EFFECTIVENESS OF NATURAL SOIL AND ACTIVATED CARBON MIXTURE AS BARRIER MATERIAL IN RIVERBANK FILTRATION SYSTEM

NOOR AMIRA BINTI LUXMAN

A report submitted in partial fulfilment of the
requirements for the award of the degree of
B. ENG (HONS.) CIVIL ENGINEERING

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2014

ABSTRACT

Water is our body's principal chemical component and makes up nearly 60 percent of our body weight. Most of the water resources come from the river. However, water pollution in Malaysia increase every day. Therefore, river water's quality is an important parameter that must be preserved and monitored. One of the alternative ways to improve the water quality is by using Riverbank Filtration Method (RBF). It is used as an alternative for an efficient and economical drinking-water treatment technology. Riverbank material and its nature soil may not be suitable to treat water until standard water quality achieved, so the alternative design should be considered, by adding artificial barriers to the soil. The main objectives of this study are to determine the effectiveness of nature soil and activated carbon as an artificial barrier in order to get the improvement of water quality for drinking involving natural filtartion. Based on the findings, the mixture of natural soil and activated carbon can be used as filtration media in the riverbank filtration system, but need further treatment because the natural soil of the river itself does not efficient enough to support this system.

ABSTRAK

Air adalah komponen utama di dalam badan manusia dan merupakan komponen kimia yang membentuk hampir 60 peratus daripada berat badan kita. Kebanyakan sumber air datang dari sungai. Walau bagaimanapun, pencemaran air di Malaysia meningkat setiap hari. Oleh itu, kualiti air sungai perlu dipelihara dan dipantau. Salah satu cara alternatif untuk meningkatkan kualiti air adalah dengan menggunakan kaedah 'Riverbank Filtration' (RBF). Ia digunakan sebagai alternatif untuk teknologi rawatan air minuman yang cekap dan ekonomik. Bahan Riverbank dan tanah semulajadi mungkin tidak sesuai untuk merawat air sehingga standard kualiti air bersih dicapai, rawatan air alternatif harus dipertimbangkan. Objektif utama kajian ini adalah untuk menentukan keberkesanan tanah semulajadi dan 'activated carbon' sebagai medium untuk mendapatkan peningkatan kualiti air minuman yang hanya melibatkan penapisan air secara semulajadi. Berdasarkan kajian yang telah dibuat, campuran tanah semulajadi dan activated carbon boleh digunakan sebagai media di dalam sistem "riverbank filtration system" tetapi memerlukan kajian yang lebih lanjut bagi mendapatkan hasil kajian yang lebih menyeluruh. dan efisien.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RBF	Riverbank Filtration
AC	Activated Carbon
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Total Suspended solids
TDS	Total Dissolve Solids
HRT	Hydraulic Retention Time

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Nowadays the world populations increased by 20 percent while the use of water increased by 60 percent even though there are many water resources in Malaysia, water that can be used safely by us right now are decreases. In Malaysia, the key components of demand for water supply include water consumption by the industrial, commercial, agriculture, residential and domestic use. Water pollution in Malaysia increased every day and most of the river cannot meet class 1 classification according to Water Quality Index (WQI). There are many water resources in Malaysia, which are rivers, pond, lake, sea water and ground water. Even though there are a lot of water resources, but the water cannot be consumed directly as clean water, it must be pass a standard from National Water Quality Standards (NWQS).

For this time being, conventional system is used to treat water and this system is very costly and includes many chemicals. It is a combination of coagulation, sedimentation, filtration and disinfection to provide clean and safe drinking water to the public. Worldwide, a combination of this process is the most widely applied water treatment technology and has been used since the early 20th century but this system very costly because involve the use of chemicals, high investment and energy (Schlick, 2001).

In order to get the best quality of water without use a lot of process, riverbank filtration system need to be done in Malaysia. Protection of ground water and surface water are very important to obtain a sustainable water usage. Riverbank filtration (RBF) offers a good practice to treat and protect the surface water as well as groundwater. It is because RBF uses the bed of a reservoir, lake or river and an adjacent sand and gravel aquifer as a natural filter. Currently Riverbank filtration system eliminates chemical content in the water naturally.

