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Water Quality Considerations in Rainwater Harvesting Case Study of Heavy Metal Contamination in Kampala City

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Abstract— *Past studies have established a link between industrialization and heavy metal contamination of rainwater. However, no such study has been done in Kampala, or elsewhere in Uganda. In view of industrialization and the proliferation of iron roofs, this study aimed at addressing the suitability of rainwater harvesting and its quality as an alternative source of drinking water supply. The specific objectives were; to identify the predominant roof-covering materials in use in Kampala; to determine the level of heavy metal contamination obtained from each of these roof materials; and to compare the quality of water obtained, with various accepted standards for drinking water. The roof coverings considered were clay tiles, plain Galvanized Corrugated Iron (GCI) sheets and painted GCI sheets. In each of these types, they were further classified as relatively new, medium age and the relatively older. Samples were collected from each of the five divisions, including a control sample that was intercepted directly from open space. In the laboratory, heavy metal tests were performed on these samples, using a Flame Atomic Absorption Spectrophotometer. The metals tested were Cadmium, Copper, Lead, Zinc and Nickel.*
***Keywords*— Rainwater, Kampala City, Heavy Metal**

I. INTRODUCTION

The Development Technology Unit (DTU) [2] appreciates the fact that much research work has been done in the world on domestic Rainwater Harvesting (RWH). They, however, contend that there is a lot more to be researched in humid tropics, especially in regard to health concerns associated with domestic RWH; storage capacity versus cost; and implementing domestic RWH in the sphere of integrated water resource management. In order to change the attitude by which RWH is treated as "second class" water supply source, a wide-sweeping awareness and sensitization campaign targeting users, promoters and planners is necessary. If widely practiced in urban areas, RWH helps reduce runoff, hence less flooding and ultimately saving on cost of extending storm water drainage infrastructure [5].

According to [3], wastewater released by some Ugandan industries into agricultural land has heavy metal content above internationally accepted concentration levels, thus posing a health risk to consumers. Soil was sampled from thirty-five sites with a history of waste disposal and was subsequently tested for Cadmium, Copper, Lead, Zinc and Nickel contents using a Flame Atomic Absorption Spectrophotometer.

Consequently, analytical results showed that vegetables sampled from the industrial area have higher concentrations of zinc, lead and copper than those grown at sites irrigated by municipal wastewater and solid waste from dumping sites. The high heavy metal content in these vegetables was attributed to multiple exposure routes (contaminated soil, soil splash onto leafy vegetables, absorption from aerial emissions, and direct contact with effluents during the rainy season). This view has given this study the impetus to further pursue the possibility that heavy metal-laden aerial emissions remain in the atmosphere for long enough to mix with the rain-causing clouds, and thus contaminate the rain.

The comparison of RWH to other technologies that provide the same level of service can be properly appreciated when approached in a wider context in which in addition to cost considerations, encompasses other concerns that may include social, economic technical and environmental aspects. RWH systems provide appropriate and economically attractive technologies in regard to operation and maintenance requirements, horizon of service and environmental concerns. The technology has very minimal environmental impact and is predicated on the use of a renewable resource, unlike other sources, which are subject to depletion and increased pollution. As such, RWH is commensurate development in the new world order [5].

Further, the piped water from the Ggaba Water Treatment Plant might not in the future be feasible due to either the

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chemical content, or its prohibitive costs of treatment, should the Nakivubo wetland's deterioration continue unabated [6]

Kampala is known to receive at least 1000 mm of rainfall a year which makes RWH a viable alternative to provide drinking water, in addition to other domestic requirements.

II. METHODOLOGY

2.1 Geographical Area

The study confined itself to areas in Kampala City. Each of the administrative divisions in Kampala, which are, Kawempe, Makindye, Nakawa, Rubaga and Central, were represented in the study. The main reasons for the choice of this geographical area were the budgetary and time constraints, as well as keeping the study relevant.

2.2 Sampling Population and Strategies

The population of the study included the three predominant different types of roof coverings in use in Kampala. Hence, the study essentially confined itself to clay tiles; plain galvanized corrugated iron sheets and painted galvanized corrugated iron sheets. In each of these types, there was a further sub-classification of the relatively new, medium age and the relatively older. Samples were collected from each of the five divisions, including a control sample that was intercepted directly from open space, from each division. There were therefore fifty rainwater samples in all for the study. The random sampling strategy was engaged to pick the sampling sites. Maps of each Kampala administrative division were obtained, where each parish was clearly marked out. Each parish was assigned a number, and the ten sites for sample collection were randomly picked from a set of random numbers. This was done for each of the five divisions. Each of the fifty rainwater samples was tested for five heavy metals.

2.3 Data Collection

The samples of rainwater were collected in appropriately coded plastic anaesthised sampling bottles. The codes for each sample were formulated in the following manner: The code for each sample contained three digits. The first digit of the code would give the administrative division where the sample was collected. The second digit would give the roof covering material. It would also denote the control sample if labeled appropriately. The third digit would denote the age of the roof. For example, "KX1" refers to Kawempe New Clay Tile roof. The coding scheme was as shown in Table 1, below:

Table.1: Coding Scheme for Data Collection

Location	***Material***	***Age***
Kawempe – K	Clay Tiles – C	New (1-2 yrs) – 1
Central – C	Plain GCI Sheets – Y	Medium Age (2-10 yrs) – 2
Nakawa – N	Painted GCI Sheets – Z	Old (>10 yrs)
Rubaga - R	Control - O	

For each sample, a Sample Collection Form (Appendix 3) was completed and thereafter taken to the laboratory for analysis of the various heavy metal concentrations. Thereafter, comparison with various guideline values was done, and appropriate conclusions drawn. The following procedures were generally followed for sampling:

1. The sampling bottle was ensured clean and with nothing inside except the water to be sampled to come into contact with the inside or cap of the bottle.
2. The rainwater was allowed to run for an ample period of time, approximately 2-3 minutes, to ensure a simulation of standard domestic rainwater collection principle, that the debris from the roof have been washed off before collecting the water. Care was taken to ensure that the water does not make contact with any object before running into the bottle. This entailed holding the bottle just below the eave, and trapping the water between the eave and the ground.
3. For the control sample, it involved situating a bottle with a funnel approximately 1 metre above the ground, to prevent the splashed raindrops from getting into the bottle. Each sample was immediately preserved by acidifying with concentrated nitric acid to a pH less than 2.
4. The sample was then capped immediately to preserve volatile compounds in the water and prevent atmospheric contamination. Samples were then refrigerated to await analysis.

