STUDY ON WATER QUALITY ON THE PAHANG RIVER, MALAYSIA

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ABSTRACT

From now on, the Ecological status of Malaysia is not bad with other countries, because many developing nations have same situation with Malaysia. Even though the government set up the Environmental Quality Act (EQA) in 1974, the water quality of the Malaysia still Worsening, especially the inland rivers. The main pollution is from point and non-point source in the river, department of environment can controlled the point sources, there are lots of the point sources from the runoff and sullage. However, the government can take the steps which are used before to control the non-point source pollution and untreated sullage which are main factor on the status in the river. The objectives of study were To determine the water quality status of the Pahang River based on water quality index (WQI) and To obtain the factors that affected the water quality at the Pahang River. There are two types of test was performed in this study, which are site visit and experiment in laboratory. For in-situ test, the tests are PH, Turbidity, ammonia nitrogen, biochemical oxygen demand, and dissolved oxygen, chemical oxygen demand, suspended solid ate the tests that was been carried out in the laboratory. From the results: AN (0.09-0.204mg/L), BOD (3.2-6.2mg/L), COD(22-50mg/L), DO(3.64.63mg/L), Turbidity(22-66 NTU), Temperature(29-30°C), TSS (11-102 mg/L), pH(6.7-7.82).in the conclusion One of the main pollutants which are ammoniac nitrogen (NH3-N) has been identified by the department of environment. But the new regulation show that sewage and industrial set allowable NH3-N concentration quite high (5mg/L), so many result got lower value in the water quality index for the river. The water quality can be affect by the forest, human activities and construction sit.

ABSTRAK

Mulai sekarang, status ekologi Malaysia tidak buruk dengan negara-negara lain, kerana negara-negara membangun mempunyai situasi yang sama dengan Malaysia. Walaupun kerajaan menubuhkan Akta Kualiti Alam Sekitar (EQA) pada tahun 1974, kualiti air daripada Malaysia masih semakin teruk, terutamanya sungai-sungai pedalaman. Pencemaran utama ialah dari sudut dan punca bukan titik-dalam sungai, jabatan alam sekitar boleh dikawal sumber titik, terdapat banyak sumber-sumber mata daripada air larian dan air dapur. Walau bagaimanapun, kerajaan boleh mengambil langkah-langkah yang digunakan sebelum untuk mengawal pencemaran punca bukan titik dan air endapan keladak yang tidak dirawat yang faktor utama kepada status dalam sungai. Objektif kajian adalah untuk menentukan status kualiti air di Sungai Pahang berdasarkan Indeks Kualiti Air (WQI) dan Untuk mendapatkan faktor-faktor yang memberi kesan kualiti air di Sungai Pahang. Terdapat dua jenis ujian telah dijalankan dalam kajian ini, iaitu lawatan tapak dan eksperimen di makmal. Untuk ujian in-situ, ujian adalah PH, kekeruhan, ammonia nitrogen, permintaan oksigen biokimia, dan oksigen yang terlarut, permintaan oksigen kimia, pepejal terampai memakan ujian yang telah dijalankan di makmal. Daripada keputusan: AN (0.09-0.204mg / L), BOD (3.2 6.2mg / L), COD (22-50mg / L), DO (3.64.63mg / L), kekeruhan (NTU 22-66), Suhu (29-30 ° C), TSS (11-102 mg / L), pH (6,7-7,82). dalam kesimpulan Salah satu pencemar utama iaitu nitrogen ammonia (NH3-N) telah dikenal pasti oleh jabatan alam sekitar. Tetapi menunjukkan peraturan baru yang kumbahan dan set industri yang dibenarkan kepekatan NH3-N agak tinggi (5mg / L), hasilnya begitu banyak mendapat nilai yang lebih rendah dalam indeks kualiti air untuk sungai. Kualiti air boleh memberi kesan oleh hutan, aktiviti manusia dan pembinaan duduk.

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CHAPTER 1

INTRODUCTION

1.0 BACKGROUND STUDY

Fresh water resources are the most assets of any human civilization. Surface water quality is influenced by various natural processes and human activities. Water environment in the world faces two major problems: first is the shortage of water recourses and river pollution increase. The second is massive emission of industrial wastewater and urban sewage to rivers, lakes and soil, surface water and ground waters, water quality is deteriorating, exacerbated by the tension of the water, has seriously hampered the development of the economy and endanger human health. The grim situation of water increased attention to the extent of the water pollution, countries are increasing speed up the intensity and speed of the water pollution.

