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Microbial quality of irrigation water and irrigated vegetables in Kano State, Nigeria

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Abstract

This work examined the quality of wastewater used for irrigation of vegetables in Kano State, Nigeria. It also assessed the sanitary quality of the irrigated vegetables by detecting the incidence of faecal indicator bacteria over a 9 months period between May 2010 to March 2011. Irrigation water sources received pollutants from various effluents discharged from industries, domestic sewage, abattoir and other non point sources of pollution. Physicochemical parameters of irrigation water were observed to be higher than acceptable limits. The counts of faecal coliform in the water and irrigated vegetables also exceeded the 1,000 CFU/100 ml guideline for water used in fresh produce. The presence of faecal-indicator bacteria in the irrigation water and vegetable samples suggests faecal pollution raising the possibility of the presence of pathogenic microorganisms in these vegetables and a threat to public health. We recommend adequate treatment of effluents before discharge. The need for proper disinfection of raw vegetables before consumption cannot be overemphasized.

Introduction

Wastewater reuse in irrigation is largely considered an inevitable option to compensate water shortages in developing countries. Hence, crop irrigation with wastewater is a widespread practice in these countries (Sou *et al*., 2011). In the urban areas the use of wastewater in agriculture is a centuries-old practice that is receiving renewed attention with the increasing scarcity of freshwater resources in many arid and semi arid regions (Ackerson *et al*., 2012). The growing wastewater volumes are driven by rapid urbanization (Scott *et al*., 2004). Economic and agronomic advantages are sometimes promoted in wastewater reuse but there are several studies warning about health risks and environmental impacts (Sou *et al*., 2011). One of the most economically feasible agricultural uses of reclaimed water is the irrigation of vegetables which typically have high returns per volume of water invested in it (Toze *et al*., 2006). Although, the environmental and public health risks posed by wastewater irrigation are alarming, especially when untreated and/or partially treated wastewater is used for such purposes (Ackerson *et al*., 2012). Point sources of contamination to water bodies include industrial effluents, municipal/domestic wastewater, abattoir waste, while, non point sources include wild animal defecation, storm water drainage and urban runoff (Odjadjare *et al*., 2010). Health impacts are mainly due to pathogens (bacteria, viruses, protozoa, cysts and helminthes eggs) and other organic and inorganic toxic substances which are likely to exceed health protection standards (WHO, 2006). The pathogens are transmitted to the public through consumption of irrigated produce, especially crops eaten raw (Blumenthal *et al*., 2000). Several studies throughout the world have demonstrated a very close relation between the consumption of fruits and vegetables irrigated with raw wastewater and many food borne diseases like gastroenteritis, cholera, chemical toxicity etc (Sou *et al*., 2011). The World Health Organization estimates 200, 000 deaths from food borne pathogens in Nigeria (WHO, 2009). *Vibrio cholerae*, the aetiologic agent of cholera is consumed from contaminated water, foods including vegetables and seafood (Adesida *et al*., 2012) with water playing a central role in its transmission (Madoroba and Momba, 2012). Igomu *et al.* (2011) reported that in the last quarter of 2009, more than 260 people died of cholera in the northern part of the country. Epidemiological data from Public Health Department of Kano State Ministry of Health, revealed that the frequency and distribution of cholera epidemics in the State during 1995 to 2001, were 2,630 in 1995/1996, 847 in 1997 and 2, 347 in 1999 (Usman *et al*., 2005). Many of the sources that are thought to contribute to the epidemiology of diseases associated with raw fruits and vegetables are impacted by ecological conditions that affect survival or growth of pathogenic microorganisms (Steele *et al*., 2005). These sources include raw manure, inorganic amendments, irrigation water and dust (Selma *et al.*,

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2007). The microbial quality of vegetables grown with wastewater is highly alarming (Ajayi *et al.*, 2008). Thermal processing is one of the domestic techniques of processing vegetables in Nigeria but for fear of denaturation of beneficial nutrients during heating (Udousoro *et al*., 2013) vegetables are served and consumed raw.

Faecal coliforms are the indicator bacteria most commonly used in discussions of wastewater reuse (Blumenthal *et al*., 2000). They are broadly equivalent to "thermotolerant coliforms". The preferred grouping would be thermo tolerant "coliforms/*Escherichia coli* " which would eventually allow *E. coli* to be used as the preferred and exclusively faecal indicator bacterium (Edberg, 2000). Hence are considered an indicator of microbial pollution (Halablab *et al.*, 2010).

