The influence of wastewater on soil chemical properties on irrigated fields in Kaduna South Township

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ABSTRACT

The study examines the influence of wastewater on soil chemical in Kaduna South. Sixteen water and fifteen soil samples were collected in drains and on irrigated fields. The samples were subjected to laboratory analyses to determine properties related to sodicity, salinity and toxicity. The result of analyses has shown that soils in Kaduna South township are experiencing salinity built up which inturn affects the productive capacity of the soil. However, the low concentration of nutrients in the soil can be ameliorated by wastewater especially when proper management is adopted.

INTRODUCTION

Soils in most urban centers of Nigeria are fastly depleting from human abuse, ignorance and mismanagement. Despite the importance of soil as a major interface on which all forms of life revolves, in Nigeria most development plans seems not to envisage the role of soil *as* a resource base. During most human and industrial processes, waste materials are produced, some could be put to useful purposes while most have to be disposed off (Ogezi, 1990).

The re-use of wastewaters from either domestic or industrial processes for irrigation is a common phenomenon of most urban industrial centers in Nigeria. The diversion of wastewater from drains and or canals into irrigated fields may leach from the waste harmful ionic substances into the soil root zone to concentrate at intensities and levels to impair and degrade the soil. Wastewater when used directly for irrigation can increase the quantities of solutes thereby raising the concentration of certain ions and eventually lowering the quality of the water for irrigation (Ayers and Westcots, 1976). The major constrains to the use of wastewater for irrigation are the issues of environmental pollution and health hazards posed to both the farmers and consumers of the irrigated crops.

The soil as a medium of wastewater disposal

The management of wastewater in most urban areas is a serious environmental problem that has defied most possible solutions of both policy makers and environmental planners.

The disposal of wastewater into open drains, canals and streams, is not only inadequate but a worst threat to human health and marine biodiversity. The re-use of wastewater for irrigation is a very promising water conservation alternative. Feachem et al, (1982) were of the view that the use of wastewater for irrigation often allows the free discharge of wastewater.

The disposal of wastewater on land presents not only an appropriate medium for many wastes but is a cheaper way of some form of waste treatment. Treatment prior to re-use of wastewater on land are less than those for disposal to surface waters since the land will provide subsequent treatment and recycle. Loehr (1977) observed that elements considered as pollutants are necessary in some desired quantities for all living organisms. In support to this Hansen et al (1980) posits that not only is mall amounts of salts in water are harmless but also stimulate the growth of crops under some condition. However, excessive concentration of ionic substances in water may lead to potential built up of harmful elements in the soil, which in turn will affect the productive capacity of the soil.

The re-use of wastewater for irrigation has the advantage of recycling and enriching the soil with nutrients. As observed by Musa et al (1993) wastewaters apart from augmenting the available water resources, the re-use of wastewater for irrigation on agricultural lands is advantageous as wastewater contain some valuable plant nutrients.

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Though the re-use of wastewater for irrigation is advantageous researches conducted of the phenomenon have indicated that harmful ionic substances may accumulate in the soil to chronic levels to be injurious to normal crop processes (Ogbalor 1991, Musa et al 1993, Tanko and Ahmed 1994 and Samaila, 1996).

According to Whipple (1977), large scale application of wastewater on the soil may lead to danger of insect infestation, pollution of groundwater and bulding up of heavy metals, salts and other toxicants in the soil. The capacity of plants to take up chemicals elements should be a factor to consider in establishing wastewater application rates. For successful application of wastewater on soil, there is the need to understand the reactions and transformation which occur when wastes are applied to the soil. The biological physical and chemical processes in a soil may provide a treatment of waste but the capacity of a soil to handle complex organic substances varies with soil properties and climatic condition.

