APPLICATIONS OF QUAL2KW TOOL FOR WASTE ALLOCATION ON RIVER YAMUNA IN NATIONAL CAPITAL TERRITORY OF DELHI, INDIA

A DISSERTATION

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ENVIRONMENTAL ENGINEERING

Submitted by:

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CANDIDATE'S DECLARATION

I, Rohit Agrawal, Roll No.2K19/ENE/04 student(s) of M. Tech, Environmental Engineering, hereby declare that the project Dissertation title "Application of Qual2Kw tool for waste allocation on river Yamuna in National Capital Territory of Delhi, India" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi **ROHIT AGRAWAL**

Date: 29th July,2021

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CERTIFICATE

I hereby certify that the Project Dissertation title “Application of Qual2Kw tool for waste allocation on river Yamuna in National Capital Territory of Delhi, India” which is submitted by Rohit Agrawal, Roll No 2K19/ENE/04, Environmental Engineering Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under me supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi **PROF.S.K. SINGH**

Date:29th July,2021 **SUPERVISOR**

ABSTRACT

Increasing water pollution is a rising concern due to industrial and domestic waste disposal in water bodies. River in the Delhi vicinity is highly polluted for the past few years due to receiving a large amount of wastewater disposal, where the in-organic waste of industrial disposal and domestic disposal are drained from 16 drainage points in the stretch of 21.9 Kilometres in river Yamuna. The purpose of this study is to investigate the cause of the pollution and compare it with the permissible parameter values using software tool. Using the Qual2Kw tool, this study analysed the water quality parameters along with the flow of the river. It is Waste load, Dissolve oxygen and pathogenic contain that plays the greatest role in the degradation of the river that leads to pollution by receiving discharge through different drain points in the length of 21.9 Kilometre along with the flow of the river in Delhi. This study defiantly explains the reason for increasing pollution and compares the calibrated data with the permissible standard values. It can be concluded that River Yamuna falls in Class D and highly polluted state, having a much higher value of waste load than permissible.

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ROHIT AGRAWAL

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The Yamuna tributary is one of the tributaries that cross the metropolis of Delhi having a length of about 21.9 km in Delhi. This river runs from the top in the Himalayas area and bottom in various parts or states of India. The Yamuna River has a basin area of approximately 366,223 sq. km (CPCB, 2006). The Yamuna stream crosses exchanging zones, office regions, thickly populated settlements, and enterprises. These various activities produce waste that has the potential to pollute the Yamuna River. Following the Central Pollution Control Board of India, the Yamuna River is planned for agriculture, horticulture, farming, tourist attractions, and transportation services (Mishra, 2010). The water quality of the Yamuna River exceeded the class B water quality standards for parameters TSS, BOD_5, COD, DO, and pH. This demonstrated that the Yamuna River is in dirtied conditions. By comparing and the predefined water quality principles, water quality status is the degree of water quality conditions that indicate polluted conditions or great conditions in a water supply within a specific period. The comparison of the essence of the boundaries and the water class quality principles has been completed, but no further review has been done concerning the contamination states of the Yamuna River. The degree of contamination in the Yamuna River can be seen from the situation with the water quality (Dubey, 2019; Sharma, 2011). Along these lines, research is expected to decide the situation with water quality in the Yamuna River. By knowing the status of water quality, thereafter, policymakers can develop a management strategy for the Yamuna River to control the pollution level. Determination of water quality status can use water quality modeling, but this method requires in-depth knowledge of hydraulics and hydrodynamics and strict validation. In addition to using water quality modeling, the statistical analysis approach of various existing parameters into the water quality index system can be used. The water quality index is used more because it can provide a value that includes the measurement of many pollutant parameters simply and can be interpreted easily. The use of the water quality index can be adjusted in different areas (Rai, 2020; Muthaiyah, 2020; Dubey, 2013).

Determining the status of water quality in this study using the Qual2KW method for Water Quality Status. In principle, the Qual 2KW (Barnwell, 1987; Sarda, 2013) methods are to compare the water quality data with the water class according to its designation to determine the water quality status. The way to determine water quality status in the Qual 2kw was developed by the team of the US – EPA (Environmental Protection Agency) value system by classifying water quality into five classes. The pollution index system, on the other hand, is calculated by comparing the maximum and average values of the concentration ratio per parameter to the quality standard value. Temperature, TSS, pH, NO_3^-, PO_4^{3-}, BOD, COD, and DO were the parameters used in this analysis. (Barnwell, 1987;Sarda, 2013; Kh, 2018). Water pollution is the entry or inclusion of living things, matter, energy, and/or other components inward water by human activities so that it exceeds the water quality standard waste that has been determined. Water Pollution Control is an effort to prevent and overcome Pollution water and water quality restoration to ensure water quality to comply with water quality standards. Control activities are carried out through an inventory of water pollution sources (Agrawal, 2020; Spellman, 2020).