This technology can be applied directly to existing surface water reservoirs, streams, lakes and rivers, and now it is often a guiding factor in the hydro geological investigation of new source supplies (Suratman, 2000).

1.2 PROBLEM STATEMENT

To make our raw water safe to drink, it must be treated. Conventional water treatment usually used but it involve of many chemical usage. Riverbank filtration systems however uses the riverbank to instantly filter water and at the same time treat water. The main concern over the performance of RBF is that the type of soil that resides in the riverbank may not be suitable to directly treat water and thus, some alteration may be required to improve the performance of the RBF.

1.3 RESEARCH OBJECTIVE

In this research, there are a few objectives need to be achieved.

(i) To identify the applicability of activated carbon and natural soil mixture as artificial barrier in riverbank filtration system.

(ii) To identify the effectiveness of activated carbon and natural soil in removing biological, inorganic and contaminants of the river.

(iii) To improve water quality for drinking involving natural filtration.

1.4 SCOPES OF STUDY

This research focuses on Tasik Chini's areas where the water and soil sample were taken. Laboratory investigation will be carried out and determined following standards laboratory procedures for the both samples. Test that to be conducted by using natural soil and activated carbon as filtration medium. There will be 5 water quality parameters considered in this research which are Biochemical oxygen demand (BOD), Chemical oxygen demand (COD), Total suspended solid (TSS), Total dissolved solid (TDS) and Turbidity. Several physical properties for the soil samples which are particle sieve analysis, hydrometer test, specific gravity and atteberg limits were also determined.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Water is colourless, transparent, odourless, liquid which forms the Seas Rivers, and lakes. Rain is the basis of the fluid of living organism. Water is continuously moving through the cycle of evaporation, precipitation and runoff. All known forms life in this earth needs water. Humans consume "drinking water" - water which has qualities compatible with the human body.

Soil is a natural element formed from igneous rocks, metamorphic rocks and broken rocks. Weathering and erosion wear down rock into soil. Soil exists for a long time on this earth but there is no study about the soil over the century. During the year, Coulomb was the first people for solving problems of soil using mechanical skills. Many of the problems related to the soil when it is not resolved, until Karl Terzaghi (1883 - 1963) appeared (Budhu, 2000). According Singth and Prakash (1990), the term ' Soil Mechanics ' is the original outburst by late Dr. Karl Terzaghi.

2.2 WATER DEMAND AND SUPPLY

Water resources in Malaysia are abundant and available throughout the year. 76 percent of water was used for agriculture and 11 percent used for municipal water supply. Examples include municipal use for cooking, bathing, washing, sanitary and others. Municipal purposes depend to climate factors, social status, quality, quantity, and cost of the water, water pressure, sanitary system and type of water supply. In the backward and forward, the average water use for the purpose of municipal is between 100-3501 litre/person/day. While another 13 percent of water resources in Malaysia are for industries. However, there is only 1 percent of water left for the drinking purpose. The table 2.1 below shows the different need for water for industries in Malaysia.

Table 2.1: Different need for water in industries

Product	The mass of water / mass of product
Cotton / Wool	150-750
Steel / wood / pulp / paper	10-300
Slaughter and packing	15-25
petroleum production	3-10
dairy production	3-35

Source: Persatuan Air Malaysia

2.3 SOURCE OF WATER

Water resources are sources of water processed to be used as input in the production process, such as agriculture, industry and for municipal use. Malaysia's water resources are divided into two parts, which is surface water and ground water.