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Fig.1: KX3

Fig.2: RZ3

2.4 Data Quality Control, Analysis and Interpretation

As a first measure, the research assistants were educated on the research aims in general, and specifically on the need to obtain unadulterated samples. They were trained on the correct procedures to follow during collection, preservation and storage of samples.

All the plastic bottles used for collection of the samples were sterilized using the following procedure. They were first cleaned with a laboratory detergent and rinsed with tap water. Next, the container was rinsed in 1:1 hydrochloric acid solution. The container was then rinsed with de-ionized water three times and allowed to air dry.

At the lab, suitable tests were carried out using a Flame Atomic Absorption Spectrophotometer and the results represented in Test Result Sheets (Appendix 3). During the analysis, the treated water samples were directly aspirated on the Flame Atomic Absorption Spectrophotometer.

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Matrix interference was eliminated by standard addition, that is, they were also acidified by addition of nitric acid to a pH of less than 2. Two different models of the Spectrophotometer were used; Perkin-Elmer 2380 model at the Geology Department, Makerere University; and Shimadzu 6200 model at the Government Chemist & Analytical Laboratory, Wandegeya.

The detection limits on the Perkin-Elmer 2380 model were higher than the WHO limits; hence it was necessary to use the Shimadzu 6200 model, due to its higher sensitivity.

Fig.3: Flame Atomic Absorption Spectrophotometer

The Perkin-Elmer 2380 model at the Geology Department, Makerere University.

The detection limits, wavelengths and slit width used for the various elements by the Perkin-Elmer 2380 model were:

Table.2: Settings for Perkin-Elmer 2380 model

	Zinc	Copper	Nickel	Cadmium	Lead
Detection Limit (mg/L)	0.01	0.01	0.1	0.01	0.1
Wavelength, λ, (nm)	213.9	324.8	352.5	228.8	217.0
Slit width (nm)	0.7	0.2	0.2	0.7	0.7

The wavelengths and detection limits used for Lead, Cadmium and Nickel by the Shimadzu 6200 model were:

Table.3: Settings for Shimadzu 6200 model

	Lead	Cadmium	Nickel
Detection Limits (mg/L)	0.001	0.001	0.001
Wavelength, λ, (nm)	283.3	228.8	232.0

2.5 Presentation of Results

The WHO Drinking Water Guideline values; the Draft UNBS Standard (1999) for Bottled/Packaged Waters Other Than Natural Mineral Waters; and NEMA Standards for the Discharge of Effluent into Water or on Land are also indicated for each metal, for comparison, as shown in Table 4 [1]; [7];[8].

Fig.4: Heavy Metal Tests Being Run Using Perkin-Elmer 2380 model

Table.4: Water Quality Guidelines Used

	Zn (mg/l)	Cu (mg/l)	Ni (mg/l)	Cd (mg/l)	Pb (mg/l)
WHO limits	3.0	2.0	0.02	0.003	0.01
Draft UNBS Standard	0.5	1.0	0.02	0.003	0.05
NEMA Limits	5.0	1.0	1.0	0.1	0.1

The results of the analysis of the samples were presented in result sheets, as seen in Appendix 4. However, they have been simplified as follows;

Table.5: Kawempe Division Results

Sample Code	Zn (mg/l)	Cu (mg/l)	Ni (mg/l)	Cd (mg/l)	Pb (mg/l)
KX1	0.03	< 0.01	< 0.001	< 0.001	< 0.001
KX2	0.10	0.02	< 0.001	< 0.001	< 0.001
KX3	0.77	< 0.01	< 0.001	< 0.001	< 0.001
KY1	0.12	< 0.01	< 0.001	< 0.001	< 0.001
KY2	1.59	0.01	< 0.001	< 0.001	< 0.001
KY3	0.24	< 0.01	< 0.001	< 0.001	< 0.001
KZ1	0.01	< 0.01	< 0.001	< 0.001	< 0.001
KZ2	0.04	< 0.01	< 0.001	< 0.001	< 0.001
KZ3	0.24	0.01	< 0.001	< 0.001	< 0.001
KO	0.10	0.01	< 0.001	< 0.001	< 0.001

Where Cd – Cadmium, Cu – Copper, Pb – Lead, Zn – Zinc, Ni – Nickel, mg/l – milligrams per litre, or parts per million

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Table.6: Central Division Results

Sample Code	Zn (mg/l)	Cu (mg/l)	Ni (mg/l)	Cd (mg/l)	Pb (mg/l)
CX1	0.22	0.02	< 0.001	< 0.001	< 0.001
CX2	0.02	0.01	< 0.001	< 0.001	< 0.001
CX3	0.26	< 0.01	< 0.001	< 0.001	< 0.001
CY1	< 0.01	< 0.01	< 0.001	< 0.001	< 0.001
CY2	1.06	0.02	< 0.001	< 0.001	< 0.001
CY3	0.02	0.01	< 0.001	< 0.001	< 0.001
CZ1	1.55	0.01	< 0.001	< 0.001	< 0.001
CZ2	< 0.01	< 0.01	< 0.001	< 0.001	< 0.001
CZ3	1.56	0.01	< 0.001	< 0.001	< 0.001
CO	< 0.01	0.01	< 0.001	< 0.001	< 0.001

Table.7: Rubaga Division Results

Sample Code	Zn (mg/l)	Cu (mg/l)	Ni (mg/l)	Cd (mg/l)	Pb (mg/l)
RX1	0.61	0.01	< 0.001	< 0.001	< 0.001
RX2	0.02	0.01	< 0.001	< 0.001	< 0.001
RX3	0.01	0.01	< 0.001	< 0.001	< 0.001
RY1	1.01	0.02	< 0.001	< 0.001	< 0.001
RY2	0.40	0.01	< 0.001	< 0.001	< 0.001
RY3	0.43	< 0.01	< 0.001	< 0.001	< 0.001
RZ1	0.42	0.01	< 0.001	< 0.001	< 0.001
RZ2	0.13	0.02	< 0.001	< 0.001	< 0.001
RZ3	0.42	< 0.01	< 0.001	< 0.001	< 0.001
RO	0.98	< 0.01	< 0.001	< 0.001	< 0.001