The current study aims to develop a framework for the calibration of waste loading rate in River Yamuna in Vicinity of Delhi using the calibration tool Qual2kw considering the water parameters and using the hydraulic parameters for water quality assessments. The Qual2kw calibration tool will also compare the present and predicted waste loading rate in river Yamuna in the Delhi region (Shushobhit Chaudhary, 2018).In the past few studies the water quality is assessed in terms of BOD, COD Nitrogen content, pH, DO, etc, and its variations which are being used to carry the further research work (Parmar. D.L, 2014).

The sources of water pollutants can be geographically located precisely. The amount of waste disposed of can be determined in various ways, including direct measurement, mass balance calculations, and other estimates. Sources of water pollutants that come from certain sources include, among others, industrial activities and integrated domestic waste disposal. Water pollution data from specific sources are usually obtained from information collected and generated at the activity level through direct measurement of the effluent and its displacement or through the use of methods for estimating or calculating the amount of water pollution. Data required for an inventory of certain sources include (Agrawal, 2020; Spellman, 2020; Bansal, 2020):

i. Classification of types of waste generators, such as categories of types of business or activities
ii. Specific pollutant data discharged, for example, the measured or estimated amount of pollutant load discharged into the water in mass units per unit time.

Information on the location and specific types of pollutants that are disposed of, for example, a certain type of industry in an area produces several specific types of pollutants. large individual sources are relatively small. The resulting waste, among others, comes from agricultural activities, settlements, and transportation. Determination of the amount of waste disposed-up cannot be determined directly, but by using statistical data activities that describe the activities of producing waste. Diffuse sources usually come from agriculture, animal husbandry, small-medium industrial activities, and domestic activities, or the use of consumer goods. These water pollutant sources generally consist of a combination of several small or individual activities that have the potential to produce wastewater, which in the inventory of water pollutant sources cannot be classified as a specific source (Roy, 2021; Tietenberg, 2019;Mitra, 2020).

Its basic information input and output environment are presented in Microsoft Excel 2000 or higher, through electronic sheets where the input and output information of the model is entered. The input information is divided into the segmentation of the model, the computational requirements, the climatological and hydraulic information of each of the sections, and the water quality values measured in the stream and at the inputs and outputs of the same. The output information presents only water quality values for the defined sections, delivered in tabular form and graphical form for better understanding by the user. The program can be executed using two different programming platforms, visual basic for excel and Fortran 90. A variation of the QUAL2K model has been the realization of a version called QUAL2Kw, which is also available freely but on the page of Washington State University. This improved version includes a genetic algorithm called PIKAIA used for mathematical optimization of the kinetic constants of the different processes that the program models. In the development of this chapter, it is intended to introduce the reader to the basic understanding of the theory of the program, the way of introducing the information, and interpreting the results. As well as highlighting the main differences between the QUAL2K and QUAL2Kw models so that the user can determine which of the two is the most applicable for their study. Finally, as does Dr. Chapra and many QUAL2K users around the world, to be able to work on this platform some experience in water quality modeling must be required, since how the information necessary to run smoothly will be seen. The correct model is quite voluminous, represented by the introduction of more than 100 variables that influence the processes to be modeled. (Pelletier, 2016)

1.2 PROBLEM FORMULATION

Currently, the Yamuna River is polluted because it exceeds class II water quality standards. The monitoring that has been done is to compare the quality of the parameters with the water class quality standards, but no further study has been carried out on the level of pollution in the Yamuna River which is represented by the water quality status. The level of pollution in the Yamuna River can be measured through the water quality status. So it is necessary to determine the status of water quality to determine the level of pollution in the Yamuna River with results that are compared with one another. The method used is Qual2Kw to evaluate the parameters pH, BOD, COD, DO, and TSS.