From the world point of view, water quality is nearly a century to carry up a new career as the development of the social productive forces and the progress of science and technology continue to be innovative. Mid-19th century steam engine is widely used, and an important factor in the impact of the steam engine service life of good or bad sleep high hardness that are enough thickening, resulting in performance degradation, shortening of the economic life of the boiler. Water harness is a project of the boiler water must be measured. The late 19th century, microscopy and microbiology rise so that

People understand the cholera, typhoid fever spread by bacteria in the water and pop up. The water quality of life project is the number of E. coli. The end of the 19th century, serious pollution of the River, the river black smelly fish and shrimp extinct, in order to protect the ecosystem, the British decided to use dissolved oxygen, biochemical oxygen demand, suspended solids as the river water quality will test the project.

The Pahang River is located in West Malaysia. It is the longest river in the Malaysia. It start on the Jelai and Tembeling, about 10 miles north of Jerantut and flows south past Temerloh, paralleling the Main Range to Mengkarak, where, at the break of slope between the mountains and the plains, it abruptly turns eastward. The river then completes its 271-mile (436-kilometre) course, through alluvial plains more than 20 miles (32 km) wide, to empty into the South China Sea at Pekan. Though this study, the water quality in the Pahang River can be identified.

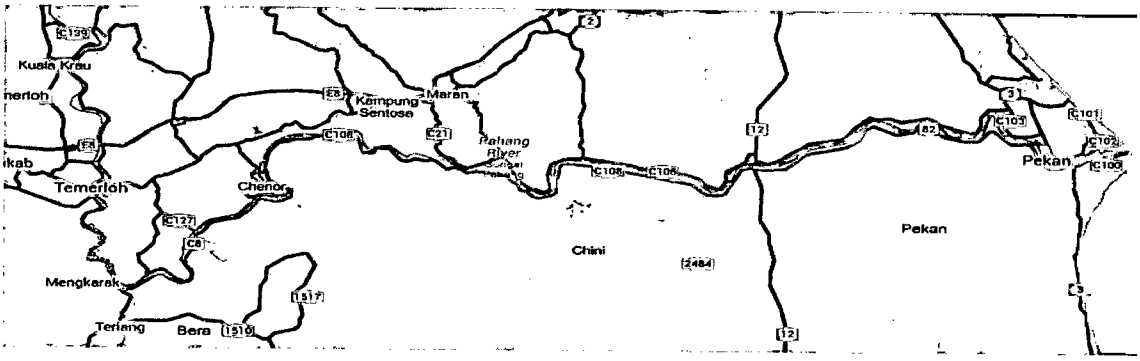

Figure 1.1: map of Pahang River

1.1 PROBLEMS STATEMENT

The water qualities of river are one of the world most common problems. The public and the government have concerned about the future of the river. The Pahang River between Mengkarak to pekan has been selected as the study of water quality, because of it is importance and function of the

community. Because is a very important to natural resource, the people living around the area. However, with the emission of the surrounding industrial development and the living water the water quality of the river has gradually deteriorated.

River water pollution is a great concern all over the world. This pollution is a result of environmentally degrading activities, which directly affect the river water quality. In Malaysia, the International Conference on Energy, Environment and Sustainable Development, Pakistan, 2012 main sources of chemical, organic, and thermal water pollution are the effluents of palm oil industry, percolation of uncontrolled solid waste disposals and untreated wastewaters of human settlements. A study conducted by the Department of Environment (DOE) on 120 rivers in 2001 found that 13 rivers (10.8 %) were seriously polluted while 47 rivers (39.2 %) were slightly polluted based on Water Quality Index (WQI). The WQI serves as the basis for environment assessment of a water body in relation to pollution load categorization and designation of classes of beneficial uses as provided under the National Water Quality Standards for Malaysia (NWQS).

The criteria that must be followed are ammonia nitrogen (AN), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid, dissolved oxygen (DO), pH, total hardness, TDS, calcium, and chloride.

The source of pollution in the Pahang River must determine in order to ensure that preventive measures can be taken to stop pollution. Is leisure important is to keep our country and all living things in there, because it provides a lot of benefits.

