WATER QUALITY ASSESSMENT OF PUTRAJAYA LAKE FOR ALTERNATIVE SOURCE OF WATER SUPPLY

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ABSTRACT

This study focused on determining water quality of Putrajaya Lake. Water Quality is an important guideline to describe the physical, chemical, and biological properties of water that classified them into each class with different suitable purposes. A study was conducted on physical, chemical, and biological parameter of Putrajaya Lake in 2015 water bodies at five stations with three times sampling in the month of September, October, and November. Physical parameters were temperature and suspended solids. Whereas, chemical parameters were pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen, and selected heavy metals. Biological parameter were Total Coliform and E. Coli. The water was classified based on Water Quality Index (WQI) and National Water Quality Standard for Malaysia (NWQS). According to WQI, the classifications of water quality were based on each station. The most stations in Putrajaya Lake were classified into Class I and II. Station 3 possessed the highest quality surface water sources with WQI value 95 and belongs to Class 1. Station 4 followed by 92, continues with Station 2, Station 5, and Station 1 with value 91,89, and 87 respectively and all of them belong to Class II. Based on NWQS, Most of parameters are belong to Class I. However, BOD, DO, Total Coliform, and lead presence are belongs to Class II. Station 4 chosen as most suitable sources for alternative water supply. The large area covered is the characteristic include in choosing Station 4 as the most suitable alternative water supply. However, in order to provide safe water supply, the raw water sources need to undergo conventional water treatment. According to the Raw Drinking Water Quality Standard the water in Lake Putrajaya did not pass the standards for COD and lead. The main source of lead in the Putrajaya Lake is due to the boating activities that became attraction of Putrajaya. Therefore, it is important to apply new technologies and ideas to control lead contamination. Overall, water quality determination is important to identify different suitable purpose of water body. It is important to conserve and preserve the source of surface water for water supply purpose to avoid water shortage in future.

ABSTRAK

Kajian ini memberi tumpuan dalam menentukan kualiti air Tasik Putrajaya. Kualiti air adalah satu garis panduan penting untuk menggambarkan ciri-ciri fizikal, kimia, dan biologi yang diklasifikasikan ke dalam setiap kelas dengan tujuan kegunaan yang berbeza. Kajian telah dijalankan ke atas ciri-ciri fizikal, kimia dan biologi Tasik Putrajaya pada tahun 2015 di lima stesen dengan tiga kali persampelan pada bulan September, Oktober dan November. Parameter fizikal yang diuji adalah suhu dan pepejal terampai. Manakala, parameter kimia adalah pH, oksigen terlarut (DO), keperluan oksigen biokimia (BOD), permintaan oksigen kimia (COD), nitrogen ammonia, dan logam berat terpilih. Parameter biologi adalah E. Coli dan koliform. Jumlah. Air itu dikelaskan berdasarkan Indeks Kualiti Air (WQI) dan Nasional Standard Kualiti Air Malaysia (NWQS). Menurut WQI, pengelasan kualiti air adalah berdasarkan pada setiap stesen. Semua stesen di Tasik Putrajaya telah dikelaskan kepada Kelas I dan II. Stesen 3 memiliki sumber air permukaan yang berkualiti tinggi dengan nilai WQI 95 dan tergolong dalam kelas 1. Stesen 4 diikuti oleh 92, manakala Stesen 2, Stesen 5, dan stesen 1 dengan nilai 91,89, dan 87 dan semua daripadanya tergolong dalam Kelas II. Berdasarkan NWQS, kebanyakan parameter adalah milik kepada Kelas I. Walau bagaimanapun, BOD, DO, jumlah koliform dan kehadiran plumbum adalah tergolong dalam Kelas II. Stesen 4 telah dipilih sebagai sumber air yang paling sesuai untuk bekalan air alternatif. Kawasan yang diliputi besar dengan kriteria pengambilan air yang sesuai adalah dapat dilihat di stesen 4 sebagai sumber bekalan air alternatif yang paling sesuai. Dalam usaha untuk menyediakan bekalan air bersih, sumber air mentah perlu menjalani rawatan air konvensional. Walau bagaimanapun, menurut standard air mentah bagi tujuan minuman, air di Tasik Putrajaya tidak melepasi standard bagi COD dan plumbum. Sumber utama plumbum di Tasik Putrajaya adalah berpunca daripada bot-bot yang menjadi tarikan aktiviti rekreasi di sini. Oleh itu, adalah penting untuk mengaplikasikan teknologi dan idea baru untuk mengawal pencemaran plumbum. Secara keseluruhan, penentuan kualiti air adalah penting untuk mengenal pasti tujuan penggunaan air yang berbeza. Ia adalah penting untuk memelihara dan memulihara sumber air permukaan untuk tujuan bekalan air untuk mengelakkan kekurangan air pada masa hadapan.

