RAINWATER HARVESTING SYSTEM FOR LANDSCAPE USE IN GAMBANG CAMPUS, UNIVERSITI MALAYSIA PAHANG (UMP)

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JANUARY 2014

ABSTRACT

Rainwater harvesting system is the collection of rainwater mostly via rooftop and stored in cistern for potable and non potable use. The purpose of this study is to find out rainwater quality harvested from rooftop and to obtain a rainwater harvesting system for collecting natural water. This research only considers determination of rainwater storage tank size by estimating rainwater supply and landscape water needs. Qualitative assessment of rainwater collected via rooftop was determined using two selected roofing materials namely galvanized iron roofing sheet and clay tiles roofing sheet. The samples were collected directly from downpipe and the quality of rainwater was determined using standard method in laboratory. The test included chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), ammoniacal nitrogen, escherichia coli (E-Coli) and total coliform. The study water quality classified as Class IV compared with National Water Quality Standard (NWQS). It was found that rainwater from galvanized iron roofing sheet was more polluted, followed by clay tiles roofing sheet. The rainwater also is suitable to use for landscape irrigation, due to the water quality classification. For landscape watering in KK1 Student Park, $50m^3$ is the monthly maximum volume of water needed for irrigation.

ABSTRAK

Sistem penuaian air hujan adalah merujuk kepada pengumpulan air hujan untuk kegunaan minuman dan bukan minuman. Kebiasaannya, air hujan dikumpul di dalam tangki setelah melalui permukaan bumbung atau dikumpul secara terus. Tujuan penyelidikan ini adalah untuk mengenalpasti kualiti air hujan dari larian bumbung dan memperoleh satu sistem penuaian air hujan untuk mengumpul air semulajadi. Penyelidikan ini hanya menyentuh pengiraan tangki air hujan dengan mengira bekalan air hujan dan keperluan air untuk pengairan lanskap. Penilaian kualiti air hujan yang dikutip dari bumbung dibuat keatas dua jenis bumbung iaitu bumbung jenis besi bergalvani dan jubin tanah liat. Sampel air hujan yang dikutip kemudiannya diujikaji di dalam makmal mengikut kaedah standard yang ditetapkan. Antara ujian yang dibuat ialah chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), ammoniacal nitrogen, escherichia coli (E-Coli) dan total coliform. Keputusan ujian kemudiannya dibandingkan dengan Kelas 4 Standard Kualiti Air Negara (NWQS). Daripada keputusan yang didapati, dapat disimpulkan bahawa kesemua air hujan mengandungi bakteria (E-Coli>1) kecuali dua sampel air hujan dari larian bumbung besi bergalvani. Didapati bahawa air larian hujan dari bumbung besi bergalvani lebih tercemar berbanding air larian hujan dari bumbung berjubin tanah liat.Air hujan yang dikutip melalui bumbung juga sesuai untuk tujuan pengairan kerana semua nilai yang dikehendaki kurang daripada nilai maksimum bagi Kelas 4. pengairan lanskap pula, didapati isipadu maksimum air hujan yang diperlukan untuk pengairan selama sebulan adalah $50m^3$.

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LIST OF ABBREVIATIONS

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
CERRM	Centre for Earth Resources Research & Management
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
E-Coli	Escherichia Coli
ETo	Reference Evapotranspiration
FAO-56PM	FAO Penman-Monteith Paper No 56
JPS	Jabatan Pengairan dan Saliran
Kc	Landscape Coefficient
Kd	Density Factor
KK1	Kolej Kediaman 1
Kmc	Microclimate Factor
Ks	Species Factor
mg/L	milligram per litre
mL	millilitre
MMD	Malaysian Meteorology Department
MPN	Most Probable Number
NWQS	National Water Quality Standard
PAIP	Perbadanan Air Pahang
PE	Polyethylene
TSS	Total Suspended Solids

UV	Ultra Violate
WUCOLS	Water Use Classifications of Landscape Species

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Water is essential to all life on earth- human, animal and vegetation. Increasing population, expansion of urbanization, industrialization as well as agriculture imposed the growing of demand and pressure on water resources. A new development of water resources such as new water supply scheme results in rising costs and significant impact to the environment. The developments of urban areas increase the imperviousness of land, which affect or alters the hydrological processes. The potential problems include an increase of total runoff volume, increase of peak runoff flow, decrease on time to concentration, and deteriorated water quality (Dietz, 2007).

