Water Quality Assessment of Rainwater Collected from Rooftop at UTM

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Abstract. This paper describes the rainwater quality of rainwater taken at Universiti Teknologi Malaysia. A study was conducted to evaluate the level of quality of rainwater, the relationship with rainfall duration, to determine the presence of heavy metal inside rainwater and determine the potential usage of rainwater. It is reduce the dependence toward tap water to be used as non-potable water such as gardening, agriculture and general cleaning. Rainwater samples were collected six times from February to March of 2016 at six sampling stations. Samples of rainwater are taken from rooftop of building in UTM during 30 minutes of rain duration with interval of 5 minute for each consecutive sample. The determination of rainwater quality was by physicochemical method There are 8 parameters namely pH, (TDS), (BOD), (COD), (NH_3-N), Turbidity, Fe2+ and Zn2+ are tested to determine the quality of rainwater. The results showed that the range of reading for pH 5.84 until pH 7.02, TDS is between 9.10 and 67.4 mg, BOD was 1.43-3.2 mg/L, COD was ranged 1-35 mg/L and the NH_3-Nis 0.02 - 0.88 mg/L. The range of parameter of Turbidity readings were between 6-19 NTU, Fe2+ was ranged 0.01 mg/l and 0.38 mg/L and the Zn2+ is 0.01 - 0.20 mg/L. For the relationship between rainwater quality and the duration, it shown that the quality is improve with the increasing duration of rain. The comparison with Recommended Raw Water Criteria by World Health Organization (WHO) shows that 20 samples exceed the limit which is in COD parameter. To be used as raw water, treatment is needed.

Introduction

Water is one of the important issues our country nowadays. Of all the issues related to water management, governance is considered the most important. Our water tariffs are among the lowest in the world, and most of the resident get the water supply. However, population growth cannot be avoided. In Malaysia, population has increased from 8.1 million in 1960 to 27 million in 2008 [10]. As the population increases, the demand towards clean water will increases as well. As the demand keep increasing, with the limited water resources, eventually the demand will exceed the supply and this will create problems to the country. Thus, the water that is used can be substituted by using alternative water sources such as precipitation.

As an alternative to solve the water crisis in the future, a rainwater harvesting system and its implementation has been proposed as part of the settlement by the government [2]. Malaysia is blessed with adequate water supply because of the rain that falls in large quantities. Typically, the average rainfall is around 2400mm in Peninsular Malaysia, 3830mm in Sabah and 2360 mm in Sarawak throughout the year.

Rainwater is selected as an alternative to reduce the dependent towards the existing water resources because it is natural water that falls from the sky which is precipitate throughout the year especially for country tropical rainforest climate country like Malaysia. Since clean water is important, it is seen as a waste for it to be used for outdoor use, agriculture, gardening, washing the car, and for flushing of toilets. Rainwater can be used as a substitution of the clean by collecting and utilize it rather than let it go to waste. By using rainwater as an alternative, clean water can be saved and be used for other purposes and simultaneously decrease the demand of clean water which will resulted in lower cost of water bill and cost of operation in the water plants. It can seriously reduce the dependent for the treated water.

The objective of this study is to determine the quality of rainwater collected from the roof of the building. This study also to establish the relationship of rainfall duration and the effect towards quality of rainwater. This study also to determine the presence of heavy metal in harvested rainwater from roof which is Iron (II) (Fe^{2+}) and Zinc (II) (Zn^{2+}).This study also to determine the suitability of rainwater for the domestic usage with references to standard set by WHO which is Recommended Raw Water Quality Criteria.

The scope of this study encompasses research on rainwater where the experiment was conducted to gauge the quality of rainwater. The activities of rainwater harvesting is carried out in the vicinity of residential students at Universiti Teknologi Malaysia (UTM). 6 selected places are Kolej 10, Kolej Tun Hussein Onn, Kolej Tun Razak, Kolej Tun Dr. Ismail, Block C07, and Kolej Tunku Canselor. 6 samples taken within the 30 minute duration with interval of 5 minutes for each station. All the experiments conducted in the laboratory. The parameters involved in this study were pH, total dissolved solids (TDS), turbidity, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3-N), iron (Fe^{2+}), and Zinc (Zn^{2+}).

Previous Studies

When dealing with rainwater applications, there are two important aspects that must be taken into account which is the water quality requirements and potential uses. The quality standards are usually determine according to the potential uses of the water, particularly with regard to the analysis of potential health risks. This means that a specific water source will require a specific level of treatment, depending on the potential use. Therefore it is really important to know the initial quality of each water resource, in order to evaluate potential uses, and to determine the required level of treatment, the appropriate storage and the system requirements regarding on the distribution. Due to the importance of collected rainwater especially towards sustainable future, rainwater harvesting and its quality are the focal point of on-going research. For example, a study by Yaziz [12] concluded that there were significant variation in the concentration of pollutant considering faecal coliform and total coliform of water sample collected from tile roof and galvanised iron roof. Additionally, it was found that the concentration of various pollutant were lower in the later spill of rainfall compared to early spill. Jiries [7] determined the metallic content and inorganic constituent were detected during the low rainfall. However, high level of copper and lead were recorded which might be caused by traffic pollution.