With increasing consumption of vegetables as a result of awareness of its health benefits (Klansmewyer *et al*., 2004) and with reports on the health impact of the use of untreated wastewater (Salem *et al*., 2011). The need to assess the microbial quality of irrigation water and irrigated vegetables in Nigeria is eminent in order to propose alternatives to prevent consumers from disease outbreaks. Hence the present study was undertaken to examine the quality of irrigation water and irrigated vegetables from Kano State, Nigeria.

Materials and Methods

Study background

Nigeria, like most developing countries is facing demographic expansion and its agricultural sector is experiencing rising pressure to meet the steadily growing food demands both globally as well as in Africa. Kano state has many rivers, ponds and dams. It is one of the most irrigated States in the country with more than 3 million hectares of cultivable land and two of the most ambitious irrigation projects in West Africa; Challawa Gorge and Tiga dam, which ensure all year round farming. Kano State is the second most populated state in Nigeria with a population of about 9,401288 million people (NPC, 2010). Kano State is historically a commercial and agricultural State, infact the centre of commerce. It is one of the most developed industrial cities in Nigeria. Tannery and textile are some of the dominating industries and this could be one of the reasons for her high population density (Ogunshe *et al.*, 2010). Urban and livestock farming are also a major activity in the State. Farmers are involved in irrigated vegetable cultivation. High value and easily perishable exotic vegetables are grown. These include lettuce, carrot, cabbage, spring onions, green pepper, green beans etc. Vegetables are cultivated on raised beds and irrigated by surface irrigation system. Sources of irrigation water are shallow wells, streams and rivers. Large amounts of untreated wastewater are discharged into urban drainage systems and other natural waterways, rivers receive waste from tanneries and textile industries, abattoirs, urban water storm and agricultural runoffs from farming communities along its course. These water bodies serve as source of water for irrigation and animal watering.

Sampling

Sampling sites selection was based on; the availability of vegetables on the farms, the cooperation of the farmers, the type of vegetables grown, the source of irrigation water and its point source of contamination. Five designated irrigation sites were selected for the study. Samples were obtained from four different irrigation water sources including river, well/ponds, tap and dam. Point sources of contamination to various irrigation water sources included abattoir waste, refuse dumpsite composed of domestic waste and human waste, waste from mechanic workshops and industrial effluent terminals. One hundred and fifty one samples consisting of ninety four vegetables and fifty seven irrigation water samples were collected and analyzed during the study. Samples were collected in the wet (May-October, 2010) and dry (November-March, 2011) seasons. Water samples were collected according to the procedure recommended by American Public Health Association (APHA, 1992). Water samples were collected in sterile wide mouth, screw capped 250 ml bottles. Using 90% ethanol sterilized scissors, vegetables were cut into factory sterile polythene bags. All samples were packed on ice during the transportation to the laboratory.

Determination of faecal coliform count (FCC) from samples

About twenty five grams of each vegetable was soaked for 15 mins and washed by shaking thoroughly with 225 ml of 0.1% sterile peptone water. Serial dilutions of each vegetable washing was made in sterile peptone water at dilutions 10^1 to 10^8. Faecal coliform count of water samples was determined using the serial dilution and spread plate method (Ajayi *et al.*, 2008). Serial dilution of each water sample was made in sterile peptone water at dilutions 10^1 to 10^8. Aliquot of 0.1 ml of appropriate dilutions for both sample types were each inoculated on Eosine Methylene Blue (EMB) agar plates by spread plate technique. Inoculated EMB agar plates were incubated at 44.5°C for 24 h. Characteristic colonies which appeared as green black with metallic sheen on EMB agar were counted as faecal coliforms. Typical colonies were inoculated into lactose broth in test tubes containing inverted Durham`s tubes and were incubated at 44°C for 24 h for confirmatory tests. Gas and acid production confirmed faecal coliform test (Ogunshe *et al*., 2006). Temperature of each water sample was measured in the field using a thermometer and the pH was determined using a pre-calibrated pH meter (Norylab; LM8). The digested oxygen and a five day biological oxygen demand (BOD_5) was determined after incubation in tightly stoppered BOD bottle in the dark at 20°C and titrimetrically determining oxygen consumed (APHA, 1992).

Statistical analysis

Faecal coliform counts were normalized by log transformation. Using the statistical software SPSS for windows 17.0, student's t-test and analysis of variance were used to evaluate statistical significance of the data and results were quoted at $P < 0.05$ levels of significance.

Results

One bacteriological parameter, faecal coliform counts (FCC), two physical parameters; water temperature, electrical conductivity (conductance) and three chemical parameters, including hydrogen ion potential (pH), digested oxygen (DO) and five-day biochemical oxygen demand (BOD_5) were determined for water quality indicators. Faecal coliform counts of all vegetables obtained were analysed.