Table.8: Nakawa Division Results

Sample Code	Zn (mg/l)	Cu (mg/l)	Ni (mg/l)	Cd (mg/l)	Pb (mg/l)
NX1	0.69	< 0.01	< 0.001	< 0.001	< 0.001
NX2	0.05	< 0.01	< 0.001	< 0.001	< 0.001
NX3	0.72	0.01	< 0.001	< 0.001	< 0.001
NY1	0.02	< 0.01	< 0.001	< 0.001	< 0.001
NY2	0.01	< 0.01	< 0.001	< 0.001	< 0.001
NY3	0.10	0.02	< 0.001	< 0.001	< 0.001
NZ1	0.01	0.02	< 0.001	< 0.001	< 0.001
NZ2	0.01	< 0.01	< 0.001	< 0.001	< 0.001
NZ3	6.77	0.02	< 0.001	< 0.001	< 0.001
NO	1.47	< 0.01	< 0.001	< 0.001	< 0.001

Table.9: Makindye Division Results

Sample Code	Zn (mg/l)	Cu (mg/l)	Ni (mg/l)	Cd (mg/l)	Pb (mg/l)
MX1	1.21	< 0.01	< 0.001	< 0.001	< 0.001
MX2	< 0.01	0.01	< 0.001	< 0.001	< 0.001
MX3	0.01	< 0.01	< 0.001	< 0.001	< 0.001
MY1	0.15	0.01	< 0.001	< 0.001	< 0.001
MY2	0.31	0.01	< 0.001	< 0.001	< 0.001
MY3	0.36	0.01	< 0.001	< 0.001	< 0.001
MZ1	0.15	0.01	< 0.001	< 0.001	< 0.001

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Sample Code	Zn (mg/l)	Cu (mg/l)	Ni (mg/l)	Cd (mg/l)	Pb (mg/l)
MZ2	0.13	< 0.01	< 0.001	< 0.001	< 0.001
MZ3	0.75	< 0.01	< 0.001	< 0.001	< 0.001
MO	0.02	< 0.01	< 0.001	< 0.001	< 0.001

III. ANALYSIS, INTERPRETATION AND DISCUSSION OF RESULTS

3.1 General Descriptions

From the test result sheets, some general determinations were made, regarding the presence of some of the heavy metals in a particular division. These have been arranged for the individual heavy metals.

3.1.1 Lead

Lead detection limit was 0.001 mg/L. Lead concentrations in all the samples obtained from the study were in such small quantities that they were not detected. The lead concentration in the samples thus appears to be more than ten times lower than the WHO drinking water guideline value, and more than one hundred times lower than the NEMA Effluent Discharge Standards. The Lead level is still safe enough compared to the Draft UNBS Standard.

3.1.2 Cadmium

The detection limit for Cadmium was 0.001 mg/L. As with Lead above, Cadmium was not detected in any of the samples in the study. This implies that the Cadmium concentration in the water is less than 0.001 mg/L. Cadmium concentration thus is at least three times lower than the WHO guideline value and Draft UNBS Standard, and one hundred times lower than the NEMA Effluent Discharge standards.

3.1.3 Nickel

The Nickel detection limit was 0.001 mg/L. In no instance was Nickel detected, implying that any Nickel present was in levels less than 0.001 mg/L. Nickel concentration is therefore at least twenty times lower than the WHO guideline value and Draft UNBS Standard, and one thousand times lower than the NEMA Effluent Discharge standards.

3.1.4 Copper

The detection limit for Copper was 0.01 mg/L. In Kawempe division, Copper was detected in the medium age clay tile roof sample; medium age plain GCI sheet roof sample; old painted GCI sheet roof sample and in the control sample. In Central division, Copper was detected in every sample, except the old clay tile roof sample; the new plain GCI sheet roof sample and the medium age painted GCI sheet roof sample. In Rubaga division, Copper was also detected in every sample, except the old plain GCI sheet roof sample; the old painted GCI sheet roof sample and the control sample. In Nakawa division, Copper was detected the old clay tile roof sample; the old plain GCI sheet roof sample; and the new and old painted GCI sheet roof samples.

In Makindye division, Copper was detected in the medium age clay tile roof sample; all the plain GCI sheet roof samples, and the new painted GCI sheet roof sample. However, even the highest contamination level obtained, of 0.02 mg/L, was still one hundred timed lower than the WHO guideline value, and fifty times lower than the NEMA Effluent Discharge standards and Draft UNBS Standard.

3.1.5 Zinc

The detection limit was 0.01 mg/L. In Kawempe, Rubaga and Nakawa divisions, Zinc was detected in all the samples. In Central division, no zinc was detected in the new plain GCI sheet roof sample; medium age painted GCI sheet roof sample, and the control sample. In Makindye division, Zinc was not detected in the medium age clay tile roof sample. Zinc was detected in much higher concentrations than the other heavy metals. There was one case that more than doubled the WHO guideline value. Only 36 cases had Zinc levels lower than the Draft UNBS Standard. Hence, Zinc represents a real challenge to the drinking water quality; in as far as heavy metal contamination is concerned.

3.2 Overall Distribution of Contaminants

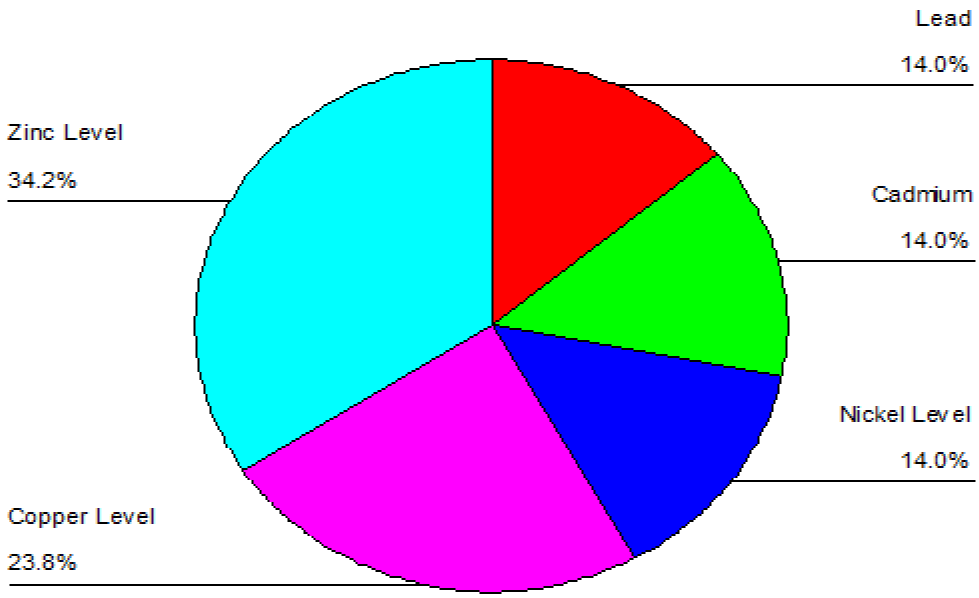

Fig.5: Overall Distribution of Heavy Metals

Overall, Zinc was the overwhelming contaminant with 34.2% of the distribution chart, as can be seen from the figure above. Copper was second likely to detect, while Lead, Cadmium and Nickel had equal chances of occurrence, at 14% chance each.
All Lead, Cadmium and Nickel values were in the range “less than 0.001 mg/L”. The frequency distribution for Copper and is as shown in Tables 10 and 11;

