QUALITY ASSESSMENT OF SOILS UNDER IRRIGATION ALONG THE JAKARA STREAM IN METROPOLITAN KANO

By

Mansur Usman Dawaki*, Maharaz A. Yusuf and Garba K. Adamu****
***Department of Agricultural Science Education, Sa'adatu Rimi College of Education, P.M.B. 3218, Kumbotso, Kano, Nigeria.**
mansurdawaki@hotmail.com (+2348029029330)
****Department of Geography, Bayero University, Kano, Nigeria**

ABSTRACT

This study was conducted on the irrigated lands along the banks of the Jakara Stream in metropolitan Kano, with the aim of assessing its quality for the land use being practiced. Two sites (Hajj Camp and Magami) were selected based on concentration of irrigation activity and irrigation water source. Analytical methods were employed in determining the levels of various fertility related parameters and heavy metal pollutants in relation to water source. The fertility parameters determined were organic carbon (means = 1.87% and 0.63%), organic matter (means = 3.22% and 1.09%), CEC (means = 14.50 and 6.82 cmol/kg), exchangeable bases (K (means = 1.68cmol/kg and 1.54 cmol/kg), Ca (means = 5.52cmol/kg and 4.54cmol/kg), Mg (means = 2.30cmol/kg and 2.16cmol/kg), and Na (means = 0.43cmol/kg and 2.64cmol/kg)), available nitrogen (means = 0.021% and 0.007%), pH (means = 6.6 and 7.26) and available phosphorus(means = 322.72mg/kg and 179.06mg/kg) respectively for sample taken at the Hajj Camp and the Magami sites. Most of the values were falling between medium to low except for organic matter at Hajj Camp which was high. On the overall, results of the research revealed soils of marginal fertility when USDA/NRSC (2001) guideline for soil quality assessment was adopted and values were compared with values recommended by Landon (1991). The metals determined included copper, lead and cadmium. The result shows that only the means of copper for the two sites were significantly different, while the means of all the three metals (Cadmium, Cd (mean = 0.029mg/kg and 0.034mg/kg for the two locations respectively), Lead, Pb (mean = 2.98mg/kg and 2.76mg/kg for the two locations respectively) and Copper (mean = 2.48mg/kg and 1.74mg/kg for the two locations respectively) when compared with internationally approved limits (European soils and American literature); were significantly different at 0.05LSD and very low.

Key words: Quality, Soil, Fertility, Heavy Metals, Irrigation

INTRODUCTION

Soil Quality is relatively a new concept that is gradually gaining popularity among land users, developers, planners and soil scientists. Quality as Eswaran *et al* (2000) explained is the essential character, distinguishing feature or property of an object, and is the feature which makes the thing useful or performs a task in a beneficial way. Soil quality has been defined in several ways (Eswaran *et al*, 2000). USDA (2002) definition is however more related with conservation and it states that the term implies the capacity of a soil to function within the natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality and support human habitation.

Many factors are responsible for the quality of any given soil and these factors are generally called indicators and they include agro-climatic, hydrogeology and cropping/cultural practices (NAS, 1993). Although, it is difficult to measure (Cannon and Winder, 2004), however it still needs to be evaluated regularly, because nearly all land uses depend on healthy soil functions (USDA, 2002). The necessity for regular investigation of soil in order to evaluate its quality is further heightened because of the simple fact that land use and management can change the capacity of the soil to function (Karlen, 1997; USDA, 2002). There are three basic processes through which soil quality can be degraded namely, physical (erosion); chemical (salinization, alkalinity, nutrient deficiency and heavy metal contamination) and biological (which borders on loss of organic matter) (NAS,1993).

