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AN ASSESSMENT OF THE PUBLIC HEALTH HAZARD POTENTIAL OF WASTEWATER USE IN SALAD CROP PRODUCTION AT UMGUZA IRRIGATION LOTS

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ABSTRACT

Farmers at Umguza Irrigation Lots practise unrestricted crop production using undertreated wastewater. This presents potential public health risk to producers, vendors and consumers of the produce. The aim of the study was to establish the level of public health risk of wastewater use in unrestricted crop production at Umguza Irrigation Lots. Water samples from the dam, canal and overnight reservoir and vegetables: *Lactuca sativa*, *Brassica oleracea* and *Solanumlycopersicum* were obtained and analysed for physiochemical and microbial characteristics. The results of the study revealed that thefarmers grew salad crops using wastewater. The mean pH, EC, DOof the waterwas 8.9, 866.9µS/cm and 607.6 ppm. The EC value was far less than the 2000µS/cmFAO guidelines. *Escherichiacoli O157, Shigella,Salmonella* and *Staphylococcus aureus* were isolated in the wastewater with a steady decrease in pathogenconcentration as the rain season progressed. The same trend of decreasewas also observed on vegetable samples. The level of contamination by pathogen was noted tobe ranging fromsignificantly low to nil, where drip irrigation system was used. Future research isrecommended to determine the extent of contamination and conduct confirmatory test like Biochemical tests or Quantitative Real- Time Polymerase Chain Reaction.

INTRODUCTION

Urban and/or peri-urban agriculture is a phenomenon that is practised in bothdeveloping and developed nations. Wastewater use in agriculture is growing due to fresh water scarcity, population growth and urbanisation, which in turn, lead to the generation of yet more wastewater in urban areas. Wastewatercan be used to substitute for other better quality water sources, especially in agriculture (Carr *et al.,* 2004). Other benefits of re-using wastewater are recovery of nutrients (nitrogen, potassium and phosphorus). Re-use of wastewater reduces pollution load in rivers and also offers a reliable water supply throughout the year (FAO, 2010).In Bulawayo, Zimbabwe, the municipality encourages urban agriculture as stated in the Urban Agriculture Policy of 2000 (Thebe and Mangore 2010). Urban agriculture has notably improved the general household income to the families directly involved while at the same time helping meet the increasing urban population's dietary needs. However, if leftunchecked, the use of wastewater in agriculture has important health implications for thefarmers, produce consumers, produce vendors and communities in wastewater irrigated areas (Carr *et al.,* 2004). The Public Health Act through Statutory Instrument 638 of 1972 gazetted asthe Public Health (Effluent) Regulations sets guidelines for wastewater irrigation with regards to public health (Thebe and Mangore 2010). Theseguidelines forbid the irrigation of root crops such as potatoes and sets restrictions are not greatly enforced presently in Zimbabwe. Van der Hoek, in Carl and Mara (2010) defines wastewater as a combination of domestic effluent consisting of black water (faeces, urine and associated sludge), greywater (kitchenand bathing wastewater), water from commercial establishments and institutions, including hospitals, industrial effluent wherepresent and/or storm water and other urban runoff.

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The earliest documented sewage farms, where wastewater is applied to land for disposal and for agricultural use, were operated in the sixteenth and seventeenth centuries in Bunzlau, Germany and Edinburgh, Scotland (Carl and Mara 2010).The benefits cited included the prevention of river pollution and the provision ofwater and nutrients to agriculture. According to Carl and Mara (2010), in Kumasi, Ghana, 80–90 per cent of the perishable vegetables consumed in the city are produced using wastewater. McCornick *et al* (2004), in Carl and Mara (2010) states that Jordan is one of the most water deprived countries of the MiddleEast and has some of the highest groundwater depletion rates. Wastewater use or reuse is an established practice inZimbabwe that started in the1950s in Bulawayo at Aisleby Farm and in 1959 with the reclamation of wastewater from Thorngrove Wastewater Treatment Plant for non-potable use (Thebe and Mangore 2010).