Rainwater harvesting (RHS) is an ancient practice that has been increasingly receiving attention in the world, fuelled by water shortages from droughts, pollution and population growth (Nolde 2007; Meera and Ahameed 2006). Historically, harvested rain water provided water for drinking, landscape watering, and for agricultural uses. Recently, environmental concerns have increase the appeal of green building practices, including rainwater harvesting systems, in urban areas. Rainwater harvesting is especially appealing as it combines the benefits of water reuse with runoff reduction and groundwater recharge. Additionally, rainwater is available free of charge and puts no added strain on the municipal supply.

RHS is consisting of 4 components; catchment areas usually roof, conveyance systems, storage and distribution systems to control where the water goes. For conveyance systems, the gutter and downspouts direct the water from the catchment area to the storage container. Gutters are either concealed inside the walls of buildings or attached to the exterior of buildings. The purpose of storage is by making water available when it is needed. Storage can be underground or above-ground. Storage containers can be made of polyethylene, fibreglass, wood, or metal. The distribution system can be a hose, constructed channels, pipes, or manual drip system that directs the water from the storage containers to landscaped areas.

1.2 PROBLEM STATEMENT

Population growth is inevitable. In Malaysia, population has increased from 8.1 million in 1960 to 27 million in 2008. As the population increases, the water demand from clean water increases as well. And to cater the demand, dams and water treatment plant has to be constructed to meet the needs of the people. As the supply and demand are in a cat and mouse race, with the limited water resources, eventually the demand will exceed the supply and this situation will create problems to the country.

The people's attitude also plays an important part towards creating a sustainable living. Campaigns had been going to educate and remind the public that water is precious thus it is not to be wasted. Not only will it save the water bill but also reduce the water stress on water demand as well as possess sufficient reserves for emergencies uses such as droughts and dry spells.

Since water is important, it is seen as a waste for it to be used for flushing toilets and for watering plants. Furthermore, rainwater can be used as a substitute by collecting and utilise it rather than let it go to waste. Besides, 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 resulted in lower cost of water bill and cost of operations in the water plants. The use of untreated rainwater for non-potable uses that would otherwise be supplied by potable water ultimately conserves municipally supplied potable water (Persyn, 2004).

1.3 OBJECTIVES

The study objectives are as follows:

i. To determine the quality of collected rainwater.
ii. To obtain a rainwater harvesting system (RHS) for collecting of natural water.

1.4 SCOPE OF STUDY

Once the rainwater falls on rooftop catchment, the quality can be doubted. Two types of roofing materials will be considered for water quality assessment namely galvanised iron and clay tiles roofing sheet. Several test need to be carried out using standard method and classification of water quality will be based on Class IV National Water Quality Standard (NWQS). The tests involved are Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids, Ammoniacal Nitrogen, Escherichia Coli and Total Coliform.

To obtain rainwater harvesting system for collecting of natural water, it was necessary to obtain weather data from Kuantan weather station. Since the proposed building for rainwater catchment already has gutter and downpipe installed, thus this study only focused on estimating rainwater storage tank size. The catchment area which is rooftop area of the building will be calculated based on the aerial map of the campus. The potential rainwater harvesting volume is estimated based on the total rooftop area, the monthly rainfall and the runoff coefficient. After that, volume of rainwater needed by landscape plant is calculated based on evapotranspiration, landscape coefficient, irrigation efficiency and total area of landscape.

1.5 EXPECTED OUTCOME

i. By testing the parameter, the quality of collected rainwater can be classified based on National Water Quality Standard.
ii. With proper calculation and estimation, adequate storage tank to capture rainwater for rainwater harvesting system can be obtained for landscape use in KK1 Student Park.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

According to the Regent of Perak Raja Dr Nazrin Shah, the global competition and even conflicts in water usage are likely to occur if proper water resource management is not carried out immediately. The world's population was expected to increase by 30% in 2005 and the pressure of fresh water for human consumption would be more critical (The Star, 2008). Malaysia is considered rich in water resources with an annual average rainfall of about 3,000mm generating 556 billion m^3 of surface runoff and renewable water resources amounting to 120 billion m^3 per year (Salmah and Rafidah, 1999). Even then, water supply disruption due to a tight water supply and demand situation aggravated by a lack of rainfall over catchment areas coupled with river pollution problems at the water intakes, do occur, as in the 1998 drought which brought unpleasant water supply disruption for some 1.8 million Klang and Langat Valley residents (Jamalluddin and Adhityan, 2007).

