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Research Article

Evaluation of Harvested Rainwater Quality As a Drinking Water Source in Urban Land Uses in Western Province Sri Lanka

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Abstract Increasing of population around the world has imposed considerable strains on the water resources. Hence, regulatory authorities have faced significant challenges to expand their water supply schemes not only due to financial constraints but also due to limited water resources. Consequently, there has been a growing interest, especially in developing countries, in harvested roof run off as an alternative source of drinking water. However, in determining the end use and the potential success of such an option, the possible problems associated with water quality need to be analyzed and the feasibility of using rainwater as a source of water for household use should be determined. Therefore, this research study was focus on evaluating roof runoff as a drinking water source in different urban land uses where different urban activities are present. For this purpose, a roof runoff samples were collected from three selected land uses namely industrial, commercial and residential. The samples have collected from each land use with three selected roofing materials which are common to the area. This is to evaluate the roof runoff quality based on the variability of land use pattern as well as the variability on roofing materials. All the collected samples have tested for a range of water quality parameters namely, pH, alkalinity, Hardness, Turbidity, TS, COD, Nitrogen (Ammonia), chloride and biological contaminations.

Both uni-variate and stacked area analysis techniques were used in the analysis of test results. Based on the outcomes, recommendations are provided to use harvested roof runoff as a drinking water source in urban land uses in Sri Lanka.

Keywords *urban land uses; drinking water quality parameters; rainwater harvesting*

1. Introduction

With the increase number of population in urban areas, the demand for drinking water sources is increased. As a result, urban authorities had to move to alternative water sources which are economical. However, finding for safe and economical water sources for increase population is still problematic due to several reasons.

As a result of urbanization around the world number of water sources has become limited. In addition, quality of the water also a significant issue (Ruth M. and Paul P.A, 2000). There are more sources supplying drinking water like, gravity fed pipe water supply, pumped pipe water supply systems and well water supply systems. Urban water supply in developing countries is usually more complex, with a variety of different sources used by the population with cost and quantities available and quality of water. Different sources of water supply to urban area in Sri Lanka are by piped systems or protected public shallow and deep wells. However, it is recognized that wells in urban areas may not be suitable in the long term due to increasing risk of contamination by wastewater from septic tanks and leaching pits. Pipe water supply too is not continuous in most areas (Brend H.D., 1963). Pipe born water also couldn't supply to the expanding population in urban area due to increasing cost of production, depletion of resources because of over utilization & delivery losses. Sri Lanka gets an annual average rainfall of 2000 mm, ranging from 900 mm to 6000 mm in different regions. Several researchers noted that rainwater harvesting is one of the best solutions for upcoming scarcity of drinking water (Ariyananda, 2007).

Rainwater harvesting is the collecting and storing of rainwater for reuse. It has been used to provide drinking water, water for livestock, water for irrigation, as well as other typical uses. If carefully collected, rainwater is relatively safe for domestic use but problem may arise if the roofs become heavily contaminated due to settlement of variety of pollutants from the atmosphere and also animal droppings (Johnson and Kirk, 2009).

The characteristics of the roof surface hence quality of harvested rainwater is depended on several factors such as material composition of the surface, type, weathering process, development age, surface slope, exposure and spatial location (Mendes C.B., 2011). Specialized land uses such as trade centers in commercial and industrial areas may contribute additional pollutant loading such as heavy metals and hydrocarbons (Roy M., 2009). Rainwater contains major ions like sulphate, chloride, ammonium, nitrates and phosphates in measurable concentrations. Heavy metals such as Pb, Zn, Cr in the storm water partially occurs as dissolved solids. Storm water runoff also contaminated with organic pollutants. Leaves, bird excrement, flowers are example for macropollution, dust particles from combustion of fossil fuel are example for organic micro-pollutants in the rain water.

Pollutant characteristics are varied with the location of collecting of harvested rainwater samples. Researches done in urban land use in Sri Lanka are very less and from those researches, quality of the harvested rainwater is unpredictable hence; use of harvested rain water from urban land uses as safe drinking water is still problematic.

2. Significance of the Research

Rainwater harvesting is a foremost topic in sustainable development and it has been already taken into account in town planning and urban development. In Sri Lanka, there is more rainwater water harvesting projects in rural areas where people cannot find a drinking water source easily. However, most of these projects based on supplying water for domestic purposes such as washing, cleaning, gardening and agricultural purposes. However, currently there’s growing attention on use of harvested roof runoff as a drinking water source where water scarcity is a significant issue. Although rainwater harvesting from urban roof surfaces is considered as a viable solution for water scarcity in urban areas. Very limited or no research has been conducted to examine the potential use of harvested rainwater as a drinking water source in different urban land uses in Sri Lanka, where different urban activities are present. This impedes the effectiveness of the mitigation actions on safeguard the harvested rainwater quality. In addition, peoples’ different perceptions and myths on using harvested roof runoff as a drinking water sources is attributed to the lack of knowledge on health risks associated with harvested roof runoff. Consequently, this research study has been carried with the key objective of evaluating roof runoff quality in different urban land uses and to check the suitability of using harvested roof runoff as a direct drinking water source in urban areas. Such a research study eventually supports to reduce high demand on piped water hence, to reduce the cost associated with.

3. Methodology

3.1. Overall Data Collecting Procedure

The research is centered on experimental observations and analytical results. Major portion of the research project covers sampling, testing and data collection. The basic approach of data collecting procedure can be shown as follow (Figure 1).

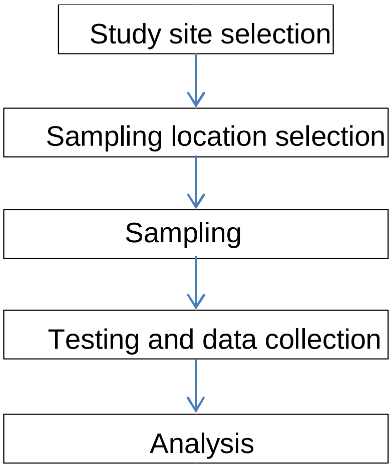


Figure 1: *Data collection procedure*

3.2. Geographical Region of the Research

According to the research project, the location is specified to Western province in Sri Lanka. This research is conducted in Rajagiriya and Nawela. Normal annual precipitation is 2500mm and average annual temperature around 27 ^{0}C with a peak temperature of 32^{0} C.

As the administrative city and as an ancient city of Western province, a wide range of activities take place in the city such as tourism, agriculture, different types of industrial and commercial activities. Industrial, commercial and residential areas can be clearly recognized as regions.
Industrial and commercial areas are very closed by in the urban region.

3.3. Study Site Selection

Three types of key land uses were selected in Rajagiriya and Nawela city which are namely residential, commercial and industrial where different urban activities are present (Figure 2). In each land use, three types of roofing materials were selected which are typical to the area. A description of the study sites are shown in Table 1.

Table 1: *Sampling location details*

Site ID	Land use type	Location name	Building type	Roofing material
RGA	Residential	Girl's Annex	Four story building	Asbestos sheets
RPS		Private House	Two story building	Slab
CGC	Commercial	Grocery Shop	Single story building	Calicut tile
CHA		Hardware	Two story building	Asbestos sheets
IHA	Industrial	Hardware	Single story building	Asbestos sheets
IGAS		Grocery Shop	Single story building	Amano Sheet

Figure 2: *Arial view of selected sites*

3.4. Sample Collection and Preservation

After a minimum 5 days of antecedent dry period, roof runoff three samples were collected from each sampling location. The selection of antecedent dry period was based on the findings of research literature such that it allows sufficient time to pollutant build-up on the impervious roof surface. Even though the researchers have noted that build-up may vary with the antecedent dry days, it was not used as a variable in this study. Runoff water draining through gutters and downspouts was collected (1000ml-2000ml) to standard polypropylene containers. The samples were started to collect at least 10 minutes after the beginning of rainfall event to ensure that the first flush is not collected as noted by several research studies first flush contains higher amounts of pollutants compare to latter part of runoff. All the collected samples were labeled with sample number, sample location, date and time.

The collected samples were transported as quickly as possible to the Polonnaruwa and Anuradhapura National Water Supply & Drainage Board Regional laboratory. Immediate tests were carried out as specified by APHA (2005) for the parameters such as pH, Dissolved Oxygen, Electric Conductivity and Turbidity. Then the samples were preserved according to the above standard as given in following table for the testing of other parameters (Table 2).

Table 1: *Details of water sample preservation for tests, according to APHA (2005)*

	Parameters	Units	Preservative Method	Holding Time
Physical	TS	Mg/L	Refrigeration at 4 ^{0}C	7 days
	EC	µs/cm	Refrigeration at 4 ^{0}C	28 days
	Turbidity	NTU	Refrigeration at 4 ^{0}C	48 hours
Chemical	pH		On-site measurement	2 hours
	Total Hardness	mg/L	Refrigeration at 4 ^{0}C	2 day
	Phenolphthalein Alkalinity	mg/L	Refrigeration at 4 ^{0}C	14 days
	Total Alkalinity	mg/L	Refrigeration at 4 ^{0}C	14 days
	Chloride	mg/L	Refrigeration at 4 ^{0}C	28 days
	Ammoniacal N	mg/L	Refrigeration at 4 ^{0}C, Sulphuric pH< 2	24 hours
	COD	mg/L	Refrigeration at 4 ^{0}C, Sulphuric pH< 2	24 hours
	DO	mg/L	On-site measurement	-
Biological	Total coliform	Colonies/100ml	-	< 6 hours
	BOD_5	mg/L	Refrigeration at 4 ^{0}C	24 hours

Note: - TS – Total Solids
EC – Electrical Conductivity
COD – Chemical Oxygen Demand
BOD – Biological Oxygen Demand

3.5. Laboratory Testing Procedure

Collected samples were brought to the laboratory as soon as possible due to immediate testing are required for particular parameters which is mentioned in the section 3.4 that has less preservation time. Polonnaruwa and Anuradhapura National Water Supply & Drainage Board Regional laboratory was used to test samples and testing standard published by the American Public Health Association (APHA) in 2005 was used as the standard testing methodology.

This following section describes the methodologies and steps that were used in laboratory to measure mentioned physical, chemical and biological parameters.

3.5.1. pH

PH indicates the log rhythm value of the H^+ ion concentration of the sample and should be measured quickly as much as the sample arrive to the laboratory as well it is unit less. A pre calibrated pH meter with standard buffer solvents was used. Higher pH values are due to increases the solubility of salts, heavy metals and ammonia. Higher level of pH occurs mainly due to HCO_3^- alkalinity. Low level of pH value causes carbonic and dissolved carbon dioxide concentrations.

3.5.2. Electrical conductivity

2510 B Standard methods for the Water and Waste Water (APHA-1999) is used for measure electrical conductivity of the sample by using Electrical conductivity meter and gives value with unit of µs/cm. As well, conductivity depends on the sample temperature. The instrument is calibrated with standard KCl (0.01M) solvent.

3.5.3. Turbidity

Turbidity was measured using turbidity meter and it measures the disturbance to the emitted light wave through the sample. There is a trivial effect to turbidity due to solids in the sample. Standard of testing procedure is 2130B, Standard methods for the Water and Waste Water (APHA-2005).

3.5.4. Total Solids

Solids were added to harvested rain water due to solid accumulation on roof tops. Total solids value gives material residue left after evaporation of sample in an oven at defined temperature. Dry and clean evaporation dish was prepared by washing with distilled water and keep in oven at 105 ^{0}C for half an hour. The weight of the empty evaporation dish was measured and 50 ml of the sample is added. Then kept in the oven at 105 ^{0}C for 24 hours and weight of the evaporation dish is measured. Calculation is as follows,

$$\mathrm{TS} = \frac{W_2 - W_1}{W_1} \times \frac{1000}{50} mg/l$$

Equation…………………..(1)

W_1 = Weight of the dry and clean evaporation dish
W_2 = Weight of the evaporation dish after keeping in for 24 hours
The testing method was 2540 A in the Standard methods for the Water and Waste Water (APHA-2005).

3.5.5. Hardness

Calcium hardness is determined by EDTA (ethylene diamine tetra acetate acid) titration. Standard EDTA titrant (0.01 M) can be prepared by accurately weighted 3.723 g EDTA disodium salt diluted with de-ionized distilled water (DDW) until total volume equals to 1L. Eriochrome black T; a dye is used as an indicator. When the indicator is added to hard water at pH of 10± 0.1, the solution has become wine red in color. When EDTA is added to solution, color changes from wine red to blue (purple) at the end point. The sample pH is adjusted to 10± 0.1 by adding buffer solution. The buffer solution is made of mixing 240 ml of concentrated NH_4OH with de-ionized distilled water into 1L solution.