Analysis of variance showed that there was a significant ($F = 3.631$, $P = 0.007$) difference in the faecal coliform counts of water between the sites in the study. Sites 1-3 had higher faecal coliform counts than sites 4 and 5. The temperature range showed that site 4 had the highest temperature, site 5 recorded a high temperature while sites 1-3 had the same range of mean temperature. The pH value obtained shows that site 3 had the highest pH value, sites 1-2 were in the same range of pH value while sites 4 and 5 recorded the least pH value. However, there was no significant difference in the electrical conductivity, digested oxygen and the five day biochemical oxygen demand (Table 1).

Comparing the means of faecal coliform counts and physicochemical parameters of water used for irrigation in the wet and dry seasons using Student's t-test, there was a significant difference ($t = 4.011$, $P < 0.001$) in mean faecal coliform counts for the two seasons with the wet having higher counts than the dry. A significant difference ($t = 2.259$, $P = 0.028$) was obtained in the mean temperature values of irrigation water for the two seasons, with a record of higher mean temperature value in the wet than dry. No significant difference was observed in the pH values for both seasons. Analysis of the electrical conductivity of the water showed that there was a significant difference ($t = 3.708$, $P = 0.001$) in seasonal variation with the wet season having higher value of conductance than the dry. Dissolved oxygen also showed a significant difference ($t = 2.185$, $P = 0.034$) with the dry season having higher values than the wet. However, no significant difference was observed in the biological oxygen demand of irrigation water in Kano state, although higher mean values were recorded in the dry than wet (Table 2).

There was significant difference in counts on vegetables in between seasons, with a record of higher counts in the wet than dry (Table 3).

Discussion

The presence of faecal coliform is an index of the bacteriological quality of water (Chigor *et al*., 2012). The levels of faecal coliform counts observed were high and greater than 1000 MPN/100 ml at all the sampling sites. The observed higher counts recorded in sites 1-3 is a reflection of the level of effluent from the point source of contamination. The low faecal coliform counts at site 4 (control site at Kano) could be attributable to storage and to dying off or possible transformation of cells into viable but non-culturable states (Wang and Doyle, 1998). This site has a waste stabilization pond in which water passed through some form of treatment (storage) before application to the vegetables. The significant ($P < 0.05$) difference in the faecal coliform counts in Kano State could be due to the difference in the point source of pollution to the sites, while site 1 receives effluents from adjacent abattoir, site 2 receives pollutants from domestic waste and site 3 receives sewage/effluents from mechanic workshop.

None of the water samples from the sites met the international standards for the guideline limit for faecal coliform bacteria in unrestricted irrigation of crops likely to be eaten raw : 10^3 to 10^5 (WHO, 2006). Hence these waters are not suitable for human consumption and irrigation of vegetable and salad crops without prior treatment. Site 4 recorded the highest temperature, this must have resulted from the action of storage of the water for a while before flow and would have contributed to the lower counts of faecal coliform. Oliver, 2005 and WHO, 2006 reported that bacteria may become viable but non culturable (VBNC) when exposed to sublethal

Table 1. Comparison of mean values of water quality parameters in parts of Kano State

Site	Mean ± SEM					
	FCC	Temp	pH	EC	DO	BOD
Site 1	$1.67 \times 10^8 \pm 3.05 \times 10^{7\,a}$	25.80 ± 0.73^b	6.97 ± 0.77^{ab}	1473.57 ± 222.55	177.71 ± 24.93	79.93 ± 16.02
Site 2	$1.42 \times 10^8 \pm 2.56 \times 10^{7\,a}$	25.46 ± 0.77^b	7.07 ± 0.08^{ab}	1884.00 ± 266.73	200.09 ± 23.83	87.90 ± 25.23
Site 3	$1.46 \times 10^8 \pm 2.82 \times 10^{7\,a}$	25.83 ± 0.75^b	7.21 ± 0.13^a	1325.38 ± 237.17	201.92 ± 24.71	57.69 ± 11.10
Site 4	$1.31 \times 10^5 \pm 4.77 \times 10^{4\,b}$	30.50 ± 0.89^a	6.71 ± 0.01^b	1145.00 ± 199.20	255.00 ± 14.58	105.00 ± 37.58
Site 5	$3.85 \times 10^7 \pm 2.67 \times 10^{7\,b}$	28.40 ± 1.95^{ab}	6.74 ± 0.03^b	649.20 ± 359.59	244.00 ± 14.78	140.00 ± 12.35

*For each parameter, mean values with different superscripts are significantly different ($P < 0.05$)
Key: SEM = Standard Error of mean
FCC = Faecal Coliform Counts, Temp = Temperature, pH = Hydrogen ion, EC = Electrical conductivity, DO = Digested oxygen and BOD = Biological oxygen demand.
Site 1(Abattoir liquid waste), site 2 (Domestic sewage drain), site 3 and 5 (Industrial waste) and site 4 Tiga dam (Control).