An investigation of rainwater quality found that there is relationship between rainwater quality and the intensity of rainfall. Values of pollutant (Chemical Oxygen Demand, Biochemical Oxygen Demand, Nitrate and Phosphate) were found to be higher during a moderate rainfall, while in sample taken during a heavy rain, the component found to be less concentrated, as the rain flush away the contaminant [11]. Other studies showed that the location of sampling point, industrial, urban or agricultural activities have significant effect on chemical composition of harvested rainwater. Zunckel [13] found that there is strong relationship between the present of contaminant in the catchment area and rainwater quality. A correlation between nitrate and ammonium is mainly contributed from trees, livestock and fertiliser used in that area.

A research on rainwater quality found that relationship between rainwater quality and period of rain. The values of parameter which are DO, BOD, COD, NH_3-N, Total Coliform and E. coli showing a high concentration of pollutant at the early duration of the rain. The concentration of pollutant is decreasing when the duration of the rain is increasing as the rain flush away the contaminant on the roof [6].

Methodology

In Study Area

The selected location of the research is the rooftop of residential college in Universiti Teknologi Malaysia. Identification of the study location was the vital parts in this study. The details of the study area are as follows:

Table 1: Sampling area description

Sample	Research Area	Coordinate	Description
Station 1	Kolej Tun Hussein Onn (L35)	1°33’46.0”N 103°37’48.2”E	Urban environment (some trees nearby). Near road with high traffic density
Station 2	Kolej 10	1°33’36.0”N 103°39’00.5”E	Surrounded by trees. A few trees branches overhanging the roof
Station 3	Block C07	1°33’40”N 103°38’11.8”E	Urban environment (some trees nearby). Near road with high traffic density.
Station 4	Kolej Tunku Canselor	1°33’17.7”N 103°38’41.2”E	Urban environment (no trees nearby)
Station 5	Kolej Tun Dr Ismail	1°34’00.5”N 103°37’48.2”E	Urban environment (no trees nearby).
Station 6	Kolej Tun Razak	1°33’37.2”N 103°37’38.6”E	Urban environment (no trees nearby)

Data Collection and Analysis

36 samples were taken from the 6 sampling station. 6 samples taken within the 30 minute duration with interval of 5 minutes of each station. Sample were taken and analyzed for quality parameter. The parameters involved in this study were pH, total dissolved solids (TDS), turbidity, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH3-N), iron (Fe2+), and Zinc (Zn2+).In addition, these samples were tested for contamination using physicochemical method at environment laboratories at UTM according to standard method for water examination by American Public Health Association [1]. The determination of this parameter TDS, COD, NH_3-N, Fe^{2+} and Zn^{2+} was carried out using the spectrometer(HACH DR6000) as described in standard method [1]. While, turbidity was measured using Turbidimeter.

Results of analysis were further compared with recommended raw water criteria by World Health Organization (WHO). In the addition to the assessment of water quality, this study investigated the relationship between rainwater qualities with the duration of rain and the presence of metal. This comparison will determine the suitability of the harvested rainwater either fit or not to be used as raw water.

Result and Discussion

Water Quality Of Collected Rainwater

Table 2 illustrates the average value of measured parameter to evaluate the suitability for non-potable purpose. In regard of pH, TDS, COD, BOD, Turbidity, Fe2+ and Zn2+ parameter, all samples comply with recommended raw water criteria set by WHO. While parameter COD, 20 samples exceed the limit of raw water.

Table 2: Rainwater quality analysis of parameter involved

Parameter	Unit	Station 1	Station 2	Station 3	Station 4	Station5	Station 6
pH	-	6.6 - 7.0	5.8 - 6.9	6.2 - 6.9	6.5 - 6.7	6.5 - 6.9	6.4 - 6.8
TDS	mg/L	26.0 - 50.7	29.9 - 46.2	45.3 - 67.4	13.5 - 15.6	18.9 - 38.4	9.1 - 16.3
BOD	mg/L	2.2 - 3.2	2.1 - 3.1	1.7 - 3.0	1.7 - 2.1	1.4 - 2.1	1.8 - 2.3
COD	mg/L	7.0 - 33.0	9.0 - 32.0	8.0 - 29.0	6.0 - 35.0	8.0 - 16.0	4.0 - 22.0
NH_3-N	mg/L	0.14 - 0.65	0.27 - 0.88	0.23 - 0.54	0.03 - 0.49	0.02 - 0.31	0.06 - 0.51
Turbidity	NTU	15.0 - 18.0	11.1 - 19.2	11.0 - 18.1	7.7 - 11.7	8.4 - 12.1	6.3 - 12.6
Fe2+	mg/L	0.02 - 0.27	0.01 - 0.19	0.09 - 0.28	0.00 - 0.11	0.01 - 0.12	0.01 - 0.08
Zn2+	mg/L	0.01 - 0.12	0.03 - 0.18	0.01 - 0.20	0.02 - 0.07	0.02 - 0.07	0.01 - 0.08

