STUDY ON QUALITY AND NEUTRALIZATION OF RAINWATER

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ABSTRACT

This thesis has discussed about the quality and neutralization of rainwater samples from Semenyih in Selangor and also Gambang area in Pahang. The rainwater samples were compared based on their physicochemical characteristics and neutralization factor in both areas. The physicochemical parameters that were conducted included pH, temperature, biochemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, total suspended solid (TSS), total dissolves solid (TDS), electric conductivity, turbidity, selected heavy metal concentration and ionic concentration. The objectives of the study were to determine the physicochemical characteristics of the rainwater in the study area and also to investigate the neutralization potential of the rainwater for agricultural and domestic purposes. The used method for all the physicochemical parameters was according to the APHA and HACH standard. Based on the result taken, the pH value of the rainwater that obtained from Semenyih area showed that it was 4.24 and 4.40 which indicates as acidic rain (pH<5.6) based on two samples taken. The concentration of Ca^{2+} ranged from 0.10 to 0.13 mg/L while for the concentration of Mg^{2+} varied from 1.26 to 1.44 mg/L. The electrical conductivity varied from 122 to 338 μ^5/cm while the total hardness ranged from 1.36 to 1.57 mg/L $CaCO_3$. For the rainwater at Gambang area, the pH was 8.50 and 8.63 which was considered as alkaline rain by considering 5.6 as the neutral pH of cloud water with atmospheric CO_2 equilibrium. The concentration of Ca^{2+} varied from 1.09 to 1.48 mg/L while for the concentration of Mg^{2+} ranged from 0.59 to 1.96 mg/L. The electrical conductivity varied from 239 to 325 μ^5/cm while the total hardness ranged from 2.07 to 3.05 mg/L CaCO3. From the results it also showed that Semenyih area major neutralization factor was on NH_4^+ that caused by NH_3 emission at agricultural (urea application) activities and intensive animal production facilities while for the Gambang area, Ca^{2+} was the major neutralizing agent that might be caused by the dust-rich local and surrounding limestone environment. For the future research, it is recommended that the research should be conducted at least ten days and the number of samples that should be taken must be more than five at each location so that a more accurate readings and conclusion could be made based on the extra results that have been taken.

ABSTRAK

Tesis ini telah membincangkan mengenai kualiti dan peneutralan sampel air hujan dari Semenyih di Selangor dan juga kawasan Gambang di Pahang. Sampel air hujan dibandingkan berdasarkan ciri-ciri fizikokimia mereka dan faktor peneutralan di kedua-dua kawasan. Parameter fizikokimia yang dijalankan ialah pH, suhu, permintaan oksigen biokimia (BOD), permintaan oksigen kimia (COD), kekerasan, jumlah pepejal terampai (TSS), jumlah pepejal larut (TDS), kekonduksian elektrik, kekeruhan, kepekatan logam berat terpilih dan kepekatan ion. Objektif kajian ini adalah untuk menentukan ciri-ciri fizikokimia air hujan di kawasan kajian dan juga untuk menyiasat potensi peneutralan daripada air hujan untuk tujuan pertanian dan domestik. Kaedah yang digunakan untuk semua parameter fizikokimia adalah mengikut APHA dan HACH standard. Berdasarkan keputusan yang diambil, nilai pH air hujan yang diperolehi dari kawasan Semenyih menunjukkan bahawa ia adalah 4.24 dan 4.40 yang menunjukkan hujan sebagai berasid (pH <5.6) berdasarkan dua sampel yang diambil. Kepekatan Ca^{2+} antara 0.10-0.13 mg / l manakala bagi kepekatan Mg^{2+} pelbagai 1.26-1.44 mg/L. Kekonduksian elektrik diubah 122-338 μ^5/cm manakala jumlah kekerasan antara 1,36-1,57 mg/L $CaCO_3$. Untuk air hujan di kawasan Gambang, pH adalah 8.50 dan 8.63 yang dianggap sebagai hujan alkali dengan mempertimbangkan 5.6 pH neutral air awan dengan atmosfera keseimbangan CO_2. Kepekatan Ca^{2+} pelbagai 1.09-1.48 mg/L manakala bagi kepekatan Mg^{2+} adalah antara 0.59-1.96 mg/L. Kekonduksian elektrik diubah 239-325 μ^5/cm manakala jumlah kekerasan antara 2.07-3.05 mg/L $CaCO_3$. Dari keputusan itu juga menunjukkan bahawa kawasan Semenyih faktor peneutralan utama adalah pada NH_4^+ yang disebabkan oleh pelepasan NH3 pada aktiviti pertanian (permohonan urea) dan kemudahan pengeluaran haiwan intensif manakala bagi kawasan Gambang ini, Ca^{2+} adalah ejen meneutralkan utama yang mungkin disebabkan oleh persekitaran batu kapur tempatan dan sekitarnya debu yang kaya. Bagi kajian akan datang, adalah disyorkan bahawa kajian perlu dijalankan sekurang-kurangnya sepuluh hari dan bilangan sampel yang perlu diambil mesti lebih daripada lima di setiap lokasi supaya bacaan yang lebih tepat dan kesimpulan yang boleh dibuat berdasarkan kepada tambahan keputusan yang telah diambil.