2.4 WATER QUALITY STANDARD

Water quality standards are foundation of the water quality-based control program mandated by the Clean Water Act. Water Quality Standard define the goals for a water body by designating its uses, setting criteria to protects those uses, and establishing provisions to protect water quality from pollutants. A water quality standard consists of four basic elements (Gullick, 2006)

(i) Designated uses of the water body (e.g., recreation, water supply, aquatic life and agriculture)
(ii) Water quality criteria to protect designated uses (numeric pollutants concentrations and narrative requirements)
(iii) An antidegradation policy to maintain existing uses and high quality waters.
(iv) Generals policies addressing implementations issues (e.g., low flows, variances and mixing zones)

2.4.1 Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) refers to the amount of oxygen that would be consumed if all the organics in one litre of water were oxidized by bacteria and protozoa (ReVelle, 1988). BOD is an important standard parameter commonly used to monitor organic load for environmental and process control in a vast range of industries. BOD is the most common generic indices used to assess aquatic organic pollution and often used to evaluate the biodegradable fraction. BOD provides a good approximation of the biologically consumable organic fraction in waterways, the test takes 5 days.

2.4.2 Chemical Oxygen Demand

The amount of oxygen dissolve in water is important to aquatic life. Decaying matter in sewage, industrial discharge, agriculture and urban runoff uses up the dissolve oxygen in water. Chemical oxygen demand (COD) is a measured of the amount of chemicals that consume dissolve oxygen (Mancy, 1971).

2.4.3 Total Suspended Solid

Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter. Suspended solids are present in sanitary wastewater and many types of industrial wastewater. There are also nonpoint sources of suspended solids, such as soil erosion from agricultural and construction sites.

As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels.

TSS can also destroy fish habitat because suspended solids settle to the bottom and can eventually blanket the river bed. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Most people consider water with a TSS concentration less than 20 mg/l to be clear. Water with TSS levels between 40 and 80 mg/l tends to appear cloudy, while water with concentrations over 150 mg/l usually appears dirty.

2.4.4 Total Dissolve solid

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The presence of dissolve solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/litre; good, between 300 and 600 mg/litre; fair, between 600 and 900 mg/litre; poor, between 900 and 1200 mg/litre; and unacceptable, greater than 1200 mg/litre (*1*). Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste (Fawell, 2002).

Water containing TDS concentrations below 1000 mg/litre is usually acceptable to consumers, although acceptability may vary according to circumstances. However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances.

2.4.5 Turbidity

Turbidity is the amount of cloudiness in the water. This can vary from a river full of mud and silt where it would be impossible to see through the water (high turbidity), to spring water which appears to be completely clear (low turbidity). Turbidity can be caused by;

(i) silt, sand and mud
(ii) Bacteria and other germs
(iii) Chemical precipitants

It is very important to measure the turbidity of domestic water supplies, as these supplies often undergo some type of water treatment which can be affected by turbidity. For example, during the rainy season when mud and silt are washed into rivers and streams high turbidity can quickly block filters and stops them from working effectively. High turbidity will also fill tanks and pipes with mud and silt, and can damage valves and taps. Where chlorination of water is practiced, even quite low turbidity will prevent the chlorine killing the germs in the water efficiently.

Some treatment systems, such as sedimentary, coagulators and gravel pre-filters are designed to remove turbidity. It is important for operators of both large and small treatment systems to know how well these systems are working. Measuring the turbidity of the water before and after each part of the system can tell the operator where maintenance or cleaning is needed.

2.5 WATER TREATMENT

Drinking water is treated to kill or inactivate any pathogenic micro-organisms such as viruses, bacteria and parasites, to remove inorganic and organic trace contaminants which have found their way into the water system because of pollution and to reduce the naturally occurring organic compounds such as humid acid and algal metabolites. In general, surface waters such as lakes and rivers contain higher levels of micro-organisms and are more prone to contamination than groundwater and require different treatment regimes. To reduce the risk to consumers, more and more countries are introducing new drinking water regulations containing stricter limits on pathogens and contaminants.