Table 3: Suitability of collected water for raw water

Parameter	Unit	Min	Max	Average	Recommended raw water criteria by WHO
pH	-	5.84	7.02	6.62	5.5 - 9.0
TDS	mg/L	9.1	67.4	30.2	1500
BOD	mg/L	1.4	3.2	2.2	6.0
COD	mg/L	4.0	35.0	15.1	10
NH_3-N	mg/L	0.02	0.90	0.30	1.50
Turbidity	NTU	6	19	13	1000
Fe^{2+}	mg/L	0.01	0.4	0.1	1.0
Zn^{2+}	mg/L	0.01	0.2	0.05	3.0

Relationship between rainwater quality and rainfall duration

pH. Figure 1 shows a relationship between pH of rainwater and during the rainy period (minutes). From the figure, it observed that the pH readings for rainwater were between pH 5.84 until pH 7.02. pH readings recorded minimum at 5 minutes which is from station 2. That means rainwater collected from roof was acidic to neutral along the duration.

From Figure 1, it can observe that the value of pH is increasing to normal value as the increase of duration of rain. Rainwater that fall through is a little bit acidic because the CO_2 in the atmosphere and of the emission of gasses from vehicle. The changes of pH also happen because rainwater that fall through the roof system was mix in with leaves, dust and bird dung. These depositions of particulates were contributing tothe differences in pH [8]. Water with pH less than recommended criteria may bring bad effect to users such as corrosion of steel when used to wash vehicle. Acidic water also not good towards vegetation if used in agriculture [6].

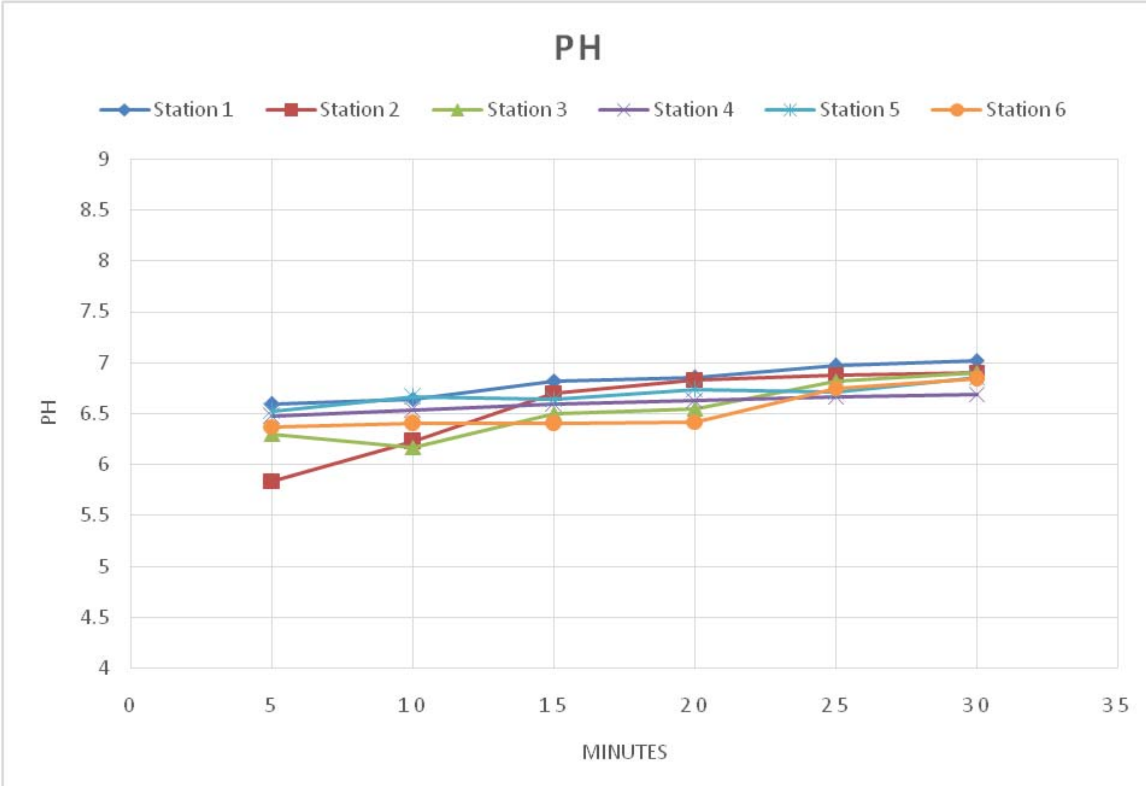

Figure 1: pH of rainwater and during the rainy period (minutes)

Total Dissolved Solids. Total dissolved solid readings during the period of sampling (minutes) are shown in Figure 2. The average value of TDS is 30.21 mg/L with a reading range between 9.10 and 67.4 mg/L. Minimum reading of 9.1 mg/L was recorded in minutes to 30 minutes at station 6 while the maximum is 15 minutes of 67.0 mg / L at Station 3. From the graph, it can be said that TDS is decreasing along with the increase of the rain.