Study area

Kaduna State lies between Latitude 09° 00 — 11^0 00' and longitude 06^0 00'. The State occupies an area of about 45, 567 sq km. The state capital Kaduna town lies on latitude 10^0 35' and longitude 7° 25'. Kaduna town experiences, the tropical continental type of climate and with the climatic regime characterized by seasonality. The area is well within the northern limit of the movement of the Inter Tropical Convergence Zone (1TCZ). This phenomenon of the global circulation of air masses is responsible for the general climatic characteristics. The raining season begins from March and terminates in October. The dry season starts from late October to early March.

The study is restricted to the Southern part of Kaduna metropolis, where most industries are sited and wastewaters from both industrial and domestic processes find their way into the drainage system. The study therefore covers Makera, Kakuri and Kudenda industrial axis. (Fig. 1)

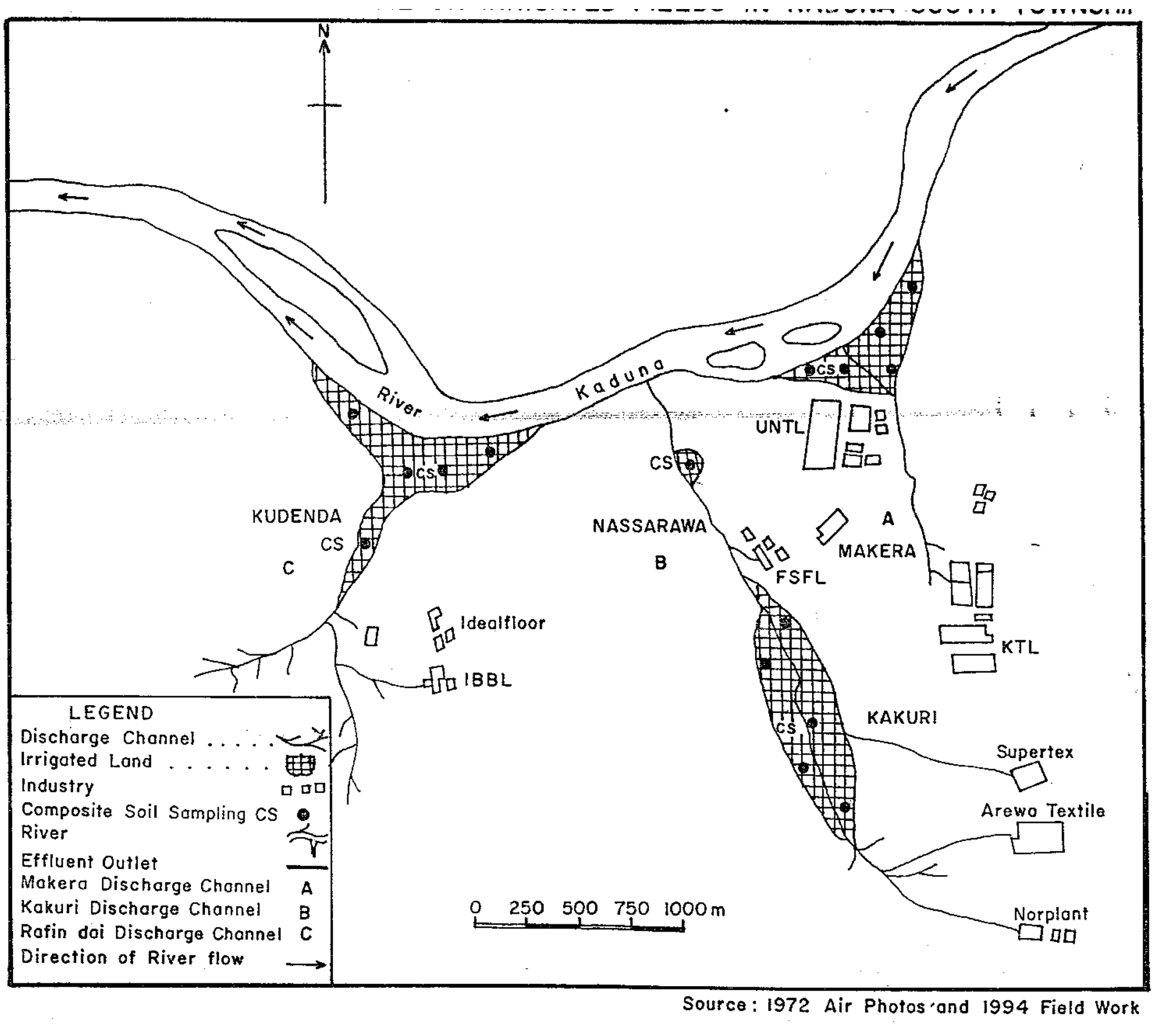

Fig.1. The study area and sampling points for soil on irrigated fields in Kaduna South Township.

The pedogenetic processes in the area are responsible for the formation of ferrugenous soils commonly found on most parts of the area and hydromorphic soils found in restricted places along River Kaduna and streams. The pedogenetic processes which are active have resulted in:

(1) The formation of a coarse textured surface layer

(2) The formation of an argillic horizon.

(3) The segregation and hardening of iron on the lower profile.

The formation of a single profile in this term is compounded by periodic surface reworking which has produced discontinuities in many cases. The reworking brought about erosion, sometimes completely of extensive ironpan capping formed by iron segregation process during a previous period and the colluvial distribution of eroded fragments down slope.

MATERIALS AND METHODS

To evaluate the effect of wastewaters on soil properties, both soil and water samples were taken on the field for laboratory analyses. sixteen water and fifteen soil samples were taken along Makera, Kakuri and Rafin Dai drains and on irrigated fields in Kaduna South township.