Conventional treatment system utilises several processes in treating water. This include of coagulation, sedimentation, filtration and disinfection process. The coagulation process involves adding iron or aluminium salts, such as aluminium sulphate, ferric sulphate, ferric chloride or polymers, to the water. These chemicals are called coagulants and have a positive charge. The positive charge of the coagulant neutralizes the negative charge of dissolved and suspended particles in the water. When this reaction occurs, the particles bind together, or coagulates (this process is sometimes also called flocculation). The larger particles, or floc, are heavy and quickly settle to the bottom of the water supply. This settling process is called sedimentation.

2.5.1 Ground Water

Some water underlies the Earth's surface almost everywhere, beneath hills, mountains, plains, and deserts. It is not always accessible, or fresh enough for use without treatment, and it's sometimes difficult to locate or to measure and describe. This water may occur close to the land surface, as in a marsh, or it may lay many hundreds of feet below the surface, as in some arid areas of the West. Water at very shallow depths might be just a few hours old; at moderate depth, it may be 100 years old; and at great depth or after having flowed long distances from places of entry, water may be several thousands of years old.

Ground water is stored in, and moves slowly through, moderately to highly permeable rocks called aquifers. Aquifers literally carry water underground. An aquifer may be a layer of gravel or sand, a layer of sandstone or cavernous limestone, a rubbly top or base of lava flows, or even a large body of massive rock, such as fractured granite, that has sizable openings. In terms of storage at any one instant in time, ground water is the largest single supply of fresh water available for use by humans. Ground water has been known to humans for thousands of years. Scripture (Genesis 7:11) on the

Biblical Flood states that "the fountains of the great deep (were) broken up," and Exodus, among its many references to water and to wells, refers (20:4) to "water under the Earth." Many other ancient chronicles show that humans have long known that much water is contained underground, but it is only within recent decades that scientists and engineers have learned to estimate how much ground water is stored underground and have begun to document its vast potential for use. An estimated one million cubic miles of the world's ground water is stored within one-half mile of the land surface. Only a fraction of this reservoir of ground water, however, can be practicably tapped and made available on a perennial basis through wells and springs. The amount of ground water in storage is more than 30 times greater than the nearly 30,000 cubic-miles volume in all the fresh-water lakes and more than the 300 cubic miles of water in all the world's streams at any given time.

2.5.2 Surface Water

Surface water is water that is found in lakes, rivers, streams, ponds, and other natural watercourses. It is also found in marine bays, estuaries, and oceans. This valuable resource provides drinking water, and supports important industries such as fishing, farming and electric power generation. Surface water supports various recreational activities such as swimming and boating, and provides habitat for aquatic life. Overall, a clean, abundant supply of surface water supports the health of humans and aquatic ecosystems, a strong economy, and provides a high quality of life for humans.

2.6 RIVERBANK FILTRATION SYSTEM

River bank filtration is the influx of river water to the aquifer induced by a hydraulic gradient. Collector wells located on the banks at a certain distance from the river creates a pressure head difference between the river and aquifer, which induces the water from the river to flow downward through the porous media into the pumping wells. By applying this system of drinking water extraction, two different water resources are used. On the one hand, surface water from the river percolates towards the well; and groundwater of the surrounding aquifer is utilized (Schon, 2006).

Most RBF systems are constructed in alluvial aquifers located along riverbanks. These aquifers can consist of a variety of deposits ranging from sand: sand and gravel, to large cobbles and boulders. Ideal conditions typically include coarse-grained, permeable water-bearing deposits that are hydraulically connected with riverbed materials. These deposits are found in deep and wide valleys or in narrow and shallow valleys. RBF systems in deep and wide valleys may have a wider range of options since wells (vertical and horizontal collector wells) can be placed at greater depths (which can provide higher capacities) and can be placed further away from the river to increase the degree of filtration. Picture below shows the principles of riverbank filtration system. Figure 2.1 below shows the principles of riverbank filtration system.