1.3 OBJECTIVES

The objectives of this study are as follows:

1. The study area of the Yamuna River in Delhi has a stretch of about 22.9KM length that runs from Wazirabad barrage to Okhla barrage, which has 16 drains point that end discharging into the river.
2. Determine the water quality status of the Yamuna River using Qual2Kw for evaluating the parameters pH, BOD, COD, DO, and TSS.
3. Comparing the calibrated parameters value with prescribed standard values given by DPCC (Delhi pollution control committee) and CPCB (Central pollution control board).

1.4 METHOD BENEFITS

The benefits of this study are as follows:

1. Provide scientific information regarding the quality status of water of the Yamuna River
2. Provide reference information for the management of Yamuna River water

1.5 SCOPE

The scope of this research is as follows:

1. The study area includes the Yamuna River from Upstream (Wazirabad Barrage) to Downstream (Okhla Barrage) in Delhi Region
2. The data needed to be obtained is to take water samples at several points periodically from Delhi Pollution Control Committee.
3. Sampling starts from Upstream at Wazirabad Barrage (Delhi) and Downstream Okhla Barrage (Delhi).
4. Water quality parameters analyzed include temperature, TSS, pH, BOD, COD and DO.
5. Determining the water quality status of Yamuna River in Delhi using the Qual2Kw method.
6. To Evaluate water class quality standard refers to Delhi Pollution Control Committee for Pollution.

CHAPTER 2

LITERATURE SURVEY

2.1 RIVER

Rivers are known as open waters, which mean they are strongly influenced by the state of the surrounding environment. So that a river is a place for solid waste, both coarse and fine (fine grain). When these two types of waste materials are discharged into the river environment, it is possible that solid waste deposition can occur at the bottom of the flowing river and the formation of colloids that float along with the flow of water. These colloids are fine solids, some are soluble and some are insoluble and continue to float with the flow of water (Tripathy, Biplab & Raha, Subhechya & Mondal, Tanmoy, 2021).

2.2 WATERSHED

Watersheds are generally defined as a stretch of area or area bounded by topographical boundaries (ridges) that receive, collect rainwater, sediment, and nutrients and drain them through tributaries and out of the main river into the sea or to the lake. A Watershed is an ecosystem, where elements of organisms and the biophysical environment, as well as chemical elements, interact dynamically and there is a balance in its inflow and outflow of materials and energy (Rey, Lester, 2021).

Watershed can be viewed as a natural system that is a place for hydrological biophysical processes as well as complex socio-economic and cultural activities of the community (Chin, David. (2021). Concerning water resources, the river area is a combination of several watersheds. Meanwhile, the river channel system (a combination of river flow and river border flows) is a river basin system that divides the watershed into three sub-watersheds several smaller sub-watersheds. Therefore, all changes that occur in the watershed will result in the river flow of the watershed area covering the entire river channel plus the area where any rain that will fall in the area flows into the river in question. The river borderline consists of flood banks, landslide banks, ecological banks, and security banks.

A watershed consists of 2 main parts, namely the catchment area (catchment area) which forms the upstream area, and the water distribution area which is under the catchment area. The water distribution area can be divided into two areas, namely the middle area and the downstream area. While the water supply area is powered (functions) channeling water (excess water) from water sources to water reservoirs can be in the form of lakes or seas. Viewed from the hydrological point of view, a watershed is a hydrological unit that is round or intact. (Kurniawan, Nur Muhammad Azizi, 2008).

2.3 WATER QUALITY

River water quality is influenced by river conditions and water supply conditions from river buffer areas. The condition of the water supply from the buffer zone is influenced by the activities and behavior of its inhabitants. In general, upstream areas have better water quality than downstream areas. From the point of view of land use, upstream areas are relatively simple and natural, such as forests and small villages. The further downstream the diversity of land use increases. In line with this, the supply of liquid waste from upstream areas to downstream areas also increases. In the end, the downstream area is where the accumulation of the liquid waste disposal process starts from upstream. Upstream areas with relatively uniform land-use patterns have better water quality than downstream areas with diverse land-use patterns. The smaller the forest cover in the sub-watershed and the more diverse types of land use in the sub-watershed, the condition of river water quality is getting worse, mainly due to agricultural and residential activities (Bratton, Susan. ,2020).

River water quality is a qualitative condition that is measured based on certain parameters and with certain methods following applicable laws and regulations. River water quality can be expressed by parameters that describe the quality of the water. These parameters include physical, chemical, and biological parameters (Juyal, G & Patra, Sridhar, 2021).