Rainwater harvesting and utilization has been practiced in Malaysia especially in the villages since long ago. Subsequent to the 1998 April drought, the Minister of Housing and Local Government on 7 May 1998 has expressed the Government's interest for houses to be designed to include facilities for collecting rainwater. In 1999, the Ministry of Housing and Local Government has produced a Guideline on Installing a Rainwater Collection and Utilization System (Jamalluddin and Huang, 2007).

However, there are several factors that need to be put into consideration when using rainwater harvesting system. One of the factors is harvested rainwater quality. Initially, rainwater is free of microbial contamination, but it may become contaminated by animals and humans or, alternatively, human pathogens may grow in stored rainwater resulting in significant human health risk from infectious diseases (Schets, Italiaander, van den Berg and De Roda Husman, 2010.) Although the water quality requirement for non potable uses is low compare to potable use, assessment of water quality need to be carried out in order to confirm the water will not caused harm to the people skin.

2.2 RAINWATER HARVESTING SYSTEM

In scientific term, rainwater harvesting refers to the collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of looses through evaporation and seepage and all other hydrological studies and engineering interventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit as a watershed (Agrawal and Narain, 1999). The category of rainwater harvesting is shown in Figure 2.1.

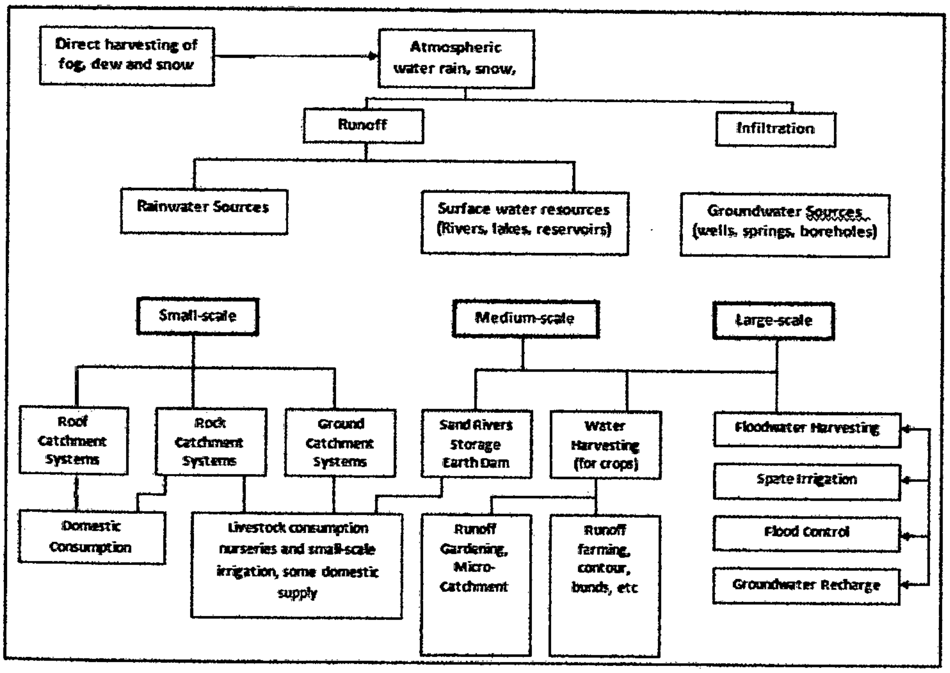

Figure 2.1: Rainwater Harvesting Category

Source: Jamalludin and Huang (2007)

2.2.1 Common Rainwater Harvesting Components

Ideal domestic rainwater-harvesting systems generally composed of six basic components and these components are the roof (catchment), gutters and down pipes, primary screening and first flush diverters, storage tanks, the pipes, and water treatment unit.(TWDB, 1997). Figure 2.2 shows the elements of rainwater harvesting system.