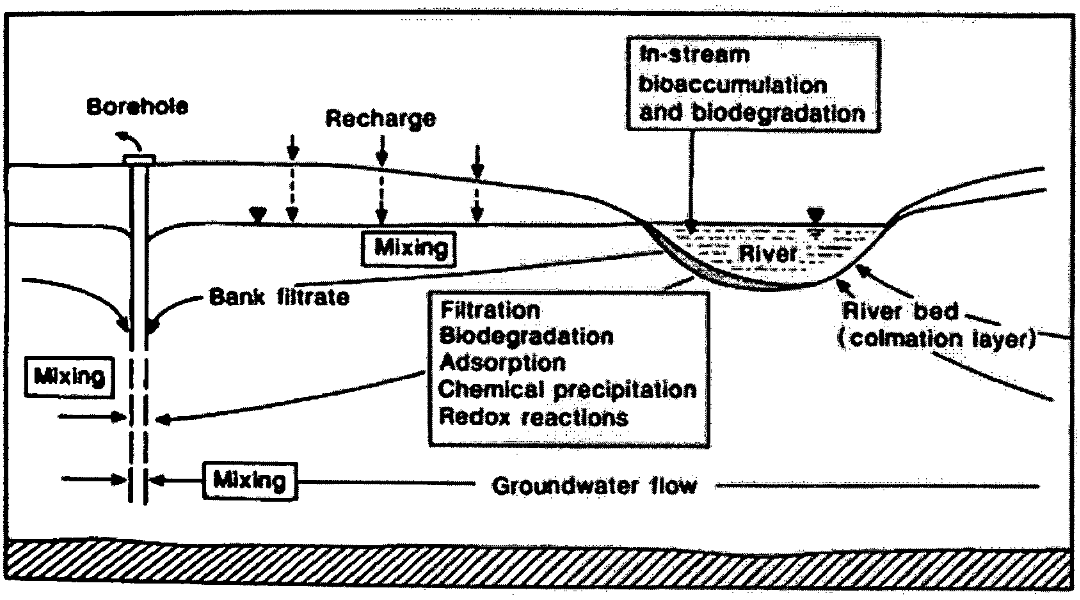

Figure 2.1: Principles of Riverbank Filtration System

Typical aquifers used for RBF consist of alluvial sand and gravel deposits with hydraulic conductivity greater than approximately 10 m/day (Goldschneider et al., 2007). The advantages of RBF include reductions in turbidity, total coliforms, microbial contaminants, natural organic matter and organic contaminants (Tufenkji et al., 2002). Several studies have revealed that RBF is highly effective in reducing the risk of Giardia and Cryptosporidium contamination of drinking water when flow path length and filtration time are sufficient (Berger, et al., 2003) besides removing some pesticides and pharmaceuticals (Kuehn, 2000).

Undesirable effects of bank filtration on water quality can include increases in hardness, ammonium and dissolved iron and manganese concentrations and the formation of hydrogen sulphide and other malodorous sulphur compounds as a result of changing redox conditions (Hiscock, 2002). Local factors such as river hydrology, hydrogeological site conditions (i.e., aquifer thickness and hydraulic conductivity), and the aims of water withdrawal determine not only the capacity of the wells, but also the travel time of the bank filtrate, and distance between the river and the well (Grischek, et al., 2002)., Siting and design issues for riverbank filtration schemes.

Riverbank filtration wells can be designed either vertically (as the most common practice especially for the extraction of low water quantities) or horizontally (for higher extraction rates). Horizontal wells (sometimes with a radial pattern), also known as *collector* wells, are usually directed toward the river and extract water from beneath the riverbed, whereas vertical wells extract water along the riverbed (Ray, et al., 2002). A perspective of riverbank filtration. Also, RBF wells can be distributed parallel to the riverbank in galleries or groups. Grischek et al. (2002) compiled available information from RBF systems in the United States and Europe, and concluded that the most important parameters for success during RBF are the flow path length, the thickness of the aquifer, and the infiltration area in the river. Finally, the authors conclude that the sitting and design of an RBF system does not only depend on hydrogeological factors, but also on technical, economical, regulatory, and land-use factors.