However, the challenges in maintaining wastewater infrastructure mean that water is channeled away from the households and industries but could fail to get adequate treatmentbefore re-entering the water courses or being used in irrigation of crops. Policy review of regulations in Bulawayo has shown policy inconsistencies and isrecommending the development of separate guidelines that focus on wastewater use inagriculture with clearly defined terms of different typologies of wastewater use to ensureadequate regulation or enforcement of standards (Thebe and Mangore 2010). There arepresently no mechanisms for quality control of wastewater irrigated produce/products due tothe lack of traceability of agricultural produce. The growing demand for agricultural produce in Bulawayo calls for an increased crop production, however, the increased demand for fresh water in the region leaves producers faced with a dire need for an alternative water source. Although wastewater use in crop productionposes a risk to those manning the irrigation scheme, the immediate communities and the consumers (WHO, 2005), producers are lured into using it as a way of self- sustenance.

Restricted wastewater use in crop production is often practised as a public health concern, however, at Umguza Irrigation Lots unrestricted wastewater crop production is being practiced despite the lack of a credible research on the quality of the wastewater as required by legislation(WHO, 1989).The aim of the study was to assess the quality of irrigation water used in crop production atUmguza Irrigation Lots withrespect to pathogenic microorganisms by identifying the types and levels ofpathogens in the irrigation water at different pointsalong the conveyance canal in irrigation water at different times of the year, establishing the level of pathogenic contamination of vegetables produced undersprinkler irrigation and comparing the level of contamination in tomatoes produced under sprinkler and drip irrigation methods.

MATERIALS AND METHODS

Study Area

Umguza Irrigation Lots is situated in Umguza District of Matabeleland North, (19^0 35' 0" South, 28^0 2' 0" East) and20 kilometres from Bulawayo. The 1200 hectares area is apportioned into 6 to 250 hectare plots allocated to farmers. Irrigation water is from Upper and Lower Umguza dams, which are fed by water from two sewage works.

Sample collection

Water samples from Lower Umguza Dam, canal and night storage reservoir were collected for this study and the samples were collected following standard procedure as described by APHA (1992) and the samples containers were labelled on the field using appropriate codes. Pre-washed plastic bottles were used to collect water sample for physico-chemical analysis, while a sterilised universal sampling bottle was used to collect samples for microbial analysis. The sample samples were temporary stored in ice packed cooler and transported to the laboratory immediately for analysis. These samples were collected inOctober and December 2013 and February 2014.

Vegetable Samples

Two tomato fruits were randomly picked using sterile surgical gloves from a tomato field and placed in plastic bags. Two cabbage and lettuce heads were randomly uprooted from one sprinkler irrigated field, another set from a drip irrigated field and placed in separate plastic bags.

Microbiological analysis

The total coliform colonies counts were determined using the spread and streak plate method (APHA, 1992).

RESULTS

The study revealed that horticulture was the main enterprise (60%) with 20% each being into cereals and cereal and horticulture production respectively.Eighty per cent and 20% of the respondents used water from Lower Umguza Dam and Zimbabwe National Water Authority boreholes for irrigation. The irrigation methods used were sprinkler irrigation (50%), drip and sprinkler (30%) and10% each for surface and sprinkler and drip irrigation respectively.The salad crops grown were tomato, lettuce, cucumber, carrots, onions, green pepper, cabbage and beetroot.The vegetables were supplied to markets in Bulawayo, Hwange and Victoria Falls. The study also revealed that 80% of the respondents wash their produce upon harvesting using water in the canals, whilst 20% of the respondents did not clean their produce.

Physicochemical Analyses

The physico-chemical parameters were determined according to procedures outlined in the Standard Method for the Examination of Water and Waste water (APHA, 1998) (Table 1).