TABLE OF CONTENTS

CHAPTER 3 METHODOLOGY

CHAPTER 4 RESULTS AND DISCUSSION

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

°C	Celsius
μ^5/cm	micro to the power of 5 per centimeter
mg/L	milligram per litre
NTU	Nephelometric Turbidity Units

LIST OF ABBREVIATIONS

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
Ca	Calcium
Ca^{2+}	Calcium Ion
$CaCO_3$	Calcium Carbonate
Cd	Cadmium
Cl^-	Chlorine Ion
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
E	East
F^-	Fluoride Ion
Fe	Iron
H^+	Hydrogen Ion
HCl	Hydrochloric Acid
HCO_3^-	Bicarbonate Ion
H_2SO_4	Sulfuric Acid
K	Potassium
K^+	Potassium Ion
Mg	Magnesium
Mg^{2+}	Magnesium Ion
Mn	Manganese
N	North
Na	Sodium
NaOH	Sodium Hydroxide

NF	Neutralization Factor
NH_3	Ammonia
NH_4^+	Ammonium
NO_2	Nitrogen dioxides
NO_3	Nitrate
NO_3^-	Nitrate Ion
Pb	Lead
Pb^{2+}	Lead Ion
SO_2	Sulfur Dioxide
SO_4	Sulfate
SO_4^{2-}	Sulfate Ion
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
W	West

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Rainwater is one of the natural water that can be obtained easily for living organism to consume and use. Rainwater contain a few major ions (H^+, NO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, Na^+, NH^{4+}, Cl^-, Pb^{2+}, HCO_3^-) that caused it to be either alkaline or acidic. Neutralizing agents such as NH_4^+, Ca^{2+} and Mg^{2+} can be used to neutralize the rainwater so that it is safe to be used by consumers.

Ahiarakwem (2012) stated that the continuous emissions of CO_2, SO_2 and NO_2 gases into the atmosphere in industrialized urban areas result in the formation of acid rain. The acid rain can infiltrate into the aquifer resulting in its pollution (Ahiarakwem, 2012). Chemical pollutions in rainwater and river water systems are derived through a combined effect of both industrial and municipal effluents, flaring of gases and runoffs from surrounding areas (Kaizer and Osakwe, 2010). If the source is influenced by anthropogenic activities, the nature of rainwater becomes acidic because anthropogenic activities contribute acidic gases like SO_2 and NO_3 and a basic gas like NH_3 by Kulshrestha et al. (2003). In a recent research, Das et al. (2005) reported that Ca^{2+} and NH_3 are the primary neutralizing agents of rainwater acidity in Bhubaneswar, India.