2.4 WATER POLLUTION

Water pollution is the entry or inclusion of living things, matter, energy, and/or other components inward water by human activities so that it exceeds the water quality standard waste that has been determined. Water Pollution Control is an effort to prevent and overcome Pollution water and water quality restoration to ensure water quality to comply with water quality standards. Control activities are carried out through an inventory of water pollution sources (Spellman, Frank., 2021).

The sources of water pollutants can be geographically located precisely. The amount of waste disposed of can be determined in various ways, including direct measurement, mass balance calculations, and other estimates. Sources of water pollutants that come from certain sources include, among others, industrial activities and integrated domestic waste disposal. Water pollution data from specific sources are usually obtained from information collected and generated at the activity level through direct measurement of the effluent and its displacement or through the use of methods for estimating or calculating the amount of water pollution. Data required for an inventory of certain sources include:

- Classification of types of waste generators, such as categories of types of business or activities
- Specific pollutant data discharged, for example, the measured or estimated amount of pollutant load discharged into the water in mass units per unit time.

Information on the location and specific types of pollutants that are disposed of, for example, a certain type of industry in an area produces several specific types of pollutants. large individual sources are relatively small. The resulting waste, among others, comes from agricultural activities, settlements, and transportation. Determination of the amount of waste disposed of cannot be determined directly, but by using statistical data activities that describe the activities of producing waste. Diffuse sources usually come from agriculture, animal husbandry, small-medium industrial activities, and domestic activities, or the use of consumer goods. These water pollutant sources generally consist of a combination of several small or individual activities that have the potential to produce wastewater, which in the inventory of water pollutant sources cannot be classified as a specific source.

However, water pollution is the entry or inclusion of living things, substances, energy, and/or other components into the water by human activities so that water quality decreases to a certain level which causes water to not function according to its designation. Water is said to be polluted if its quality drops to a certain level because the levels of substances or energy in the water have reached a certain level that exceeds the tolerated level in the water so that it is said that the water has exceeded the specified quality standard so that it cannot be used according to its designation (Agarwal, Satish, 2020). Sources of pollution can be divided into liquid form, solid form, and gaseous form as well as noise. Sources of pollution in river water will affect life in the river, due to the addition of chemicals or industrial waste from households and can poison organisms that live in the water (Bansal, Neeru & R., Parthasarathy, 2020).

River pollution is defined as a change in the quality of waters due to human activities, which in turn will interfere with human life itself or other living creatures. These changes can be caused by compounds entering the river flow that move downstream with the water flow or are stored at the bottom, accumulate (especially in sediment), and at some point, washing or dilution can also occur.

These compounds (mainly toxic) accumulate and become a certain concentration that is harmful to the chain of life. According to (Bansal, Neeru & R., Parthasarathy, 2020) there are two forms of pollutant depending on the source, namely:

1. Point Sources that are, the source of the pollutant that throws away effluent (liquid waste) through sewer pipes or dirty water channels into water bodies at certain locations. For example, factories that discharge their waste directly into water bodies (in this case rivers) or if the research is the main river, then tributaries can also be classified as a river. Point Sources.
2. Non-Point Sources consist of many scattered sources that discharge effluent into both water bodies and groundwater over a large area. For example, land-use activities, such as construction, public facilities, agriculture, and logging Some of the main types of activities that cause river pollution include:
    i. Domestic activities, including health activities (hospitals) and food additives (such as food preservatives) as well as activities originating from household and residential environments (Salim, Nur & Abdullah, Noorul & Mat Lazim, Zainab. ,2021) both in urban and rural areas. The effluent that is usually disposed of is usually in the form of organic pollutants, but can also be

inorganic compounds, metals, salts (such as detergents) which are quite dangerous because they are pathogenic.

ii. Industrial activities; has many variations; In industrial and technological activities, water that has been used (industrial wastewater) should not be discharged directly into the environment because it can cause pollution (Salim, Nur & Abdullah, Noorul & Mat Lazim, Zainab ,2021).