Table.10: Copper Overall Frequency Distribution

	Frequency	Percent	Cumulative Percent
less than 0.01	23	46.0	46.0
0.01	19	38.0	84.0
0.02	8	16.0	100.0
Total	50	100.0	

46% of the total number of samples had Copper values of less than 0.01 mg/L; 38% of the total number had values of 0.01 mg/L; whereas the remaining 16% had values of 0.02 mg/L. Therefore, most of the samples had Copper concentration of less than 0.01 mg/L. It is also clear that 84% of the samples had a concentration of 0.01 mg/L, or less.

Table.11: Zinc Overall Frequency Distribution

	Frequency	Percent	Cumulative Percent
less than 0.01	4	8.0	8.0
0.01 to 0.49	32	64.0	72.0
0.50 to 0.99	6	12.0	84.0
1.00 to 1.49	4	8.0	92.0
Over 1.50	4	8.0	100.0
Total	50	100.0	

Here, 64% of the total number of samples had Zinc concentration of between 0.01to 0.49 mg/L; 12% have a concentration of between 0.50 to 0.99 mg/L; and with 8% each, are those with concentrations of less than 0.01 mg/L; 1.00 to 1.49 mg/L; and over 1.5 mg/L. It is thus safe to conclude that the majority of samples have Zinc concentrations of between 0.01 to 0.49 mg/L.

3.3 Interpretation & Discussion on Contamination

Various analyses for each of the heavy metal contamination were made. From the analyses, inferences were made from

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the results. For Lead, Cadmium and Nickel, all samples returned values of less than 0.001 mg/l, that is, below the detection limit of the spectrophotometer. Therefore, no further interpretation was deemed necessary.

Copper Contamination

On the vertical axes on Figures 8, 9 and 10, '1.0' represents 'less than 0.01 mg/l'; '2.0' represents 0.01 mg/l; '3.0' represents 0.02 mg/l, as used to input the raw data into the SPSS statistical program.

Copper Contamination Vs. Roof Type by Location

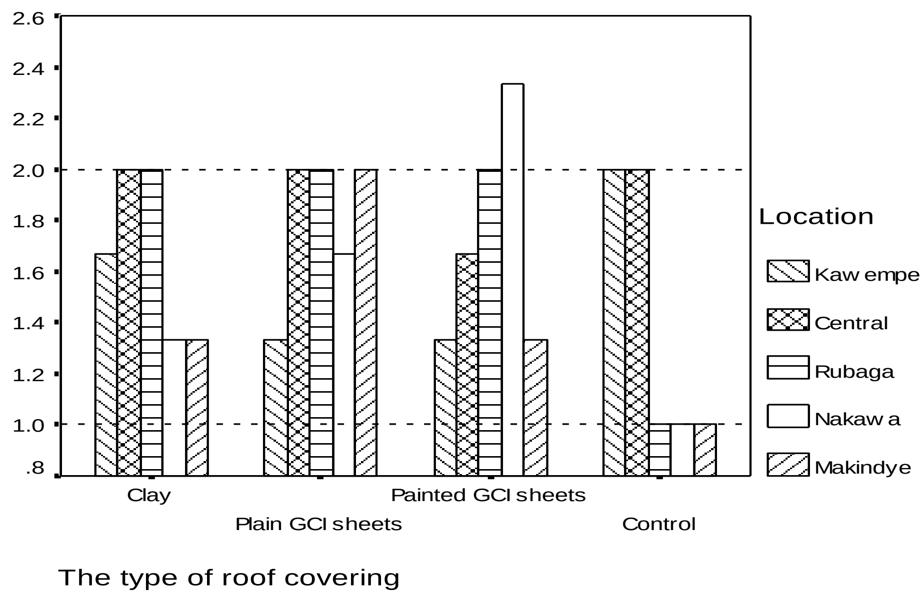

Fig.6: Mean Copper Level against Roof Type by Location

From the Figure 8 above, mean Copper levels here showed a slightly different variation, as compared to previous heavy metals. The control samples from Rubaga, Nakawa and Makindye divisions showed a uniform mean level of less than 0.01 mg/L; while the control samples from Kawempe and Central divisions gave mean Copper levels of 0.01 mg/L. For the painted GCI sheet roof samples, none of them gave a mean level of less than 0.01 mg/L; only Nakawa division had a mean level of more than 0.01 mg/L. None of the samples from plain GCI sheet roofs gave a mean Copper level of less than 0.01 mg/L; Central, Rubaga, Nakawa and Makindye samples all having concentrations of 0.01 mg/L. All of the clay tile roof samples had means of 0.01 mg/L.