50 ml of sample is chosen and buffer solution is added until the sample pH adjusted to 10± 0.1. 0.5 ml of indicator was added and solution is turned in to wine red. If the solution is blue in color, that means there is no hardness in the sample. Else, sample was titrated with 0.01 M EDTA. Stirring the sample

is essential and EDTA was added very slowly when reddish color disappears. The volume of titrant consumed is recorded. Meanwhile titrate blank sample of 50 ml and EDTA volume consumed is recorded.

1.0 ml 0.01 M EDTA = 1.0 mg CaCO

$$\text{Total Hardness as } CaCO_3(mg/l) = \frac{(A-B)\times D\times 1000}{\text{Volume of sample,ml}}$$

Equation…………..(2)

Where, A = volume of titrant consumed for sample, ml
B = volume of titrant consumed for blank, ml
D = mg CaCO equivalent to 1.00 ml EDTA titrant. = 1

SM 2340 C Standard methods for the Water and Waste Water (APHA-2005) were followed.

3.5.6. Alkalinity

Alkalinity is determined by titration sample with 0.1N sulfuric acid until end point of pH 8.2 and pH 4.3. Unpreserved samples were analyzed within twenty-four hours after collection. Preserved sample is brought to room temperature and stirred gently before analysis (Table 5).

SM 2320 B Standard methods for the Water and Waste Water (APHA-2005) were followed during testing samples. 50 ml of sample is measured to a beaker and 3-5 drops of Phenolphthalein was added and color changing is observed. If the solution color is pink, sample was titrated using 0.1N sulfuric acid to a colorless end point. 0.1 N sulfuric acid volume (X ml) required was recorded. Then 3 – 5 ml of methyl orange indicator is added and again sample was titrated using 0.1N sulfuric acid to end point color change from yellowish orange to reddish blue. 0.1 N sulfuric acid volume (Y ml) required was recorded. Calculations for phenolphthalein and methyl orange alkalinity are as follows,

$$\text{phenolphthalein alkalinity (P)} = \frac{X\times 1000\times 50\times 0.1}{50}(mg/L)\text{as } CaCO_3$$

Equation…………….(3)

$$\text{methyl orange alkalinity (T)} = \frac{Y\times 1000\times 50\times 0.1}{50}\ (mg/L)\text{as } CaCO_3$$

Equation………………(4)

Where, X = 0.1 N sulfuric acid volume required when phenolphthalein present
X = 0.1 N sulfuric acid volume required when Methyl orange present

Table 3: *Interpretation of carbonate and bicarbonate alkalinity (APHA 2005)*

	Carbonate Alkalinity as $CaCo_3$	Bicarbonate Alkalinity as $CaCo_3$	Total Alkalinity as $CaCo_3$
P = 0	0	T	T
P<	2P	T-2P	T
P=	2P	0	T
_< P < T	2(T-P)	0	T
P = T	0	0	T

3.5.7. Chloride

Chloride content of the samples was determined according to the Argentometric (Mohr) method and standard used is SM 4500-Cl^--G Standard methods for the Water and Waste Water (APHA-2005) for testing at the laboratory. 50 milliliter of sample was titrated with 0.014 N $AgNO_3$ until chloride neutralization is reached. The 0.014 N $AgNO_3$ nitrate titrant is repaired by dissolving and diluting 2.395 g $AgNO_3$to one liter with de-ionized distilled water. Required volume of $AgNO_3$ for titration of blank was recorded. A blank 50 milliliter of deionized water is titrated for background correction. 50 milliliter sample was taken into a flask and one milliliter of K_2CrO_4 was added as an indicator. Sample is titrated from 0.014 N $AgNO_3$ until color changes to pinkish yellow at the end point. Required volume of $AgNO_3$ for titration of sample was recorded.

$$\text{Chloride } (mg/L) = \frac{(A-B)\times 0.0141\times 35450}{Volume\ of\ sample{,}ml}$$

Equation……………………(5)

Where, A = mL of $AgNO_3$added for sample
B = mL of $AgNO_3$added for blank

3.5.8. Nitrogen (Ammonia)

Nitrogen (Ammonia) was tested according to the phenate method and the procedure was followed by standard of SM 4500 – NH_3 Standard methods for the Water and Waste Water (APHA-2005). Standard calibration curve of absorption vs. ammoniac nitrogen concentration should be obtained for standard nitrogen solution before testing samples by using spectrophotometry. Most importantly, range of absorption should be within the standard curves' range. At the first nitrogen (Ammonia) was unpredictable and range of absorption is also unpredictable. Due to this reason samples should be diluted as 5:1 and 25:1. Dilution was done by mixing properly 2 milliliter of filtered sample with 48 milliliter de-ionized distil water and 10 milliliter of filtered sample 40 milliliter of de-ionized distil water respectively.

Standard ammonium solution is prepared by diluting stock ammonium solution according to the appropriate concentration of the diluted samples. With using spectrophotometer, the standard calibration curve can be drawn.

Sample preparation is done with mixing after adding each reagents of 1 milliliter of phenol solution, 1 milliliter of sodium nitroprusside solution and 2 milliliter of oxidizing solution. Samples were covered by plastic wrap and kept in a dark place at room temperature for 24 hour for developing of color in 640 nm wave length. Blank sample of 50 milliliter was prepared.

The phenol solution is made up mixing 11.1 ml of liquefied phenol with 95% V/V ethyl alcohol to a final volume of 100 milliliter. When mixing these two chemicals, personal exposure is avoided and mixture was discarded after a week.

0.5 g of sodium nitroprusside was dissolved into 100 milliliter of de-ionized to prepare sodium nitroprusside solution and it is last for 1 month and kept in amber bottle.

Oxidizing solution was prepared daily by mixing 100 milliliter of alkaline citrate and 10 g of sodium hypochlorite. Alkaline citrate was prepared with mixing 200 g of trisodium citrate and sodium hydroxide with de-ionized distilled water and dilute into 1 liter. Sodium hypochlorite should be refreshed in every 2 months.

Samples and blanks were tested by using spectrophotometer at 640 nm range and abortions were recorded and nitrogen (Ammonia) concentrations were computed using standard calibration curve and gives values in units of mg/L.

3.5.9. Chemical Oxygen Demand

COD is a measure of the oxygen equivalent of the organic matter susceptible to oxidation by strong oxidizing chemical (Quality analysis of water and waste water). Strong oxidizing chemical is a mixture of chromic acid and sulfuric acid. Combination of chromic acid and sulfuric acid produces potassium dichromate and nascent oxygen. Nascent oxygen and dichromate reacts with organic oxygen and color of the sample was green. The excess dichromate was titrated with ferrous ammonium sulfate (FAS) with ferroin indicator and gives reddish-brown color at the end.

Glassware were cleaned before use sue to organic contaminant may give false results. Hence, flask and condensers were washed with 50% H_2SO_4 and clean with chromic acid to prevent deposit buildup on the walls.

Blank sample with de-ionized distill water was prepared to prevent the error occurred due to external source of organic matters. Molarity sample was also a blank sample but it kept in room temperature all time.

There is a possibility of all of dichromate oxidant used up and shows green color after refluxing. To prevent lacking of dichromate, dilution of the sample is essential and COD o the sample couldn't be predicted and dilution of 5:1 and 25:1 was used. $HgSO_4$ was used to prevent interference of chloride ions in samples, because Cl^- consumes dichromate to produce Cl_2.

0.0417M (0.25 N) standard potassium dichromate solution was prepared by 12.259 g of K_2CrO_4 which previously dried at 103 ^{0}C for 2 hours mixing with distilled water and diluted to 1L.

10 milliliter of diluted sample was mixed with 14 milliliter of sulfuric acid reagent mix very carefully and cool. 6 milliliter of 0.0147 M K2CrO4solution was added to sample mixed it well. The mixture was refluxed in 150 ^{0}C for 2 hours in an oven and cools it to room temperature. 2 milliliter of ferroin indicator was added and titrated with FAS for all samples including blank and molarity samples until a

color change from bluish green to reddish brown. Volume of FAS used was recorded and calculated as follows.

$$\text{Molarity FAS} = \frac{\text{Volume of 0.0147 M K2CrO4 ,mL}}{Volume\ of\ FAS\ used{,}ml} \times 0.25$$

Equation………………………(6)

$$\text{COD}\ (mgO_2/L) = \frac{(A-B)\times M\times 8000}{Volume\ of\ sample{,}ml}$$

Equation……………………….(7)

Where, A = mL of FAS used for blank
B = mL of FAS used for sample
M = Molarity of FAS

SM- 5220 C Standard methods for the Water and Waste Water (APHA-2005) was used during testing sample for COD.

3.5.10. Biological Oxygen Demand

The BOD experiment was carried out using SM-5210 B Standard methods for the Water and Waste Water (APHA-2005). It was measured at 20 ^{0}C under 5-day incubation. 400 milliliter sample was poured to BOD track apparatus sample bottle. BOD nutrient buffer pillow was added for optimum microbial cell growth. Lithium hydroxide powder pillow was also added and stirred using magnet bars. Sample bottle was placed at the BOD track apparatus inside the incubator at temperature of 20^{0}C. BOD results were taken after 5-day incubation.

3.5.11. Total Coliform

No of colony of total coliform was calculated according to the membrane filter method. Following this method, results can be obtained in a short period of time and method is more accurate.

In this membrane filter method; 50 milliliter of sample was filtered through a membrane filter made up of cellulose esters. Pore size of filter is 0.45 µm and it can retain organisms to be detected on the surface of membrane. Filtration unit and funnel base must be in as autoclave at 151lb/in^2 pressure. Membrane filter paper also is to be sterilized by autoclave at 115 ^{0}C for 10 min. pre sterilized membrane filters are preferred. Absorbent pads were sterilized by keeping in autoclave at 121 ^{0}C for 20 minutes. Forceps was kept in a small beaker containing 95% alcohol.

Absorbent pad was placed on petri dish using a forceps and special medium of M-Endo broth was added to absorbent pad.

A sterile membrane filter was placed on filter base, grid side up with the help of forceps. Sterile funnel was placed on the top of the filter disc and clamped funnel to filter base by means of screw threads. Suction flask was attached to the vacuum pump. Pour the 50 milliliter of sample to the funnel and filter it through membrane filter under vacuum. Surface of funnel was washed by de-ionized distil water when entire sample has been filtered. Transfer the membrane carefully to a petri dish containing absorbent pad.

The petri dish was then incubated at 35 ^{0}C for 24 hours. Total coliform colonies can be counted using colony counter. A coliform colony can be seen as pink or dark red spots.

$$\text{Total coliform}/100\ \text{ml} = \frac{\text{no.of colonies counted}}{\textit{Volume of sample filtered}} \times 100$$

Equation……………..(8)

SM - 9222 B Standard methods for the Water and Waste Water (APHA-2005) was followed at the laboratory.

3.6. Data Analysis Techniques

Data analysis is carried out using both uni-variate and stacked area analysis techniques. The generated runoff quality data was compared with the standard drinking water quality guidelines of World Health Organization's and Ministry of Health Sri Lanka. Finally, based on the findings improvements, recommendations and suggestions has been provided to use roof runoff as a direct drinking water source the area where scarcity of water is a significant issue in Sri Lanka.

3.6.1. Uni-variate data analysis

Uni-variate analysis is the basic and simplest form of quantitative (statistical) analysis which carried out prior to the other complex types of analysis such as stacked area analysis. The analysis is carried out with the description of a single variable and its attributes of the applicable unit of analysis. Numeric method and graphical method are the main two ways of analyzing uni-variate data. The numeric method involves using descriptive statistics to summaries the main features of the data in table form, while the graphic method involves using various graphs and charts to visualize the main aspects of the variable. Information of each variable such as range, median, mean, skewness and standard deviation can be found through the uni-variate data analysis (Melissa D., et al., 2003). Sometimes mean doesn't provide better description about the data series when a higher dispersion of data exist. Therefore standard deviation should be considered because low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data points are spread out over a large range of values.

3.6.2. Stacked Area Analysis

Stacked area graphs work in the same way as simple area graph do, except for the use of multiple data series that start every point from the point left by the previous data series.