To prove its importance, a system of land use that is being practiced in metropolitan Kano will be considered. This system of land use that has been going on for centuries involves the use of stream water to irrigate land at the banks. Principal of these streams are *Challawa*, *Getsi*, *Jakara* and *Salanta*. The main objective is to produce fruits and vegetables for the consumption of the city dwellers. This system of land use has been called by Binns *et al* (2003), by the name urban and peri-urban agriculture (UPA). The continuous use of these lands throughout the year for both irrigation and rain-fed conditions (Binns *et al*, 2003) is what may likely trigger fertility depletion which may likely affect the quality of the soil. This has been established in some other lands under similar usage (Alhassan, 1996; Dawaki, 1996).

Studies have established contamination of urban and peri-urban surface water through such processes as defeacation, urination, bath, wash, inadequate sewerage facilities landfill, agro-chemicals and industrial effluents (Birley and Lock, 1998). The use of these waters therefore poses the greatest risk potential to this system of land use.

Irrigation in the Jakara Basin involves the application of stream water that flows through industrialized and residential areas to irrigate vegetable crops, which are mostly consumed by the city dwellers. The use of these sources of water for irrigation in addition to the exposure of the land to exhaust discharge from motorized vehicles that are ever on the increase in the city, constitutes the risk of the soils of these irrigated lands to be contaminated with both organic and inorganic pollutants. Of major concern is the concentration of heavy metals that are neither rapidly removed, nor readily detoxified by metabolic activities (Dix, 1978). Already previous studies have established their presence in some of the effluents that are being discharged into the streams, the waters of the stream and some of the plants tissue grown in or around the area (Sahoo and Klopker, 1985; Binns *et al,* 2003; Anonymous, 2003 and Ya'u, 1995). If this is the case, then the soil must be at risk of also being polluted and there by affecting its capacity to function as would be expected.

Heavy metals exist in various forms in the soil; of greatest concern of which are the ones retained in the form of exchangeable cations and precipitates, which may occur in the form of oxides and hydroxides, carbonates and/or bonded to organic matter depending on soil condition (Calace *et al*, 2002) because these, are the forms that are available to plants. All negative effects of heavy metals start from their absorption by plants, and to a lesser extent by ground water contamination through leaching. The effects of heavy metals pollutants in the soil could be enormous. Major amongst which is their effects on microbial activities (Wyszkowska and Wyszkowska, 2002). Other negative effects of heavy metals, especially as they are being discharged through industrial effluents include negative effects on porosity and water holding capacity, CEC, mineral composition and seed germination as established on an Indian soil contaminated by discharges form fertilizer factory (Tripathi et al, 1990).

The aim of this research is to assess the quality of the soil under this system of land use using some fertility indices and heavy metal pollutants presence. The objectives of this paper include;

1. To determine the mean values of some key fertility indices in the soil
2. To compare the values with a base value
3. To determine the concentration of three major heavy metal pollutants; namely Lead (Pb), Cadmium (Cd) and Copper (Cu) in two sites irrigated with water contaminated by domestic and industrial discharges.
4. To determine the variation of the concentrations of the different metals for the different sites.
5. To compare the values with internationally approved concentration levels.

THE STUDY AREA

This research was conducted on the irrigated soils along the banks of the *Jakara River* within the metropolitan Kano and its suburb. Samples were collected between latitude $11^o59'$ and $12^o\ 08'$N and longitude $8^o34'$ and $8^o\ 42'$E at an altitude of 486.5m. In the *Jakara* Plains, there is a pre-dominance of sand particles in some of the analytical works conducted (Faruk, 1999; Foloronsho, 1998). Hydromorphic soils tend to occur in areas where annual flooding occurs. These hydromorphic soils are dark-grayish in color and have a high content of clay. These hydromorphic soils are also called *fadama* and according to Nichol (1992), these soils are normally utilized in the production of crops under limited irrigation because of their high amount of residual moisture.