Copper Contamination Vs. Roof Age by Location

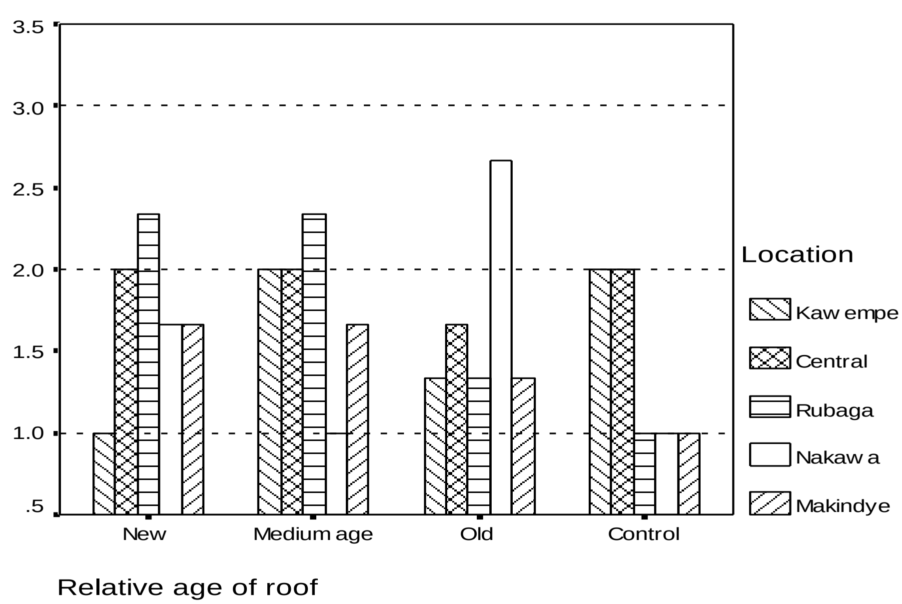

Fig.7: Mean Copper Level against Roof Age by Location

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For old roofs, there was no sample with a mean less than 0.01 mg/L. They all lay generally at 0.01 mg/L, except Nakawa division, where the mean was around 0.02 mg/L. For the medium age roofs, only Nakawa division had a mean of less than 0.01 mg/L; while the Kawempe, Central and Makindye divisions had means of 0.01 mg/L, with Kawempe and Central divisions having uniform concentrations for all roof types. Rubaga division had a mean of 0.02 mg/L. For new roofs, Kawempe division had the lowest mean of less than 0.01 mg/L. Rubaga division had the highest mean of 0.02 mg/L; while the rest had 0.01 mg/L.

Copper Contamination Vs. Roof Age by Roof Type

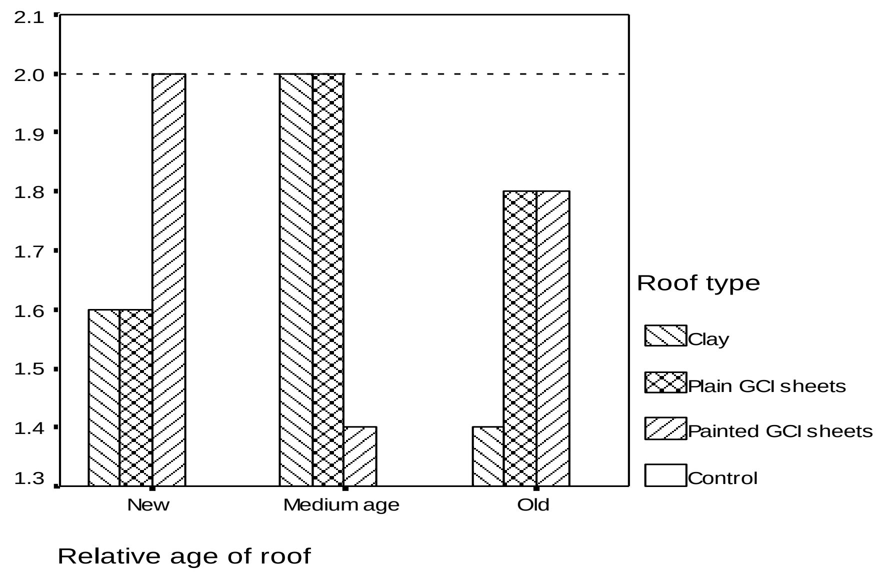

Fig.8: Mean Copper Level against Roof Age by Roof Type

The mean copper levels, based on the relative age of the roof, were all at 0.01 mg/L. Among the new roofs, painted GCI sheet roofs had a uniform copper concentration, while for medium age roofs, clay tiled and plain GCI sheet roofs had uniform copper concentrations.

Zinc Contamination

During the analysis of Zinc, the data was grouped. Therefore, on the vertical axes on Figures 11, 12 and 13, the bar graphs on Zinc contamination, '1.0' represents 'less than 0.01 mg/l'; '2.0' represents '0.01 to 0.49 mg/l'; '3.0' represents '0.50 to 0.99 mg/l', and '4.0' represents the group '1.00 to 1.49 mg/l', as used to input the raw data into the SPSS statistical program.

Zinc Contamination Vs. Roof Type by Location

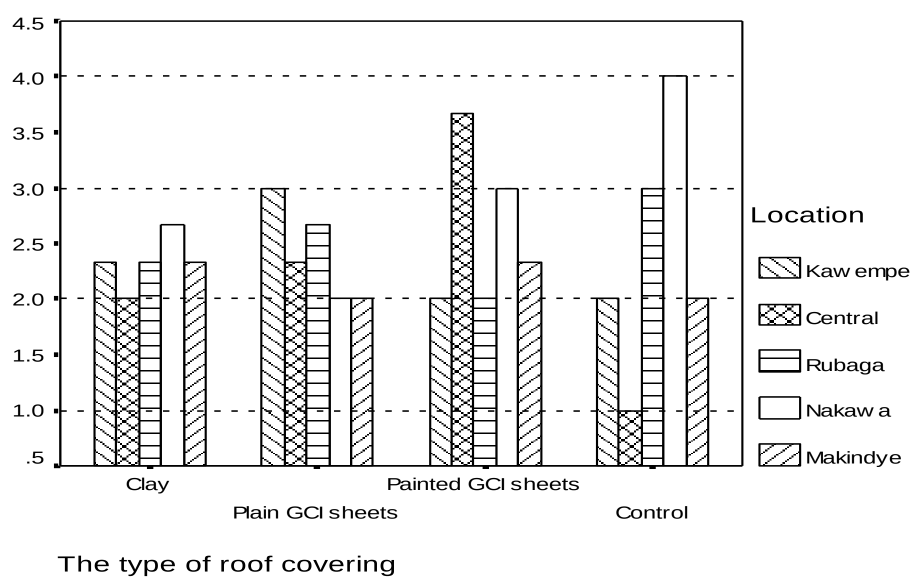

Fig.9: Mean Zinc Level against Roof Type by Location

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Central division control samples showed a uniform mean level of less than 0.01 mg/L; Kawempe and Makindye divisions exhibited a uniform mean level of 0.01 to 0.49 mg/L; Rubaga division showed a uniform mean level of 0.50 to 0.99 mg/L; and Nakawa division had the highest mean, at 1.00 to 1.49 mg/L. There was a mean level of 0.01 to 0.49 mg/L for Kawempe and Rubaga painted iron sheets; while in Nakawa and Makindye divisions the mean was 0.50 to 0.99 mg/L. Central division painted iron sheets had the highest mean of 1.00 to 1.49 mg/L. Makindye plain iron sheets had a mean of 0.01 to 0.49 mg/L, while the rest had means of 0.50 to 0.99 mg/L. Central division clay tiles had a mean of 0.01 to 0.49 mg/L, while the rest had means of 0.50 to 0.99 mg/L.