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LIST OF SYMBOLS

^{o}C	Degree Celcius
mg/L	Miligram per Liter
MPN	Most Portable Number

LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DID	Department of Irrigation and Drainage Malaysia
DO	Dissolved Oxygen
DOE	Department of Environment Malaysia
ERL	Express Rail Link
MARDI	Malaysian Agricultural Research and Development Institute
NWQS	National Water Quality Standard
Pb	Lead
TSS	Total Suspended Solids
UMP	Universiti Malaysia Pahang
UNICEF	United Nations Children's Fund
UPM	Universiti Putra Malaysia
WHO	World Health Organization
WQI	Water Quality Index
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

Water is valuable natural resources to human, all living things, and healthy environment. According to non-government organization, the fact that more than 840,000 people die each year from a water related disease and 750 million people lack access to clean water. A healthy environment is one in which the water quality supports a rich and varied community of organisms and protects public health. In earth, there is only 3% of Earth's water is fresh water and the rest of 97% of the water consist of salt water (WHO, 2015). However, the fresh water might be decreasing due to high demand and increasing of population around the world.

There are many types of water resources on earth. The common water resource is from the water surface for instance stream, pond, river or freshwater wetland. These surface water resources basic function for the agricultural use, for industrial use and for the generation of different types of energy such as hydro electrical energy. However, it is important to conserve the quality of surface since other resources such as groundwater comes in limited volume and takes longer time to renew the source.

In Selangor , there were water issues that occurred because of a tanker overturned, spilled diesel into Sungai Selangor, which led to the closing of four treatment plants which supply water to about 10,000 consumers in Kuala Lumpur and Selangor. About 2.67 billion liters of water daily, catering to 57% of water demands in Kuala Lumpur, Putrajaya and Selangor were produced by the four plants (Ruban and Habibu, 2013).

1.2 PROBLEM STATEMENT

The growth of population and expansion in urbanization, industrialization and irrigated agricultural is imposing growing demand and pressure on water resource. The existing water resources nowadays were facing the pollution because of this phenomenon (Che-Ani et al., 2009). This evaluation is importance since Selangor and Lembah Klang area faced shortage of water nowadays. The recent global experience of the 1998 El Nino has caused a long drought in Malaysia. The lack of rainfall in the catchment areas especially in the state of Selangor given result the two dams that supply water to Kuala Lumpur and surrounding regions to almost critical levels. The water crisis lasted from March to September 1998 and affected 1.8 million residents (Aini et al., 2001). Water crisis has become severe problem and further study need to be done to find the solutions.

Besides that, many rivers in Malaysia polluted due to improper chemical disposal. This chemical disposal may cause health problem to people. The water need to go through complex treatment before it can be consumed. According to the report by the Department of Environment (1998) there were 25 rivers (21.4%) that were polluted in 1997, a doubling of the figure in 1996. This is of grave concerned since rivers are the main sources of water supply to the country. They were due to the dumping of industrial waste, domestic effluent, agriculture and livestock production processes (DOE, 1994). Study of lake as alternatives source of water supply is important since water demand increase by time and populations at Selangor area due to rapid development. Besides that, the climate changes also affect the availability of water supply.

1.3 OBJECTIVE

The main objectives of this study are :

- To determine the water quality status consisting physical, chemical, and biological parameter based on Water Quality Index and National Water Quality Standard Malaysia.

- To identify whether Putrajaya Lake are suitable as water supply resources based on Raw Drinking Water Quality Standard.