Water samples were determined from three sources namely industrial effluent outlets, wastewater in drains and river Kaduna. In determining the sampling points care was taken in deciding at what points problems exist and where mixing is adequate to allow drawing representative samples. Samples collected were fed into 500mls clean plastic bottles, treated with 3 to 4mls of nitric acid, firmly closed and stored in a refrigerator at temperature of 3 to 4°C to preserve them.

Fifteen soil samples were also determined on irrigated fields in Makera, Kakuri and Kudenda by use of free traverse method to allow flexibility in the choice of the sampling points. The samples were taken by burrowing a hole 30cm deep using a soil auger, the soils were thoroughly mixed to form a composite sample for each sampling point.

Laboratory analyses

Both soil and water samples were subjected to laboratory analyses to determine chemical properties associated to salinity, sodicity and toxicity so as to be able to relate concentration of substances in water to that of the soil.

Soil

Parameters investigated included soil pH using a pH digital meter, electrical conductivity by use of portable conductivity meter, particle size analysis by hydrometer method, total phosphorus by ignition 0.2NH2S04 extraction method, total nitrogen percent by macro Kjedahl method while exchangeable cations were obtained by ammonium acetate leaching method.

Water

Water pH and electrical conductivity were determined same as in soil samples, ascorbic acid method was used for phosphate while calcium and magnesium by EDTA titrimetric method, oven dry method was used for total dissolved solids, sodium and potassium were determined by flame emission photometric method, boron and lead by atomic absorption spectrometric method and nitrates by ultra-violet spectrophotometric screening.

RESULTS AND DISCUSSION

The textural analysis of soil in Kaduna South has indicated that, soils on irrigated fields are sandy loams. The result of the analysis agrees with that obtained by the Kaduna Sewerage and Drainage Project (1978). The result has however, shown a decline in the clay portion of the soil. The implication of this to the soil is that it will result in the decline in nutrients and water retention capacity in the soil. Essiet (1987) also observed, a decline in the fine portion of Kadawa post irrigation soils which he posited can lead to depletion of soil structure causing reduced infiltration and accelerated run off. Table I gives particle size of Kaduna South soils.