Zinc Contamination Vs. Roof Age by Location

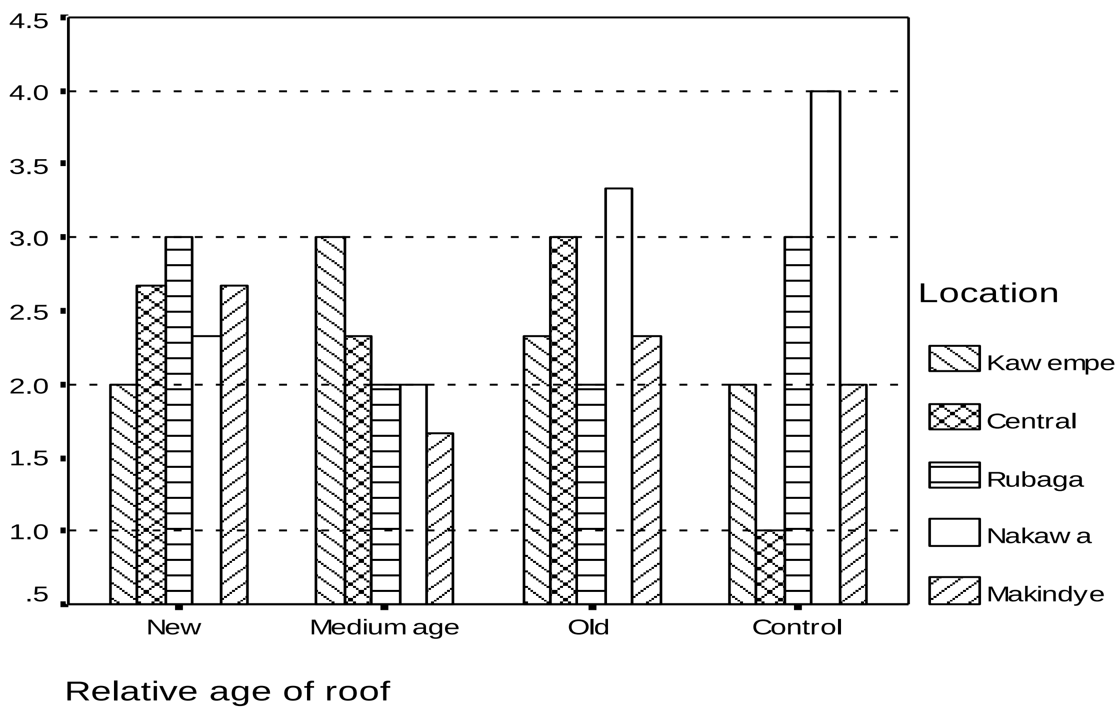

Fig.10: Mean Zinc Level against Roof Age by Location

For the old roofs, Rubaga division had a mean level of 0.01 to 0.49 mg/L; Kawempe, Central and Makindye had a mean of 0.50 to 0.99 mg/L; while in Nakawa had a mean of 1.00 to 1.49 mg/L. For medium age roofs, Rubaga, Nakawa and Makindye had a mean level of 0.01 to 0.49 mg/L; while Kawempe and Central had a mean of 0.50 to 0.99 mg/L. For new roofs, Kawempe had a mean level of 0.01 to 0.49 mg/L; while the rest had a mean of 0.50 to 0.99 mg/L.

Zinc Contamination Vs. Roof Age by Roof Type

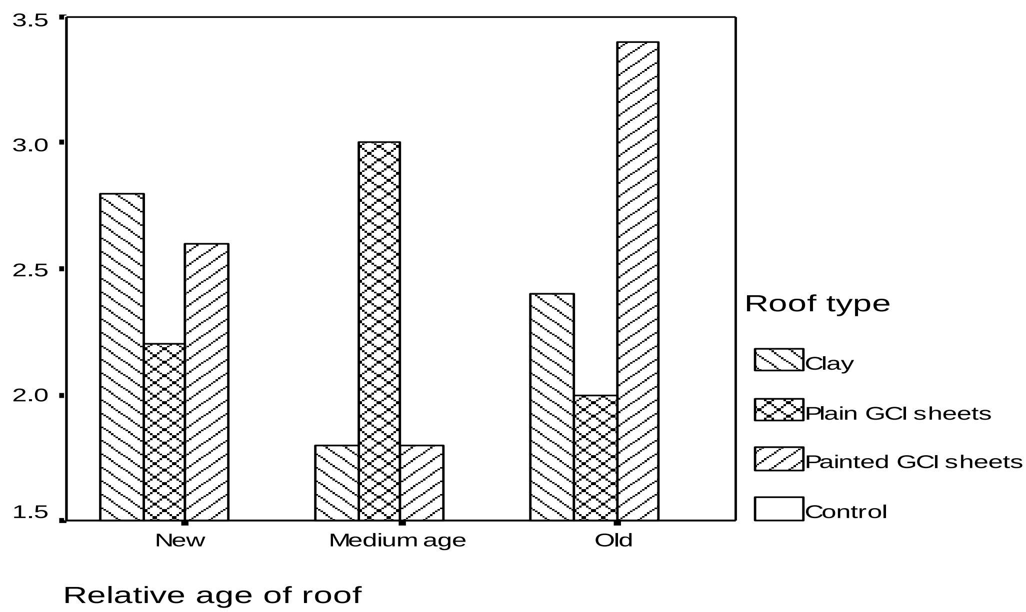

Fig.11: Mean Zinc Level against Roof Age by Roof Type

For new roofs, the mean level was 0.50 to 0.99 mg/L. For medium age roofs, clay and painted GCI sheet roofs had mean levels of 0.01 to 0.49 mg/L, while plain GCI sheets had a mean of 0.50 to 0.99 mg/L. For old roofs, plain GCI sheet roofs had a mean of 0.01 to 0.49 mg/L; clay tile roofs had a mean level of 0.50 to 0.99 mg/L; while painted GCI sheet roofs had a mean of 1.00 to 1.49 mg/L.

Discussion of Means

These tests were not many enough to justify the use of statistical tests of significance. Therefore, judgment and deductions have been majorly used in this analysis.