1.4 SCOPE OF STUDY

Putrajaya is located 25km away at the south Kuala Lumpur. Putrajaya plays a role as federal administrative centre of Malaysia. The location of Putrajaya Lake located at water crisis problem most occur in Malaysia. Shortage of water occur in most Selangor state and Lembah Klang area which located near the boundaries of Putrajaya Lake.

Sampling stations in this research area was located at various points according to their different depth, current flow, and surrounding activities around the lake. Besides that, sampling points also based on water intake criteria. Water intake criteria consists of best available water quality, far from strong current, quantity of water demanded can be achieved at very low water flow rate, easy accessible and possess adequate space and facilities for maintenance. The sample from each sampling point will be taken once since lake is not a stream flow that may show frequent changes.

The study includes physical, chemical, and biological characteristic parameters. The physical parameter consists of temperature, conductivity and suspended solid test. Whereas chemical parameter consists of pH test, Dissolve Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and test for heavy metal presence. Biological parameter consists of Absence-Presence Test.

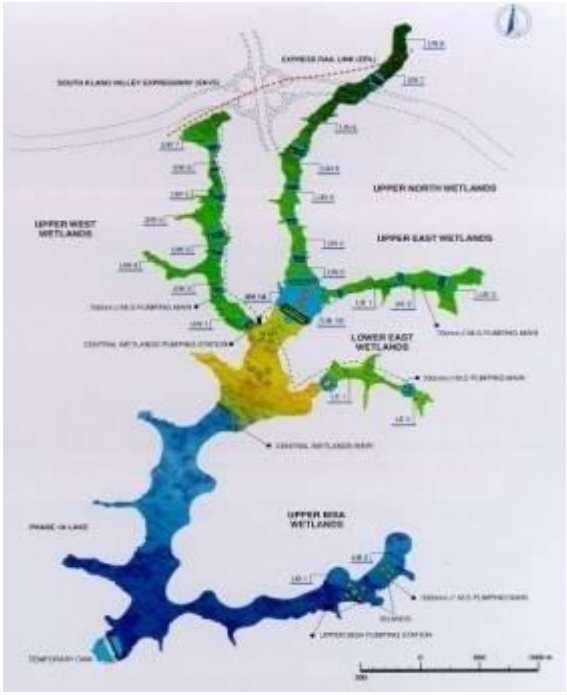

Figure 1.1 : Shape of Putrajaya Lake

Source : Perbadanan Putrajaya 2015

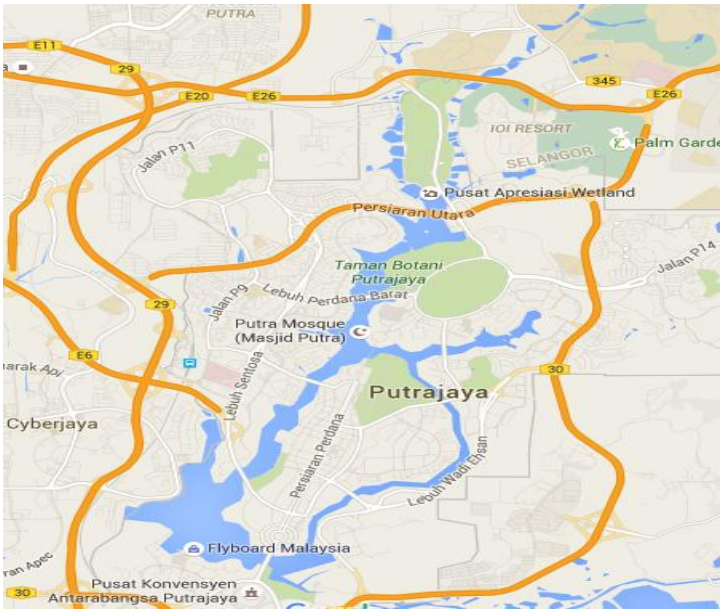

Figure 1.2 : Location of Study Area, Putrajaya Lake

Source : Google Maps 2015

1.5 JUSTIFICATION OF STUDY

The tendency of water demands in Malaysia was estimated to increase from 9,543m^3/day in 1995 to 15,285 m^3 /day in 2010, or the increase of 60% during 15 years, to 20,338 m^3 /day in 2020, or 113% during 25 years (DOE, 2003). It is important to study other alternative source of water supply besides the river due to this rapid increasing of water demand.