2.6.1 Properties of Natural Soil

An important feature of a soil is that it changes with depth. To properly analyze a soil, it should be examined from the surface to the parent material. Soil texture (e.g. loam, sandy loam or clay) refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil. For example, light soil refers to a soil high in sand relative to clay, and heavy soils are made up largely of clay. Texture is important because it influences the amount of water that the soil can hold, the rate of water movement through the soil as well as its workability and fertility. For example, sand is well aerated but does not hold much water and is low in nutrients. Clay soils generally hold more water, and are better at supplying nutrients. Soil structure refers to the way soil particles group together to form aggregates (or peds). These aggregates vary in size and shape from small crumbs through to large blocks. For plants to be healthy, they need a steady supply of nutrients.

2.6.2 Artificial Barrier

Activated carbon has been used as artificial barrier to filter the water sample. AC filtration is most effective in removing organic contaminants from water. Organic substances are composed of two basic elements, carbon and hydrogen. Because organic chemicals are often responsible for taste, odor, and color problems, activated carbon filtration can generally be used to improve aesthetically objectionable water. Activated carbon filtration will also remove chlorine and remove some organic chemicals that can be harmful. Some municipal systems have had difficulty in meeting this standard. Activated Carbon filtration is a viable alternative to protect private drinking water systems from organic chemical contamination. Figure 2.2 shows the image of activated carbon.

Figure 2.2: Crushed AC powder

2.6.3 Contaminant Removal

There is no such thing as naturally pure water. In nature, all water contains some impurities. As water flows in streams, sits in lakes, and filters through layers of soil and rock in the ground, it dissolves or absorbs the substances that it touches. Some of these substances are harmless. In fact, some people prefer mineral water precisely because minerals give it an appealing taste.

However, at certain levels minerals, just like man-made chemicals, are considered contaminants that can make water unpalatable or even unsafe. Some contaminants come from erosion of natural rock formations. Other contaminants are substances discharged from factories, applied to farmlands, or used by consumers in homes and gardens.

2.6.3.1 Organic Contaminant

Organic pollutants such as pesticides, herbicides, odorous compounds, oil sub-products, and pharmaceuticals are of great concern for water quality. Riverbank filtration has been extensively used for drinking water pretreatment in places with such pollution problems (Juttner, 1995). The removal and the behavior of organic compounds during RBF depends on factors specific to pollutants such as the hydrophobicity of the compound, the potential for biochemical degradation, the amount of organic matter in the aquifer, microbial activity, infiltration rate, biodegradability, etc. (Tufenkji, Net al., 2002).

Another aspect that apparently influences the removal of certain organic contaminants such as antimicrobial residues is the redox condition of the aquifer together with the travel time. (Heberer, et al., 2008). Although RBF has proven to be a good pretreatment technique for a large number of organic compounds, it has been found that some compounds, such as certain pesticides, pharmaceuticals, and halogenated organic compounds are more resistant to removal (Doussan, et al., 2003).

2.6.3.2 Inorganic Compound

The main and most common processes that control the transport and fate of inorganic compounds in RBF (Tufenkji, et al., 2002) are:

(i) Redox reactions: manganese and iron oxides are mobilized under reducing conditions and adsorbed, precipitated, or co-precipitated under oxidizing conditions.

(ii) Microbial degradation of organic matter: this can alter the geochemical conditions and mobilize metals usually associated with natural organic matter such as copper and cadmium.

(iii)Dilution: high concentrations of inorganic compounds in river water are depleted by the mixing of surface and groundwater.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the methodology that is used in this study. The first section describes the steps involve, follows by the data experiment. The third part describes the parameters that are required in the riverbank filtration system. Subsequent sections explicate the conducted experiments and analysis to investigate the effectiveness of natural soil and activated carbon mixture as barrier material in riverbank filtration system.

This research study was conducted based on the flow chart of research methodology as shown in Figure 3.1. The study starts by identifying the problem and survey research literature before. Then the study will be followed by the collection and preparation of samples for the laboratory testing. While in the laboratory, the basic test will be performed for the purpose of soil properties and water quality parameter. All of the parameter was determined following laboratory procedures. This study then will be recorded in a written report.