Table.12: Comparison of Statistics

		Lead Level	Cadmium Level	Nickel Level	Copper Level	Zinc Level
N	Valid	50	50	50	50	50
	Missing	50	50	50	50	50
Mean		1.00	1.00	1.00	1.70	2.44
Median		1.00	1.00	1.00	2.00	2.00
Mode		1	1	1	1	2
Std. Deviation		.00	.00	.00	.74	1.03
Minimum		1	1	1	1	1
Maximum		1	1	1	3	5

The mean levels of the heavy metals Lead, Nickel and Cadmium did not really need any further analysis since the levels in all the samples were identical; hence the mean, mode, median, minimum and maximum values were the same and standard deviation, zero.

However, Copper and Zinc had varying values. Zinc had a higher mean than Copper. The median Copper level is 0.01 mg/L, while the median Zinc level is in the group, ‘0.01 to 0.49 mg/L’. The modal Copper level is less than 0.01 mg/L, while the modal Zinc level is still in the ‘0.01 to 0.49 mg/L’ group. This is quite clear from Tables 10 and 11. Zinc varies more from its mean than Copper. The mean heavy metal level values were also compared by location, roof type and roof age. The results are as shown in the Tables 13 – 18.

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3.4.1 Means by Location

Table.13: Mean Copper Levels by Location

Sampling Location	Mean	N	Std. Deviation	Median
Kawempe	1.50	10	0.71	1.00
Central	1.90	10	0.74	2.00
Rubaga	1.90	10	0.74	2.00
Nakawa	1.70	10	0.95	1.00
Makindye	1.50	10	0.53	1.50
Mean	1.70	10	0.74	2.00

The means in this case, cannot be fully interpreted, since this is grouped data, which is in discrete steps, 1, 2 and 3. It is only clear that Kawempe and Makindye have lower levels than the mean, while Central and Rubaga have higher levels than the mean. The median Copper level for Kampala was 0.01 mg/L. Again from this, it is evident that Central and Rubaga divisions have the higher media.

Table.14: Mean Zinc Levels by Location

Sampling Location	Mean	N	Std. Deviation	Median
Kawempe	2.40	10	0.97	2.00
Central	2.50	10	1.58	2.00
Rubaga	2.40	10	0.70	2.00
Nakawa	2.70	10	1.06	2.00
Makindye	2.20	10	0.79	2.00
Mean	2.44	10	1.03	2.00

Again, since this is grouped data represented in discrete steps, the means here, having decimals, cannot be fully interpreted. However, it can be seen that Nakawa division had the highest dispersion from the mean, while Rubaga, the least. The mean level in Makindye seems lower than the overall mean.

3.4.2 Means by Roof Type

Table.15: Mean Copper Levels by Roof Type

Type of roof covering	Mean	N	Std Deviation	Median
Clay	1.67	15	0.72	2.00
Plain GCI Sheets	1.80	15	0.77	2.00
Painted GCI Sheets	1.73	15	0.80	2.00
Control	1.40	5	0.55	1.00
Mean	1.70		0.74	2.00

Plain GCI sheet roofs had the highest dispersion from the mean, with clay tiles, the least. Plain GCI Sheets have the highest contamination mean levels. The fact that the control samples had the least levels, even lower than the overall mean, points to the deduction that Copper actually is on the roofs.

Table.16: Mean Zinc Levels by Roof Type

Type of roof covering	Mean	N	Std Deviation	Median
Clay	2.33	15	0.72	2.00
Plain GCI Sheets	2.40	15	1.06	2.00
Painted GCI Sheets	2.60	15	1.30	2.00
Control	2.40	5	1.14	2.00
Mean	2.44		1.03	2.00

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The means were highest among the heavy metals. Zinc also had the highest standard deviations among the metals tested. Painted GCI sheet roofs had the highest dispersion, and clay tiles, the least. Overall, it seems painted GCI Sheets have higher means than the rest.

3.4.3 by Roof Age

Table.17: Mean Copper Levels by Roof Age

Relative age of roof	Mean	N	Std. Deviation	Median
New	1.73	15	0.80	2.00
Medium Age	1.80	15	0.77	2.00
Old	1.67	15	0.72	2.00
Control	1.40	5	0.55	1.00
Mean	1.70		0.74	2.00

The values appear very close to each other. However, new roofs showed marginally higher deviations for the mean value. Among the roofs there is a uniform median at 0.01 mg/l. Due to the lower value returned by the control samples, there seems to be a case for a part played by age on the contamination levels.

Table.18: Mean Zinc Levels by Roof Age

Relative age of roof	Mean	N	Std. Deviation	Median
New	2.53	15	1.06	2.00
Medium Age	2.20	15	1.01	2.00
Old	2.60	15	1.06	2.00
Control	2.40	5	1.14	2.00
Mean	2.44		1.03	2.00

Zinc showed the highest dispersion of all the metals. However, it seems that Zinc is also found in the atmosphere, since control values are higher than the values from some of the roofs.

3.5 General Discussions

Generally, the presence of some heavy metals in the rain drops reaching the ground surface, as well as rainwater collected from roofs around Kampala City is not in doubt. Rather, the issue as remains the degree of contamination. The study has endeavored to ascertain this contamination level as best as possible, and present it in well understood terms. Overall, Zinc was found to be the most prevalent metal, with a probability of 34.2% of being detected. Copper was second, while the rest of the metals; Lead, Nickel and Cadmium, were detected with the same chance of occurrence.

The study did note a consistent pattern in Lead levels in that in all instances, the levels were less than 0.001 mg/L. This is much lower than that given by the WHO value of 0.01 mg/L. Thus there is no immediate danger of lead poisoning. From the NEMA guideline value for effluent discharge into water or land, and Draft UNBS Standard, the rainwater is also within the limits. However, the exact Lead concentration was not known, due to the detection limits of the spectrophotometer used. From these findings, it was not possible to infer any relationship between either age or location of a sampling location and Lead contamination therein.

Like Lead, Cadmium showed a consistent presence in levels of less than 0.001 mg/L. The WHO and Draft UNBS Standard guideline value of 0.003 mg/L is, however, a small quantity in itself. The seriousness of the consequence of this type of contamination can be seen from the small value of WHO and Uganda Standards level.