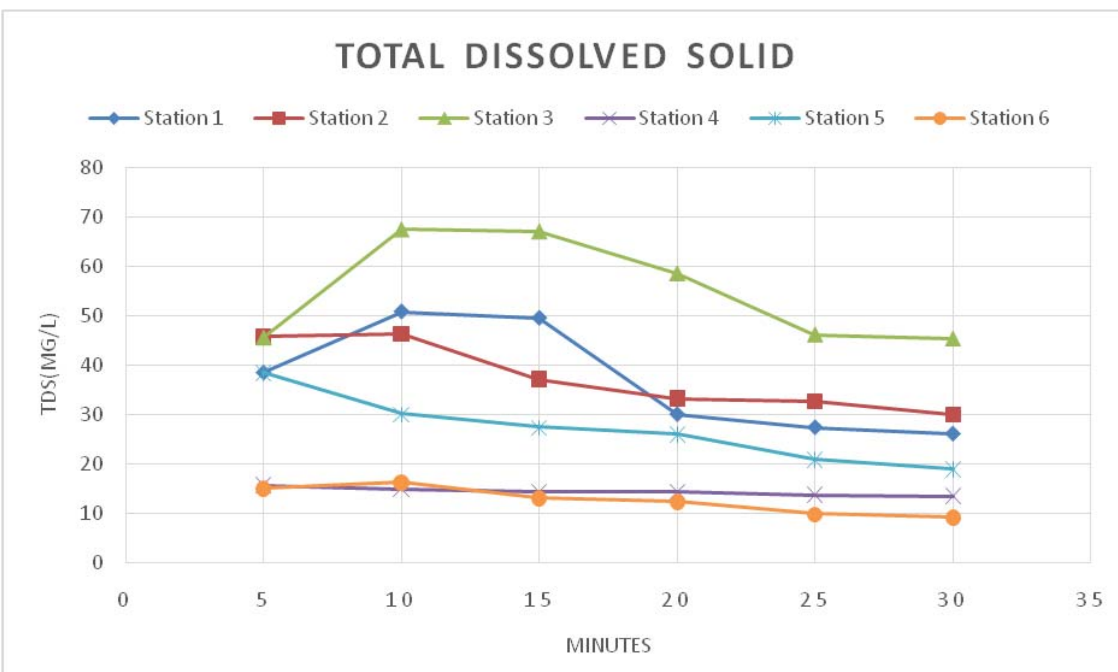

Figure 2**:** Total dissolved solid readings during the period of sampling (minutes)

Total Dissolved Solids in rainwater are caused by natural environmental features such carbonate deposits, salt deposits that happen on the roof. Pollutant such as leaves, animal dung and dust also sources of salt deposited on the roof. It is possible that pollutants such as sulphur and nitrogen oxide from the air dissolve into the rain [4].

Differences that occur between each minute is due to the intensity of the rain. Solids and dusts that is deposited on the roof was flush off in the early minutes of rain. 'Flush off' effect of the rain has cleared the contaminant on the roof of the building. Hence, the reading is decreasing with the increase of rain duration [9].

Biochemical Oxygen Demand. Figure 3 shows the concentrations (BOD) in mg/L of rain water collected during the period of rain (minutes). The average value of BOD concentration obtained from this study was 2.2 mg/L. This value does not to exceed the value set by WHO for recommended raw water which is 6.0 mg/L. High BOD requirement stated in minute 10 at station 1 which is 3.2 mg/L. The lowest values of BOD stated by station 5 in minute 30 at values of 1.43. From the figure, as the time is increase, the value of BOD is decreased.

Microorganisms such as bacteria are responsible for decomposing organic waste. When organic matter such as dead plants, leaves, manure, sewage, or even food waste is present in water, the bacteria will begin to break down this waste. When this happens, the dissolved oxygen in water is consumed by aerobic bacteria. During the decomposition of activities, high amount of dissolved oxygen will be used. The rainfall intensity is one of the major contributors towards the decreasing amount of BOD. As rainy periods are increased, it fills flush the contaminant on the roof, hence decreasing the value of BOD along the rain periods [6].