All the data plotted is represented by the entire graph. Stacked area graph also use the areas to convey whole numbers, so they do not work for negative values. Overall, they are useful for comparing multiple variables changing over an interval. Quantitative variable is depicted by stacked area graph against another quantitative variable. The various shaded areas are stacked on top of one another, so that the height of every shaded area represents the value for each particular categorical variable, and the total height is their sum. A stacked bar chart is a variant of the bar chart. A standard bar chart compares between individual data points with each other. Excel stacked area chart are used to indicate data with filled color. It is like line chart with one difference in a stacked chart – the area below the line is filled area (with color). A stacked area chart is the extension of a basic area chart of excels to display the evolution of the data of different groups on the same graphic.

Use a stacked area chart to display the contribution of each data to a total. Stacked bar charts in excel easily allow users to see changes in a series of data and where they represented in the overall area of a chart.

A variation of the stacked bar chart is the 100% stacked bar chart. In this form, each bar is the same height or length, and the sections are indicated as percentages of the bar rather than as absolute values. It can be used to represent: Ranking, Distribution, Comparisons, Part-to-whole, etc.

4. Results, Analysis and Discussion

Results were obtained testing samples with referring methodology of the research and all the results are tabulated. Analyses of the results were done in two main steps and details of analysis are discussed through this chapter.

4.1. Uni-variate Data Analysis

4.1.1. Electrical Conductivity (µs/cm)

Table 2: *Result on Electrical conductivity*

Locations	Maximum acceptable val (µs/cm)	Result of Electrical Conductivity (µs/cm)
RGA	750	22.73
RPS	750	36.28
CGC	750	33.67
CHA	750	42.34
IHA	750	65.87
IGAS	750	87.45

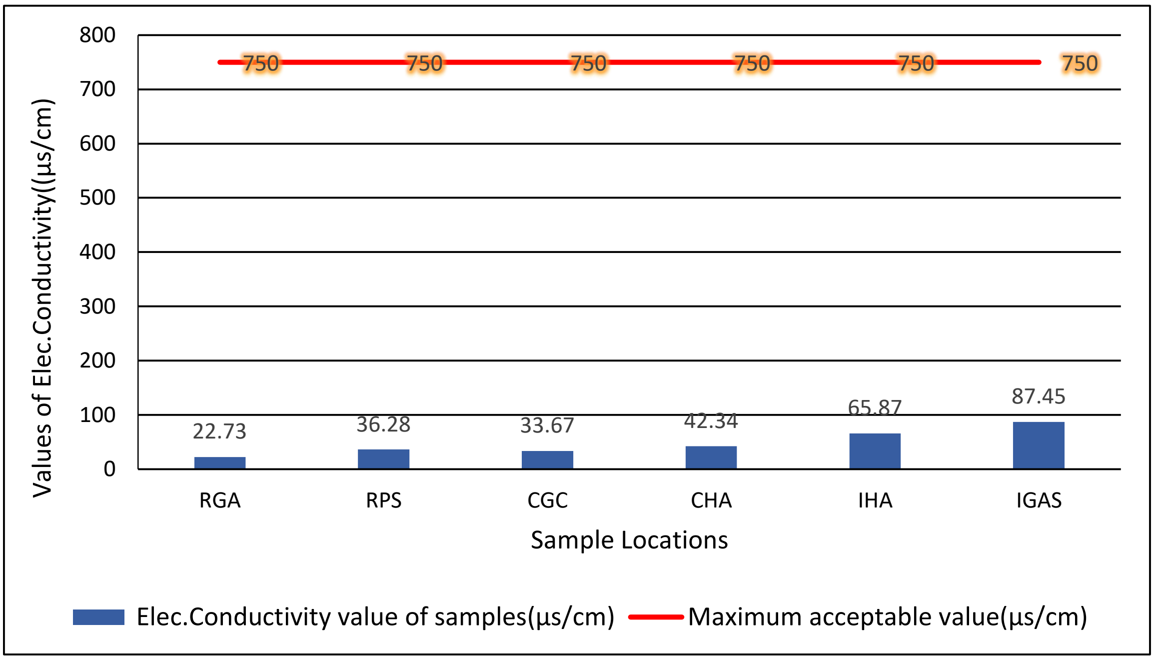


Figure 1: *Sampling locations vs value of Electrical conductivity*

As discussed in section (3.5.2.) As seen in Table 4 and Figure 5 EC show comparatively very low value than permissible electrical conductivity in collected samples for all the land uses.

However, samples from industrial land use pattern shows comparatively higher value of electrical conductivity while samples in other land use patterns show relatively low values, because air pollution in industrial land use is high. Hence possibility of deposition of particulate matters on roof surface is very high. Eventually wash off may contain more solids and large portion of deposited solids may dissolved in roof run off which indicates high EC.

4.1.2. Turbidity (µs/cm)

Table 3: *Result on Turbidity (NTU)*

Location	Maximum acceptable NTU	Result of turbidity (NTU)
RGA	2	0.87
RPS	2	0.32
CGC	2	0.43
CHA	2	0.65
IHA	2	1.52
IGAS	2	3.61

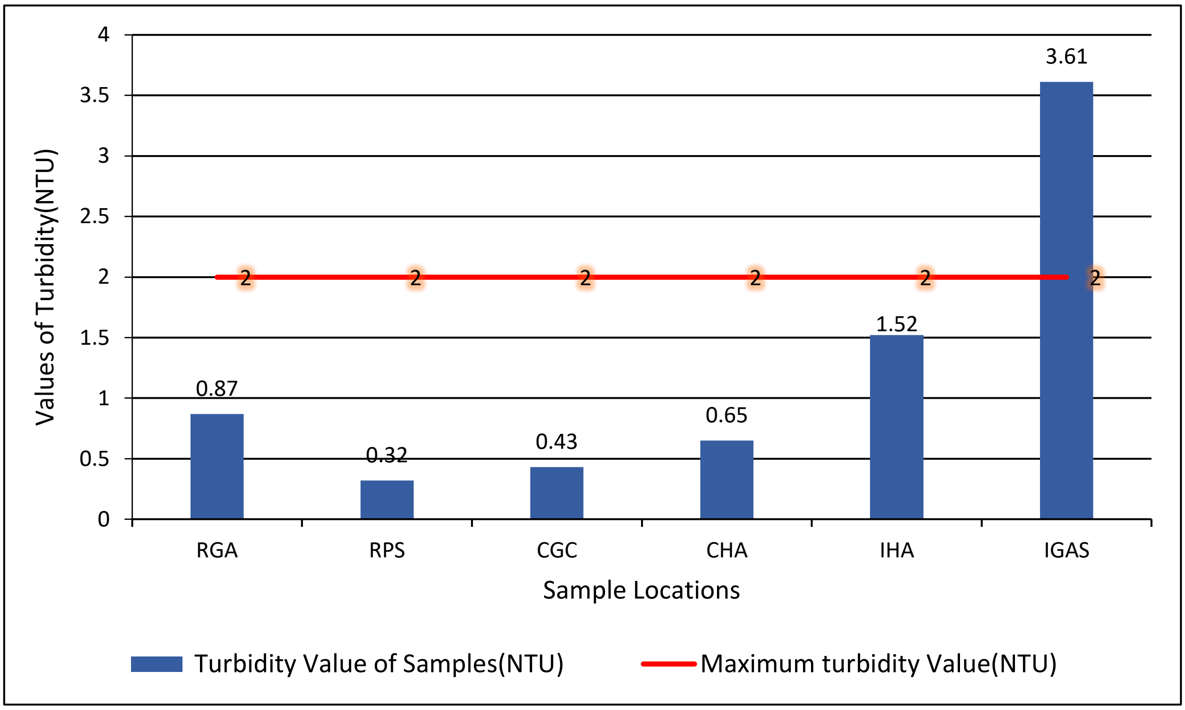


Figure 2: *Sampling locations vs. values of Turbidity*

As discussed in section (3.5.3.), effect of the unacceptable level of turbidity on drinking water is discussed. Turbidity as seen in Table (5) and Figure (6) industrial land use with Amano sheet roofing material locations exceed the acceptable turbidity level and other locations are acceptable level of turbidity on drinking water.

As seen in Figure 6 direct relationships does not indicate between turbidity and land use patterns, but highest turbidity values from each land industrial land use pattern were given by with Amano sheet roofing material while minimum turbidity values were given by residential land use Patten roof made by Calicut tile. Reason for having higher turbidity from industrial land use Patten is due to it is very close to the main road and possibility of retaining of solid on the roof surface is higher due to high wind of the area. As well as residential land use Patten, there is a no possibility of retaining of solid on the roof surface is lower due to considerably low wind. Slab surfaces are accurately smooth and chance of retaining solids is less.

4.1.3. Total Suspended Solids (mg/l)

Table 6: *Result on Total Solids*

Location	Maximum acceptable Total solid content (mg/l)	Result of total solid content (mg/l)
RGA	200	11.9
RPS	200	15.6
CGC	200	13.5
CHA	200	12.1
IHA	200	14.5
IGAS	200	26.2

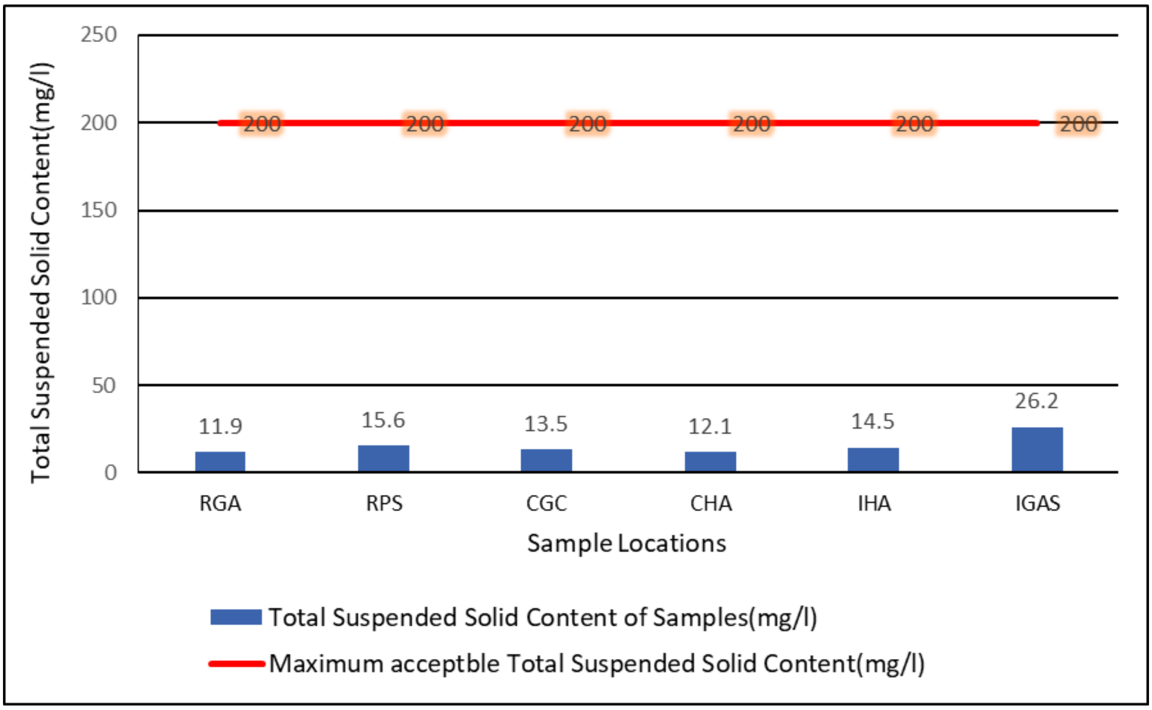


Figure 3: *Sampling locations vs. values of Total Solids*

Lesser values of total suspended solids are indicated in all sampling locations except with compare to the WHO Guidelines.

Grocery shop in the Industrial land use pattern indicates higher value of total solid content because it is very close to the main road and possibility of retaining of solid on the roof surface is higher due to high wind of the area. In residential land use pattern, higher total solid content was recorded in private house and it also has the roofing material Slab. The roofing may help to retain more solids and retained solids may wash off with rain event although first flush was avoided. According to this results most suitable land use Patterns are residential and commercial to drink the rain water but all locations are indicated acceptable level in total suspended solid values.