1.2 OBJECTIVE

The objectives of study were:

(i) To determine the water quality status of the Pahang River based on water quality index (WQI)

(ii) To obtain the factors that affected the water quality at the Pahang River.

1.3 SCOPE OF STUDY

The scopes of study can be listed as follows:

This study of water quality according to water quality index

This study was taken into condition all parameters in WQI which are ammonia nitrogen, biochemical oxygen demand chemical oxygen demand, total suspended solids, dissolved oxygen, pH .

This study was conducted from March until April 2014.

1.4 SIGNIFICANT OF THE STUY

This study was to know the level of water pollution of the Pahang River. The data regarding water quality at the river can help us to know which part of the Pahang River need to protect and increase my own ability and knowledge about water quality. The research is very important for the environment. The data of the water quality was useful to formulate the environmental standards and the impact of that waste. The data of water quality need to be getting knew by the resident of Pahang so that the public or private agency can encourage citizen for the community awareness and wastewater management planning. Furthermore .wastewater management is

an essential task which consequences for public health and well-being, the quality and sustainability of the urban environment and the efficiency and productivity of the urban economy.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A review of the literature was selected to identify to the topic which is the study of water quality at Pahang River. The source for the literature search was internet journal and article. The emergent themes may divide into: the important of river; river pollution; water quality in Malaysia; water quality index; the effects of river pollution.

2.2 THE IMPROTANCE OF RIVER

The world is cover by 75% of water. Rivers transfer or carry the water to areas all around the earth. According to WWF (2011) define river as a water flow undisturbed from its source to its mouth, either at the coast, an inland sea or at the confluence with a larger river. Small rivers may define with others name, including stream, brook, creek, run, rill, tributary, creek and rivulet.

River is a part of the hydrological cycle. Water within a river is formally collected from precipitation from surface runoff. River acting as drainage channels for surface water. Other than that, river provides habitat and road for the organism. There are many organisms live in river, such as crocodile. Other

animals use the river for food and drink for example such as horse, elephants, and lion. Birds such as kingfisher eat small fish from the river. Reeds and bulrushes grow along the river banks.

River can provide transport. Fisherman travels from the river to the sea by using boat .river also can provide commercial for example, in Thailand, floating market, is the place for tourism. River also is place for recreation for the human. Normally, we have waterfall at part of river upstream which provide beautiful recreational area with good scenery. River valleys and plains provide fertile soils. Farmers in dry region irrigate their cropland using water carried by irrigation ditches from nearby rivers. (Lim, 2008)

Malaysia Water Resource	**billion m^3**
Annual rainfall:	990
Surface runoff:	566
Evapo-transpiration:	360
Groundwater recharge:	64
Surface artificial storages (dams):	25
Groundwater storage (aquifers):	5000

Water use (year 2000)

Total for Malaysia: 12.5billion m^3 (2.2%of surface runoff)

2.3 RIVER POLLUTION

Water pollution occurs when waste products or other substances that change the physical, chemical biological or thermal characteristic of the water. A river is polluted when a substance which degrades the water quality enters the waterway and alters its natural function. Polluted water will affect the living organism and reducing the water beneficial uses. Polluted water also can harm the plants and animal, restrict recreation, damage economic use, damage scenery or pose threat to fisheries.

The river is being use as recreation, transport, irrigation, and development of port and boat facilities. The river banks are focus for residential, recreational, tourist and industrial development and roads. The human were often used as convenient dumping or throw the rubbish .industrial wastes, as part of filling marshland. Intensive agriculture including market garden and vineyards will convenient the fertile river floodplains. The wider catchments often support a range of land uses such agriculture, mining, residential and forestry.

Water pollution is caused by waste from factories and cities. Oceans are able to clean themselves, but certain seas, once they become dirty, are not able to do so. One example is the Mediterranean which lies between Europe and Africa. It has only one narrow entrance to the ocean in the west. On quarter of the shores of the Mediterranean are polluted and are no longer safe for swimming, as a lot of diseases are present in the water. In most places it is not safe to eat the fish. Lakes also have the same problems. Lake Baikal in Asia was once the cleanest in the world, with over 700 different kinds of plant and animal life. Now, however, the water of this great lake, which is also the world's deepest (over 1,740 meters), have been dirtied by waste from a chemical factory. In 1989 an oil tanker hit a rock off the northwest coast of Alaska. 35,000 tons of oil poured into the sea. The accident was one of the worst in history. More than 34,000 birds and 10,000 animals were killed. 4,800 square kilometers of ocean were polluted.