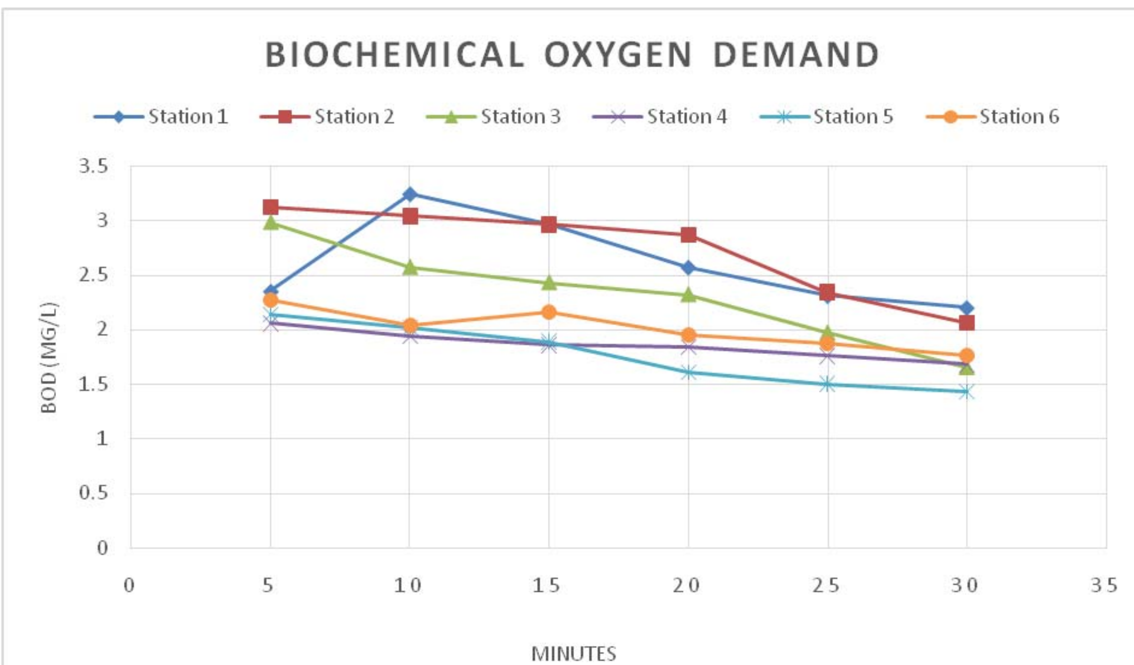

Figure 3: The concentrations (BOD) in mg / L of rain water collected during the period of sampling (minutes)

Chemical Oxygen Demand. Figure 4 shows the concentration of COD of rain water collected in the study. COD concentration reading range is between 1.0 mg/L and 35.0 mg/L. The maximum limit values of raw water standards set by the WHO is 10.0 mg/L. The study found the average reading COD in water in the study area is high which 15.083 mg / L. The maximum COD reading which are in the 5th minute at station 4 which is 34, while the minimum at minute 30 at station which is at 4 mg/L. This showing that the first spill contains high contaminant compared to the later spill. As time increasing, the value of the COD is decreasing.

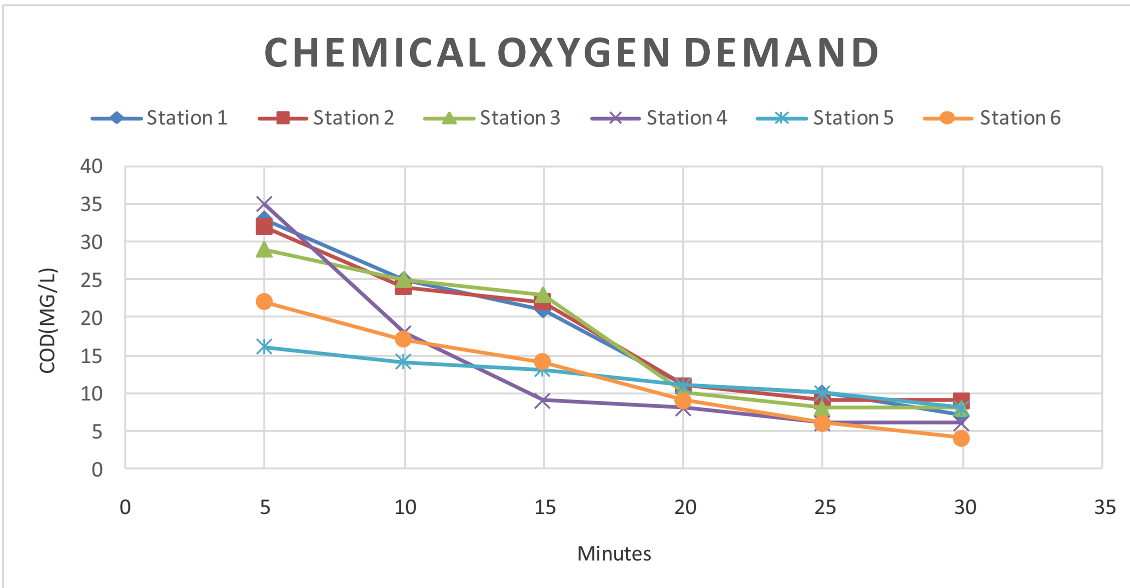

Figure 4: The concentrations (BOD) in mg/L of rain water collected during the period of sampling (minutes)

At the early interval, the reading of the COD is high. This is because of high amount of contaminant existed on the roof. Contaminant in the air such as lead and plumbum from vehicles also trap on the roof when it is carried by wind. Moss, dust and bird droppings are cleaned at earlier duration of raining. As the rain intensity is increase, it will clean the roof as the water flush away the contaminant on the roof. Hence, the concentration of the COD decreases along the increase of time. COD are increase due to the wide variety of organic materials that are chemically oxidized at the rooftop [3].To maximize usage of rainwater as raw water, treatment should be carried out since earlier duration of rain, the high value of COD is recorded.

Ammoniacal Nitrogen (NH_3-N). Figure 5 shows the readings of NH_3-N water during the rainy period (minutes). Average NH_3-N content in the samples of rain water is 0.3 mg/L. Minimum value NH_3-N content obtained at station 5 which is 0.02 mg/L, while the maximum NH_3-N is 0.88 mg / L recorded at station 2.