Table 1. Particle size analysis of soils in Kaduna state

Location	Sand %	Silt %	Clay %
Makera	66.03	24.26	9.71
Kakuri	60.03	27.60	12.37
Kudenda	66.03	20.93	13.06
Nasarawa	60.03	26.26	13.71
Along R. Kaduna	66.69	20.94	12.37
Mean	63.76	20.00	12.27

Source: Field and laboratory analysis 2001

Table 2 gives some of the chemical properties of soils on irrigated fields in Kaduna South.

The pH values ranges from 6.62 to 7.28 and with a mean of 6.89. The pH values are close to neutrality while the mean soil pH of 6.89 is slightly acidic. Kodiya (1988) recorded a mean pH value of 8.5 for the South Chad project, which is contrary to this finding. The present level of soil pH observed for the area fall within the range of pH recorded for most top soils in the West African Savannah (Essiet, 1987).

The concentration of total salts as indicated by electrical conductivity is highest for soils in Makera recording 1273 micromhos and Kudenda with lowest of 121 micromhos. The application of wastewater in Makera drain fed by textile effluents for irrigation, low water application rates and high evaporation may be the reasons for the concentration of high amounts of total salts in the soil root zone observed for the area. Tivy (1990) observed that soils of electrical conductivity above 400 micromhos are saline. For all soil sampled, only Makera is above 400 micromhos, the concentration of salts in soils along river Kaduna and Kakuri indicate that should wastewater be used continuously for irrigation salinity without proper management may be raised to toxic level in the soils.

The concentration of exchangeable cations was generally low for the soils. The mean calcium and magnesium concentrations was 1.2 me/100 grams of soils and a standard deviation of 0.54. The mean concentration of potassium was 0.2 me/100 grams of soil and sodium had a mean concentration of 1.3 me/100 grams of soil. The Kaduna Sewerage and Drainage Project (1978) also recorded very low concentration of exchangeable cations in Kaduna South soils (0.75-3.76 me/100 grams of soil for calcium, 0.28 - 0.30 me/100 grams of soils for potassium and 0.36-0.90 me/100 grams of soil for sodium). Sodium ions are slightly higher to that of other cations in the soil, this can attributed to in-part, the application of sodium rich textile effluents for irrigation and the precipitation of ions of calcium and magnesium in the soil and their replacement with sodium ion.

Cation Exchange Capacity ranges from 36.8% in Kudenda to 60% in Makera soils. The mean cation exchange capacity of 52.2% is moderately high. Kodiya (1988) also observed a similar trend in the cation exchange capacity of irrigated soils in the South Chad Project. High cation exchange capacity recorded for the area may be attributed to clay and humus contents and also the use of nutrients rich wastewater for irrigation. See table 3.

The mean nitrogen percent was 0.018 and ranges from 0.014 to 0.021. For soils of Kadawa irrigation Scheme Essiet (1987) recorded a total nitrogen percent of 0.03 pre-irrigation and 0.04 post irrigation periods. The result obtained for nitrogen percent is low like in many West African soils. Low nitrogen percent observed for the area is as a result of the farming system, which involves the removal on farm plots crop residues for domestic purposes and the burning of whatever is left during farm clearance.

Table 2. Chemical properties of soils on irrigated fields in Kaduna South.

	Soil pH	Ca me/100g	**Mg** me/100g	**K** me/100g	**Na** me/100g	**N %** me/100g	**P0** Mg/L	CEC %	Base Sat. %	**Na Abs. Ratio (SAR)**	Elect. Cond. **(EC)**
Makera	6.62	1.5	0.6	0.2	1.5	0.02	4.6	60	6	2.07	1273
Kakuri	7.17	1.02	0.2	0.1	1.0	0.014	5.0	39.2	6	1.78	242
Along R.	7.20	0.5	0.2	0.4	0.9	0.04	1.3	36.8	4	2.4	121
Ked.	7.28	0.8	0.3	0.1	1.4	0.014	4.1	56	5	6.67	303
Mean	6.89	0.9	0.3	0.2	1.3	0.18	3.9	52.2	5.25	2.46	424

Source: Field and laboratory analysis 2001.