Therefore, in as far as ascertaining the drinking quality, with respect to Cadmium levels, there is no immediate danger of Cadmium poisoning. The NEMA standard for effluent discharge stands at 0.1 mg/L. Thus, the cadmium level in the rainwater is safe to discharge to the ground. Similarly to Lead, from these findings it is not possible to infer any relationship between either age or location of a sampling location and Cadmium contamination therein.

Nickel levels are generally also less than 0.001 mg/L. In comparison to the WHO and Draft UNBS Standard guideline value of 0.02 mg/L, the amount of Nickel in the rainwater need not cause any alarm. However, the exact level of Nickel was also not established due to the detection limits of the spectrophotometer. Also, it is within the NEMA effluent discharge guidelines. The same comment as above applies.

Copper was registered in varying levels in some of the control samples. This can be taken to mean that Copper is present to some degree in the atmosphere. Actually, it would seem that in the case of Kawempe division, the mean levels in the atmosphere were higher than from the roofs; while in Central division, the levels in the roofs were quite comparable to the levels in the atmosphere. However, this would seem random at best. In Rubaga and Makindye, a clear pattern of decrease in levels with age is discerned. Such a scenario is also almost replicated in Nakawa, but the levels shoot up in the old roofs. This observation, however, does not mean a general increase of copper levels with age. More samples would be needed for such a generalization.

These appear random observations, as they are no consistent in all the sampling sites, and yet no reasonable explanation is apparent. The observations of the different roof materials with age do also show any consistency, hence difficult to make generalizations. The WHO limit is 2 mg/L, whereas the Draft UNBS Standard guideline value is 1 mg/L. None of the samples gave a value of more than 0.02 mg/L. Thus, the maximum concentration recorded is only 1% of the WHO limit and 0.5% of the Draft UNBS Standard. With the discernible pattern of reduction of levels with age, then there is no danger currently of unsafe Copper contamination of rainwater in Kampala. The detected values are also way below the recommended NEMA level of 1 mg/L.

Most Zinc detected, being in the range of 0.01 to 0.49 mg/L, is below the WHO limit of 3 mg/L. The atmosphere around Kampala also seems to have some Zinc in it. In Nakawa and Rubaga divisions, there is more Zinc in the atmosphere than from the roofs. This may be attributed to the industries therein. There is still no clear discernible relationship between contamination and either location or roof age. The levels are generally so much lower than the NEMA guideline value of 5 mg/L. Since 14 cases (28% of the samples) reported levels of Zinc above the Draft UNBS Standard, then Zinc requires intervention. As mentioned earlier elsewhere in this report, unlike the other heavy metals which accumulate in the human body to achieve their lethal levels, Zinc does not accumulate; rather, it is fatal in lethal doses taken at once. Measures have to be taken to ensure that the Zinc does not reach these lethal contamination levels.

3.6 Significance of Output

This study sought to investigate the levels of heavy metal contamination of rainwater as collected from various roofs. Several drinking water quality standards were used in this. These findings will be very helpful in the establishment of a rainfall heavy metal contamination database for Kampala in particular, and Uganda in general. As of now, such a document does not exist. Policy makers can use these findings to issue appropriate guidelines and make fitting laws regarding the RWH for drinking purposes. All other stakeholders promoting RWH, especially NGOs, local women organizations, the church and individuals can make use of these findings to better their knowledge of heavy metal contamination in rainwater, and together with the recommendations issued hereafter, better the quality of this water, if it to be used for drinking purposes.

IV. CONCLUSION

Rain water, as it is, is largely safe for human consumption in as far as heavy metal contamination is concerned, when compared to the various national and international standards. If proper water quality control and efficient management structures like proper storage facilities and first flush diversion systems are in place, RWH can provide good quality water free from heavy metal contamination.

The various types of roof covering materials predominantly in use in Kampala were identified as clay tiles, plain and painted GCI sheets. Coated metal roofs and organic roofs are also in use, but to a small extent. Clay tile roofs and painted iron sheet roofs were observed to be in use on some commercial and office buildings, high and middle income households, and government and private institutions. Plain iron sheet roofs were also observed on commercial and office buildings to a small extent; some middle income and most low income households. On the low income households, they were generally characteristically well rusted.

The study has determined the quality suitability of the rainwater from these roofs, in terms of heavy metal contamination. For Lead, Cadmium and Nickel the levels were below 0.001 mg/L. 46% of Copper cases had a contamination level of less than 0.01 mg/L, whereas 38% of the cases were at a level of 0.01 mg/L, while the rest was at 0.02 mg/L. The modal Zinc level was 0.01 to 0.49 mg/L.

The quality of the rainwater in terms of heavy metal contamination was assessed with various accepted standards for drinking water. These were WHO Drinking Water Guidelines; NEMA Uganda Standards for Discharge of Effluent into Water or on Land; and the Uganda National Bureau of Standards Draft Standard for Bottled Waters Other than Natural Mineral Waters. It has been found that heavy metal contamination is largely minimal, except for Zinc, which is lower than WHO limits in 98% of the cases, but has surpassed the Draft UNBS Standard limits in 28% of the instances.

REFERENCES

[1] Anon (1999). *National Environment (Standards for Discharge of Effluent into Water or On Land) Regulations*. Statutory Instruments Supplement, No. 5, To the Uganda Gazette No. 7, Vol. XCII.
[2] Development Technology Unit (2002). *Very Low Cost Domestic Roofwater Harvesting in the Humid Tropics: Constraints and Problems*. DFID KaR Contract R7833, pages 3-4, 16-17.
[3] Nabulo Grace (2004). Assesment of heavy metal contamination of food crops and vegetables from motor vehicles emissions in Kampala City, Uganda. *A Technical paper submitted to IDRC,* Agropolis, pages 1 – 40
[4] Khatiwada, N.R., Takizawa, S., Tran, T.V.N. and Inoue, M. (2002). Groundwater contamination assessment for sustainable water supply in Kathmanandu Valley, Nepal, Water Science and Technology, Vol 46 (9), pages 147-154.
[5] Mugisha, S., Berg, S.V. and Katashaya, G.N. (2004). Short-term initiatives to improve Water Utility Performance in Uganda: The case of National water and Sewerage Corporation
[6] NWSC (2002). Cost of Kampala Water Will Rise. (2002, October 2) http://www.nwsc.co.ug/news.php.?StoryId=124. Accessed on 27th March 2004.
[7] UNBS (1994) standard specification for Drinking (Portable) Water: US201: 1994. Uganda UDC 543.341
[8] World Health Organization (2004), Drinking water Quality: Recommendations, Vol.1, 3rd Edition, Geneva