METHODOLOGY

Sampling and sampling sites

Two sites were selected for this research, namely Hajj camp and Magami, located in the urban and the peri-urban parts of the metropolis respectively. Grid sampling was employed in which $100m^2$ of land was randomly selected in each of the two sampling areas and was divided into ten equally sized grid cells of $10m^2$ that ran horizontally along the bank of the river and vertically to the edge of a settlement where there is one. Five samples were randomly collected from each grid, and the five were mixed up thoroughly to produce a composite sample. Sampling was done using steel augur, fabricated locally in the fashion of the Dutch augur and samples were collected from the surface to a depth of 20cm. Sampling was done in the period between late May and the first week of June when irrigation activities were winding up and the rains were just setting in so as to avoid the dilution and leaching effects rainfall might have on some of the parameters. Samples collected were put in polythene bags and labeled serially based on proximity to water source. Samples were taken to the laboratory, air-dried; crushed and sieved with 2mm sieve.

Laboratory Techniques

In the laboratory, six key parameters affecting fertility were determined namely; organic carbon; available phosphorus; exchangeable bases (including sodium Na^+, potassium K^+, calcium Ca^{2+} and Magnesium $Mg2^+$); CEC, total nitrogen and pH. Organic Carbon was determined using the Walkley-Black (1934) method. Phosphorus (P) content determination was done using the colorimeter method using sodium hydrogen carbonate extraction. The determination of Exchangeable Bases was done using Flame photometry using the ammonium acetate extraction technique. The CEC was determined using the ammonium acetate saturation method as described by Hesse (1971). The total nitrogen was determined using the Kjeldal Method. pH was determined using 1:2.5 $CaCl_2$ dilution method.

The double acid digestion technique (Anderson, 1974) was used in sample extraction using $HCl.HNO_3$ to digest the soils for metals determination. The concentration of the metals was determined using an Instrumentation Laboratory IL251 Atomic Absorption Spectrophotometer equipped with two hollow cathode lamp holders and Rank-Hilger slotted cathode lamps were used. The instrument is switched on and allowed to warm up for 15 minutes. The instrument was set up at a wavelength for each analyte; Cu (324.7); Cd (228.8) and Pb (217.0). The flame was switched on and allowed to stabilize for 10minutes. Adjustments were made to achieve the most sensitive line for the element being analyzed.

Statistical techniques

The mean values obtained are compared with the set of values suggested as low, medium and high by Landon (1991) using one way analysis of variance (ANOVA).

Student's t was use to test whether each set of mean for the two sites are significantly different at 0.05 LSD for each of the metal analyzed.

RESULTS AND DISCUSSIONS

The mean values for all the parameters measured are as shown in the following Table 1;

Table 1: Mean values of the fertility indices determined for the different areas

Parameter	Hajj Camp	Magami
Organic carbon O.C (%)	1.87	0.63
*Organic matter O.M (%)	3.22	1.09
CEC (cmol/kg)	14.50	6.82
Ca (cmol/kg)	5.52	4.54
Mg (cmol/kg)	2.30	2.16
K (cmol/kg)	1.68	1.54
Na (cmol/kg)	0.43	2.64
Available Nitrogen N (%)	0.021	0.007
Available Phosphorus P ($mgkg^{-1}$)	322.72	179.06
Mean pH (1:2.5$CaCl_2$)	6.6	7.26

*% O.M calculated by multiplying % O.C with a constant, 1.724 (Brady and Weil, 1996)
Source: Lab analytical data

In trying to assess the quality of the soil in terms of fertility, mean values of the indices determined are compared with the values suggested by Landon (1991) as a baseline based on the quality assessment recommendation USDA/NRSC (2001). The results are presented in the following Table 2.