1.2 PROBLEM STATEMENT

Only two-third of the earth's surface is covered with water and even our bodies consist of 75 percent of water. Water is not only essential to our life but also to all living creatures on earth like plants, animals and micro-organism. Without water human can become dirtier, get diseases and eventually die of thirstiness. Water is so important to all but it is hardly to get clean water for people to use in daily life as the pollution at seas, lakes and rivers are getting more and more serious nowadays. So, a study on quality and neutralization of rainwater was carried out to see whether treated rainwater is suitable to be used for agricultural and domestic purposes or not.

1.3 SIGNIFICANCE OF STUDY

The biggest beneficiary was the community especially in household area where they can collect and reuse the rainwater for washing car, cleaning floor, bathing pets, watering plants and etc. After the rainwater had been neutralized, it is safe to be used in agricultural sector for watering plants so that the soil can be less acidic.

1.4 OBJECTIVES OF STUDY

The objectives of the research were:

a) To determine the physical characteristics of the rainwater in study area.

b) To obtain the chemical composition of the collected rainwater from harvesting.

c) To investigate the neutralization potential of the rainwater for agricultural and domestic purposes.

1.5 SCOPE OF STUDY

The quality of the rainwater was important to determine what the substances that contains inside the rainwater are and how to treat it. The main chemical composition of rainwater are H^+, NO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+, Cl^-, Pb^{2+} and HCO_3^-. The substances that needed to neutralize the rainwater are NH_4^+, Ca^{2+} and Mg^{2+}. Where NH_4^+ is used as neutralizing agent of acidity for monsoon period while Ca^{2+} and Mg^{2+} are used during non-monsoon season. The purpose of neutralizing the rainwater was to ensure that the rainwater was safe to be used as an alternative other than using the pipe water for daily usage. The rainwater was collected at the Universiti Malaysia Pahang Campus, Gambang and Taman Desa Mewah, Semenyih and then was stored in plastic bottles which was then be tested in the Environmental Lab in UMP. The tests that required to be done include determining the hardness, pH, electric conductivity, ionic concentration, temperature, total dissolved solids, total suspended solid, biochemical oxygen demand, chemical oxygen demand, turbidity and also the heavy metals concentration of the rainwater.

1.6 EXPECTED OUTCOME

The result of the rainwater collected for the pH value should be either alkaline or acidic. This was because it is hardly to get rainwater that is in the range of neutral with all the development that occurs around the area. The rainwater must be treated beforehand by using the neutralizing agents so that it is safe to be used and consumed. This study will enable the public to know whether the rainwater around the area is acidic or alkaline, how to used it in a proper manner and save up a lot of clean water or pipe water to be used for other purposes. This research will also be able to help in agricultural and domestic sectors.

1.7 CONCLUSION

This chapter had explained on the background information of the research itself on the effluences that affect the quality of rainwater. Problem statement, objectives of the study and significance of research are discussed to explain the purpose and needs of this research. Lastly, scope of the research and expected outcomes are stated to ensure that the research objectives could be achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discuss on the physical and chemical characteristic of rainwater, and neutralization factor of rainwater.

2.2 PHYSICAL COMPOSITION OF RAINWATER

2.2.1 Temperature

The temperature of the rainwater sample collected varied depending on the longitude, latitude and altitude of the sampling area. Olowoyo (2011) states that rainwater samples from Warri axis of Delta area in Western part of Niger Delta region lies within the longitudes 3°E-9°E and latitudes 4° 30'-5° 21'N had the temperature of the rainwater samples ranged between 28.21 – 29.38°C with mean value of 28.79 ± 0.27°C in first year while it ranged between 28.72 – 29.68°C with mean value of 29.20 ± 0.22°C in second year. In Akoto et al. (2011) research states that in the Ashanti Region of the Republic of Ghana is bounded by longitudes 5Ú35' N and 5Ú65' N, and latitudes 6Ú35' W and 6Ú90' W had a a mean annual temperature value of 25.5 °C.