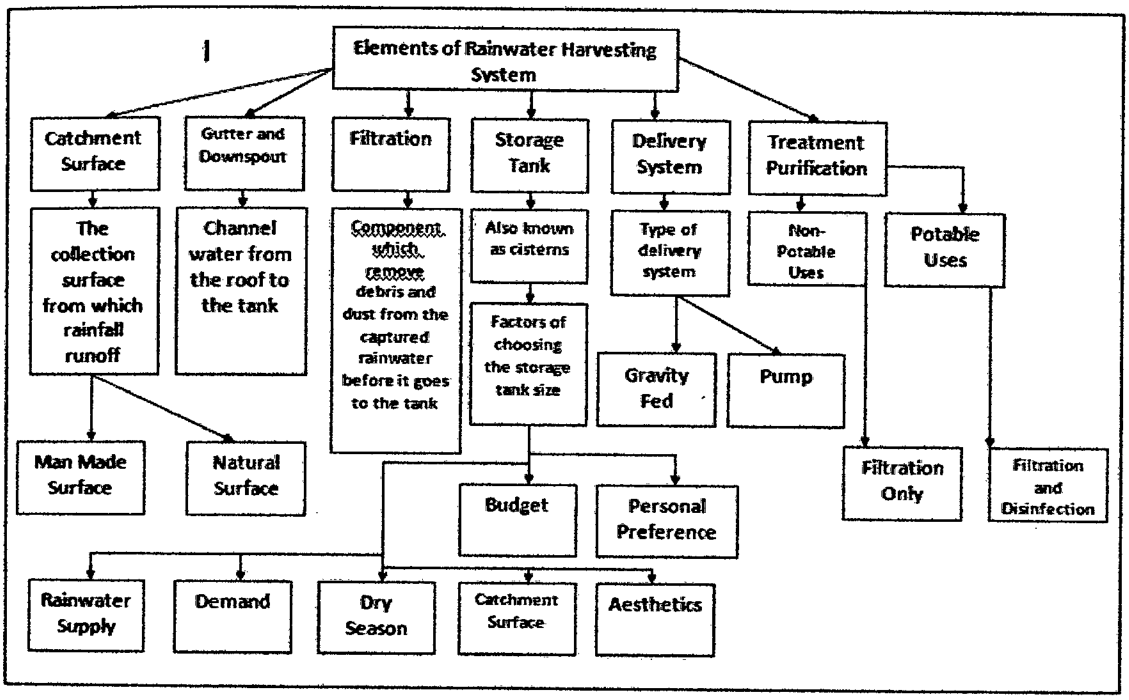

Figure 2.2: Elements of Rainwater Harvesting System

Source: Che Ani et al., (2009)

2.2.1.1 Catchment

The catchment of a water harvesting system is the surface which directly receives the rainfall and provides water to the system. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. Rooftop rainwater harvesting comprised of the rooftop as the catchment area, connected gutters and pipes to a storage container. The most suitable rooftop surfaces are corrugated iron sheets, tiles and asbestos sheets. Thatched roofs pose problems as the runoff is less and generally of a low quality (Yaziz, 1989). Other type of roof made of reinforced cement concrete (RCC), galvanised iron or corrugated sheets can also be used for water harvesting.

2.2.1.2 Gutter and downspout

Gutter refers to channels all around the edge of a sloping roof to collect and transport rainwater to the storage tank. Gutters can be semi-circular or rectangular. The function of guttering is to protect the building by collecting the water running off the roof and direct it via the downpipe to the storage tank. The gutter system should have a uniform slope of 0.5% and be large enough to collect the heavy runoff from high intensity rains (O'Brien, 1990).

2.2.1.3 First flush diverter

The purpose of first flush diverter is to remove contaminant before entering storage tank. The first flush usually contains higher concentration contaminants than rooftop runoff from later in the storm. . With all roof catchment tanks, the first 20 to 30L of rainwater running off the roof, which conltain large quantities of leaves and bird droppings, should be discarded to keep the water potable (O'Brien, 1990). A common first flush diverter is shown in figure 2.3. Water will not begin to flow into the storage tank until the diverter has filled completely.

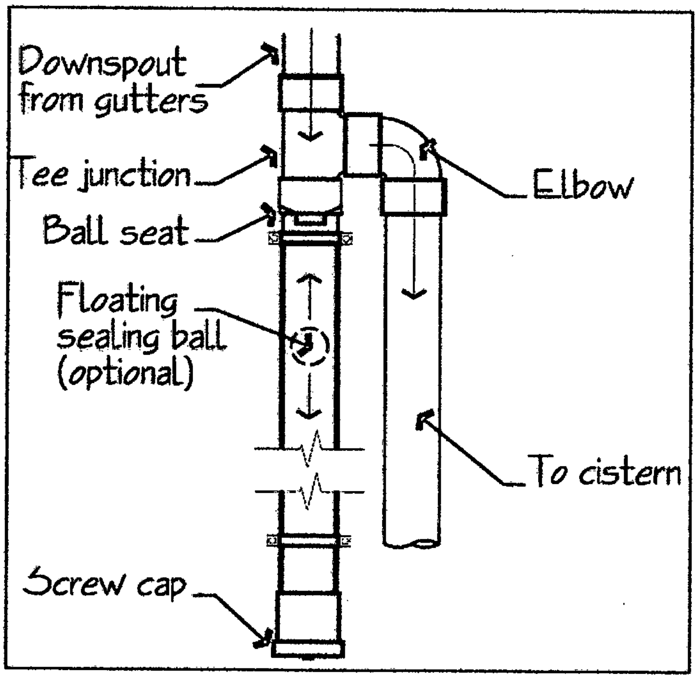

Figure 2.3: First flush diverter

Source: Waterfall (2004)