Table 2: Fertility status and quality assessment of the area

Site	Organic Matter (%)	CEC cmol/kg	N (%)	P cmol/kg	Ca cmol/kg	Mg cmol/kg	K cmol/kg	Na cmol/kg
Hajj Camp	3.22a	14.50a	0.021a	322.72a	5.52a	2.30a	1.68a	0.43a
Magami	1.09b	6.82b	0.007b	179.06b	4.54b	2.16b	1.54a	2.64b
Landon (1991)								
High	3.35a	30c	0.30c	140c	15c	8.0c	1.2b	2.0c
Medium	2.00c	15d	0.15d	60d	5a	3.0d	0.6c	0.7d
Low	0.75d	6e	0.05e	20e	2d	0.5e	0.2d	0.3e

Sources: Field Data and Landon (1991)
Values followed by the same letter in the same column are not significantly different at 0.05LSD

Using USDA/NRSC (2001) guidelines and comparing with the values suggested by Landon (1991) (Table 2) it could be said that the soil in all the respective areas sampled is only marginally fertile, especially as most of the parameters for which more is better (organic matter, CEC and nitrogen), are only within the low-medium range (except for organic matter at Hajj Camp). Marginal fertility is a characteristic of many tropical soils (Young, 1981), mainly because of the high rate at which organic matter is lost, high rate of leaching, highly weathered mineral and low input agricultural practices. The values recorded at Hajj Camp for most of the parameters may even be regarded as the only values that can be described as reasonably above marginal level probably due to the fact that higher levels of organic wastes are incorporated into the cultural practices of the areas as is clear from the difference in the organic matter values of the area compared to the other two areas. The phosphorus levels in both the two areas are excessively higher than even the values suggested by Landon (1991) as high. This could be attributed to excessive use of phosphorus fertilizer during both rain-fed and irrigation situations. This too is not an indicator of good quality soil, because, high values of phosphorus may lead to symptoms of excess in both crops and soil.

Levels of heavy metal pollutants in the soil

Table 3 shows the mean concentrations of the three metals at the *Hajj Camp* and Magami sampling sites respectively.

Table 3: Mean concentrations of the metals for the two studied sites

Location	**Metal Concentration (mg/kg)**			**Mean Soil pH**
	Cadmium (Cd)	Lead (Pb)	Copper (Cu)	**(1:2.5 $CaCl_2$)**
Hajj Camp	0.029a	2.98a	2.484a	6.6a
Magami	0.034a	2.76a	1.744b	7.26b

Means followed by the same letter in the same column are not different at 0.05LSD

The mean concentration of cadmium was not significantly different in all the two sites investigated although the mean concentration at Magami was a little bit higher. Magami is the confluence point of *River Getsi* and *River Jakara* or conversely where domestic waste water meets industrial waste water. This therefore is not very surprising as even the findings of Binns et al (2003) suggest higher concentration in the water around this area. Concentration in water from the Bompai area in some instances reaches about 41.5mg/l (Binns et al 2003).

The mean values for lead and copper were however individually different in all the two locations studied although the difference in the means of lead was not significant at 0.05LSD. The highest mean concentration of lead was detected at the Hajj Camp site (2.988mgkg^{-1}), followed by the Magami site (2.76mgkg^{-1}). In the studies of Bada et al (2001) at two selected highways, they found that concentration of the metal was correspondingly decreasing from the road side to distances away from the highway. Their values ranged from about 264.94mgPb/kg at a distance of 1m from the road edge to as low as 4.79mgPb/kg at 50m distance away. If this is taken into consideration with the findings here, correlation could be found to exist. The Hajj Camp site is located in the urban centre part of the study where road traffic is believe to be higher while the Magami site is located in the peri-urban centre part of the study. Additions therefore through traffic exhaust discharges and atmospheric deposition might have contributed to the higher values recorded here and the concentration continuously decreases as one move away from the urban centre. The concentration in the other site was however, still appreciably high because traffic deposition was not the only source of the metal as many irrigators were found to be using petrol fuelled pumping machines for irrigation in addition to discharges that enter the river from the Bompai industrial waste water as detected by Binns et al (2003).

The concentration of copper was higher again at Hajj Camp site (2.484mgkg^{-1}) than at Magami (1.744mgkg^{-1}). The high concentration of the metal at Hajj Camp corroborate with the findings of Binns et al (2003) as it was about the only metal they detected in the water of the area. The appreciably lower concentration of the metal at the Magami site despite its potential risk is explained by the fact that the area has low organic matter value (Faruk, 1999). It has been shown that metal concentration is significantly related to clay and organic matter contents and values normally are rising pH dependent (Aydinalp and Marinova, 2003; Kollender-Szych et al 1998, Wild 1996).