4.1.4. pH

Table 4: *Result on pH*

Location	Maximum acceptable pH	Minimum acceptable pH	Results of PH
RGA	8.5	6.5	6.29
RPS	8.5	6.5	6.59
CGC	8.5	6.5	6.50
CHA	8.5	6.5	6.46
IHA	8.5	6.5	6.41
IGAS	8.5	6.5	6.14

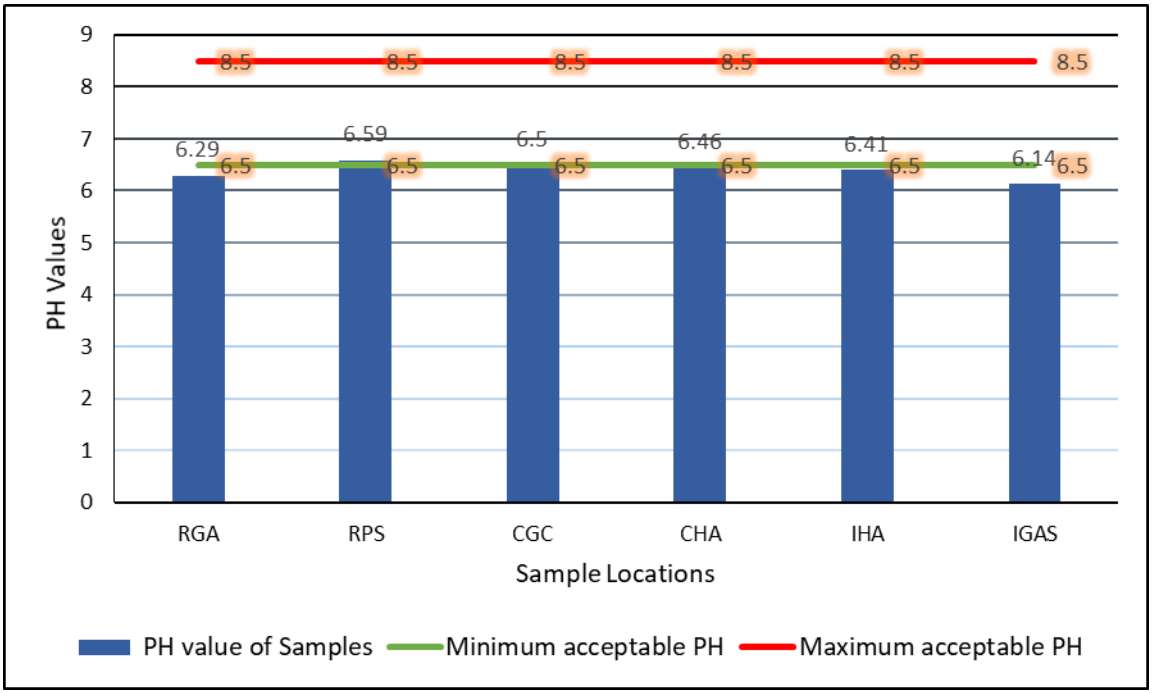


Figure 4: *Sampling locations vs. value of pH*

According to the Table 7 and Figure 8, pH values of all residential private house and commercial shop are the acceptable range and there is an approximately variance. Hence, there is a need of pH balancing before consumption.

When the sampling locations in each Patten, commercial area in PH vales approximately acceptable level. In each location Patten, residential private house has higher pH values roofing material with slab. Because more H+ irons have in this roofing materials. Lower values from each land use pattern are given by sampling locations with amono sheet.

4.1.5. Total Dissolved Solid (mg/l)

Table 8: *Result on Total Dissolved Solid*

Locations	Maximum acceptable Dissolved solids (mg/l)	Results of Dissolved sc (mg/l)
RGA	500	22
RPS	500	33
CGC	500	25
CHA	500	28
IHA	500	24
IGAS	500	51

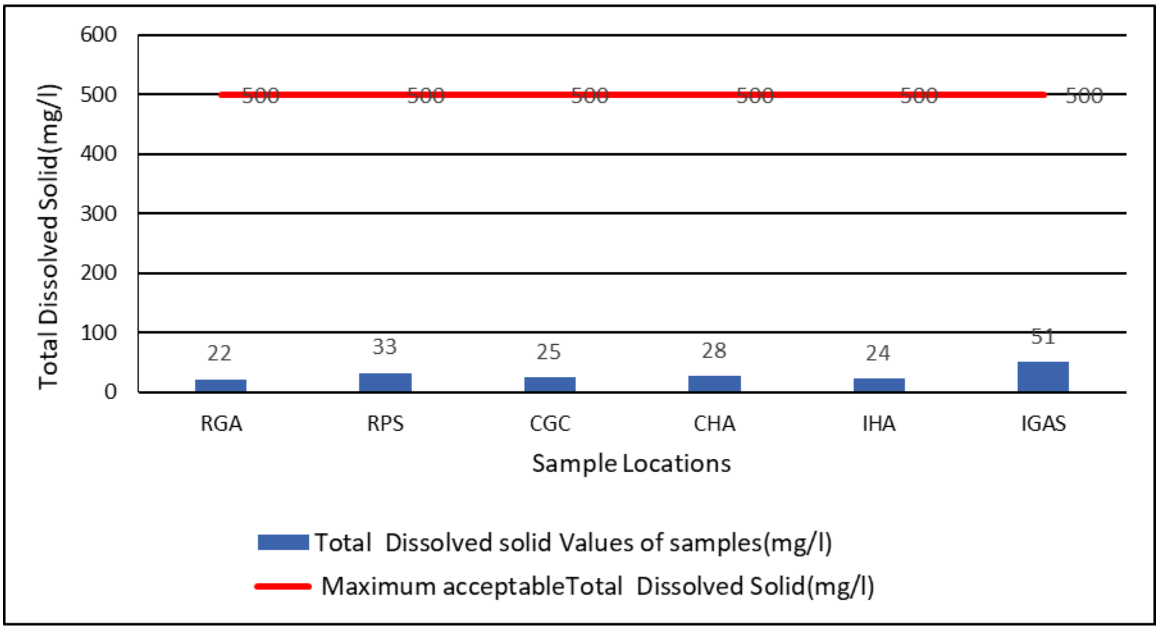


Figure 5: *Sampling locations vs. value of Total Dissolved Solid concentration*

Lesser values of total Dissolved suspended solids are indicated in all sampling locations except with compare to the WHO Guidelines.

Grocery shop in the Industrial land use pattern indicates higher value of total Dissolved solid content same as the Total suspended solid. Because it is very close to the main road and possibility of retaining of solid on the roof surface is higher due to high wind of the area. And it roofing material with Amano sheet was made in aluminum, Zinc. Hence in that roof material was damaged over time. So Total dissolved content may be increased due to AL, Zn addition to the water. In each land use pattern, lower total dissolved solid content was recorded in girl's annex and it also has the roofing material Asbestos. The roofing may help to retain more or low solids and retained solids may wash off with rain event although first flush was avoided. According to this results most suitable land use Patterns are residential and commercial to drink the rain water but all locations are indicated acceptable level in total dissolved solid values.

4.1.6. Hardness (mg/l)

Table 5: *Result on Hardness*

Locations	Acceptable Maximum concentration (mg/l)	Results of Hardness (mg/l)
RGA	250	21.45
RPS	250	10.34
CGC	250	1.24
CHA	250	6.33
IHA	250	2.32
IGAS	250	10

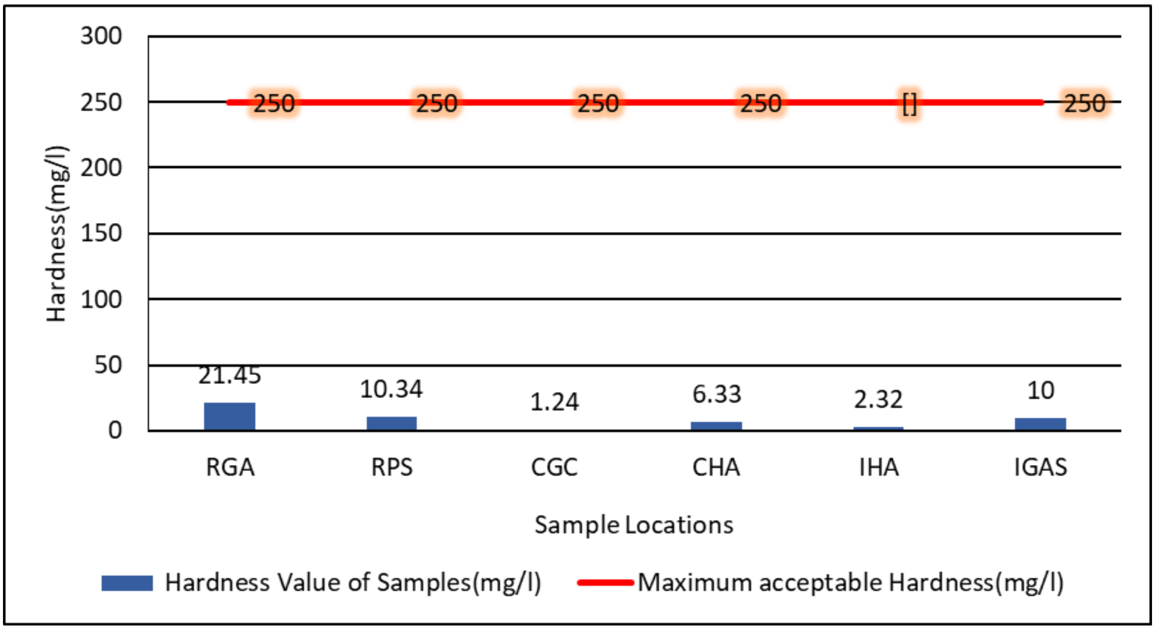


Figure 6: *Sampling locations vs. value of Hardness*

Dissolved minerals contribute taste to drinking-water according varying degrees. Acceptability of water usually depends on the individual user's taste and familiarity. Demineralized water tends to have a flat taste. The degree of hardness of drinking-water is important for aesthetic acceptability by consumers. Table 9 and Figure 10, shows that hardness values are much lesser than acceptable maximum value. Hardness of water increase when water flows through soil and road surfaces but harvested rainwater flows only on roof surface and down pipes.

There is no significant variance with land use pattern and roofing materials.

4.1.7. Total Alkalinity (mg/l)

Table 6: *Result on Total Alkalinity*

Location	Maximum acceptable concentration (mg/l)	Results of Total Alkalinity (mg/l)
RGA	200	16
RPS	200	11
CGC	200	05
CHA	200	06
IHA	200	01
IGAS	200	01

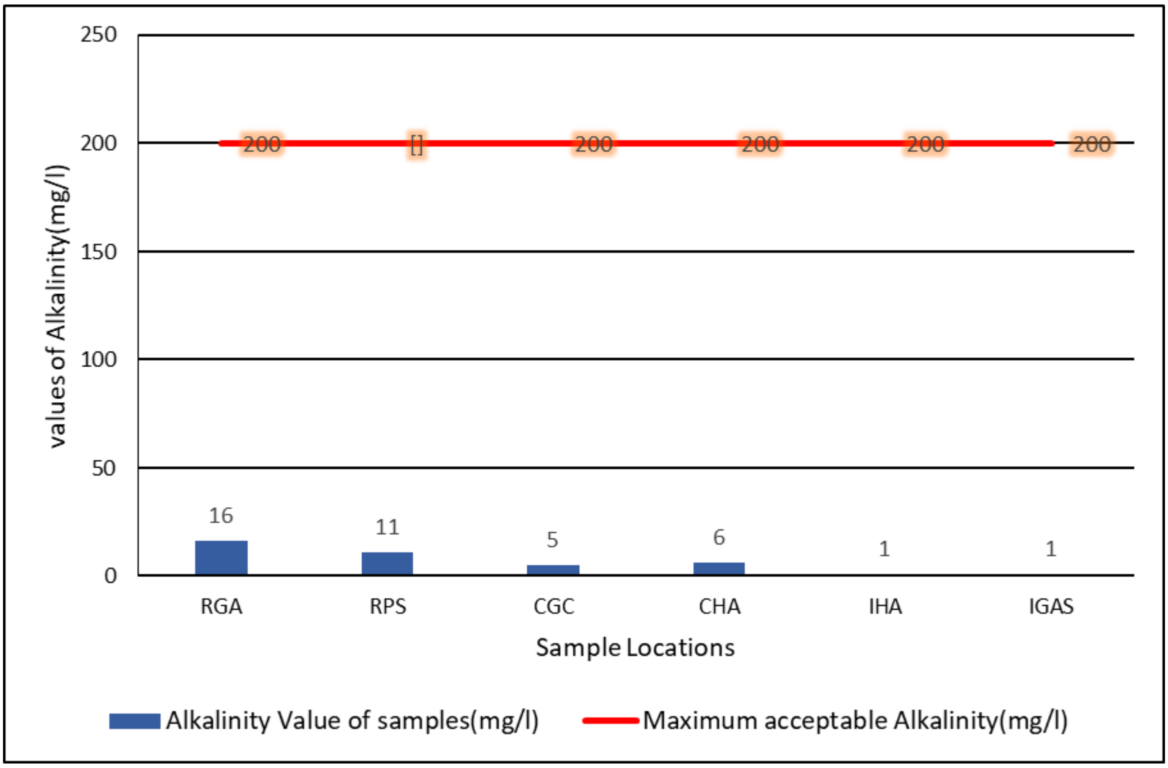


Figure 7: *Sampling locations vs. value of Total Alkalinity*

Total alkalinity measures the concentration of present substances with acid neutralizing ability. Table 10 and Figure 11 shows all the sampling locations below the alkalinity than maximum acceptable level. Hence there is no need of treating for total alkalinity.