iii. Agricultural activities; Agricultural waste consists of solid organic former plant material, the addition of fertilizers and pest and disease killers (pesticides), fertilizer materials containing nitrogen, phosphorus, sulfur, minerals (Salim, Nur & Abdullah, Noorul & Mat Lazim, Zainab. ,2021) where the compounds contained in it are not easily decomposed. although in small amounts, it is active at low concentrations. In addition, sediment includes considerable pollution when there is the felling of trees, making trenches, and others. Management of activities related to agriculture ranging from tillage, the use of inorganic fertilizers, and pesticides will increase the chemical content in the soil which in turn increases the chemical content in river water so that it will affect the quality of river water through discharge from agricultural land that enters water bodies. Some contaminants such as microbiology (bacteria, viruses, parasites), organic materials (pesticides, detergents), and some inorganic materials (salts, acids, metals), as well as several other chemicals, have been found in the water we use (Salim, Nur & Abdullah, Noorul & Mat Lazim, Zainab. ,2021).

iv. Excessive use of fertilizers and pesticides can pollute water. Fertilizer waste contains phosphate which as well as several other chemicals have been found in the water we use Salim, Nur & Abdullah, Noorul & Mat Lazim, Zainab. ,2021). Excessive use of fertilizers and pesticides can pollute water. Fertilizer waste contains phosphate which as well as several other chemicals have been found in the water we use (Salim, Nur & Abdullah, Noorul & Mat Lazim, Zainab. ,2021). Excessive use of fertilizers and pesticides can pollute water. Fertilizer waste contains phosphate which can stimulate the growth of aquatic weeds such as weeds and water hyacinth.

2.5 SELF PURIFICATION

Self-purification is the river's ability to improve itself from polluting elements. The decrease in pollutant content proves that river self-purification is indeed happening in rivers. The thing to note is that according to natural rules, there are limitations of self-purification in the river so that if a large number of pollutants enter, this ability will not mean much to restore the river in a better condition. This natural ability of the river limits the river's capacity for polluters (Wiwoho, 2005). Biological processes can occur in bacteria where bacteria help convert toxic compounds into non-toxic compounds. The existence of aquatic plants, plant roots around water bodies, aquatic animals contribute to improving the quality of river water (Wiwoho, 2005).

Fisenko, Anatoliy & Hromnysky, Roman & Fisenko, Rouslan (2004) state, self-purification is the ability of water to clean itself naturally from contaminants and pollutants. The presence of dissolved oxygen in the water is needed by bacteria for the decomposition of organic matter. The thing to note is that according to natural rules, there are limitations of self-purification in the river so that if a large number of pollutants enter, this ability will not mean much to restore the river in a better condition. It is this natural ability of the river that limits the river's capacity for polluters. Biological processes can occur in bacteria where bacteria help convert toxic compounds into non-toxic compounds. The existence of aquatic plants, plant roots around water bodies, aquatic animals contribute to improving the quality of river water. The development of natural purification or self-purification consists of several zones, namely:

i. Clean water zone, this zone is located far upstream of the river, far from sources of pollution. The indicator is that water can still be used as drinking water.

ii. Decomposition Zone, this zone is located in the source area of pollution, the flowing waste will be decomposed or oxidized by the process of dismantling organic matter by bacteria and microorganisms. This indicator area is rich in bacteria and microorganisms.

iii. Biodegradation Zone, in this area there is a decrease in dissolved oxygen (dissolved oxygen), so the COD value in the waters is very high.

iv. Recovery zone, in this zone the water quality returns to clean, the dissolved oxygen value returns to normal.

2.6 QUALITY STANDARD

Water quality standard is a measure of the limit or level of living things, substances, energy, or components that exist or must exist and/or pollutant elements whose presence is tolerated in the water. Based on the Regulation by Water Pollution Control Board Delhi concerning water quality standards in Delhi based on the classification of water quality, it is set into 4 classes:

i. Class I water, water whose designation can be used for drinking water raw water, and or other designations that require the same water quality as that use;
ii. Class II water, water whose designation can be used for water recreation infrastructure/facilities, freshwater fish cultivation, animal husbandry, water for irrigating crops, and/or other designations that require the same water quality as those uses; can stimulate the growth of aquatic weeds.
iii. Class III water, water whose designation can be used for freshwater fish cultivation, animal husbandry, water for irrigating crops, and or other designations that require the same water quality as those uses;
iv. Class IV water, water whose designation can be used to irrigate crops and or other uses that require the same water quality as that user.