The detection of these metals, despite the variability in concentration is a further confirmation of suspicions made by previous researches that studied the water of the area and other related locations. For example, Binns *et al* (2003) detected concentrations in the water that ranged from 0 – 21.94mg/l; 0 – 34.36mg/l and 1.89 – 2.22mg/l for cadmium, lead and copper respectively for samples taken at various locations along the Jakara and Getsi rivers. These values are in some cases far in excess of the recommended values for irrigation water.

Comparism of the mean values for the different sampling areas with international standards

The mean values for the different areas were compared with the mean allowable concentrations in European Community regulations and American literature and the results are as shown in the following table 4.

Table 4: Comparism of the concentration in the areas with International Standard

Metal	Area	Average
Cadmium	Hajj Camp	0.029a
	Magami	0.034a
	Bowen, 1979	0.035a
	EU Values	0.35b
Lead	Hajj Camp	2.983a
	Magami	2.76a
	Bowen, 1979	35b
	EU Values	35b
Copper	Hajj Camp	2.484a
	Magami	1.744b
	Bowen, 1979	20c
	EU Values	30d

Means followed by the same letter for the same metal are not significantly different at 0.05 LSD

Sources: - lab analytical data, Wild, (1996) and Bowen (1979) in Aydinalp and Marinova (2003).

Table 4 shows the comparism of the concentration of the metals in the sites investigated, among the sites and between the individual sites and the approved values under European regulations and American literature. Table 4 indicates that at 0.05 level of significant difference there is no difference in the mean values of the concentration of cadmium and lead in all the sites investigated while the concentration of copper was significantly different in all the sites investigated. The mean values were also significantly lower for all the three sites studied and for all the three metals investigated, than both the Bowen (1979) in Aydinalp and marinova (2003) and the EU recommended means.

CONCLUSION AND RECOMMENDATIONS

The results have indicated that the quality of the soil for cultivation is only marginal in terms of fertility, largely caused by cultural practices that result in over utilization of the land transiting from rain-fed to irrigation agriculture.

The findings in this research have also shown that the levels of these metals in the soil has not reach a level that could cause any immediate threat as all the mean values have been found to be significantly lower than the internationally recommended values. There may however be a long term risk of concentrations rising to unwanted levels. Water quality is a major factor in determining success and safety of irrigation agriculture, and pollution of irrigated soils with heavy metals is a possibility when polluted water is being used for irrigation. Studies have already established high concentrations of many of such metals in the waters being used for irrigation in the area, which probably is a major source for the small concentrations detected in the soils, along with other sources such as fertilizer, chemicals and vehicular discharges. If current land use practices are maintained the soil could be at higher risk because of the tendency of metals to accumulate in the soil as they are hardly detoxified and they form complexes with various substances in the soil.

Based on the findings therefore, the following recommendations are suggested;

1. Incorporation of higher levels of organic matter. The textural nature of the soil shows it to be predominantly sandy, which makes the soil susceptible to water loss. Incorporation of higher levels of organic matter may help to improve the water holding capacity of the soil, thereby reducing the need for frequent irrigation, which will further reduce the exposure of the soils to pollution source. Preferably, the organic matter to be used should be composted, which will rule out the need for decomposition within the soil environment, thereby enhancing utilization of the minerals released by the organic matter, and helping to reduce the chances of the metals forming complexes with the organic matter.
2. Continuous monitoring of fertility situation in the soil with the aim of evaluating its quality for the land use.
3. Diversification of income generating activities. This will go along way in shedding off some of the pressure on the land. These activities could be farm or non-farm based. For example, commercial composting may be encouraged

as an avenue to supply some of the farmers with alternative safe and cheap farm inputs. Other activities may include apiculture, renewable energy generation etc.