There is no significance variance with land use pattern or roofing material.

4.1.8. Chloride (mg/l)

Table 7: *Mean of result on Chloride*

Location	Maximum Acceptable Concentration (mg/l)	Results of Chloride (mg/l)
RGA	250	03
RPS	250	03
CGC	250	04
CHA	250	06
IHA	250	06
IGAS	250	04

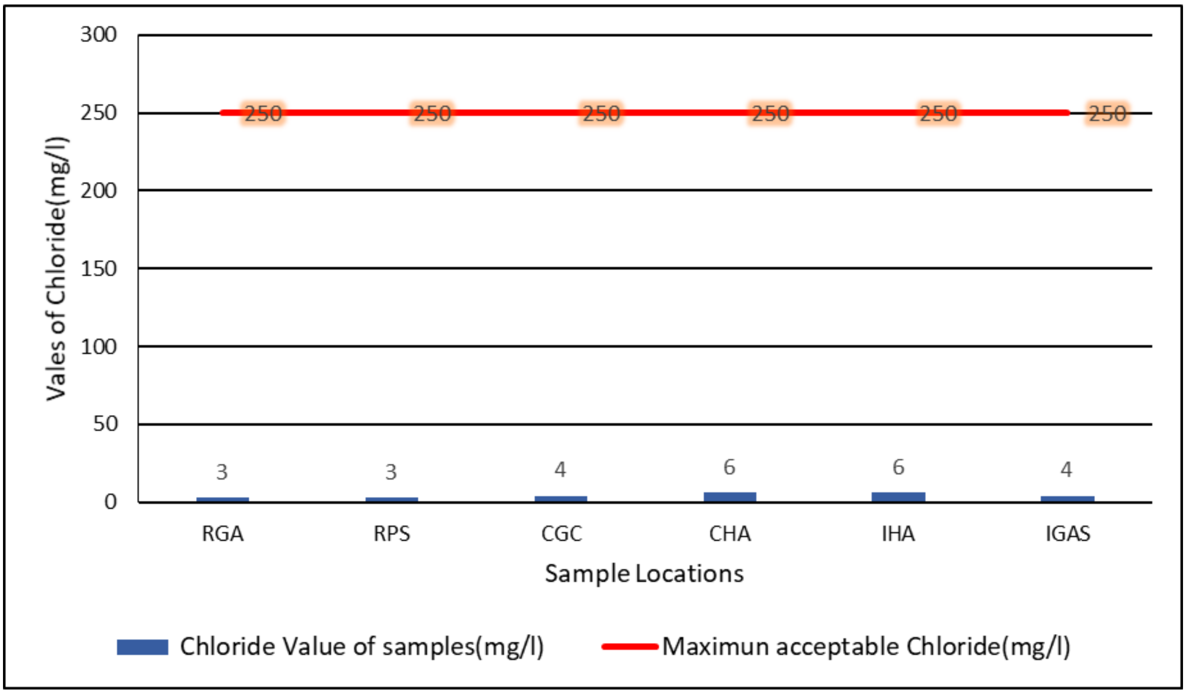


Figure 8: *Sampling locations Vs .value of Chloride*

Chloride toxicity has not observed over humans yet. Chloride increases electrical conductivity of water and increase corrosiveness. However over 250 mg per liter of chloride content give detectable unpleasant taste. Chloride ion concentrations for sampling points are indicated in Table 11 and Figure 12. All the chloride concentration values are very less than the acceptable maximum concentration.

Sampling locations in commercial area and industrial has higher chloride values while lower chloride values are given by residential land use patterns because residential area has less activity which emits chloride ions. Lower values from each land use pattern are given by sampling locations with Asbestos and slab roofing. According to the above results most suitable land use pattern is residential to drink the rain water but other land use patterns were the acceptable level in chloride values.

4.1.9. Total Phosphate

Table 8: *Result on Phosphate*

Location	Maximum Acceptable Concentration (mg/l)	Results of Phosphate (mg/l)
RGA	2	0.26
RPS	2	0.09
CGC	2	0.14
CHA	2	0.12
IHA	2	0.21
IGAS	2	0.28

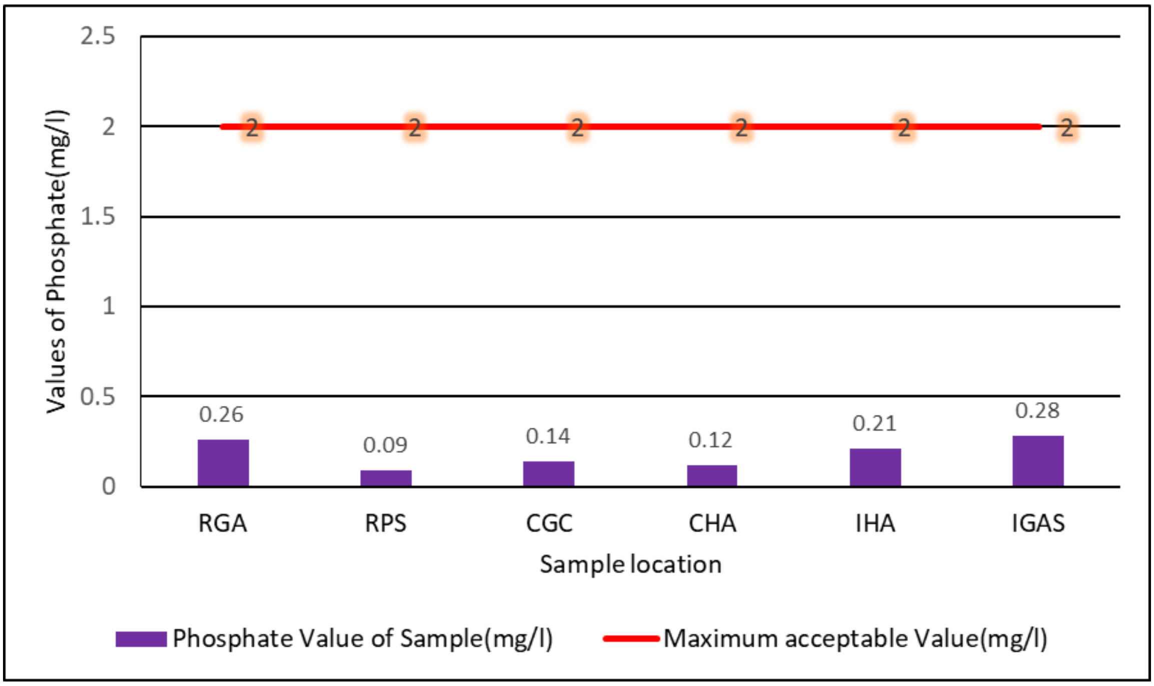


Figure 9: *Sampling locations Vs .value of Phosphate*

According to the Table 12 and Figure 13, phosphate values of all sampling locations are the acceptable range and there is no approximately variance. Hence, there is a need of phosphate balancing before consumption.

Sampling locations in industrial has higher phosphate values while lower phosphate values are given by residential land use patterns because residential area has less activity which emits phosphate ions. Lower values from each land use pattern are given by sampling locations with slab roofing. According to the above results most suitable land use pattern is residential and commercial to drink the rain water but other land use pattern was the acceptable level in chloride values.

4.1.10. Ammonias Nitrogen (mg/l)

Table 9: *Result on Ammonias Nitrogen*

Location	Maximum Acceptable Concentration (mg/l)	Results of Ammonias l Nitrogen (mg/l)
RGA	1.5	0.32
RPS	1.5	0.23
CGC	1.5	1.75
CHA	1.5	1.61
IHA	1.5	1.53
IGAS	1.5	2.54

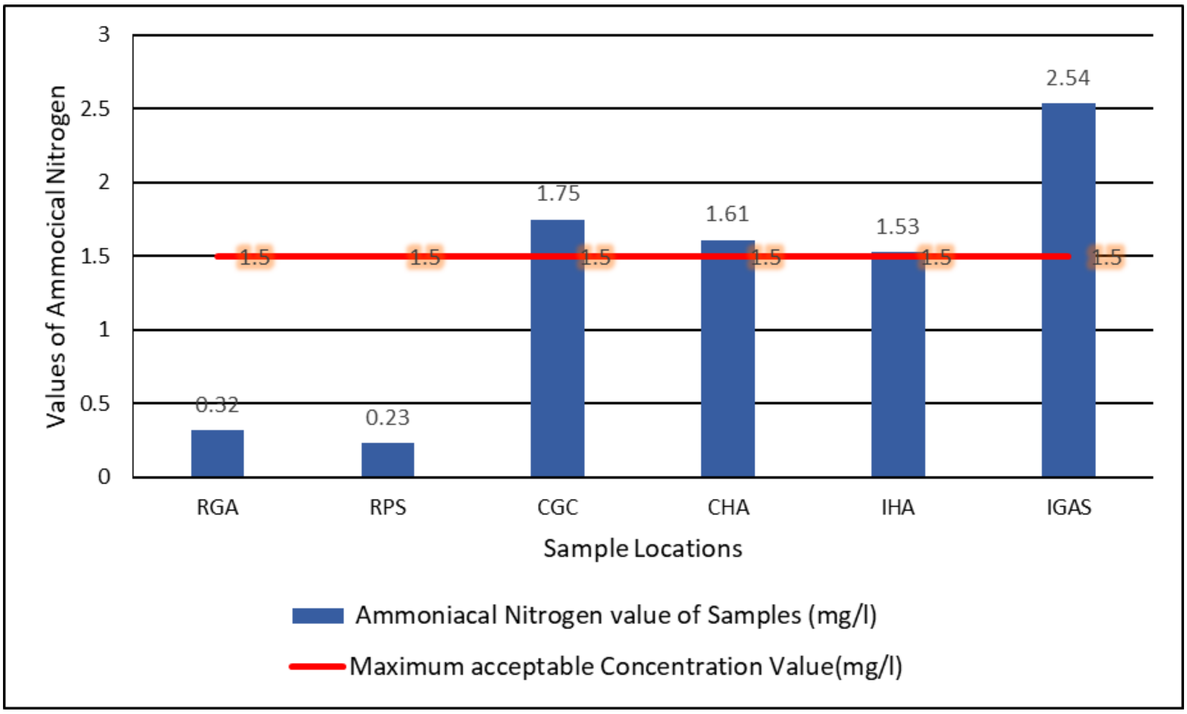


Figure 10: *Sampling locations vs. value of Ammonias Nitrogen*

Ammonia is not of direct importance for health in the concentrations to be expected in drinking-water. As seen in Table 13 and Figure 14, show the mean ammonias nitrogen concentration of harvested rainwater samples. Sample locations in residential land use pattern results were below the maximum acceptable concentration. Higher ammonias nitrogen has in industrial land use because air pollution in industrial land use is high. So ammonias nitrogen can be added to the rain water.so ammonias nitrogen was high in this land use pattern. Clear difference between pollutant parameter with land use pattern and roofing material cannot be identifies.