2.2.1.4 Storage system

Storage allows full use of excess rainfall by making water available when needed. Before water is stored, it should be filtered to remove particles and debris. Storage container can be located above ground or underground. Mostly it is made of Polyethylene, fibreglass, wood, concrete or metal (Waterfall, 2004).

2.2.1.5 Distribution

The distribution system directs water from the storage container to landscape areas. The distribution device can be a garden hose, constructed channels, pipes, perforated pipes, manual drip system and sprinkler system. A manual or electric valve located near the bottom of the storage container can assist gravity-fed irrigation. In the absence of gravity flow, an electric pump hooked to a garden hose can be used. A pump will be required to provide enough pressure to operate a typical drip irrigation system (Waterfall, 2004).

2.2.2 Rainwater Harvesting For Irrigation

It is important to estimate the volume of rainwater harvesting and also to know the water consumption. The domestic water consumption is different from country to country in the world (Mohammed et al., 2006).A rainwater harvesting system for irrigation purposes has three components, namely the supply source from the catchment surface area, the demand which is the landscape water requirements and the conveyance system to moves the water to the plants (Waterfall, 2004).

The volume of rainwater planned to be used for irrigation is mainly depends on rainfall intensity, rainfall duration, frequency of the rainfall, and degree of saturation for catchment ground surface and its nature. Water harvesting cannot provide a completely reliable source of irrigation water because it is dependent on the weather, and weather is not dependable. Water used for irrigating plant of a landscape from a rainwater harvesting system can be determined by two methods namely supply method or demand method. (Mohammed et al., 2006).

2.2.3 Determination of Potential Rainwater Supply and Landscape Water Demand

According to Mohammed et al. (2006), the equation 2.1 can calculate potential harvested rainwater from rooftop catchment.

$$S = A \times C \times R \qquad (2.1)$$

Where S is monthly yield of rainwater harvest, A is catchment area, C is runoff coefficient, and R is the monthly rainwater depth. Although in reality the amount of water available fluctuates on a daily basis but for simplicity the computation can be done on a monthly basis (Mohammed et al., 2006).

The volume of water required by the plants is computed based on monthly evapotranspiration data using the following equation:

$$D = ETo \times \beta \times A \qquad (2.2)$$

Where D is monthly water demand or volume of irrigation water, (ETo) is monthly evapotranspiration, ß is the plant factor, and A is the irrigated area. Using plants of similar water requirements will simplify the system and make the amount of water needed to maintain those plants easier to compute. Both equations above are usually used to compute yield and demand for both new and established landscapes. In case that all the units of the variables used in m^2 and m then the unit of both supply and demand will be in m^2. The plant factor represents the percent of ETo that is needed by the plant and it mainly depends on the type of the irrigated plant whether it's high, medium, or low water use (Mohammed et al., 2006).

2.3 WATER QUALITY OF RAINWATER

The quality of water collected in a rainwater harvesting system is affected by many factors, including;

- Environmental conditions such as proximity to heavy industry or major roads, the presence of birds or rodents (Forst, 1998 and Taylor, 2000).
- Meteorological conditions such as temperature, antecedent dry periods, and rainfall patterns (Evans, 2006).

- Contact with a catchment material and the dirt and debris that are deposit upon it between rainfall events (Simmons, 2001 and Van Metre an Mahler, 2003).
- Treatment by pre-cistern treatment devices such as filtration of first-flush diversion (Yaziz, 1989 and Martinson & Thomas, 2005).
- Natural treatment processes taking place within the rainwater cistern (Scott and Waller, 1987 and Spinks, 2003)
- Treatments by post-cistern treatment devices such as particle filtration, ultraviolet disinfection, chlorination, slow sand filtration or hot water systems (Coombes 2000, Kim 2005, Ahameed and Meera 2006, Sazakli 2007).

The microbiological quality of stored rainwater may depend on storage conditions such as temperature and time, but also on the materials of which the storage container are made maintenance of the system and hygiene practice at the tap (WHO, 2006).