4. Re-planned farming system. This may involve a change in the crops being grown, such that high income generating crops may be incorporated in one round of farming so as to reduce the necessity of having to go for second round within the same season.

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Appendix i: Values and ranges of the fertility indices for the sampling areas

SITE/ RANGE	OC (%)	OM (%)	Ca cmol/kg	Mg cmol/kg	K cmol/kg	Na cmol/kg	CEC cmol/kg	P mg/kg	N (%)
HAJJ CAMP	2.19	3.78	8.00	2.80	2.56	0.46	16.0	289.97	0.018
	2.37	4.09	6.00	2.20	1.34	0.41	14.0	223.80	0.016
	3.31	5.71	6.40	3.60	0.90	0.17	16.6	170.49	0.030
	2.23	3.85	5.20	2.40	0.90	0.14	14.2	223.80	0.018
	1.92	3.31	4.80	2.20	0.77	0.49	14.6	410.32	0.022
	1.05	1.81	4.60	1.80	0.56	0.41	17.2	410.32	0.011
	1.10	1.90	5.20	2.00	1.15	0.35	10.0	500.76	0.012
	1.05	1.81	5.40	2.60	6.14	0.23	9.0	279.99	0.009
	2.15	3.71	6.20	2.20	1.53	0.43	15.8	458.00	0.058
	1.30	2.24	3.40	1.20	0.90	1.20	17.6	259.7	0.012
RANGE	1.05/ 3.31	1.81/ 5.71	3.40/ 6.20	1.20/ 3.60	0.56/ 6.14	0.14/ 1.20	9.00/ 17.60	170.49/ 500.76	0.009/ 0.058
MAGAMI	0.98	1.69	4.80	2.00	1.02	2.94	8.00	114.57	0.009
	0.69	1.19	4.80	2.00	0.77	1.63	8.40	124.25	0.007
	0.58	1.00	5.40	1.80	1.79	4.02	8.40	204.58	0.007
	0.60	1.03	4.00	2.40	0.96	2.94	4.60	106.5	0.005
	0.47	0.81	2.40	1.60	0.64	3.04	4.60	298.93	0.005
	0.56	0.97	4.40	1.80	1.09	2.50	6.40	288.96	0.005
	0.92	1.59	4.20	2.60	0.77	1.30	6.80	160.23	0.009
	0.51	0.88	7.40	3.60	0.90	1.09	4.00	170.92	0.005
	0.45	0.78	4.00	2.00	5.88	1.85	5.20	205.16	0.005
	0.54	0.93	4.00	1.80	1.47	5.11	8.40	116.45	0.007
RANGE	0.45/ 0.98	0.78/ 1.59	2.40/ 7.40	1.60/ 3.60	0.64/ 5.88	1.09/ 5.11	4.00/ 8.40	106.5/ 298.93	0.005/ 0.009

Appendix ii: Values and ranges of the heavy metals concentration for the sampling areas

SITE/RANGE	CONCENTRATION (mg/kg)		
	Cadmium (Cd)	**Copper (Cu)**	**Lead (Pb)**
HAJJ CAMP	0.04	2.31	2.90
	0.04	2.20	2.00
	0.03	1.32	1.34
	0.03	1.46	1.70
	0.04	3.05	3.25
	0.03	2.60	3.20
	0.02	3.06	3.80
	0.02	3.01	4.14
	0.02	3.01	4.14
	0.02	2.82	3.50
RANGES	0.02 – 0.04	1.32 – 3.06	1.34 – 4.14
MAGAMI	0.03	2.70	3.00
	0.05	1.80	1.71
	0.04	1.51	1.65
	0.04	2.00	3.66
	0.02	2.43	3.12
	0.02	1.52	1.88
	0.02	1.36	1.70
	0.03	1.17	4.02
	0.04	1.09	3.86
	0.05	1.86	3.00
RANGES	0.02 – 0.05	1.09 – 2.70	1.62 – 4.02