Besides that, the study area lies within the equatorial belt of Nigeria had a mean monthly temperature from 25 to 28.5 °C at the elevation about 65 m above sea level (Ahiarakwem, 2012). Other than that, a place called Tamale metropolis that located at the capital of the Northern region of Ghana which is about 175 km east of longitude

1°W and latitude 9°N had a mean day temperatures range from 33°C to 39°C while mean night temperatures range from 20 – 22°C (Cobbina et al., 2013).

2.2.2 pH Values of Rainwater

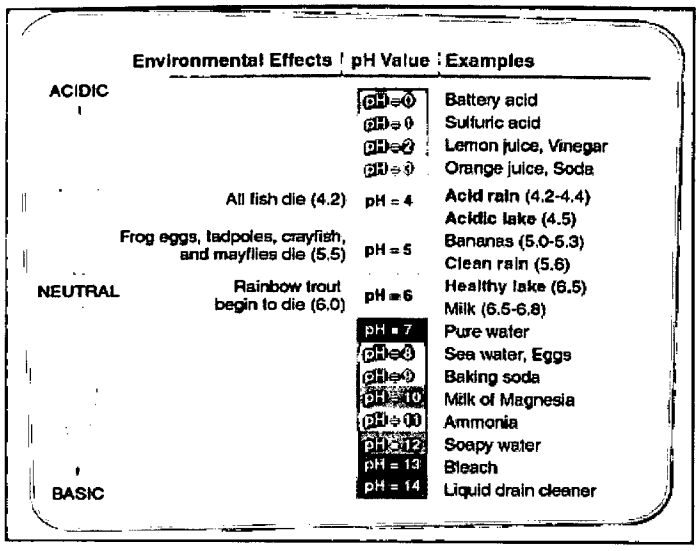

Figure 2.1: pH Scale

Source: United States Environmental Protection Agency

Acid rain refers to rainwater with pH values less than 5.6 which have been attributed to the high concentrations of NO_2 and SO_2 gaseous emissions in the study area that lies within the equatorial belt of Nigeria (Ahiarakwem, 2012). Casiday and Frey (1998) state that the acidity of rainwater comes from the natural presence of three substances (CO_2, NO_2, and SO_2) found in the troposphere (the lowest layer of the atmosphere). The average pH of rainwater has been observed to be 6.4 which is in the alkaline range. The observed alkalinity of rainwater is due to the high loading of particulate matter in the atmosphere commonly abundant in Indian conditions (Kulshrestha et al., 2003).

In addition, A pH meter (Fisherbrand Hydrus 100 model) equipped with glass electrode was used for pH measurement. The pH meter was calibrated using standard buffer solutions of pH 4.01, 7.00, and 9.20 before each measurement (Akoto et al., 2011). Besides that, the observed low pH of less ≥ 5.6 pH unit recorded in rainwater in the four year was acidic indicating high presence of CO2 in atmosphere as result of excessive bush burning within the environs. This can also be attributed to the increased use of fossil fuel which emits high amounts of SO2, NO2 (vehicular movement) and particulate matter (smoke, dust, soot suspended) in the air. pH values lower than 5.5 are considered too acidic for human consumption and can cause health problems such as acidosis (Cobbina et al., 2013).

2.3 CHEMICAL COMPOSITION OF RAINWATER

During non-monsoon period, dry conditions prevail resulting in suspension of dust and other particles during dust storms resulting in higher concentration of alkaline soil based cations (Shukla and Sharma, 2010). According to Shukla and Sharma (2010) research also, the alkaline components (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) contribute 58%, NH^{4+} contributes 4%, whereas the contribution from the acidic components is 38% during non-monsoon period with the concentration of major ionic species order: Ca^{2+}> SO_4^{2-}>Mg^{2+}> Cl^{-}> Na^{+}> HCO_3^{-}> NO_3^{-}> NH_4^{+}> K^{+}> F^{-}. These dust particles are rich in calcium bicarbonate/carbonate which is a major buffering agent for acidity generated by sulphuric and nitric acids (Kulshrestha et al., 2003).