2.7 POLLUTION LOAD CAPACITY

According to Delhi, Pollution Control Board concerning Water Quality Management and Water Pollution Control, the water pollution load capacity is the ability of water in a water source to accept inputs of pollutant loads without causing the water to become polluted. Based on the Regulation the Management of Water Pollution Control, what is meant by Pollution Load Capacity or often also called the total maximum daily load is the ability of water in a water source to accept the input of pollutant loads without causing the water to become polluted. The pollution load capacity that has been obtained can be used as a consideration tool for determining regional decisions and policies such as:

(i) determination of spatial plan,

(ii) granting business or activity licenses,

(iii) granting of waste disposal permit, and

(iv) determination of water quality and direction of water pollution control policies Several methods that can be used to determine the carrying capacity of pollution loads in water bodies are the Mass Balance method, the Streeter-Phelps method, and the Qual2E method. Determination of the pollution load capacity can be determined using the following equation:

Capacity = Maximum pollution load –initial condition pollutant load **_(2.1)_**

2.8 PARAMETERS OF RIVER WATER QUALITY TEST

Parameters that become the benchmark for monitoring in the rivers are namely: -

2.8.1 Ammonia (NH_3-N)

In water, nitrogen can be in the form of inorganic and organic nitrogen. Inorganic nitrogen consists of ammonia (NH_3), ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), and nitrogen molecules (N_2) in gaseous form. Organic nitrogen in the form of protein, amino acids, and urea. The main source of anthropogenic nitrogen in the waters comes from agricultural areas that use fertilizers intensively as well as from domestic activities. Ammonia (NH_3) and its salts are soluble in water. The source of ammonia in waters is the breakdown of organic nitrogen (protein and urea) and inorganic nitrogen that is found in soil and water from the decomposition of dead plant material and aquatic biota by microbes and fungi (Katz, Brian, 2020).

Free ammonia levels for drinking water purposes should not be more than 0.5 mg/L, while for fisheries free ammonia content for sensitive fish is 0.02 mg/L as NH_3.

2.8.2 Phosphate (PO_4-P)

In waters, phosphorus is not found in free form as an element, but in the form of dissolved inorganic compounds (orthophosphates and polyphosphates) and organic compounds in the form of particulates. Total phosphorus describes the total amount of phosphorus, both in the form of particulate and dissolved, inorganic and organic (Jamieson, George, 2002). Natural sources of phosphorus in waters are weathering of mineral rocks and also derived from the decomposition process of organic matter. Anthropogenic sources of phosphorus come from industrial and domestic waste, namely phosphorus from detergents. Runoff from agricultural areas that use fertilizers also contributes significantly to the presence of phosphorus in the waters.

In urban areas (urban) sources of nutrients are industrial and domestic activities. Detergents are the main source of causing increased levels of phosphorus in the water. In rural areas, the main source of increased phosphorus levels is agricultural activities that use large amounts of fertilizer. The loss of nutrients from agricultural areas and the entry of nutrients into the waters occurs in 2 ways, namely:

(i) Drainage, the presence of drainage will dissolve agricultural land that receives a lot of fertilizer (contains a lot of nutrients);

(ii) Erosion of nutrient-rich surface soil and movement of fine-sized soil particles, which contain nutrients and are carried away by underground drainage systems. Phosphate elements contained in fertilizer waste can stimulate the growth of aquatic weeds such as algae and water hyacinth.

The phosphorus content that is allowed for the benefit of drinking water is 0.2 mg/L in the form of phosphate (PO_4). The level of phosphorus in the form of phosphate for fishery purposes should not be more than 1 mg/L. Phosphorus is an important component and often causes environmental problems in water. Phosphorus is one of several elements that are essential for the growth of algae in water. The high phosphorus content in the waters causes the proliferation of algae and other organisms, known as eutrophication. Plant fertility will block the smooth flow of water and result in reduced dissolved oxygen.

2.8.3 Suspended Solids (TSS)

Total suspended solids or total suspended solids are suspended materials consisting of silt and fine sand and micro-organisms, mainly caused by soil erosion or soil erosion carried into water bodies. The high value of TSS content in waters can increase the value of turbidity which will further inhibit the penetration of sunlight into the water column and ultimately affect the process of photosynthesis in the waters (Abed, Nassim & Abdulla, Fayez & Zahrawi, Raed, 2007). Suspended solids are positively correlated with turbidity. The higher the value of suspended solids, the higher the turbidity value. Turbidity in stagnant waters such as lakes is mostly caused by suspended materials in the form of colloids and fine particles, while turbidity in rivers that are flooded is caused by suspended materials that are larger in the form of a soil surface layer carried by the water flow of water when it rains.