Differences in the composition are caused by several factors, principally by the amount of rainfall, nearness to the trees, and dust from the atmosphere. Referring to Figure 5, NH_3-N concentration is high at the interval 5 minutes to 10 minutes. This is caused by organic substances that are exist on the roof. Based on observation, the earliest minute intervals, concentration of NH_3-N was high while the final-minute intervals, the NH_3-N concentration decreased. This is due to the flushing of ammonia along with rain water. Ammonia and nitrate are originated from surrounding such as livestock and fertilizer and are in particles of organic matter in dust and in soils [13].

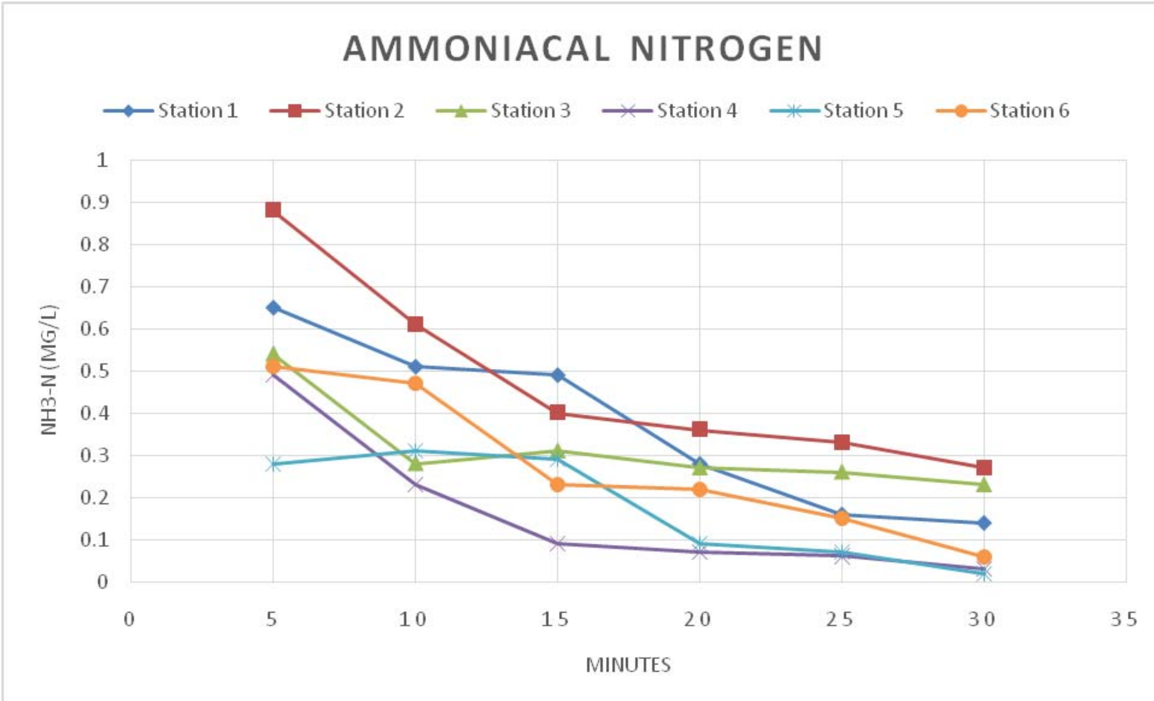

Figure 5: The readings of NH_3-N water during the rainy period (minutes)

Turbidity. Figure 6 shows the turbidity of rainwater during the rainy period (minutes). The average reading for turbidity for all station was 13 NTU. Turbidity reading range is between 6 NTU and 19 NTU. The reading was the lowest in minute 30 at station 6, while the highest reading is the minute 5 at the station 2.