Table 1. Waste water parameters

Parameter	Range	Mean
pH	8.79 - 9.2	8.9
Total dissolved solids (ppm)	526 – 724	607.6
Electrical conductivity (µS/cm)	748 – 1036	866
Dissolved oxygen (g/l)	5.5 – 9.6	7.55

The pH of water samples ranged from 8.79 to 9.2 with an average pH of 8.9 throughout the three sampling sessions and points. There was a notable increase in pH from session 1 through to session 2 with the exception of dam sample which fell by 0.1 units from 8.91 to 8.8 (Figure 1).The total dissolved solids ranged from 526-724 ppm with a mean of 607.6 ppm. There was a steady decline in the TDS from session 1 through to 3 across all sampling points.Electrical conductivity levels ranged from 748-1036µS/cm with a mean of 866.9µS/cm. There was a steady decline in the electrical conductivity from session 1 through to 3 across all sampling points (Figure 2).

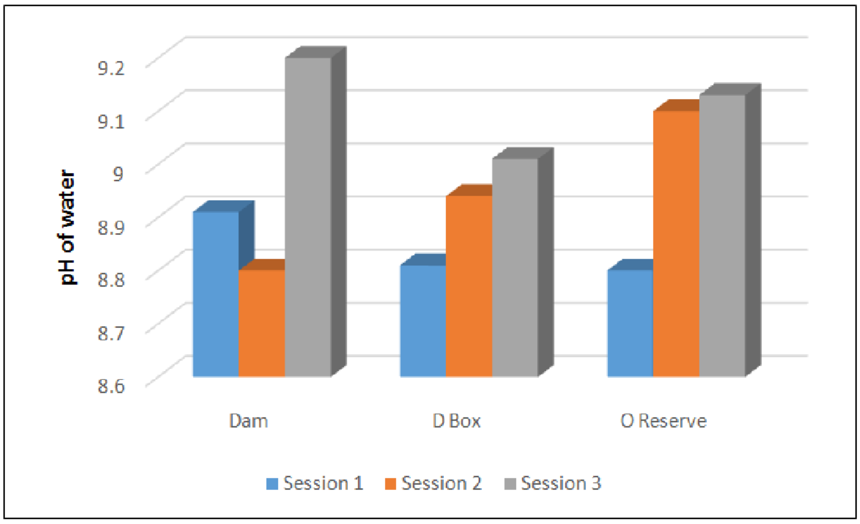

Fig.1. pH values from the 3 Sessions

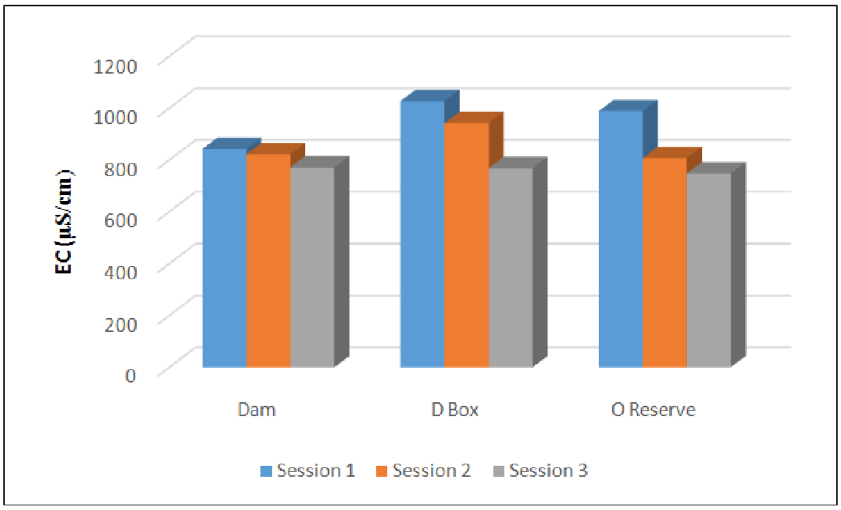

Fig.2. Electrical Conductivity (µs/cm) values from the 3 Sessions

Table 2. Irrigation Water Culture Results

	Session 1		Session 2		Session 3	
	E.coli **(cfu/ml)**		***E. coli*** **(cfu/ml)**		***E.coli*** **(cfu/ml)**	
Method	Spread	Streak	Spread	Streak	Spread	Streak
Dam	TNTC	TNTC	TNTC	18	TNTC	06
Diversion Box	TNTC	TNTC	TNTC	TNTC	17	22
O. Reservoir	TNTC	TNTC	TNTC	TNTC	35	02
	Shigella **(cfu/ml)**		***Shigella*** **(cfu/ml)**		***Shigella*** **(cfu/ml)**	
Dam	TNTC	TNTC	TNTC	TNTC	68	05
Diversion Box	TNTC	TNTC	TNTC	TNTC	11	03
O. Reservoir	17	06	TNTC	TNTC	TNTC	02
	Salmonella **(cfu/ml)**		***Salmonella*** **(cfu/ml)**		***Salmonella*** **(cfu/ml)**	
Dam	09	02	TNTC	TNTC	TNTC	01
Diversion Box	TNTC	07	TNTC	TNTC	TNTC	02
O. Reservoir	05	04	TNTC	TNTC	TNTC	02
	S aureus **(cfu/ml)**		***S aureus*** **(cfu/ml)**		***S aureus*** **(cfu/ml)**	
Dam	03	-	01	-	-	-
Diversion Box	05	01	-	-	-	-
O. Reservoir	03	-	01	-	TNTC	02

TNTC: Too Numerous To Countcfu/ml: coliforms formed per ml.
-: No viable colony formed

The dissolved oxygen in irrigation water ranged from (5.5-9.6) g/l with a mean value of 7.55 g/l. Low dissolved oxygen levels were noted in dam samples with the highest value being recorded in canal 1 sample during the third session.

Pathogenic isolates

