 Laboratory analysis

The soil were air dried and sieved with 2mm screen sieve after gentle grinding with mortar and pestle, Analysis such as routine, trace element and mechanical analysis were carried out on the soil, where the routine analysis involved the determination of PH in the soil by using PH meter with glass electrode (Mclean, 1982), Available phosphorous was extracted by using Bray1 method (Bray and Kurtz, 1945), Organic Carbon was determined by wet oxidation method of Walkey and Blacky which was modified by Allison (1965), Exchangeable bases to determine the concentration of Na^+, K^+, Mg^{2+} Ca^{2+} & Mg^+ was determined by using flame photometer while Ca^{2+}, mg^{2+} was determined by automatic adsorption spectrophotometer. Mechanical analysis was also done using hydrometer by Bouyoucos (1962) to determine the amount of sand, silt and clay present in the soil. Trace element like: Fe, Cd, Zn, Cu, Mn, Cr and Pb were determined by addition of 50 ml of 0.1NHCL solution in to 5g of soil samples and it is then determined by atomic absorption spectrophotometer.

4.0. Results and discussion

4.1 Morphology description

The morphological description of the profile Pit 1 is attached in Appendix 1. This soil unit was located at the floodplain, has geo-genetic origin with evidence of commulization due to different layers of sandy loam to loamy sand texture. The different layers probably represent different deposition from the river when it overflows the flood plain. The profile is dominated with urban waste including clothe pieces, nylon, plastic, iron sheet or pieces in the horizon. The consistence and structure varies from sub-angular blocky to very firm. The colour varies from dark brown to dark greyish brown which shows the high level of organic matter in the soil. The water table was reached at 80 cm depth. The soil is non-plastic to slightly sticky with common abundance refuse in the profile.

The morphological description of pit 2 located just above the floodplain is shown in Appendix 2. The colour ranged between very dark brown to dark yellowish brown with prominent Fe/Mn nodles, may gravels. The profile has very firm to firm moist consistency, non-sticky and non-plastic, few to may fibrous rock and few rotten rocks at 29 – 35 cm before the saprolitic hard pan. The depth to water table was 100 cm

4.2 Physical and chemical properties

Table 1 shows the physical and chemical soil properties of the profile pit located in River Ona floodplain. The table reveals that the texture varied from sandy loam to loamy sand in the profile. The clay and silt contents are low with high percent sand (68.8 – 86.8 %). There was no evidence of cutan to show illuvial formation of clay, but stratification is attributed due to different time of deposition. The chemical properties show that the pH is neutral and the cation exchangeable capacity (CEC) varied from low to high (3.93 – 7.8 cmol kg^{-1}). In spite of the heavy load of waste material the profile was not sodic. Sodium (Na) content was less than 15 % of the total CEC. Phosphorus (P) content was high (43.78 – 55.94 ppm) in the soil profile pH. The variable inclusion of urban wastes were evident, which could account for this carbon content, which varied from 0.54 – 1.44 % and nitrogen (N) from 0.05 – 0.45 %. The average concentration of heavy metal is stated in Table 2. Heavy metal distribution in the soil was also highly variable. Lead (Pb) content ranged from 40.00 – 41.40 ppm, chromium (Cr) (0.76 – 1.04 ppm), zinc (Zn) (12.83 – 254.50 ppm), copper (Cu) (5.45 – 18.06 ppm), iron (Fe) (46.00 – 181.00 ppm).

The physical and chemical properties of the soil from Pit 2, classified as Gambari series are shown in Table 3 and 4. The soil texture varies from loamy sand to sandy loam. The pH is neutral to slightly acidic (6.28 – 7.35). CEC varies from 3.94 – 9.74 cmol kg^{-1}. Potassium (K) is moderate in the topsoil (0.23 cmol kg^{-1}) and low in the subsoil (0.05 – 0.08 cmol kg^{-1}). The P content was very high in the surface horizon (87.70 ppm), but low in subsoil (2.74 – 3.87 ppm) where laterite formation is observable. N is low in the soil profile (0.05 – 1.4 %) and organic carbon is moderate at the surface, but low in the subsoil (0.02 – 0.09 %).

The concentrations of heavy metals in Pit 2 are shown in Table 4. Pb was only present in first and second horizon (33.00 – 41.00 ppm). This horizon accumulates more of the heavy metals compared to other horizons, except Fe.

4.3. Physical and chemical properties of the surface soils

The area is basically used for arable cultivation. Therefore the surface parameters were analysed to show the range and average concentration in the soil. The physical and chemical properties of the surface samples were shown in Tables 5 and 6. The soils are sandy loam to loamy sand with low silt (15.70 %) and clay content (8.16 %). pH is neutral (6.82 – 7.03). The average CEC is 6.62 cmol kg^{-1} with high content of K (0.46 cmol kg^{-1}) and low Mg content (0.6 cmol kg^{-1}). P is very high (40.49 ppm) and average % carbon content is 2.48 % with 0.25 % N.