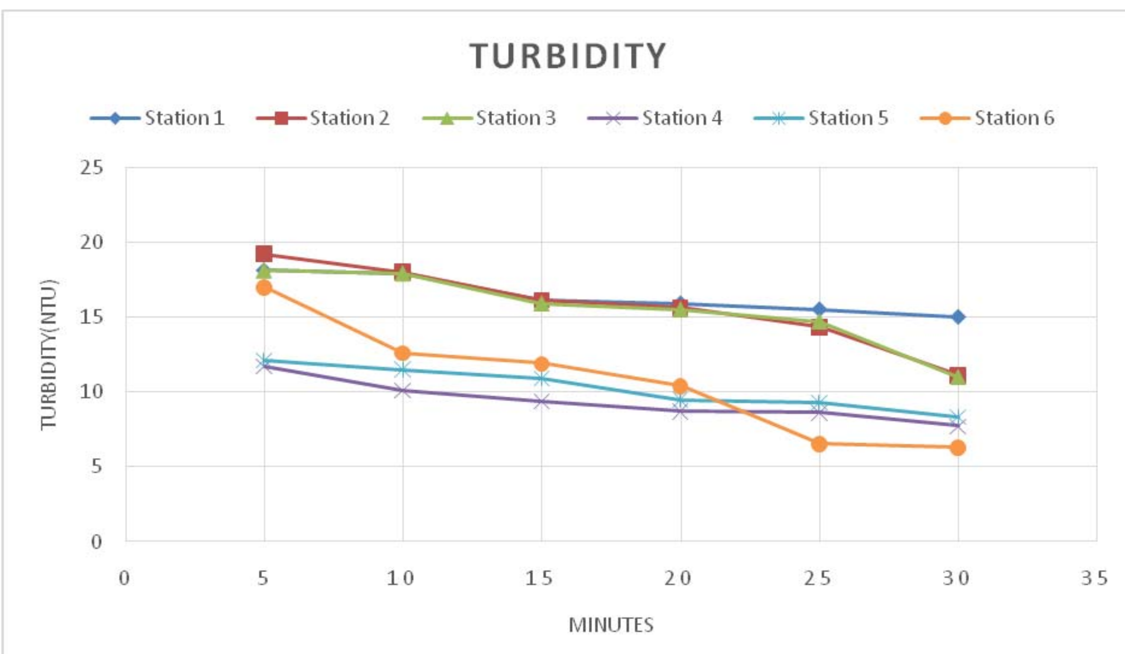

Figure 6: Turbidity readings of all station during rainy periods (minutes)

Turbidity is caused by particles exist in water and measured relative to the water clarity. Material that becomes mixed and suspended in the rainwater will reduce its clarity and make the water turbid. The increase in the turbidity of rainwater is due to more suspended and dust particles in it. The cloudiness of the rainwater is influenced by the dust, leaves, and mosses that accumulate at the roof and gutter. The value of turbidity is high at the early duration of rain is because rainwater flushes away the contaminant away from the roof. As the duration of rain is increased it will flush away the particle, hence the turbidity is decreasing as the rain duration is increased.

Presence of metal in rainwater

Iron (II) (Fe2+). Figures 7 show the relationship between the iron contents in rainwater (mg/L) during the rainy period (minutes). Fe^{2+} concentration reading range is between 0.01 mg/l and 0.38 mg/l. The reading was the lowest in minute 30 which is zero reading at station 4, while the highest reading is the minute 5 at station. Fe^{2+} concentration at all station show a decreasing trend as the duration of rainfall increases.

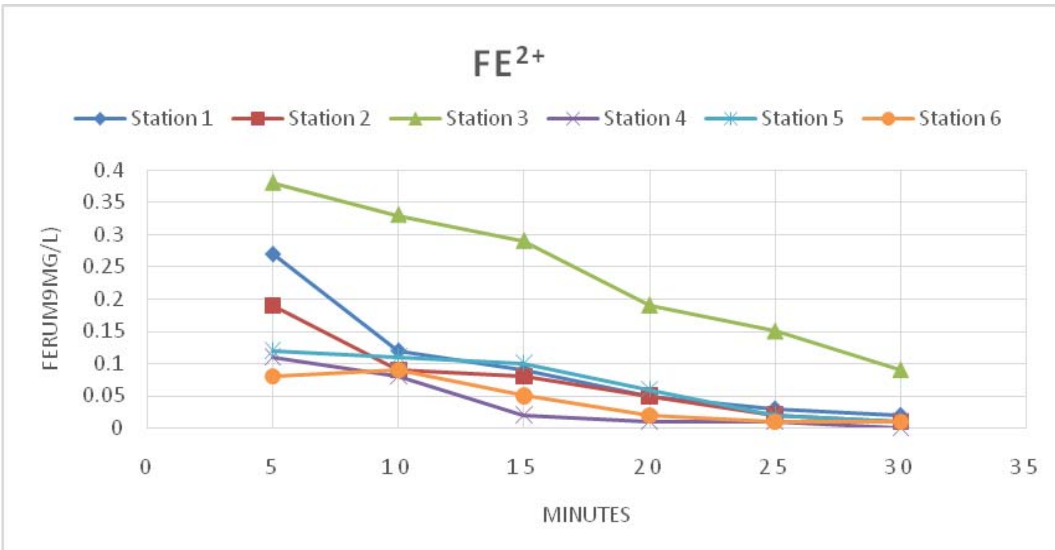

Figure 7: Fe2+ concentration readings during rainy periods (minutes)

Some of the buildings are using galvanized iron as the connection of the roof, gutter and the downpipe. The present of Fe^{2+} in the rainwater is due to rusting of gutter and downpipe. The higher the corrosion of the gutter and downpipe, the large number of Fe^{2+} concentration will get. As the duration of the rain is increase, it will flush away the corrosion from the roof system. Hence, the concentration of the Fe^{2+} is decreased and led to increase in the quality of rainwater.

Zinc. Figure 8 show relationships between concentrations of Zn^{2+} in rainwater and the raining period (minutes). The average value of the Zn^{2+} concentration was 0.05. 0.20 mg/L was the highest number of Zn^{2+}taken at station 3 during the 10 minutes of the rainfall. The least value recorded was 0.01mg/l taken from station 1, station 3 and station 6 at the last minute of the rain. Based from the overall value in the graph, the concentration of zinc in this study is decreasing with the increase in the time.