The pathogens isolated from the irrigation water were *Eschericheria coli, Shigella spp, Salmonella spp*and *Staphylococcus aureas.* The *E. coli* O157 trend was notably high as observed in the results from the dam, diversion box and overnight reservoir. A marked decrease in the trend of *E coli* O157 concentrations was noted during the third session (Table 1). *Shigella spp* had a relatively low concentration during the first session except in for the dam samples, where a constant concentration (TNTC) was observed during first and second sessions.

was observed during the second session only to fall back to low concentrations during the third session under streak plate method (Table 1). *S. aureus*exhibited the least contamination level throughout the three sessions. Overally the *S aureus* concentrations ranged from 0-5cfu/ml with the exception of overnight reservoir sample which had TNTC cfu/ml (Table 2).

Pathogenic contamination in vegetables

All vegetables were contaminated with *E coli* O157, *Shigella spp, Salmonella spp* and *S. aureus* (Table 3).

Contamination in different irrigation methods

Pathogenic contamination on sprinkler and drip irrigated tomatoshowed that vegetables produced under drip irrigation had the least contamination compared those produced under sprinkler irrigation (Table 4).

Table 3. Vegetable Culture Results

	Session 1		Session 2		Session 3	
	E. coli (cfu/ml)		*E. coli* (cfu/ml)		*E. coli* (cfu/ml)	
Method	Spread	Streak	Spread	Streak	Spread	Streak
Cabbage	TNTC	TNTC	TNTC	06	01	01
Lettuce	TNTC	TNTC	TNTC	30	*	*
	Shigella (cfu/ml)		*Shigella* (cfu/ml)		*Shigella* (cfu/ml)	
Cabbage	TNTC	-	TNTC	TNTC	-	-
Lettuce	TNTC	03	TNTC	TNTC	*	*
	Salmonella (cfu/ml)		*Salmonella* (cfu/ml)		*Salmonella* (cfu/ml)	
Cabbage	04	-	-	06	03	-
Lettuce	TNTC	26	-	-	*	*
	S. aureus (cfu/ml)		*S. aureus* (cfu/ml)		*S. aureus* (cfu/ml)	
Cabbage	-	-	-	-	07	03
Lettuce	-	-	-	-	*	*

TNTC: Too Numerous To Countcfu/ml-: No colony forming units were observed
*: No sample was obtained

Table 3. Contaminationtrend in drip and sprinkler irrigated tomato

	Session 1		Session 2		Session 3	
Method	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip
E.coli O157	33	21	27	13	*	*
Shigella	20	19	25	11	*	*
Salmonella	11	07	09	-	*	*
S aureus	05	02	-	-	*	*