2.8.4 Temperature

Temperature ^oC is one of the key parameters of the air quality model of a water. Biological activity and gas solubility processes in water are highly dependent on temperature conditions. At the optimal temperature, biological activity with sufficient nutrients will be effective in the growth and decomposition of organic matter. On the other hand, in cold waters the activity will be used. Meanwhile, the highest oxygen solubility in clear water occurred at 4^oC at 14.62 mg/l and the lowest at 30^oC at 7.63 mg/l. Therefore, in tropical waters the saturated DO never exceeds 9 mg/l. Temperature plays an important role in the material cycle, which will affect the physical, chemical and biological properties of water. Temperature affects the solubility of oxygen in the air, reaction processes and chemical reactions in the waters. The increase in temperature in the waters can increase the body's metabolism, including decomposing bacteria, so that the decomposition process of organic matter also increases. This process causes the need for dissolved oxygen to be high which further reduces the dissolved oxygen content in the water (Smith, D., 1990).

2.8.5 Degree of Acidity (pH)

Degree of Acidity (pH) is a measure of the hydrogen ion concentration to determine acids and bases. hydrogen ion concentration is a measure of air quality with a good level is a level where it is still possible for biological life in water to run well. Changes in pH in an air greatly affect the physical, chemical, and biological processes of the organisms that live in it. The degree of several things greatly affects the toxicity of polluting materials and gas solubility, and determines the form of substances in water (https://en.wikipedia.org/wiki/PH).

The degree of acidity indicates the level of acidity and is a by-product of the results of bio-chemical processes in water. In a neutral atmosphere, the pH of natural waters will be proportional to the oxygen concentration in the organic decomposition process. The lower the response to oxygen concentration in the water, the more acidic and smaller the pH value. Measurements in the field showed that the pH value of the river waters ranged from 6-7 measured in situ using a pH meter. The DO value in the range of 2.01-0.98 mg/l on the segment was not followed by a proportional decrease in pH. This shows the high content of soap or detergent that is disposed of directly by the dense population in the vicinity, thereby increasing the pH value (https://en.wikipedia.org/wiki/PH).

2.8.6 Dissolved Oxygen (DO)

Sugiharto (1987) explains that dissolved oxygen is the amount of oxygen contained in water and is measured in milligrams per liter. This dissolved oxygen is used as a sign of the degree or level of dirtiness of the existing waste. The greater the dissolved oxygen, the lower the level of dirtiness of the waste. So DO size is inversely proportional to BOD. Dissolved oxygen in water comes from photosynthesis, air diffusion and turbulence. Dissolved oxygen in water is needed by aquatic organisms for respiration and metabolism so that dissolved oxygen becomes very important for the survival of aquatic organisms. Dissolved oxygen is also needed by bacteria in the decomposition process to degrade the input load in the form of organic matter. Where the higher the content of organic matter in the waters, the need for dissolved oxygen in the decomposition process by bacteria also increases so that it will reduce the dissolved oxygen content in the waters (Hauser, Barbara, 2018).

The dissolved oxygen parameter shows the amount of oxygen dissolved in the water. Dissolved oxygen content is important for the survival of aquatic organisms, so that the determination of dissolved oxygen levels in water can be used as a measure to determine water quality. Waters contaminated with organic matter will experience a decrease in dissolved oxygen content because the oxygen available in the water will be used by microorganisms to decompose organic pollutants. The more organic matter that can be broken down by microorganisms, the more oxygen is needed by microorganisms. In addition, the decrease in DO levels is also caused by the large amount of organic waste originating from domestic waste and industrial waste (especially around Kali Tengah) which exceeds the self-purification capacity of the river and the presence of chemicals that can be oxidized by oxygen. In addition, re-suspension events due to the sudden addition of water discharge resulted in toxic solutions at the bottom of the river to be lifted and suspended in the water thereby increasing turbidity (Deacutis, Christopher, 2016).