A phenomenon of zinc occurs in rainwater was almost similar to ferum. It is influence by the material of the roof. As it is exposed to the atmosphere, with changes of weather, it will lead towards the corrosion of the material. Rainwater runoff will flush away the metal deposited on the roof. As the intensity of the rain is increase, the quality of the rainwater is increase as the zinc is taken away by the earlier rainfall.

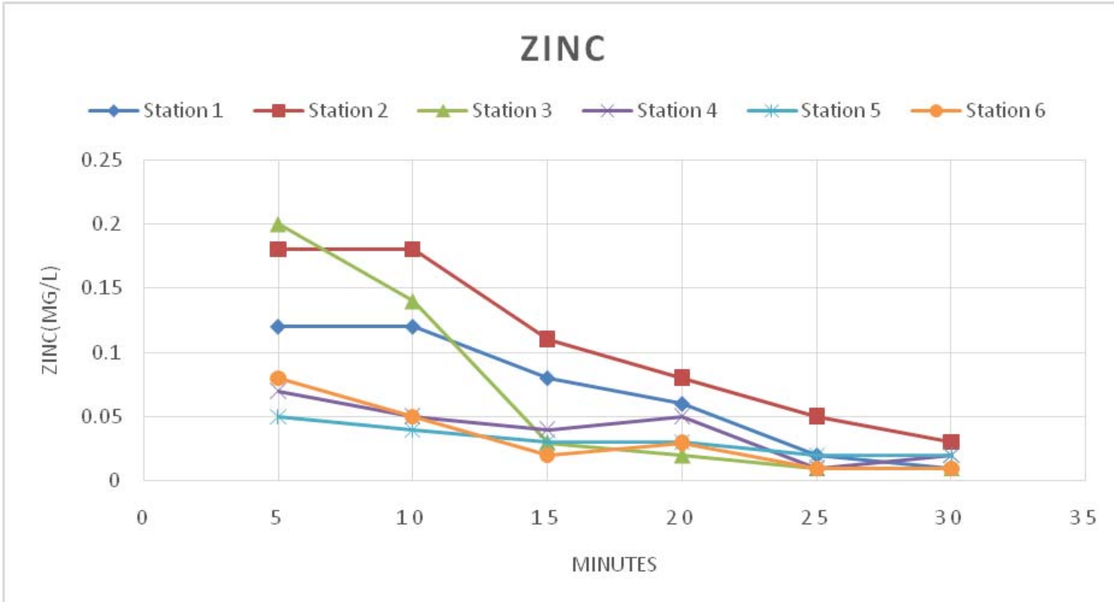

Figure 8: Zinc concentration readings during rainy periods (minutes)

Conclusion

In regard of pH, TDS, COD, BOD, Turbidity, all sample comply with recommended raw water criteria set by WHO. While parameter COD, 20 sample exceed the limit of raw water. The COD parameter only obey the limit after 20 minutes of rain duration. This shows that treatment is needed. Water from rooftop can be used as non- potable usage such as car washing, gardening and many more. To maximize the usage of the rainwater, a rainwater harvesting with proper treatment such as filtration and first flush diversion in the system. For the relationship of the rainwater quality and the rainfall duration, it can be conclude that the quality of the rooftop-harvested rainwater generally increased with the rainfall, as contaminant is flush away from the roof by the rainwater. This indicated that the importance the needs of an effective first-flush rainwater diverter. For a better quality of collected rainwater, treatment should be carried out to maximize the usage of rainwater since during late duration of rain have better quality. For the objective to determine the presence of heavy metal in the rainwater. Only 1 sample does not shows the presence of metal in the rainwater. The highest value of 0.28 mg/l for Fe^{2+} and 0.19 for Zn^{2+}. However, all this value are obeys the limits of raw water criteria by WHO. Hence, it still fit to be used as non-potable water.

For the conclusion, it can be said that rainwater can be used as the raw water with treatment needed. Rainwater harvesting should be carried out by any parties in effort to maximize the sustainable development. The effectiveness of this method and information about the quality of water need to be upgraded from time to time. Here is a proposal that should be taken into account for the purposes of further research and the effectiveness of these methods:

i) The duration of the sampling should be increase to improve the findings of the rainwater quality.
ii) Do the sampling at housing, commercial area, industrial and village to determine another factor that influence the rainwater quality, such as air pollution factors
iii) Study the effect of different type of roof material towards the rainwater quality.
iv) Study the relationship between rainwater quality and the dry period.

As we are moving forward in developing a green development, there are few steps that must be taken. One of the challenges is saving water. Water is precious and therefore should be appreciated. Alternative methods have to be applied in order to save the water. One of the methods is by applying rainwater harvesting. To implement the system, system need to be done effectively. Here is the suggestion:

a) Ensure that the material selection for gutter, downpipe and tank are not easily corrode such as PVC.
b) For the system, the first flush diverter need to be design to flow away the contaminant into the drain since the early period if rain is highly contaminated.
c) Insert a gutter trap to prevent the leaves and dust from entering the tank.
d) Do the rainwater quality assessment from time to time to monitor the effectiveness of the system

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