The infrastructure has been strained by rapid urban growth and there are high needs of improvement of amenities such as water supply, electricity, transportation, environment and drainage (Weng, 2004). A new development of water resource like lakes is very important to make sure that there is no water shortage in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Water is an important element to all living things. Water also plays an important role in environmental ecosystem. Therefore, study on water quality is important especially on fresh water that consist lake, groundwater, and river. Water quality is use to describe the microbiological, physical and chemical properties of water that determine its fitness for a specific use. These properties are determined by substances where are either dissolved or suspended in the water. Water quality should be assessed based on the characteristics of the water relative to the beneficial uses of the water. This study purpose is to identify whether the lake is suitable as water supply source. There are several valuable benefits expected by implementing this study. This study will improve the living standards of human using safe water supplied from lakes which also can be as alternative source of supply water during the dry season.

2.2 HYDROLOGICAL CYCLE OF WATER SOURCE

Ecosystem consist of plants, animals, fungi, and bacteria that interacting with one another in the environment that plays a role as their habitat. The hydrologic cycle is a continuous cycle of water that consists above and below the surface of the earth. Climatic variables affect the volume of water in earth according to time. There are several major reservoirs in earth that consist of ice, fresh water, saline water and atmospheric water. The physical process of evaporation, condensation, infiltration, precipitation, subsurface flow, and runoff takes place in water movement from one reservoir to another or from ocean to atmosphere. In order to complete the cycle, the

water may change their physical state from liquid to solid to gas and vice versa. Hydrological cycle links all water bodies in continents of oceans, and studies in different scales in global extent and in local area. It is essential for scientifically assessing available fresh water resources (Beniston, 2006).

The hydrologic cycle begins with the evaporation of water from the surface of ocean. The air is lifted, become low in temperature and form a water vapor. The water vapor condenses and forms the clouds. The moisture of clouds transported all over places by wind and return to earth surface as precipitation. Once the water reaches ground, they form two processes that consist of evaporation and penetration of water to form groundwater. Groundwater form seeps its way into the oceans, rivers, and streams. Some of it may release back into the atmosphere by transpiration. The remaining water on the earth surface is runoff where move to ocean through the lakes, rivers, and streams to allow the cycle repeats.

Figure 2.1 shows the graphic explanation regarding overall hydrological cycle process. This process takes place continuously.