4.1.11. Chemical Oxygen Demand (mg/l)

Table 10: *Mean of result on Chemical Oxygen Demand*

Locations	Maximum acceptable concentration (mg/l)	Results of COD (mg/l)
RGA	15	8.23
RPS	15	11.23
CGC	15	34.87
CHA	15	17.35
IHA	15	65.67
IGAS	15	54.23

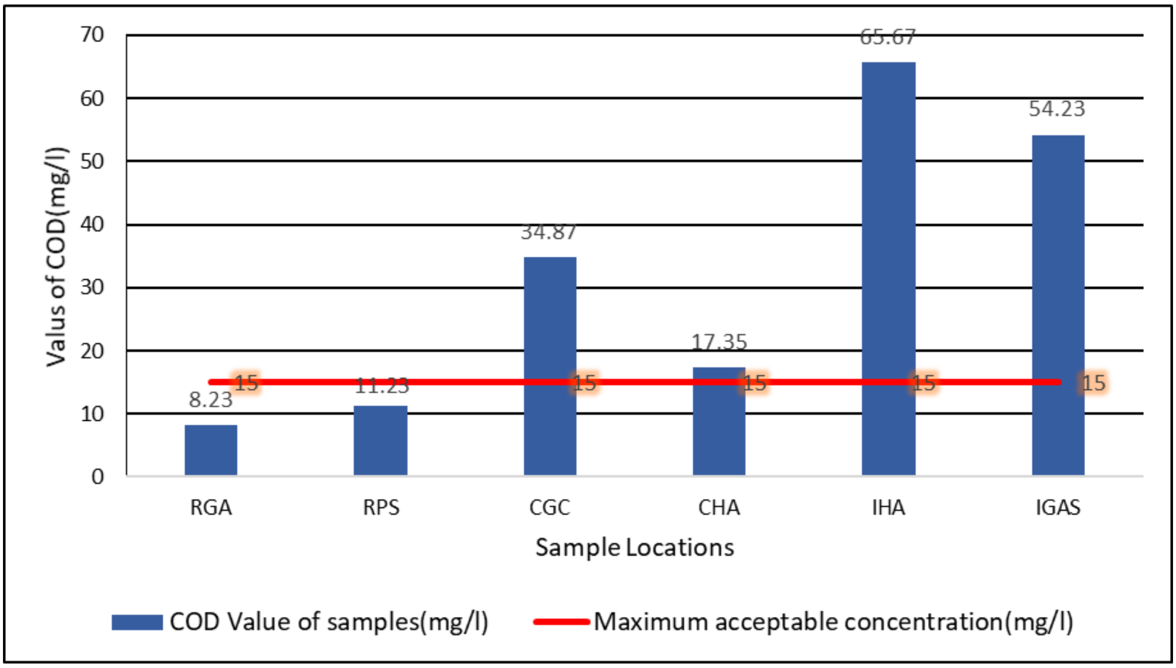


Figure 11: *Sampling locations vs. value of Chemical Oxygen Demand*

As shown in the Table 14 and Figure 15, chemical oxygen demands in commercial and industrial sampling locations exceed the acceptable concentration. Comparatively higher COD values are observed in industrial land use pattern. Because air pollution in industrial land use is high. Hence possibility of deposition of organic matters on roof surface is very high. So COD Vales can be higher than other land use pattern. Lowest COD values in each land use pattern can be observed in residential girl's annex with asbestos. Because air pollution in residential land use is low. Hence possibility of deposition of particulate matters on roof surface is very low. So COD values can be lower than other land use pattern.

4.1.12. Biological Oxygen Demand (mg/l)

Table 11: *Result on Biological Oxygen demand*

Location	Maximum Concentrations (mg/l)	Results of BOD (mg/l)
RGA	8	5.6
RPS	8	4.2
CGC	8	3.9
CHA	8	4.3
IHA	8	4.2
IGAS	8	3.7

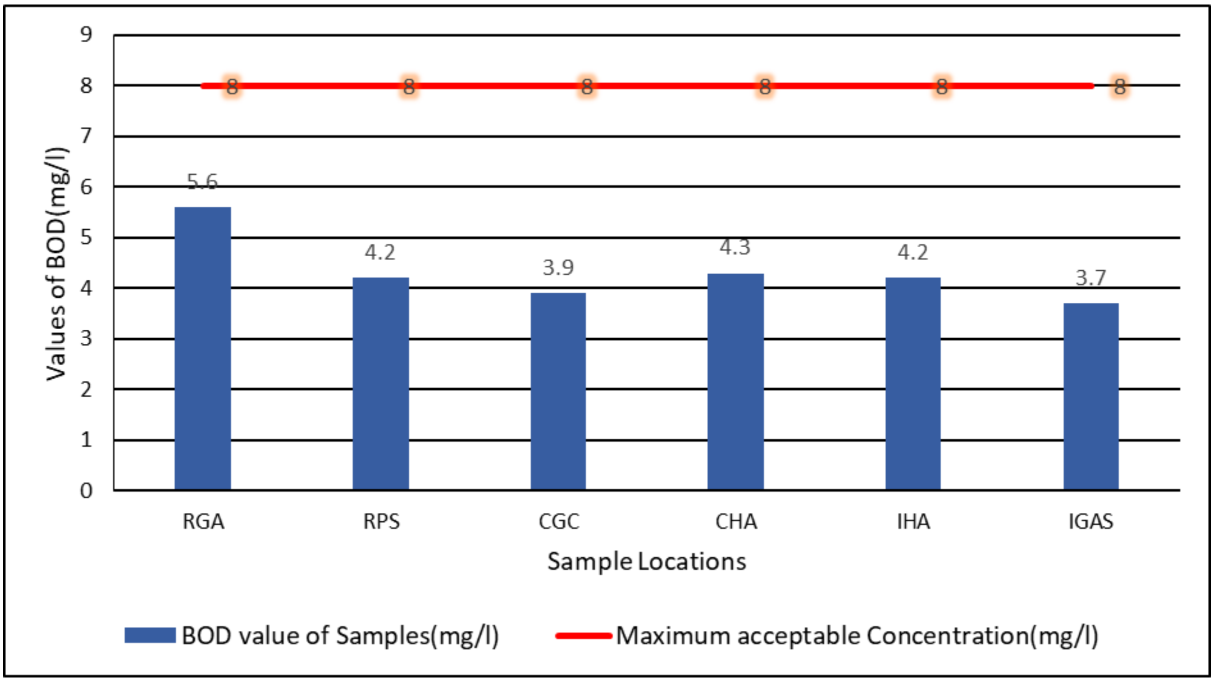


Figure 12: *Sampling locations vs. value of Biological Oxygen demand*

BOD is a measure of the quantity of dissolved oxygen in milligrams per liter necessary for the decomposition of organic matter by microorganisms such as bacteria. Graph of BOD5vs.Sampling (As in Table 15 and Figure 16) locations indicates biological oxygen demands in all locations are lower than the permissible level. Most of time organic matters such as tree leaves and animal dump collect on roof tops, so in each land use pattern BOD values was higher in residential land use pattern. In each land use pattern, higher BOD concentration was observed from roofing material from asbestos. Because asbestos surface was ruff and due to this reason organic matters increased ability to stayed. So BOD values may be higher. There is significant variance with land use pattern and roofing materials. According to above analysis most suitable land use pattern was residential to drink the rain water.

4.1.13. Total Coliform

Table 12: *Mean of result on Total Coliform*

Location	Maximum no of colonies	No of colonies
RGA	<3	00
RPS	<3	242
CGC	<3	00
CHA	<3	00
IHA	<3	00
IGAS	<3	00

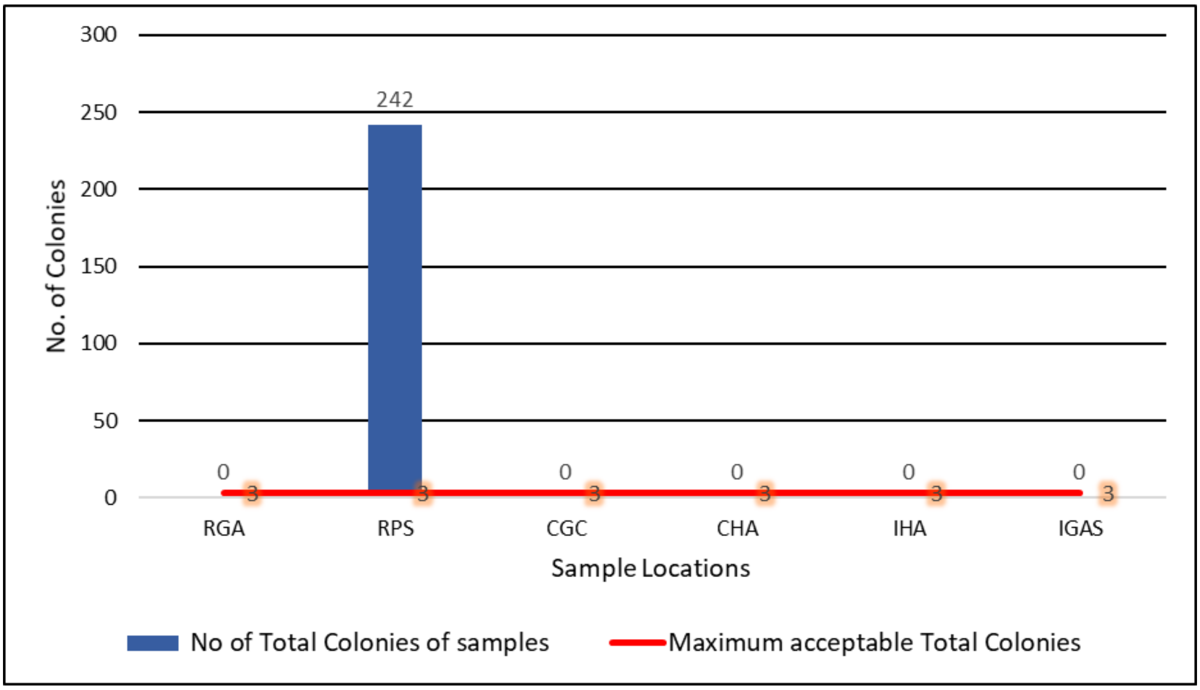


Figure 13: *Sampling locations vs. value of Total Coliform*

The total coliform group is a large collection of different kinds of bacteria. Most coliform bacteria do not cause illness. However, their presence in a water system is a public health concern because of the potential for disease-causing strains of bacteria, viruses, and protozoa to also be present. Waterborne disease from these organisms typically involves flulike symptoms such as nausea, vomiting, fever, and diarrhea.

As shown in the Table 16 and figure 16, total coliform bacteria in residential private house with roofing material slab sampling locations exceed the acceptable total colonies. Because most of time slab in rain water and collected tree leaves and animal dump increased ability to stagnated. So coliform bacteria can be growth. Due to this reason total coliform bacteria was higher in roofing material with slab. There is no significant variance with land use pattern and there is variance with roofing materials. According to above analysis slab was not accepted as a roofing materials to drink the rain water.

4.1.14. E-Coli Bacteria

Table 13: *Result on Total Coliform*

Location	Maximum no of colonies	No of colonies
RGA	00	00
RPS	00	90
CGC	00	00
CHA	00	00
IHA	00	00
IGAS	00	00

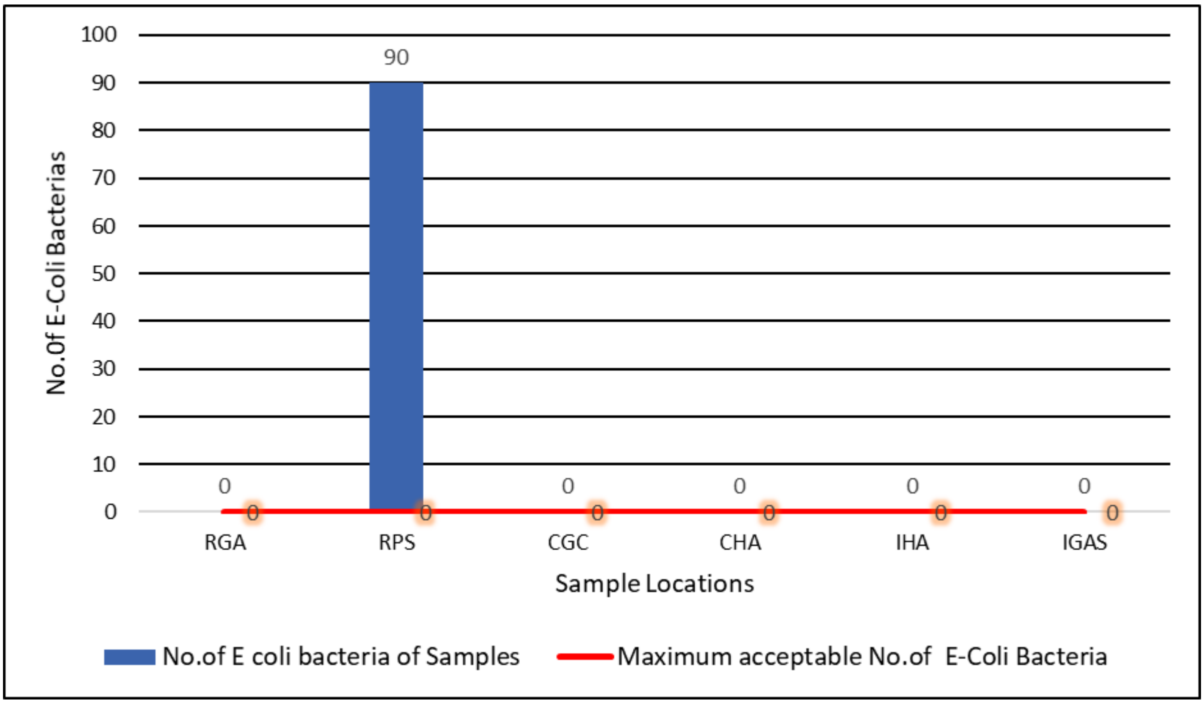


Figure 14: *Sampling locations Vs. E-coli Bacteria*

The E-coli bacteria group is a large collection of different kinds of bacteria. Most E-Coli bacteria do not cause illness. However, their presence in a water system is a public health concern because of the potential for disease-causing strains of bacteria, viruses, and protozoa to also be present. Waterborne disease from these organisms typically involves flulike symptoms such as nausea, vomiting, fever, and diarrhea.