2.3.1 PHYSICAL POLLUTANTS

Physical pollutants include litter and sediment from dredging activities or erosion. Rubbish in the river can kill birds, dolphins and fish especially plastic. Sediment in the water can clog fish gills, smother bottom-living plants and animals, reduce the clarity of the water, and restrict the light available for growth of sea grass.

2.3.2 NUTRIENT

High nutrient levels can cause excessive growth of algae, disturbing ecological balance in estuary and reducing the recreational values. Other than that, high nutrient can caused lower oxygen level in bottom water which will lead to fish kills. The major sources of nutrients are come from storm water drainage, fertilizers from parks and garden, sewage, agricultural runoff which containing fertilizers and animal wastes, detergents, leachates from rubbish, organic industrial wastes, and estuary sediment banks.

2.4 WATER QUALITU OF MALAYISIAN RIVERS

According to ODE (2010), in 2010, a total of 1055 water quality monitoring stations located at 573 rivers were monitored. 50% were found to be clean, 40% slightly polluted and 10% are polluted. From the previous study, the number of clean rivers decreased from 306 rivers in 2009 to 2003, slightly polluted rivers decreased from 217 in 2009 to 203 while number of polluted river increased to 74 from 54(2009). The decreases in the number of clean rivers were attributed to an increase in the number if pollution sources such as sewage treatment plants and agro-based industries which contributed to high pollution loading.

Almost 60% of the major rivers are regulated for domestic, agricultural, and industrial purposes(Department of Irrigation and Drainage 2001).According to Rosanne (2001), the major pollution sources affecting rivers in Malaysia are sewage disposal, discharges from small- and medium sized industries that are still not equipped with proper effluent treatment facilities and land clearing and earthworks activities. In 1999, 42% of the river basins were recorded to be polluted with suspended solids (SS) resulting from poorly planned and uncontrolled land clearing activities,30% with biological oxygen demand (BOD) from industrial discharges, and 28% with ammonia Cal nitrogen(AN) from animal husbandry activities and domestic sewage disposal.

Surface water pollution is identified as the major problem affecting the Langat River Basin in Malaysia. The increase of developing areas within the river basin increases pollution loading into the Langat River. As an effort to avoid the Langat River from becoming more polluted, the Department of Environment (DOE) of Malaysia, Ministry of Natural Resources and Environment of Malaysia, has installed telemetric stations along the river basin to continuously monitor its water quality. Based on the water quality data, the water quality index (WQI) was developed to evaluate the water quality status and river classification. WQI provides a useful way to predict changes and trends in the water quality by considering multiple parameters. WQI is formed by six selected water quality variables, namely, dissolved oxygen (DO),BOD, chemical oxygen demand (COD), SS, AN, and pH (DOE 2010).

Rapid urbanization along the Langat River plays an important role in the increase of point source (PS) and non-point source (NPS) pollution loading. The water quality in the basin has been deteriorating over the years, as evidenced from the water quality database compiled for 15 years. The recorded WQI ranged from 58.1 to 75, which corresponds to pollute (WQI, 0–59) and moderately polluted (WQI, 60–80).

2.5 WATER QUALITY INDEX

According to Zainudin (2010), water quality index ascribes quality value to aggregate set of measured parameters. WQI normally consists of sub-index values assigned to each pre-identified parameter by comparing its measurement with a parameter- specific rating curve, optionally weighted, and combined into the final index. The purpose of a WQI is to summarize large amounts of water quality data for a specific river into simple terms. This makes it easily for understanding for the communities in the river basin management. In Malaysia, WQI also referred to as the DOE.EQI primarily used in Malaysia is an opinion-poll formula where panel of experts is consulted on the choice of parameters and on the weight age to each parameter. Six parameters of WQI include dissolved oxygen (DO), biochemical oxygen demand (COD), suspended solids (SS), ammoniac nitrogen (AN) and PH.