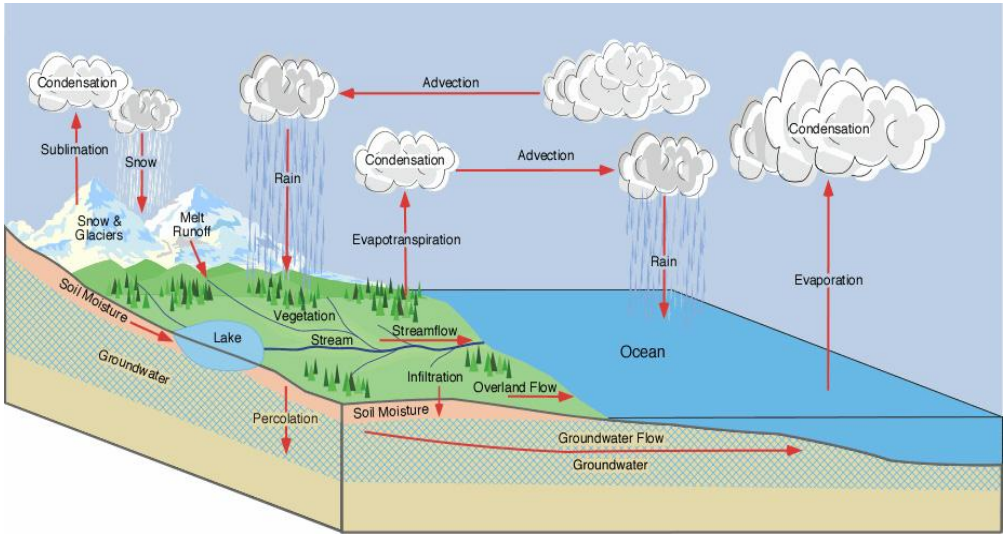

Figure 2.1 : The Hydrological Cycle Movement of Water

Source : PhysicalGeography.net

The combined effects of urbanization, industrialization and population growth affect natural landscapes and the hydrological response of watersheds (Marsalek et al., 2008). Besides that, climate change nowadays gave a great impact towards hydrological cycle that limits the source of fresh water to living things on earth. Observational evidence shows that many natural systems are affected by Global Change, among which the hydrological system is predominantly influenced. Because of the aforementioned projected large- scale patterns of precipitation and warming, it can be postulated the Global Change will impact the hydrological cycle and the availability of fresh water. A shortage of fresh water is expected to be the dominant water problem of the 21 century. Water shortages coupled with reduced water quality may jeopardize efforts to secure sustainable development (Speth et al., 2010). Therefore, it is important to study various alternative water sources to support future water demand.

2.3 WATER QUALITY PARAMETER

Water quality is used to describe the physical, chemical, and biological properties of water that classified them into each class with different suitable purposes. Substance that suspended and dissolve in water body need to be analyzed in order to identify the water quality level. The raw water source should be free from any toxic elements and dangerous organisms that may hazardous to health. Advanced water quality or ecologically based standards that integrate physical, chemical and biological numeric criteria offer the potential to better understand, manage, protect, and restore water bodies (Magner, 2006). Pesce et al. (2000) defined the quality of surface water has become a critical issue in many countries, especially due to the concern that freshwater will be a scarce resource in the future so a water quality monitoring program is necessary for the protection of freshwater resources.

2.3.1 Parameter of Physical Water Quality

The parameter of physical characteristics water quality in this study consists of temperature, conductivity and suspended solid.

2.3.1.1 Temperature

Temperature measurement can help detect sources of thermal pollution and suggest the size of habitat for organism that is more sensitive to temperature variation. The water temperature is a measure of the heat content of the water mass and influences the growth rate and survivability of aquatic life (Department of Irrigation and Drainage, 2009).

2.3.1.2 Conductivity

Conductivity in water is affected by the presence of inorganic dissolved solids such as anions and cations. Conductivity is a measure of the ability of water to pass an electrical- current. The higher concentration of charges ions in the water, the higher is value of conductivity of the water. Conductivity and suspended solid is correlated to each other.

2.3.1.3 Total Suspended Solis (TSS)

Water quality parameters that are used to gauge the clarity of water is determination of suspended solid (Salleh, 2011). Suspended solid, used to measure the total suspend solids in the water. This solid may consist of inorganic and organic particles. Example of inorganic particles commonly found in water is clay, slit and other constituents meanwhile for organic particles is plant fibbers and biological solids. Low suspended solids, does not only ensure the desirable clarity of the water for supply but also ensures maximum disinfection potency. Suspended solids also interfere with the disinfection process as the particles can shield microbes from the chlorine compound and even from ultraviolet (UV) sterilization (Salleh et al., 2011).

Total Suspended Solids includes all particles suspended in water where will not pass through a filter. Suspended solids are present in sanitary wastewater and many types of industrial wastewater. There are also non-point 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 level of Dissolved Oxygen (DO). Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in DO levels (Government of Michigan, 2015).

2.3.2 Parameter of Chemical Water Quality

The chemical characteristics of water quality are determination of pH value, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and determination of selected heavy metals.

2.3.2.1 Determination of pH Value

pH of the pure de-ionized water contains equal numbers of H+ and OH- ions, and has a pH of 7. It is considered neutral, neither acidic nor basic. If a water sample has more H+ than OH- ions, it is considered acidic and has a pH less than 7. If the sample contains more OH- ions than H- ions, it is considered basic with a pH greater than 7. Low pH will cause compounds and toxic elements spread easily. Heavy metals element presence increase when pH level of water low.

2.3.2.2 Biochemical Oxygen Demand (BOD)

Dissolved oxygen is essential for the maintenance of healthy lakes and rivers. The presence of oxygen in water is a good sign. The lack of oxygen is a signal of severe pollution. Rivers range from high to very low levels of dissolved oxygen. Sometimes the level gets so low that there is little aquatic life. Biochemical oxygen demand is when organic matter decomposed, it is fed upon by aerobic bacteria. In this process, organic matter is broken down and oxidized (combined with oxygen).