Heavy metals concentrations in the surface soil as shown in table 6 shows high content of Pb (34.33 ppm). Zn (171.2 ppm), Fe (97.0 ppm). The uptake of this nutrient was examined using soil –plant metal transfer coefficient as shown in tables 7 and 8.The results show probability of high uptake of Zn, Fe, Cu, in plants if other factors that affect the uptake remain conducive. Phosphorus to zinc ratio was calculated. A ratio below 54 has been reported to result to deleterious concentration in plants (Agbede, 2009).

4.3 Discussion

The soil morphology shows that the floodplain soil is geogenetic because the accumulation of sandy loam soil with various urban wastes in the profile. A placic-like layer (thin layer of iron pan) was found in the flood plain profile, which formation is attributed to geogenetic process because of waste materials not yet decomposed visible throughout the profile (i.e. Pit 1) and Pit 2 is a pedo-genetic soil with increase in clay to the ferruginous layer, but no evidence of cutan and the size of the horizon is too small to an argillic horizon (6 cm). The soils from the floodplain are classified as Entisols. The pit is shallow (100 cm) with formation of hardened Fe and Mn concretions. The pit occupies break of slope just above the floodplain and occasionally flooded. The depth to water table during the wet season was 90cm. At the second Pit, there is increase in clay content up to 42.86 %, which shows soil development, but not quantity as argillic and classified as Inceptisol.

The surface soil properties show that the soil is rich in nutrient, except Mg. The fertility is high due to high N, P and K in the soil and field evidence shows average yield of about 5 tha^{-1}.The heavy metal concentrations are high for Zn, Cu, Fe, Pb and Mn. The highest Fe concentration was recorded in anaerobic horizons in Pits 1 and 2. It has been reported that Fe becomes more soluble in anaerobic condition as Fe^{2+}. When the soil dries it oxidises to Fe 3+ which is less available to plant, likewise, low level of Cr recorded which according to Agbede, 2009 that at neutral pH, Cr becomes less available. Cr has been reported to be more soluble in acidic environment (Ryabova, 2001).

The soil plant metal transfer coefficient table of Kloke *et al*. (1984) indicate that some of the heavy metals in high concentration might become too concentrated in the plant growth in this area. The neutral pH enhances the release of their metals in soil solution, but the high level of organic matter may also inhibit luxurious uptake of heavy metals (Jan, 1984), except Fe and Cr. It has been reported that root crops store more of such elements in their roots; therefore, root crops should not be encouraged in this environment. It is expected that high concentration of heavy metals will be present based on soil-plant transfer coefficient, but high level of phosphorus at toxic level has been reported in Agbede, 2009 to inhibit translocation of excess Zn, Fe, Cu to plants. The P/Zn ratio shows that there might be deleterious accumulation of Zn in plants. Hence, Zn concentration is too high for high content of P to inhibit excess uptake of Zn from the soils.

5. Conclusion and recommendation

5.1 Conclusion

The floodplain associated with Ona River in Oluyole Local Government area in Ibadan is fertile with high nitrogen, phosphorus and potassium. The phosphorus was available up to toxic level, but its effect was probably neutralized by high organic carbon at the surface. The high level of phosphorus can also be deduced to inhibit toxic absorption of heavy metals such as iron, copper and zinc, which were very high in the soil. There is probably a balance in chemical dynamic of the soil where toxic level of some anions were deduced to have reduced uptake of excess heavy metals resulting to high yield based on farmers interaction and field evidence of arable crop (maize and vegetable). The area will be good for dry season farming with little input because fertilizer will not be necessary for production. However the actual concentration in plants of the area should be studied.

5.2 Recommendation

The urban waste should not be dumped into rivers because their presence in the soil horizon as decomposed materials like plastic, iron, and nylon make cultivation of land difficult since more time and labour will be required to remove this from the surface of soils.

Farmers’ efforts have been noticed on the field with local rubber tubes, which is laborious for irrigation purposes. Government should come to farmers’ aid in terms of irrigation during dry seasons for maximum production. Further study is also recommended to analyse the nutrients in the plants to complement the predicted values.