Mean phosphorus concentration was 3.9 me/100 gram of soil. Phosphorus concentration was generally low compared to 243.00ppm recorded for the Kadawa soils (Essiet, 1987). The low phosphorus observed may be due to over cropping which tends to remove too much nutrients from the soils, low application of phosphorus rich fertilizers and the leaching of the nutrient from the soil root zone.

Influence of wastewater on soil chemical properties

Table 3 . Mean concentration of cations and bicarbonate in wastewaters of Kaduna south (me/l)

	Makera	Kakuri	Rafin Dai	R. Kaduna
Sodium	6.8	2.5	5.3	0.4
Magnesium	2.2	2.1	2.3	2.8
Calcium	1.3	4.0	1.2	0.5
Potassium	0.14	0.09	0.1	0.02
Bicarbonates	0.03	0.03	0.04	0.06
SAR	6.6	2.3	6.7	0.40
Permeability index	11.2	5.3	11.4	2.7

Source: Field work and laboratory analyses 2001.

The suitability of soils for waste water irrigation in Kaduna south.

The mean pH values for wastewater in drains (7.7) fall within the pH 6.6 —8.4 suitable (Ayers and Westcots, 1976). The present level of soil pH (6.89) does not pose problem for use of wastewater in the area for irrigation development. The wastewater in Rafin Dai drain (pH 8.89) if used for irrigation may raise soil pH . High pH values indicate alkalinity problem with sodium ion being the dominant cation in the soil colloid which can lead to deflocculating soil condition thus retarding plants growths see table 4

Table 4. Concentration of some chemical properties in Kaduna South wastewaters

SOURCE OF WATER	EC micromhos	Water pH	Cl mg/L	HCO_3 mg/L	$P0_3$ mg/L	'NO_3 mg/L
River Kaduna	135	7.5	125	3.8	1.7	0.3
Makera Drain	2254	7.7	920	2.1	9.9	0.8
Kakuri Drain	969	7.4	435	2.0	4.6	2.28
Rafin Dai Drain	834	8.9	46.2	2.3	3.0	0.4
Textile/Garments	3515	9.5	1358	3.0	16.8	0.45
Retrochemical	595	4.7	113	1.5	5.8	3.4
Foods, Drinks and Beverages	849	7.5	42.5	2.0	7.5	0.9

Source: Field and Laboratory Analysis (2001)

Salinity

The electrical conductivity of wastewater as indicated in table 4 is above the 750 micromhos considered suitable for irrigation under most conditions (Ayers and Westcots, 1976). The mean electrical conductivity of soil extracts shows that soils fall above 400 micromhos considered for saline soils. The prolonged use of wastewaters in the area for irrigation will gradually be accompanied by salinity built up in the soils especially when proper management is not adopted. The particle size analysis has however, shown that the soils made up of sandy loam are better drained and so can withstand wastewater application when proper management practices such as increase in frequency of application of irrigation water, selection of tolerant crops and the dilution with clean water. Feachem et al (1982) observed that good drainage and proper management will lower the contact period between the plant and saline waters.

The lethal concentration of total salts in irrigation water will result in soil salinisation which raises the osmotic pressure of the soil and so prevents the absorption of water by plants. Table 5 gives crops response to soil salinity.

Table 5. Crops response to soil salinity

Electrical conductivity of soil at 25°C extract micromhos/cm	Crop response
0-200	Largely negligible
200-400	Yields of sensitive crop may be restricted
400-800	Yields of many crops restricted
800-1600	Only salt tolerant crops
Above 1600	Very few tolerant crops

Source: Tivy, 1990.