BOD is a measure of the quantity of oxygen used by these microorganisms in the aerobic oxidation of organic matter. Biochemical oxygen demand represents the

amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic conditions at a specified temperature (Delzer et al., 2003).

When BOD levels are high, DO levels decrease because the oxygen that is available in the water is being consumed by the bacteria. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive.

BOD is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The term 'decomposable' may be interpreted as meaning that the organic matter can serve as food for the bacteria and energy is derive from its oxidation.

In aerobic processes (O_2 is present), heterotropic bacteria oxidise about 1/3 of the colloidal and dissolved organic matter to stable end products (CO_2 + H_2O) and convert the remaining 2/3 into new microbial cells that can be removed from the wastewater by settling.

The overall biological conversion proceeds sequentially, with oxidation of carbonaceous material as the first step known as carbonaceous oxygen demand:

$$\text{Organic matter} + O_2 \longrightarrow CO_2 + H_2O + \text{new cells}$$

Under continuing aerobic conditions, autotrophic bacteria then convert the nitrogen in organic compounds to nitrates (known as nitrification oxygen demand)

$$\text{Organic-Nitrogen} \xrightarrow[\text{(decomposition)}]{} \text{Ammonia-Nitrogen}$$

$$NH_3 - N + O_2 \xrightarrow{\text{Nitrifying bacteria}} \text{Nitrate-Nitrogen (nitrification)}$$

The ultimate BOD (L_o) is defined as the maximum BOD exerted by the waste. The carbonaceous oxygen demand curve can be expressed mathematically as

$$BOD_t = L_0 (1\text{-}10^{-Kt})$$

Where,

BOD_t = Biological oxygen demand at the time t, mg/L

L_0 = ultimate BOD, mg/L

t = time, days

K = reaction rate constant, day^{-1}

Most biological processes speed up as the temperature increases and slow down as the temperature drops. The rate of utilization is affected by temperature the relationship for the change in the reaction rate constant (K) with temperature is expressed as

$$K_T = K_{20} \times \theta^{T-20}$$

Where,

K_T = reaction rate constant at the temperature T, per day

K_{20} = reaction rate constant at 20°C, per day

θ = temperature coefficient = 1.047

T = temperature of biological reaction, °C

Ultimate BOD (L_0),

$$_TL_0 = {}_{20}L_0 [1 + 0.02(T\text{-}20)]$$

Where,

$_TL_0$ = ultimate BOD at the temperature T, mg/L

$_{20}L_0$ = ultimate BOD at 20°C, mg/L

2.3.2.3 Chemical Oxygen Demand (COD)

Chemical oxygen demand usually used to determine the amount of organic pollutants in the water. The amount of oxygen in the water used to oxidize all organic pollutants in the water. High level of COD can affect the ecosystem of the river especially for the aquatic lives. COD does not differentiate between biologically available and inert organic matter, and it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. COD values are always greater than BOD values, but COD measurements can be made in a few hours while BOD measurements take five days (Environmental Protection Agency, 2008).

The COD measures the amount of organic contamination in waste water, for example water contaminated with sewage, water from food processing plants, textile factories or water containing organic chemicals. This test is reasonably fast but can give erroneous results with some contaminants. For example, ethanoic acid contamination will not be detected but the test will include cellulose. Potassium dichromate will react with chlorine and this will give an error with water with high levels of chlorine. The oxidation rate varies for different compounds so it is important to adhere strictly to the reaction time specified to allow comparisons between samples. (Chemical, Forensic, Food & Environmental Technology, 2009)

2.3.2.4 Ammoniacal Nitrogen

Ammonia nitrogen is present in variable concentrations in many surface and ground water supplies. A product of microbiological activity, ammonia when found in natural water is regarded as indicative of sanitary pollution. Ammonia is one of several forms of nitrogen that exist in aquatic environments. Unlike other forms of nitrogen, which can cause nutrient over-enrichment of a water body at elevated concentrations and indirect effects on aquatic life, ammonia causes direct toxic effects on aquatic life. Ammonia is produced for commercial fertilizers and other industrial applications. Natural sources of ammonia include the decomposition or breakdown of organic waste matter, gas exchange with the atmosphere, forest fires, animal and human waste, and nitrogen fixation processes (Environmental Protection Agency, 2008).