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Table 1: Physical and chemical soil properties of the profile pit located at River Ona floodplain (Pit 1)

Properties	0 – 15 cm	15 – 35 cm	35 – 82
Sand (%)	84.80	86.80	68.80
Silt (%)	8.80	6.40	20.80
Clay (%)	6.40	6.80	10.40
pH	7.35	7.28	7.38
Na (cmol kg^{-1})	0.41	0.28	0.33
K (cmol kg^{-1})	0.38	0.18	0.18
Mg c(mol kg^{-1})	0.20	0.20	0.41
Ca (cmol kg^{-1})	6.81	5.01	8.82
CEC (cmol kg^{-1})	7.80	5.67	3.93
P (ppm)	54.84	43.78	55.02
C (gkg^{-1})	11.02	5.4	11.40
N (%)	0.10	0.05	0.14

Table 2: Physical and chemical soil properties of the profile pit located at the lower slope above River Ona floodplain (Pit 1)

Property	0 – 15 cm	15 – 35 cm	35 – 82	Ave. pit content	Range in soil
Pb (mg kg^{-1})	ND	41.40	40.00	27.13	33 – 40
Cr (mg kg^{-1})	0.76	1.03	1.04	0.94	0.21 – 1.21
Zn (mg kg^{-1})	12.83	254.50	18.27	95.20	3.09 – 263.50
Cu (mg kg^{-1})	5.45	18.06	17.65	13.72	4.57 – 17.87
Fe (mg kg^{-1})	64.50	46.00	181.00	97.17	86.20– 181.00
Mn (mg kg^{-1})	28.30	24.50	25.00	25.93	7.90 – 34.60
Cd (mg kg^{-1})	ND	0.30	ND	0.10	0 – 0.01
P:Zn	4.27	0.17	3.01	2.48	

ND – Not Detected

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Table 3: Physical and chemical soil properties of the profile pit located in River Ona floodplain (Pit 2)

Property	0 – 21 cm	21 – 29 cm	29 – 35	35 – 100
Sand (%)	74.80	72.80	74.80	76.8
Silt (%)	18.80	18.80	2.40	8.40
Clay (%)	8.40	8.40	1.20	14.80
pH	7.27	6.28	6.74	6.68
Na (cmol kg^{-1})	0.35	0.24	0.20	0.24
K (cmol kg^{-1})	0.23	0.08	0.05	0.07
Mg (cmol kg^{-1})	2.41	0.61	0.60	1.22
Ca (cmol kg^{-1})	7.62	3.01	2.01	2.40
CEC (cmol kg^{-1})	10.61	3.94	3.86	9.74
P (cmol kg^{-1})	87.70	2.74	3.87	3.73
C (gkg^{-1})	11.44	4.6	1.8	9.0
N (cmol kg^{-1})	0.14	0.05	0.02	0.09

Table 4: Heavy metals in the profile pit located in River Ona floodplain (Pit 2)

Property	0 – 21 cm	21 – 29 cm	29 – 35	35 – 100	Ave. pit content
Pb (mg kg^{-1})	33.00	41.00	ND	ND	18.50
Cr (mg kg^{-1})	1.21	0.97	0.21	0.98	0.84
Zn (mg kg^{-1})	263.50	207.00	3.09	1.90	118.87
Cu (mg kg^{-1})	17.87	17.56	4.57	4.24	11.06
Fe (mg kg^{-1})	80.80	115.00	86.20	72.30	88.58
Mn (mg kg^{-1})	34.60	12.30	7.90	9.20	16.00
Cd (mg kg^{-1})	0.10	0.10	0.10	ND	0.08
P:Zn	0.33	0.01	1.25	1.96	0.89

ND – Not Detected

Table 5:Distribution of physical and chemical of the surface samples at River Ona floodplain

Property	T_1	T_2	T_3	T_4	T_5	Average
Sand (%)	81.33	76.53	75.70	73.72	74.10	76.28
Silt (%)	10.93	15.60	16.40	18.00	16.90	15.57
Clay (%)	7.73	7.87	7.90	8.30	9.00	8.16
pH	6.82	6.84	6.87	6.98	7.03	6.91
Na (cmol kg^{-1})	0.28	0.40	0.31	0.41	0.36	0.35
K (cmol kg^{-1})	0.28	0.56	0.61	0.51	0.36	0.46
Mg (cmol kg^{-1})	0.41	0.40	0.61	1.17	0.41	0.60
Ca (cmol kg^{-1})	3.27	6.55	5.16	6.71	4.32	5.21
P (cmol kg^{-1})	28.99	51.25	40.42	43.59	38.20	40.49
C (g kg^{-1})	1.48	1.90	2.25	3.29	3.47	2.48
N (%)	0.15	0.19	0.23	0.33	0.35	0.25
CEC (cmol kg^{-1})	4.24	7.91	6.69	8.80	5.45	6.62

Table 6: Distribution of the heavy metals in surface soil sample at River Ona floodplain

Property	T_1/T_2	T_3/T_4	T_5	Average
Pb (mg kg^{-1})	22.70	34.60	48.70	34.33
Cr (mg kg^{-1})	ND	0.45	0.93	0.69
Zn (mg kg^{-1})	155.10	12.50	346.00	171.20
Cu (mg kg^{-1})	11.87	13.56	31.90	19.11
Fe (mg kg^{-1})	9.41	230.00	12.50	83.97
Mn (mg kg^{-1})	9.90	11.60	71.80	31.30
Cd (mg kg^{-1})	ND	ND	0.30	0.30