2.3.1 Roofing Sheet Material

Contamination from roof surfaces can come from two main sources. Particles can accumulate on the roof surface either from direct atmospheric deposition, or from overhanging foliage or bird and rodent debris (Despins, Farahbakhsh and Leidi, 2009). From the study of Radaideh et al. (2009) found that harvested rainwater from rooftops have better quality than water collected from the catchment areas.

Metal roofs are often associated with the leaching of trace elements, detected in the dissolved form in the runoff itself and adsorb to the particulate matter washed from the roof. Concentrations of dissolved and particulate copper from copper flashings are increased compared with both pure rainwater and runoff collected from clay or concrete tiles (Forster, 1996). The same situation also applied to zinc concentration in runoff from a zinc sheet roof and, to a lesser degree, from zinc gutters. Van Metre and Mahler (2003) compared galvanized metal roofs to be a greater source of both zinc and cadmium contamination, while asphalt was associated with higher levels of lead and possible mercury. However, there is no significant difference between concentrations of lead, zinc or copper in runoff from asphalt roofs and metal roofs (Hart and Wide, 2006).

2.3.2 Storage Material

Rainwater is often slightly acidic, the increase in pH caused by contact with a concrete tank is beneficial for the protection of the distribution system and the chemical quality of the water by minimizing the potential for leaching materials (Despins, Farahbakhsh and Leidi, 2009). According to Scoot and Walker (1987), in a study evaluating the quality of stored water in a concrete cistern it is report that a rise in pH from 5.0 on the roof surface, 9.4 in the tank and 10.3 from the tap. A higher pH can inhibit coliform growth.

Although it is generally considered as a quality enhancer, storage cisterns also cause some concern over the potential for chemical leaching. Leaching of zinc from metal tanks was found to be significantly in one study, but concrete or plastic tanks did not have any notable impact on the concentration of zinc, lead or copper (Hart and White, 2006).

2.3.3 Location

Depending on where the system is located, the quality of rainwater itself can vary, reflecting exposure to air pollution caused by industries such as cement kilns, gravel quarries, crop dusting, and a high concentration of automobile emissions (Mohammed et al., 2006).In most industrialized urban areas, the atmosphere has often been polluted to such a degree that the rainwater itself is considered unsafe to drink (Thomas , 1993).Heavy metals such as lead are potential hazards especially in areas of high traffic density or in the vicinity of heavy industries (Yaziz et al., 1989, and Thomas et al., 1993). Organic chemicals such as organ chlorines and organophosphates used in biocides can also contaminate rainwater. Although serious atmospheric contamination of rainwater is normally limited to urban and industrial locations, studies in the north eastern of United States revealing the presence of pesticides and herbicides in rainwater do give some cause for concern (Richards et al., 1987). Despite the numerous sources of atmospheric pollution, in most parts of the world, especially in rural and island locations, levels of contamination of rainfall are low. Most contamination of rainwater occurs after contact with the catchment surface (roof or ground) and during subsequent delivery and storage (Waller, 1989).

2.3.4 Types of contaminants in rainwater tank systems

From the study conducted by Mosley (2005), the types of contaminants commonly found in rainwater collection systems are listed below. However the type of contaminants may varies from places to places and depends on the design of rainwater collection system as shown in the following tables:

Table 2.1: Types of contaminants commonly found in rainwater collection system

Contaminant	**Source**	**Risk of entering rain tank**
Dust and ash	Surrounding dirt and vegetation Volcanic activity	Moderate : Can be minimized by regular roof and gutter maintenance and use of a first-flush device.
Pathogenic bacteria	Bird and other animal droppings on roof, attached to dust	Moderate : Bacteria may be attached to dust or in animal droppings failing on the roof. Can be minimized by use of a first-flush device and good roof and tank maintenance.
Heavy metals	Dust, particularly in urban and industrialized areas, roof materials	Low : Unless downwind of industrial activity such as a metal smelter and/or rainfall is very acidic (this may occur in volcanic islands).
Other inorganic contaminants (e.g. salt from seaspray)	Seaspray, certain industrial discharges to air, use of unsuitable tank and/or roof materials	Low : Unless very close to the ocean or downwind of large-scale industrial activity

Table 2.1: Continued

Contaminant	**Source**	**Risk of entering rain tank**
Mosquito larvae	Mosquito laying eggs in guttering and/or in tank	Moderate: If tank inlet is screened and there are no gaps, risk can be minimized

Source : Mosley (2005)