Sodicity

The effect of sodium depends on the relative presence of other cations in the soil. The mean sodium concentration is slightly higher to that of calcium and magnesium. High amounts of sodium ions can result in the precipitation of calcium and magnesium ions from the soil thus affecting their effectiveness in enhancing permeability. An increase in the proportion of sodium as indicated by wastewaters in drains will promote higher levels of soil alkalinity. Sodium absorption ratio of the soil extracts fall below 3 considered suitable (Ayers and Westcots, 1976) and with no degree of problem. The re-use of wastewater in drains in the area for irrigation may gradually be followed by adverse sodicity problems. The implication on the soil and plants is that it will have marked influence on permeability resulting in a soil with poor internal drainage thus affecting infiltration of water and retards plant growth. High amounts of total salts as indicated by electrical conductivity can help to improve soil structure by the flocculating action which tends to counter the poor physical condition caused by high sodium concentration in the soil. Table 6 gives the sodium absorption ratio and electrical conductivity of soil extracts.

Table 6. Sodium Absorption Ratio and Electrical Conductivity of Soil Extracts in Kaduna South

Location	Sodium absorption Ratio (SAR)	Electrical Conductivity (EC micromhos
Makera	2.07	1273
Kakuri	1.78	242
Kudenda	3.62	121
Nasarawa	2.14	303
Along R. Kad.	2.67	181
Mean	2.46	424

Source: Field and Laboratory analyses 2001.

Cation Exchange Capacity: The cation exchange capacity is moderate in its distribution as shown on table 2. The implication to the soil is that it indicates high nutrients retention capacity which is adequate for plants. Kudenda and Kakuri record low cation exchange capacity of 36.8 and 39.2 respectively. Low cation exchange capacity has serious implication, under continuous cropping nutrient deficiencies are bound to occur. The supply of nutrients as present in wastewater will be of advantage for plants growth in the area.

Toxicity

Boron toxicity is generally low in wastewaters of the area. Urroz (1976) observed that boron concentration 0.4mg/l is suitable for highly sensitive crops. All values of boron for Kaduna South wastewaters fall below 0.4mg/l indicating that boron poses no prob’em for irrigation water in the area. Chloride is high in textile effluents (1350mg/l) Makera drain served by textile effluents (920mg/l) and Kakuri drain (435mg/l). chloride is toxic to crops growth when present in the soil at high concentration. The concentration of chloride at about 700 — l000mg/l causes leaf burn in fruit crops (Bayer et al, 1972).

Low nitrogen % observed for soils indicates that they are deficient in nitrogen and requires replenishment by application of organic fertilizers and chemical additives rich in nitrogen.

CONCLUSION

The re-use of wastewater for irrigation in most urban areas in Nigeria has increased food supply and the per-capita income of a portion of urban population. Wastewater when applied on agricultural lands offers a cheaper and more feasible alternative for wastewater management. The utilization of poor quality water for irrigation may raise the concentration of ionic substances to chronic levels thus affecting the productive capacity of the soil.

There is the tendency for soils to become saline by the re-use of salt rich wastewater for irrigation. For successful application of wastewater for irrigation there is need for proper management practices which include selection of tolerant crops, treatment of wastewater prior to its re-use for irrigation, liming of sodic soils and the increase in the frequency in application rates of irrigation water, to leach excess salts. The study has shown that wastewater with appreciable concentration of ionic substances and at tolerable limits enriches the soils with nutrients required for developmental processes of plants and is the source from which water is available especially during the dry season for irrigation development.

Recommendations

The following recommendations if properly observed will provide guides for wastewater management in most urban centres.

1.There is the need for both government and private enterprises to be actively involved in wastewater treatment from source before its being discharged into surface receiving bodies.

2.The disposal of wastewater on surface receiving sources is grossly inadequate. The disposal of wastewater on non-detrimental sites and non residential areas should be preferred.

3.Substances used during production processes should be separated from water for other productive purposes and the water re-cycled without causing injury to the environment.

4.There is need for establishing quality standards for wastewater disposal. There should be strict supervision of compliance by FEPA.

5. Detail researches on the reactions and transformations, which occur in soils when wastewater is applied for irrigation should be conducted so as to evaluate the suitability of wastewater for irrigation development.

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