Sub index and water quality index	Index range		
	clean	Slightly polluted	polluted
Biochemical oxygen demand (BOD)	92-100	80-90	0-79
Ammoniacal nitrgen	92-100	71-91	0-70
Total Suspended solids(TSS)	76-100	70-75	0-69
Water quality index(WQI)	81-100	60-80	0-59

2.5.1 DISSOLVED OXYGEN

Oxygen is removed from the water by chemical reactions, the decay process and respiration of living organisms, including fish, bacteria, fungi and protozoans.

Water temperature and atmospheric pressure affect the capacity of water to hold dissolved oxygen. Cold water at high atmospheric pressure holds more dissolved oxygen than warm water at low atmospheric pressure. Oxygen levels also are affected by the degree of light penetration (turbidity, color and water depth) and the degree of water turbulence or wave action. Dissolved oxygen is reported as milligrams of oxygen per liter of water (mg/L) which can be called parts by weight per million (ppm).

Aquatic plants produce oxygen by photosynthesis during daylight hours but they also use oxygen for respiration. During the night or on heavily overcast days, respiration removes oxygen while photosynthesis stops or drastically slows down. Oxygen depletion can occur because of heavy plant growth. Complete depletion of DO. can sometimes be detected with your nose. Anaerobic decay results in a rotten egg smell (hydrogen sulfide gas).

Dissolved oxygen levels are reduced by excessive amounts of organic matter such as sewage, manure, or leaves that wash into streams. Warm water released from industrial outlets, flowages, or storm sewers can also reduce dissolved oxygen levels. Erosion from any number of sources is another factor that lowers dissolved oxygen levels. However, good management practices such as planting or maintaining vegetation that filters rainwater runoff and shades the water, cooler water temperatures and protecting the stream channel in other ways to maintain or increase turbulence all promote good dissolved oxygen levels.

2.5.2 BIOCHEMICAL OXYGEN DEMAND

The invention provides improved BOD sensors, suitable for use in monitoring the quality of waste process water, industrial process water, and agricultural process water, among others uses. The invention includes sensors, systems including the sensors, methods of using the sensors to measure BOD, and dilution fluids for use with the systems of the invention. The sensors are superior to prior BOD sensors in that they are inexpensive, robust, have a fast response to BOD changes, and are able to detect a wide range of BOD.

The invention includes biological oxygen demand sensors which incorporate at least three working electrodes, at least one counter electrode, a reservoir for dilution fluid, and a sensor for measuring an electric current or a voltage which flows from the working electrodes to the counter electrode. The BOD sensors will typically also include at least one electrically active microbe disposed in proximity to the working electrode. BOD sensors of the invention may additionally include mixing chambers to receive a sample to be monitored for BOD, wherein the sample is diluted to make at least three different dilutions, all of which are measured for BOD. By measuring the BOD for at least three samples it is possible to quickly establish a BOD value, while still maintaining an ability to measure a wide range of BOD values. In some embodiments of the invention, a voltage source is operatively coupled between the working electrodes and the counter electrode.

The invention includes methods for determining the biological oxygen demand of a sample, comprising diluting the sample with a dilution fluid to obtain at least three different dilutions of the sample, measuring the BOD of each of the at least three different dilutions using a bio electrochemical system (BES) to obtain at least three BOD values, and comparing the at least three BOD values to determine a BOD of the sample. The measurement procedure will typically entail correlating a current or voltage measurement from the BES to a BOD value, for example by reference to a calibration curve for the BES. In an embodiment, the method is completed in less than 1 hour.

The invention additionally includes bio electrochemical systems (BES) utilizing one or more electrode pairs capable of real-time sensing and monitoring of BOD, including VFAs and other complex organics. The system can operate using a single electrode pair as a sensor or multiple electrode pairs as a sensor array. Where multiple BESs are used, they can be capable identifying the minimum dilution to achieve sub- saturation conditions utilizing a series of dilutions, typically prepared with a buffered dilution fluid. This approach minimizes sensor response time because it uses instantaneous current as signal. This approach also avoids pH and salinity concerns because the sample is buffered. Furthermore, the series of dilutions assure that at least one sensor is not saturated in most situations and that the sensor will have greater accuracy over a longer period without calibration.

2.5.3 CHEMICAL OXYGEN DEMAND

In environment chemistry, the chemical oxygen demand test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water or wastewater, making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/L) also referred to as ppm (parts per million), which indicates the mass of oxygen consumed per liter of solution.