T1: transect 1; T2 :transect 2; T3:transect 3; T4:transect4; T5 :transect 5

Table 7: Soil-plant heavy metal transfer coefficient

Element	Soil-plant heavy metal transfer coefficient
Cadmium	1.0 – 10.0
Cobalt	0.01 – 0.10
Chromium	0.01 – 0.10
Copper	0.10 – 10.0
Mercury	0.01 – 0.10
Nickel	0.01 – 0.10
Lead	0.01 – 0.10
Titanium	1.0 – 10.0
Zinc	1.0 – 10.0
Ascenic	0.01 – 0.10
Barium	0.01 – 0.10
Selenium	0.01 – 0.10
Tin	0.01 – 0.10

Source: Kloke *et al.* (1984))

Table 8: Heavy metals in plant based on transfer coefficient

Element	Soil-plant heavy metal transfer coefficient	T_1/T_2	T_3/T_4	T_5	T ave.
Lead	1.0 – 10.0	22.70 - 227	34.60 - 346	48.70 – 457	35.3-343.3
Chromium	0.01 – 0.10	0 - 0	0.45 – 4.5	0.93 – 9.3	0.46-4.6
Zinc	0.01 – 0.10	155.10-1551	12.50 – 125	346.00–3460	171-1712
Copper	0.10 – 10.0	11.87 –118.7	13.56 –135.6	31.90 – 319	19.1-191.1
Iron	0.01 – 0.10	9.41 – 94.1	230.00 -2300	12.50 – 125	83.97-840
Manganese	0.01 – 0.10	9.90 – 9.90	11.60 - 116	71.80 – 718	31-281.3
Cadmium	0.01 – 0.10	0 – 0	0 – 0	0.30 – 3.0	0.1-1.0

APPENDICES

Appendix 1: **Morphological description of pit and root**

Horizon depth (cm)	Colour	Texture	Structure	Consistence		Conc.	Depth of water table (cm)	Presence of waste materials	Presence
				Moist	Wet				
0 – 15	DYB	LS	VF	NP	SS			Nylon and clothing materials	MFR
15 – 35	DGB	LS	VF	NP	S			Common refuse and materials	
35 - 82	DB	SL	F	NP	SS		80	Nylon of different kinds	

Legend:

DYB – Dark yellowish brown
DGB – Dark greyish brown
DB – Dark brown
SL – Loamy sand
VF – Very firm
F – Firm
NP – Non-plastic
SS – Slightly sticky
S – Sticky
MFR – Many fibrous roots

Appendix 2: **Morphological description of pit and root**

Horizon depth (cm)	Colour	Texture	Structure	Consistence		Conc.	Depth of water table (cm)	Presence of waste materials	Presence
				Moist	Wet				
0 – 21	VDB	SL	VF	P	NS		MFR	80^{+}	Nylon
21 – 29	DYB	SL	F	P	NS		MF & MFR	80^{+}	Nylon
29 – 35	DB	S	F	NP	SS		FFR	80^{+}	
35 – 100	BY	SL	F	NS	VS		-	80^{+}	

Legend:

VDB – Very dark brown
BY – Brownish yellow
DYB – Dark yellowish brown
DGB – Dark greyish brown
DB – Dark brown
SL – Loamy sand
VF – Very firm
F – Firm
NP – Non-plastic
SS – Slightly sticky
S – Sticky
MFR – Many fibrous roots
MF & FWR – Many fibrous and few woody rots
FFR – Few fibrous roots

Appendix 3: **Soil fertility classes in Nigeria**

Element	Low	Medium	High
Nitrogen %	0.15	0.15 – 0.20	> 0.20
Phosphorus(Bray1-P)(mg kg^{-1})	8	8 – 20	20
Potassium (cmol (+) kg^{-1})	0.20	0.20 – 0.40	0.40
Organic matter (%)	2.0	2.0 – 3.0	3.0
% C	1.16	1.16 – 1.74	1.74
Soil pH (H_2O)	4.5 – 5.0	5.1 – 5.5	5.5 – 6.5
Magnesium (cmol kg^{-1})	0.3 – 1.0	1.0 – 3.0	3.0 – 8.0

Source: Agbede, 2009)

Appendix 4: **Soil acidity scale**

Reaction	pH
Strongly acidic	3.0 – 4.0
Acidic	4.0 – 5.0
Weakly acidic	5.0 – 6.0
Neutral	7.0
Weakly alkaline	7.0 – 8.0
Alkaline	8.0 – 9.0
Strongly alkaline	9.0 – 10.0

Source: Yogodin (1984)