As shown in the Table 17 and Figure 18, E-Coli bacteria in residential private house with roofing material slab sampling locations exceed the acceptable total colonies. Because most of time slab in rain water and collected tree leaves and animal dump increased ability to stagnated. So E-Coli bacteria can be growth same as the total coliform. Due to this reason E-coli bacterium was higher in roofing material with slab. There is no significant variance with land use pattern and there is variance with roofing materials. According to above analysis slab was not accepted as a roofing material to drink the rain water same as the total coliform analysis.

All the results obtained from uni-variate analysis can be summarized into a table that compare tested parameters with sampling locations whether pollutant level is within the acceptable region or not.

Table 18: *Summery of uni-variate analysis*

Land use pattern		Residential		Commercial		Industrial	
Locations	Standard acceptable limits	RGA	RPS	CGC	CHA	IHA	IGAS
Electrical Conductivity	200 µs/cm	A	A	A	A	A	A
Turbidity	2 NTU	A	A	A	A	NA	NA
TDS	200 mg/l	A	A	A	A	A	A
pH	6.5 – 8.5	NA	A	A	NA	NA	NA
TSS	200mg/l	A	A	A	A	A	A
Hardness	250mg/l	A	A	A	A	A	A
Total Alkalinity	200 mg/l	A	A	A	A	A	A
Chloride	200 mg/l	A	A	A	A	A	A
Phosphate	2 mg/l	A	A	A	A	A	A
Ammo. Nitrogen	1.5 mg/l	A	A	NA	NA	NA	NA
COD	15 mg/l	A	A	NA	NA	NA	NA
BOD		A	A	A	A	A	A
Total Coliform	3 colonies	A	NA	A	A	A	A
E-Coli Bacteria	3 colonies	A	NA	A	A	A	A

Note: -Within acceptable level are marked as A
Outside acceptable level are marked as NA

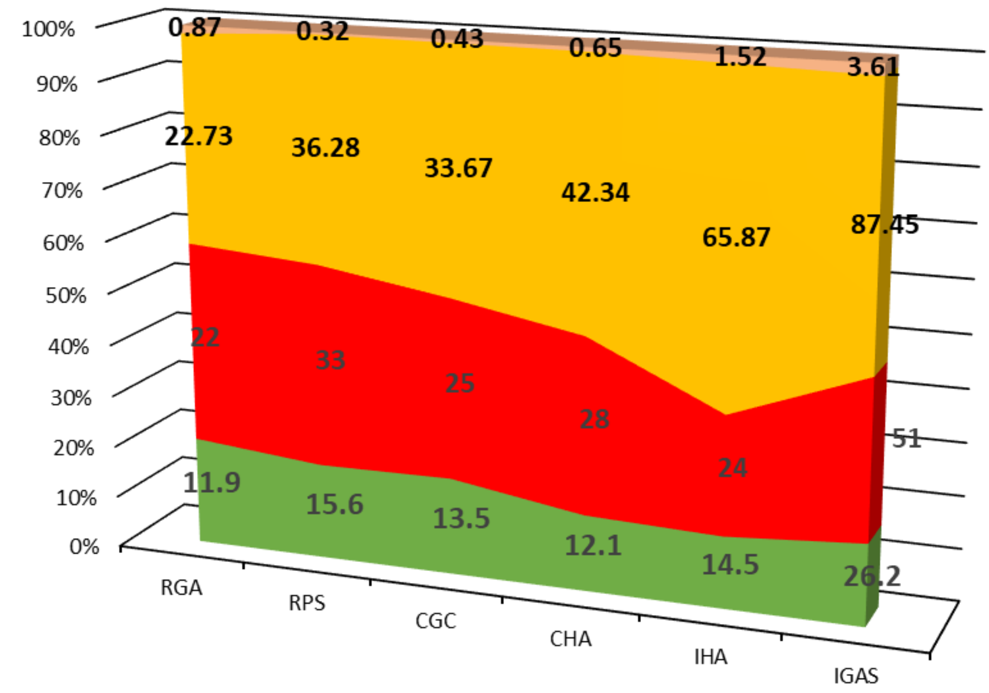
Table 18 shows that most of the pollutant parameters are within the acceptable level except total coliform, E-coli bacteria, chemical oxygen demand, turbidity, PH, ammonias nitrogen. .All the parameters that are not within the acceptable level are independent of the land use pattern whether industrial, commercial or residential.

All the results obtained from uni-variate analysis can be summarized into a table that compare tested parameters with sampling locations whether pollutant level is within the acceptable region or not.

4.2. Multivariate Data Analysis

4.2.1. Sacked Area for physical water quality parameters

To identify the stacked area between water quality parameters and identify the patterns of sampling locations, following results of stacked area analysis are used. That analysis carried out by considering all physical parameters. Furthermore, it has considered each type of parameters individually.



	RGA	RPS	CGC	CHA	IHA	IGAS
Turbidty	0.87	0.32	0.43	0.65	1.52	3.61
EC	22.73	36.28	33.67	42.34	65.87	87.45
TDS	22	33	25	28	24	51
TSS	11.9	15.6	13.5	12.1	14.5	26.2

Figure 15: *For physical parameters in residential, commercial and Industrial land uses*

According to the Figure 19 higher sacked area has been shown in electrical conductivity which is indicated in yellow color and lower sacked area has been shown in turbidity which is indicated in brown color. Under the univariate analysis TSS, TDS, EC, Turbidity has discussed individually. Here this section is discussed how all these physical Parameters is changed in each type of land uses.

Under the residential sampling locations, all physical parameters is higher in private house roofing material with slab compare to residential grocery shop roofing material in asbestos. So possibility of deposition of solid matters on slab surface is very high compare to the asbestos. So solid particles are very high in slab surface. Hence physical parameters values are very high. According to this analysis under the residential land use pattern most suitable location is residential girls annex roofing material in asbestos but other land use type is in acceptable level compare to the physical parameters permissible values.

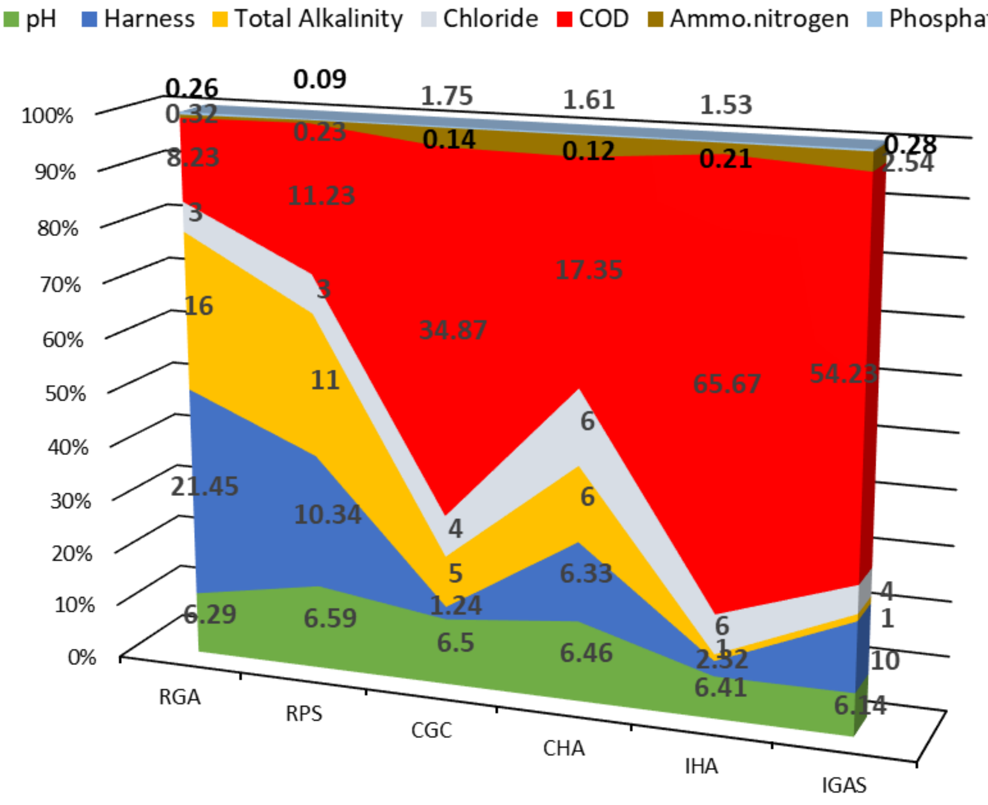
Location with commercial land use type, approximately higher physical parameters have in hardware shop in roofing material with asbestos compare to the grocery shop roofing material with Calicut tile. So possibility of deposition of solid matters on asbestos surface is high compare to the Calicut tile. Because Calicut tile surface is smooth and solid particles is not deposited. Approximately physical parameters are high in commercial land use type compare to the residential. Because air pollution, transportation and main road close to this commercial land use pattern. Hence solid particles can be deposited. According to this analysis under the Commercial land use pattern most suitable location is Commercial grocery shop roofing material in Calicut tile but other land use type is in acceptable level compare to the physical parameters permissible values.

In industrial land use type, there are higher physical parameters values in grocery shop with roofing material in amano sheet. In this sampling location some parameters are not in acceptable level which has discussed in under univariate analysis.

When, consider the overall sampling locations most suitable sampling location is commercial and residential land use type analysis with the physical parameters vales. Because industrial land use has higher air pollution and possibility of retaining of solid on the roof surface is higher due to high wind of the area.

4.2.2. Stacked Area for chemical water quality parameters

To identify the stacked area between water quality parameters and identify the patterns of sampling locations, following results of stacked area analysis are used. That analysis carried out by considering all chemical parameters. Furthermore it has considered each type of parameters individually.



	RGA	RPS	CGC	CHA	IHA	IGAS
Phosphate	0.26	0.09	0.14	0.12	0.21	0.28
Ammo.nitrogen	0.32	0.23	1.75	1.61	1.53	2.54
COD	8.23	11.23	34.87	17.35	65.67	54.23
Chloride	3	3	4	6	6	4
Total Alkalinity	16	11	5	6	1	1
Harness	21.45	10.34	1.24	6.33	2.32	10
pH	6.29	6.59	6.5	6.46	6.41	6.14

Figure 16: *Stacked Area for chemical 100% parameters in residential, commercial and industrial land uses*

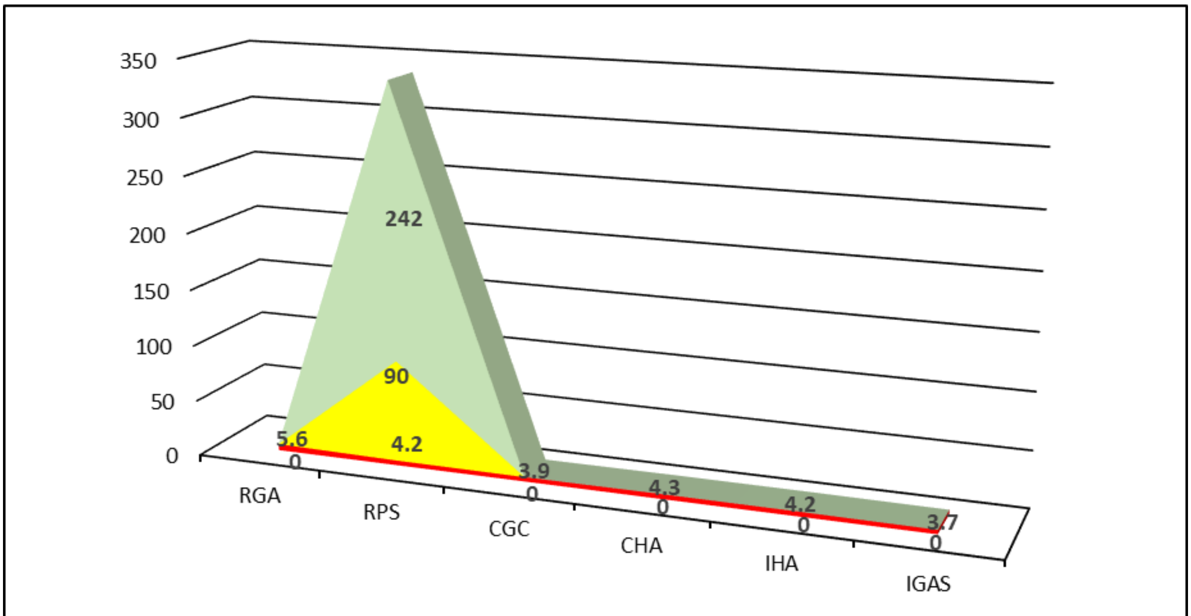
According to the Figure 20 higher stacked area is shown in COD which is indicated in red color and lower stacked area indicates in BOD which is indicated in brown color. Under the univariate analysis phosphate, ammonias nitrogen, BOD, COD, chloride, Total alkalinity, hardness, PH Turbidity has discussed individually. Here this section is discussed how all these physical Parameters is changed in each type of land uses.