As reported by Ahiarakwem (2012), Ca^{2+} ion in rainwater is presumably derived from dust in the atmosphere while NO_3^{-} is derived from plants, agriculture animal waste and fertilizers, and automobile exhausts. The chemistry of rainwater around Amazon basins shows that it has Na^{+} + K^{+} as the dominant cation with significant concentrations of Cl^{-} and SO_4^{2-}. The low concentration of Cl^{-} in the rainwater implies that it offers no salinity hazard such a laxative effects.

2.4 NEUTRALIZATION FACTOR

Calcium and ammonium are known as the principal neutralizing agents of the acidity. The main source of the calcium is the soil with high $CaCO_3$ content, and the source of the ammonium is the ammonium based fertilizers (as cited in Demirak et al., 2006). The role of NH_4^+ and Ca^{2+} has been validated by calculating neutralization factors (Kulshrestha et al., 2003). Ca^{2+} aerosols seem to be a major component for neutralization of rainwater acidity at most of Turkey sites (Tuncel and Ungor, 1996).

In addition, neutralization of the acids (H_2SO_4 and HNO_3) by these base cations (NH_4^+, Ca^{2+}, K^+ and Mg^{2+}) was obtained by calculating the NFs using:

$$NF_{NH4} = NH^+_4 / (NO^-_3 + SO_2^{-4}) \quad \text{.....(2.1)}$$

$$NF_{Ca} = Ca^{2+} / (NO^-_3 + SO_2^{-4}) \quad \text{.....(2.2)}$$

$$NF_K = K^+ / (NO^-_3 + SO_2^{-4}) \quad \text{..... (2.3)}$$

$$NF_{Mg} = Mg^{2+} / (NO^-_3 + SO_2^{-4}) \quad \text{.....(2.4)}$$

Shukla and Sharma (2010) states that the major neutralization has occurred due to NH_4^+ in monsoon and due to Ca^{2+} in non-monsoon.

2.5 CONCLUSION

This chapter discuss about the reading of temperature varied according to different location or country and the relationship between the pH value and the type of substances contain in rainwater. Later, it discusses on the chemical components that available in rainwater that come from and effects the environment. It also states on how to neutralize the rainwater with different situations.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discuss on the methods used to do research on the quality and neutralization of rainwater at Universiti Malaysia Pahang Campus, Gambang and Taman Desa Mewah, Semenyih.