According to Ellis (2005), COD is an alternative to the BOD test for determining the oxygen consuming potential of a wastewater sample. As the name implies, the carbonaceous oxygen demand is oxidized chemically in the COD test .like the units of COD are milligrams per liter. The advantages of COD test are quick and reproducible and disadvantage is not all of the measure COD can be degraded biologically. Hence, there is still a need to ascertain what the biodegradable portion of the oxygen demand is, since that is how the performance of biological wastewater treatment systems will be evaluated. In another hand, BOD is the component that is expected to induce an oxygen demand in the receiving stream.

The advantage of COD test is that it is a measure of the energetic of the system. If one wants to keep track of a biological reaction, they must know what the energetic of the reaction are electron donors and electron acceptors of the system. Microorganism degrades pollutants in biological treatment system to our benefit, but also so that they can grow and reproduce. They required carbon and energy for growth. They also need less quantity of macro, nutrients, nitrogen phosphorus and sulfur for the addition to trace amounts of micronutrients. If can keep track of the flow of carbon and the flow of energy in a system, we can understand the nature and extent of the biochemical reaction occurring.

2.5.4 TOTAL SUSPENDED SOLID

TSS includes 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 level 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 increase 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, changes to the aquatic environment may result in a diminished food sources, and increased difficulties

in finding food. Natural movements and migration of aquatic populations may be disrupted.

For point sources, adequate treatment is necessary to insure that suspended solids are not present at levels of concern in waters of the state, treatment typically consists of settling prior to discharge of the wastewater, settling allows solids to sink to the bottom, where they can be moved. Some types of wastewaters, Such as noncontact cooling water, are naturally low in suspended solids and do not require treatment.

For the nonpoint sources, control measures should be implemented to reduce loadings of suspended solids to streams, rivers and lakes. Farming practices such as no-rill minimize soil erosion and help protect water quality. For construction sites, controls such as silt fences and sedimentation basins are designed to prevent eroding soils from reaching surface waters, in urban areas, storm water retention ponds or a regular schedule of street sweeping may be effective in reducing the quantity of suspended solids in storm water run-off.

2.5.5 AMMONIACAL NITROGEN

According to EPA (2013), too much nitrogen freely available in the environment can be a bad thing. Excess nitrogen discharged into our waterways can contribute to eutrophication, the gradual change of water bodies into marshes, meadows, and then forests. It can also contribute to massive algae blooms leading to oxygen depletion in water and its associated problems. Certain forms of nitrogen can cause specific problems too. Ammonia is toxic to fish, and nitrates at high enough dosages in the drinking water cause hemoglobin in infants. (Nitrates convert to nitrites in the stomach. These nitrites then interfere with the oxygen carting capacity of the hemoglobin in plod).

In the wastewater field we ate concerned with several forms of nitrogen: ammonia, organic, nitrate, and nitrite. Under the right conditions, each of these forms is biologically convertible to one of the other forms. This creates certain

challenges in the treatment of nitrogen in wastewater. Because of these challenges, it is important to properly collect, preserve, and analyzes samples for the specific forms of nitrogen so that the appropriate treatment of these wastes can be made.

2.5.6 pH

The pH of river water is the measure of how acidic or basic the water is on a scale of 0-14.it is a measure of hydrogen ion concentration .U.S. natural water falls between 6.5 and 8.5 on this scale with 7.0 being neutral. The optimum pH for river water is around 7.4. Water acidity can be increased by acid rain but is kept in check by the buffer limestone. Extremes in pH can make a river inhospitable to life. Low pH is especially harmful to immature fish and insects. Acidic water also speeds the leaching of heavy metals harmful to fish.

According to Rogers (2013), pH is a scale for measuring goes from 0 to 14 with 7 or under representing an acidic environment and over 7 indicates an alkaline. Low pH level will because fish kill by stressing animal systems and causing physical damage. Which is turn makes them more vulnerable to disease. The effects of low pH level can be lessened by presence of limestone along river banks and in soil.

2.6 EFFECT OF RIVER POLLUTION

The commonly perceived view of pollution is a sinking tanker spilling oil, with dead fish and oiled seabird an unavoidable after affect. Fortunately, these major incidents occur rarely. However, overtime, it is the vast number of minor incidents such as silage entering a river, which affect our environment adversely. The aquatic environment is a finely balanced community of plants, invertebrates