-: No colony forming units were observed
*: No sample was obtained

The diversion box had *Shigella spp* concentrations of TNTC (cfu/ml) during the first and second session but the concentrations decreased to as 11cfu/ml duringthe third session. Low concentrations of *Shigella* colonies were observed during the first session, however a huge rise to TNTC was observed during the second and third session (Table 2). During the first session the dam, diversion box and overnight reservoir samples exhibited low concentrations of *Salmonella spp*. However, a sharp increase to TNTC cfu/ml

DISCUSSION

The study showed that salad crops: tomato, lettuce, cucumber, carrots, onions, green pepper, cabbage and beetroot were grown and supplied to various markets in the city of Bulawayo and the province. These were produced mostly under sprinkler irrigation and showed higher levels of microbial contamination than the drip irrigated ones. This level of contamination can be attributed to physical contact between the edible part of the vegetables and the irrigation water. However, the lack of direct contact between the tomato fruit and the irrigation water in drip irrigation could attribute the low level microbial contamination of the tomato. This is in concurrence with work by Keraita (2012) that revealed that reduced contact between edible parts of the vegetables and irrigation water reduces incidences of contamination. A low level of contamination was noted on the tomato produced under drip irrigation against that which was produced under sprinkler irrigation. However, according to the survey results, 90% of the farmers at Umguza Irrigation Lots use sprinkler irrigation method thus increasing the rate of contamination of their produce by pathogens.The study revealed that the level of contamination is indeed reduced with the subsequent reduction in public health risk. The study revealed that the irrigation water and vegetables were contaminated with pathogenic bacteria. FAO (1988) stated that pathogens ranging from viruses, bacteria, protozoa and helminths may be present in raw or undertreated municipal wastewater and the study is in agreement with FAO's work as bacterial pathogens were isolated from samples of irrigation water used at Umguza Irrigation Lots.

The study established that generally, the dam and overnight reservoir samples had the least number of pathogen isolated as opposed to diversion box samples. According to Keraita (2012), most disease causing microorganisms attach to silt and other particles and will eventually settle to the bottom. Since the canals are lined with concrete and narrow enough to allow a high flow rate, this prevents settling of sediments at the bottom as compared to the dam and overnight reservoir. The WHO standards for total and feacal coliforms are 1 to 10/100 ml and 0/100 ml, respectively (WHO, 2005). The results in Table 1 and 2 revealed that all the water samples had very high counts of total and faecal coliforms which could be attributed sewer spillage or undertreatment because coliforms are of intestinal origin. Therefore a potential health risk exists due to their presence in water and the result is in agreement with Poonkothai and Parvatham (2005) in India that revealed the presence of bacteria at high concentration in automobile wastewater. The pH of natural water can provide important information about many chemical and biological processes. It is typically monitored for assessments of aquatic ecosystem health, recreational waters, irrigation sources and discharges, livestock, drinking water sources, industrial discharges, and storm water runoff. The observed mean pH value from this study was 8.9. These values are higher than the maximum permissible limit of 6.5 to 8.5 set aside by WHO (2005). The values are favourable to growth of microorganisms which could have contributed to high total

Conclusion

Farmers practised unrestricted irrigation producing salad crops using water contaminated with pathogenic microorganisms, particularly *E coli* O157, *Shigella spp, Salmonella spp* and *S. aureus* from Lower Umguza Dam.There was a notable decrease in contamination with pathogenic microorganisms on crops produced under drip irrigation whencompared to sprinkler produced tomatoes.The groups with the highest risk of contracting pathogenic microorganisms are the workers and consumers of these salad crops considering the raw state in which they are oftenconsumed.

Recommendations

Research is needed into water treatment that will make the wastewater meet the WHO guidelines,economic viability analysis of using drip irrigation since it eliminates contact between the edible parts of vegetables and irrigation water thus effectively breaking the pathogen–human pathway and how the Public Health Regulations of 1972 can be enforced.There is also need to increased public awareness by relevant authorities highlighting possible pathogenic contamination of vegetable from this region and suggesting use of household disinfectantsprior to preparation and consumption of such products as sandwiches and vegetable salads.

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