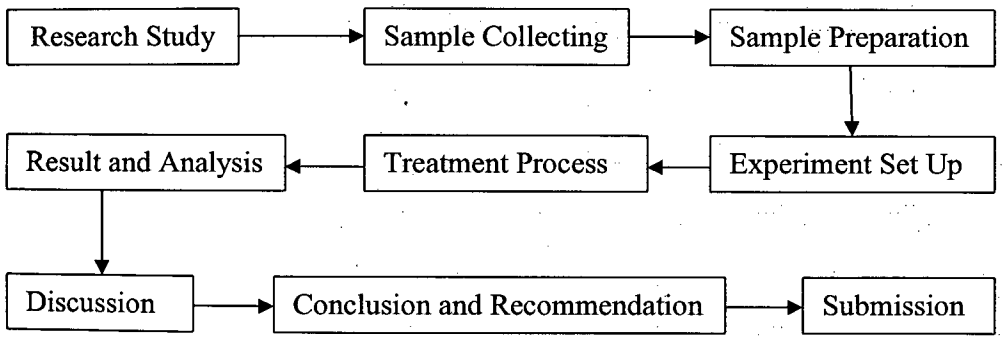

Figure 3.1: Flow Chart of the Research

3.2 STUDY AREA

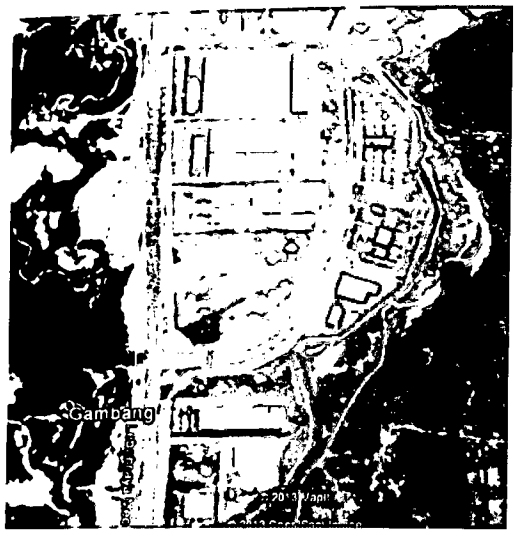

Figure 3.2: Gambang map

Figure 3.3: Semenyih map

Source: Google map

The locations of the study area were at Kolej Kediaman 3 in Universiti Malaysia Pahang and Semenyih in Selangor with the address Lebuhraya Tun Razak, 26300 Gambang Kuantan, Pahang Darul Makmur and Taman Desa Mewah, 43500 Semenyih, Selangor Darul Ehsan. Both study areas were located at residential area and industrial area.

3.3 SAMPLING STATION

There are 2 locations to collect the samples which located at Kolej Kediaman 3 and Taman Desa Mewah. Only rainwater from the roof was collected at the Kolej Kediaman 3 while for the other location, rainwater was collected by using rectangular plastic buckets on the ground level.

3.4 SAMPLE COLLECTION

The precipitations were collected in two days at the selected location. Sample collection equipment was washed using HCl and distilled water before it was used. A total of 4 samples were collected and experiments were conducted at the Environmental Laboratory. The pH value of each sample was taken before being filtered. The samples were filtered by using 0.45μm pore size membrane filters and then it was poured back to other clean bottles. Later, the bottles were kept and preserved at 4 ˚C in a refrigerator for ion analysis.

3.5 RESEARCH MATERIALS AND INSTRUMENTS

3.5.1 Materials

The materials that need to do this research include:

i. Rainwater samples
ii. Neutralizing agent (Calcium, Ammonium, Magnesium)
iii. Sodium Hydroxide (NaOH), Sulfuric Acid (H_2SO_4), HACH BOD Buffer Pillow, distilled water for BOD testing
iv. Distilled water and HCl for cleaning apparatus.

3.5.2 Instruments

There are several instruments that were used to carry out the experiments which include:

i. Plastic Bottles with cap to keep rainwater samples.
ii. BOD bottles (300ml capacity), pH meter YSI 5100, DO meter, Aeration pump, Incubator, Measuring Cylinder and Beaker for BOD testing.

iii. Glass Microfiber Filter Disc, Glass Dishes, 1000mL Suction Flask, 47mm Glass Microanalysis Filter Holder (funnel, clamp and base), Desiccator, Oven and Analytical Balance for TSS testing.

iv. DR 5000 Specrophotometer, COD Reactor and Micro Pipette for COD testing.

v. Turbidimeter

vi. Portable pH pH/SE Conductivity and DO meter.

3.6 RESEARCH PROCESS/PROCEDURES

Table 3.1: The test parameters, units and test methods used in this research

Test Parameters	Units	Test Methods
pH	-	APHA 4500H$^+$B
BOD	mg/L	APHA 5210B
COD	mg/L	HACH DR 5000 Method 8000
TSS	mg/L	APHA 2540 D
Hardness	mg/L as $CaCO_3$	HACH DR 5000 Method 8030
TDS, Electric Conductivity	mg/L, μ^5/cm	HACH Sension 5
Turbidity	NTU	HACH 2100 P

3.7 CONCLUSION

This chapter covers on how the samples are taken and the areas to collect rainwater. It discussed on the materials and instruments used in the study. It also shows the test method used to conduct Total Suspended Solid, Total Dissolved Solid, Biochemical Oxygen Demand, Chemical Oxygen Demand, hardness, pH, electric conductivity and turbidity test in the laboratory.