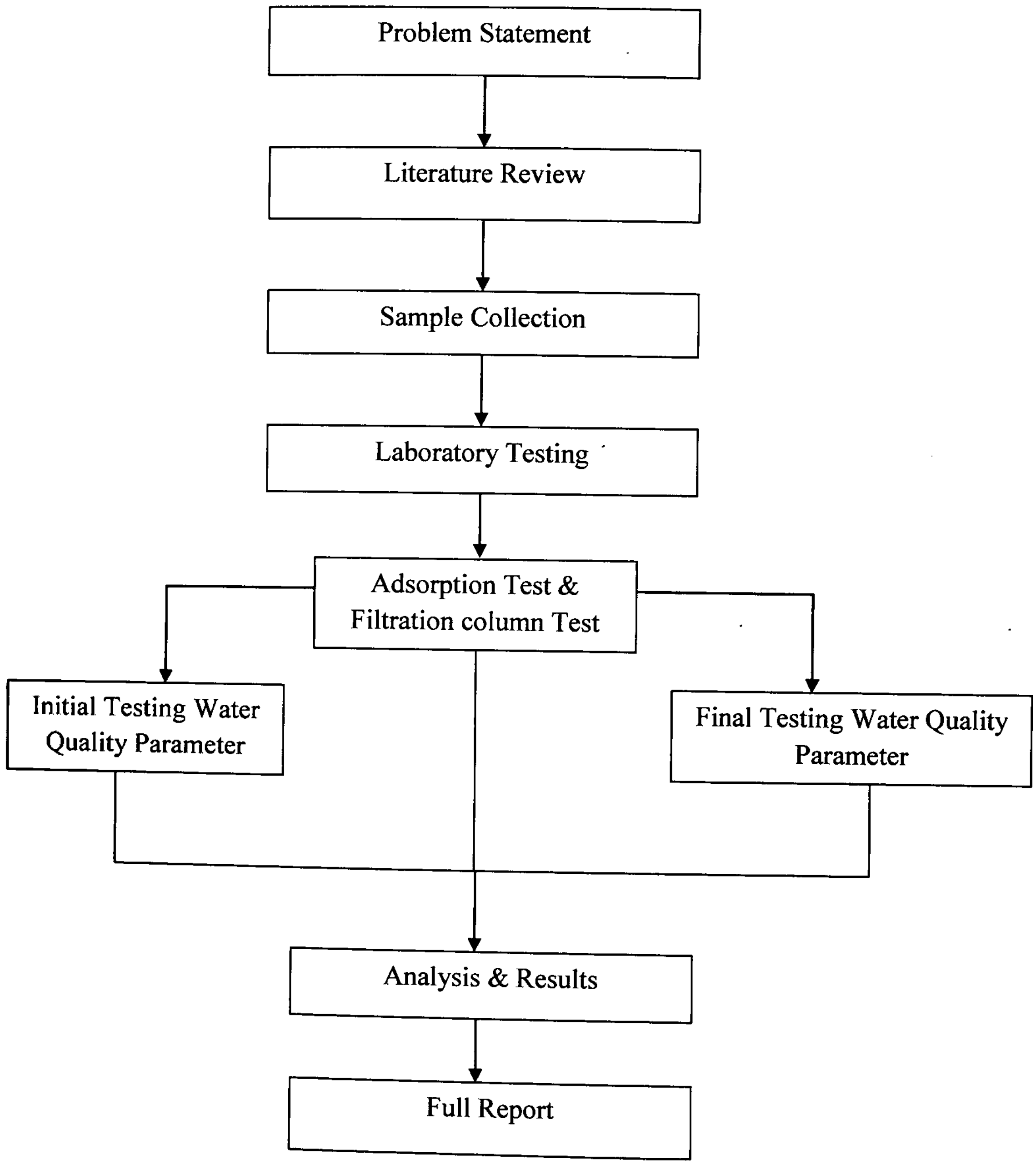

Figure 3.1: Flow chart of research methodology