Table 2. Comparison of mean values of faecal coliform counts and physicochemical parameters of irrigation water for the wet and dry season in Kano State

Variable	Season		t-value	p-value
	Wet	Dry		
Faecal coliform (Log_{10} cfu)	8.25 ± 7.34^a	7.86 ± 7.17^b	4.011	< 0.001*
Temp	27.19 ± 0.35^a	25.26 ± 0.85^b	2.259	0.028*
pH	7.02 ± 0.06^a	7.00 ± 0.10^a	0.181	0.857
EC	1733.21 ± 139.39^a	88.69 ± 183.65^b	3.708	0.001*
DO	183.59 ± 17.21^b	235.00 ± 10.85^a	2.185	0.034*
BOD	70.64 ± 11.63^a	105.00 ± 13.39^a	1.903	0.064

* = Significant difference exists. Mean values with different superscripts are significantly different ($p \leq 0.05$)
Key: FCC = Faecal Coliform Counts, Temp = Temperature, pH = Hydrogen ion, EC = Electrical conductivity, DO = Digested oxygen and BOD = Biological oxygen demand.

Table 3. Faecal coliform counts of vegetable samples obtained from Kano State by season

Site	FCC		t-test	p-value
	Dry# Mean count (cfu/g)	Wet## Mean count (cfu/g)		
I	7.75 ± 7.50^b	12.60 ± 12.20	-2.580	0.035*
II	7.82 ± 7.52^b	12.44 ± 12.08	-2.309	0.040*
III	12.65 ± 12.71^a	7.70 ± 7.50	2.530	0.035*
IV	5.54 ± 5.15^b	6.32 ± 6.23	-1.379	0.379
V	6.95 ± 6.80^b	5.31 ± 5.03	1.411	0.294
Overall	11.61 ± 11.61	12.29 ± 11.79	-2.075	0.043*

#F = 3.864; p = 0.021*   ##F = 2.050; p = 0.111
* = Significant difference exists
Site 1(Abattoir liquid waste), site 2 (Domestic sewage drain), site 3 and 5 (Industrial waste) and site 4 Tiga dam (Control).

stresses such as temperature and pH. Sites 1-3 and 5 had about ambient temperature which is seemingly conducive for bacterial growth. The pH values obtained for sites 1-3 were close to neutral which also is not lethal to bacterial survival and must have supported the proliferation of faecal coliforms.

Electrical conductivity (EC) is also an important parameter for water quality, higher conductivity indicates high amount of ions that exceed the recommended limit (Ayers and Westcot, 1985). Sites 1-3 showed higher levels of conductivity as compared to 4 and 5. This also shows high level of risk in use of water from these sites for consumption and thus irrigation of vegetables prior to treatment. Dissolved oxygen (DO) is a very crucial parameter for the survival of aquatic organisms and is used to evaluate the degree of freshness of water/river. The lower values of DO observed in sites 1-3 relative to sites 4 and 5 may be as a result of the nature of the effluent discharge into water that places a high demand on the DO (Arimoro *et al*., 2008). The observed BOD levels were noted to be above maximum permissible limit of 10 mg/l recommended by FEPA, 1999 for drinking water.

The absence of significant difference between the mean values of faecal coliform counts in between seasons is in line with the report of (Chigor *et al.*, 2012) and shows a continuous faecal pollution from point sources; domestic drain, effluents from abattoir, sewage and mechanic workshop. The higher counts observed in the wet season than dry could be attributable to runoffs. This supports the findings of (Kistemann *et al*., 2002) who demonstrated that substantial shares of the total microbial loads in water courses and drinking water reservoirs in Germany resulted from rainfall and runoff events. Vegetables analyzed showed faecal coliform levels more than the $1x10^3$ per 100 g wet weight hence can be classified as undesirable for consumption according to the International Commission on Microbiological Specifications for Food (ICMSF, 1974) guidelines.

Conclusion

Results obtained in this study show the high level of contamination of irrigation water and irrigated vegetables in Kano State, Nigeria. Point sources of effluents to the water bodies used for irrigation contributed significantly to the continuous influx of microorganisms throughout the year. The quality of the waters and the irrigated vegetables exceeded standard microbiological limits. We recommend that the government enforce strict rules and legislation on adequate treatment of wastewater and effluents before discharge to the environment. Proper washing and disinfection of vegetables before consumption is strongly advised.

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