When considered separately residential land use and commercial locations, all chemical parameters are in acceptable levels. There is no higher or lower chemical parameters values and also both types of residential land use pattern and commercial land use patterns have medium chemical parameters and those values are matched the permissible values. So roofing materials are not depended in that case. But considered together residential and commercial land use pattern higher chemical parameters is shown in commercial areas. Because air pollution is the higher in commercial area compare to the residential area.

Under the industrial land uses chemical parameters is higher. Among them COD, ammonias nitrogen are not in acceptable chemical parameters level. Because selected industrial area was high dynamic in nature. Transportation, construction and demolition activities are predominant as the industrial activities. Therefore, high possibility to deposition of dust particles, cement particles and other detergents on roof surfaces. Proximity of the industrial area to the shore is higher than the commercial and residential area.

4.2.3. Stacked Area for Biological water quality parameters

To identify the stacked area between water quality parameters and identify the patterns of sampling locations, following results of stacked area analysis are used. That analysis carried out by considering all biological parameters. Furthermore, it has considered each type of parameters individually.



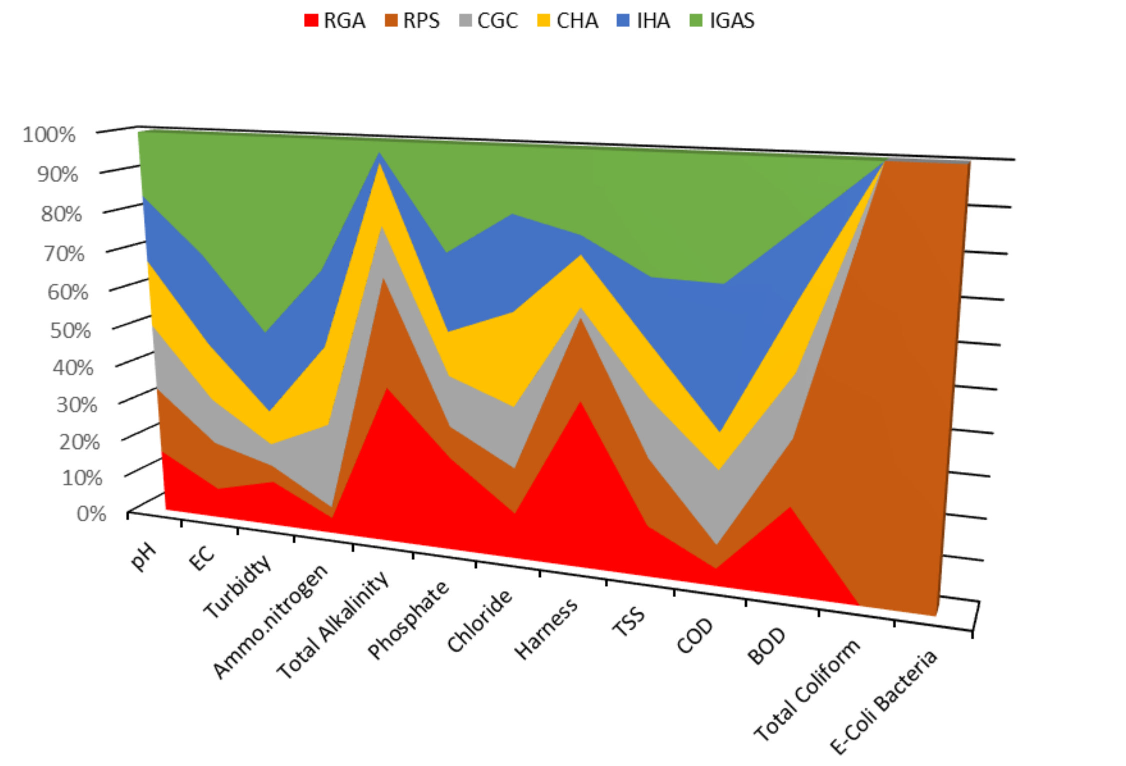
	RGA	RPS	CGC	CHA	IHA	IGAS
Total Coliform	0	242	0	0	0	0
E-Coli Bacteria	0	90	0	0	0	0
BOD	5.6	4.2	3.9	4.3	4.2	3.7

Figure 17: *Stacked area for Biological parameters) in residential, commercial and industrial land uses*

Figure 21 shows that, under the residential area, higher bacteria is in private house roofing material with slab compare to the other land use pattern and roofing materials .The reason of that has discussed in under univariate analysis (4.1.13,4.1.14).

4.2.4 Stacked area for drinking water quality parameters of residential, commercial and industrial land uses

To identify the correlation between water quality parameters and identify the patterns of sampling objects, following results of Principal Component analysis are used. That analysis carried out by considering all physical, chemical and biological parameters. Furthermore it has considered each type of parameters individually.



	pH	EC	Turbidty	Ammo.nitrogen	Total Alkalinity	Phosphate	Chloride	Harness	TSS	COD	BOD	Total Coliform	E-Coli Bacteria
IGAS	6.14	87.45	3.61	2.54	1	0.28	4	10	26.2	54.23	3.7	0	0
IHA	6.41	65.87	1.52	1.53	1	0.21	6	2.32	14.5	65.67	4.2	0	0
CHA	6.46	42.34	0.65	1.61	6	0.12	6	6.33	12.1	17.35	4.3	0	0
CGC	6.5	33.67	0.43	1.75	5	0.14	4	1.24	13.5	34.87	3.9	0	0
RPS	6.59	36.28	0.32	0.23	11	0.09	3	10.34	15.6	11.23	4.2	242	90
RGA	6.29	22.73	0.87	0.32	16	0.26	3	21.45	11.9	8.23	5.6	0	0

Figure 18: *Stacked Area for drinking water parameters of residential, commercial and industrial land uses.*

Under the univariate analysis all the water quality parameters has discussed with all the sampling locations land use patterns. According to the Figure 21, over all sampling location land uses and can be discussed comparing with the all water quality parameters.

As shown as Figure 22 there is no significantly variance of all water quality parameters in Commercial area which is indicated in yellow and ash color. Most of the parameters are in acceptable level with water quality parameters permissible values. But COD and ammonias nitrogen are not in acceptable level in this land use pattern. Over all consider the commercial land use pattern, in this area's rain water can be drunk when analysis the water quality parameters.

Consider the residential land use pattern most of the parameters are in acceptable level comparing with permissible values. But E-coli bacteria and total coliform bacteria exceed the permissible values as used roofing material of slab in residential area. Reason of that under the univariate analysis (4.1.13,4.1.14) has discussed. Overall consider the residential land use type, in this area's rain water can be drunk when analysis water quality parameters. But slab which is used as a roofing material is not suitable for take the rain water to drink.

When, analysis the water quality parameters in industrial land use pattern most of the parameters is not in acceptable comparing with water quality permissible values. Reason for that under the univariate analysis has discussed. Overall consider the land use type commercial and residential land use pattern are suitable for drink the rain water when compared water quality parameters.

5. Conclusion

Urbanization and industrialization leads the deterioration of drinking water quality and availability of safe drinking water sources. Hence, a green concept which includes rainwater harvesting is a must in modern engineering design. Throughout previous chapters in this report explained the variations of water quality parameters with respect to land use patterns and roofing material. Discussion of results may get conflicting due to the difficulty of explaining the processes of pollutant generation and transmission.

Uni-variate and stacked area analysis of results show the possibility of using harvested rainwater as drinking water and relationships between land use patterns and characteristics of sampling locations.
Effect of the land use pattern can be observed through electrical conductivity (EC), turbidity, total suspended solids (TSS), total dissolved solid (TDS), pH, alkalinity, ammonias nitrogen. and chemical oxygen demand (COD) while there is a relationship of roofing material with turbidity, total suspended solids (TSS), total dissolved solid(TDS), hardness, and, total coliform-coli bacteria. Here it should be emphasis that comparing the results only with roofing material is not hundred present valid due to it is a significantly different research area.

Most of the tested parameters such that electrical conductivity, hardness, total alkalinity, chloride, total phosphate, BOD, total suspended solid and total dissolved solid in all land use patterns are within the acceptable level of drinking water quality according to the Sri Lanka's standards and world health organization's standards. Primary water pollutant parameters were identified and discussed in the discussion as Turbidity, PH, Chemical Oxygen Demand, Total coliform and E-coli bacteria.

Due to having some parameters in unacceptable region, definitely there should be a treatment mechanism before consumption without considering land use pattern. Parameters with unacceptable pollutant levels are slightly higher than the desired values and undesired parameters need simple treatment methods like filtration and absorption.

Treatment of rainwater is often simpler than treating water from wells or surface streams. Rainwater for indoor use requires a filtration and disinfection system to remove such things as parasites, bacteria, and virus from bird droppings, as well as insects, and wind-blown materials that are carried onto the roof [RCSH, 2010]

Other than storage tank, there should be a device for removing first flush and the small filtration unit made of sand and active carbon. The filtration unit can be installed before the storage tank or before consumption. According to the literature, installing Perrier to consumption has more benefits like removing insects which fall into the storage tank.

Fine sand filters remove solid partials, hence turbidity also removes automatically. Active carbon filter is advanced biological treatment method; it may remove the excess bacteria from harvested rainwater. Removal of bacteria may reduce COD concentration and final COD value may come to an acceptable level.

References

Ariyananda, T. 2009. Recommendation for improving rainwater quality. In International Rain Water Catchment Systems Conference. New Delhi, India.

Brend, H.D. 1963. Urban water supply condition and needs in seventy five developing countries. World Health Organization, Geneva pp. 9, 10.

Carolina B. Mendez, Brandon J. Klenzendorf, Brigit R. Afshar, Mark T. Simmons, Michael E. Barrett, Kerry A. Kinney, Mary Jo Kirisits. 2011. The effect of roofing material on the quality of harvested rainwater. *Water Res.,* 45(5), pp.2049-59.

Melissa Dobbie, Bronwyn Harch, Robert Packett. 2003. Statistical analysis of the water quality of the Fitzroy River estuary (FE3). Cooperative Research Centre for Coastal Zone Estuary and Waterway Management, Technical Part 10, pp.8,9. Available at: *http://www.ozcoasts.gov.au/pdf/CRC/10-fitzroy_water_qual.pdf* [Accessed 15 December 2012].

Roy M. 2009. Studies on the Quality of Rainwater at Various Land Use Locations and Variations by Interaction with Domestic Rainwater Harvesting Systems. Available at: *http://dyuthi.cusat.ac.in/purl/2123* [Accessed 15 December 12].

Ruth Meinzen-Dick and Paul P. Appasamy. 2000. Urbanization and Intersectional Competition for Water, pp. 2,3.

Rainwater Collection & Harvesting Systems. 2010. The rainwater connection. Available at: *http://www.rainwaterconnection.com* [Accessed 8 December 12].

WHO, Guidelines for drinking water quality, 2nd ed. Vol. 2. Health criteria and other supporting information, World Health Organization, Geneva, 1996.

WHO, Hardness in drinking water, Background document for development of WHO Guidelines for Drinking-water Quality. World Health Organization, Geneva, 2011.

Your drinking water source available from *http://www.epa.gov/region1/eco/drinkwater/your_drinkwater_source.html,* accessed February 27 2012.