2.8.7 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is the amount of oxygen required by bacteria to stabilize organic matter that is easily decomposed under aerobic conditions. What is meant by easily decomposed is organic material that can be used as food for bacteria and energy obtained from the oxidation process. BOD analysis is used to determine the pollution of domestic waste and industrial waste. This analysis is one of the most important tests in controlling river pollution. This analysis is very important in determining regulations and design studies to evaluate the carrying capacity of water bodies (Montes, M.F., 2016). Theoretically, the time required for the complete oxidation process so that organic matter decomposes into CO_2 and H_2O is unlimited. In laboratory practice, it usually lasts for 5 days assuming that during that time the percentage of the reaction is quite large from the total BOD. The 5-day BOD value is part of the total BOD and the 5-day BOD value is 70 - 80% of the total BOD value In practice for the determination of BOD (Penn, M.R. & Pauer, J.J. & Mihelcic, J.R., 2009). The amount of BOD is used as a way to indicate organic pollution in waters. The more organic matter contained in the waters, the greater the amount of oxygen needed, so the higher the BOD price which indicates a high level of pollution. The measured BOD value does not always increase from upstream to downstream, because at any point there can be an entry of organic waste into the river with a certain BOD concentration and discharge which can cause a decrease or increase in the river's BOD concentration (Brenniman, Gary, 1999).

2.8.8 Chemical Oxygen Demand (COD)

(Hauser, Barbara, 2018) explain that Chemical oxygen demand (COD) describes the total amount of oxygen required to chemically oxidize organic matter, both biologically degradable and difficult to degrade into CO_2 and H_2O. The COD measurement is based on the fact that almost all organic matter can be oxidized to CO_2 and H_2O with the help of a strong oxidizing agent (potassium dichromate or $K_2Cr_2O_7$) under acidic conditions. However, there are also organic materials that cannot be oxidized by this method, such as pyridine and volatile organic matter. Glucose and lignin can be oxidized completely. Amino acids are oxidized to ammonia and nitrogen. Organic nitrogen is oxidized to nitrate. The presence of organic matter can come from nature or from household and industrial activities, such as pulp mills, paper mills, and the food industry. Waters that have a high COD value are undesirable for fisheries and agriculture (Latif, Usman & Dickert, Franz, 2015). COD testing is used to analyze industrial waste. BOD testing to identify toxic conditions and the presence of biological resistance or organic substances. Determination of COD value is considered the best in describing the presence of organic matter, whether biologically decomposable or not. The higher the COD value, the higher the pollution by organic substances (Pisarevsky, A. & Polozova, I. & Hockridge, P.., 2005).

2.8.9 Nitrates

Nitrate (NO_3^-) is a dynamic form of nitrogen and is the most dominant form of run-off, river input, ground water discharge and atmospheric deposition into the sea. Nitrate is produced from the complete oxidation process of nitrogen and ammonia compounds in water. Nitrogen found in surface water is a result of soil drainage and domestic wastewater.

Domestic wastewater which is the main source of nitrogen comes from feces, urine and food waste. The contribution per capita ranges from 8 – 12 lb nitrogen/year. Nitrogen is found in the organic form (40%) and ammonia (NH_4^+) by 60% (Oakes, D. 1996). Nitrate is a stable form of compound and its presence comes from agricultural waste, fertilizers, manure animals and humans and so on. Nitrates at high concentrations can stimulate unlimited algae growth, so that the water lacks dissolved oxygen which can cause fish death. Nitrates are one of the nutrients that are important for the growth of phytoplankton and other aquatic plants. Nitrate is a source of nitrogen in seawater and fresh water. Other combined forms of this element may be available in the form of ammonium, nitrite and organic components. The combination of these elements is often used by phytoplants, especially if the nitrate element is limited. Dissolved nitrogen can also be utilized by blue-green algae species by means of nitrogen fixation. Nitrate formation depends on the presence of oxygen and bacteria. Nitrobacter in charge of converting nitrite into nitrate aerobically (Sadate, S. & Kassu, A. & Farley, C. & Sharma, A. & Hardisty, J. & Lifson, Miles., 2011).

2.8.10 Phosphate

Phosphate is a form of phosphorus that can be utilized by plants and is an essential element for plants, so that it becomes a limiting factor that affects water productivity. Phosphate found in waters comes from resident waste water (household waste) in the form of detergents, agricultural residues (fertilizer), industrial waste, crushed organic matter and mineral phosphate. Generally, the phosphate content in natural waters is very small and never exceeds 0.1 mg/l, unless there is an addition from the outside by anthropogenic factors such as fish feed residues and agricultural waste (Kroiss, Helmut & Rechberger, Helmut & Egle, Lukas,2011). Domestic wastewater is usually rich in phosphorus compounds. Previous developments in the manufacture of detergents contained phosphorus which was usually in the range of 2-3 mg/L and the organic form varied from 0.5 – 1 mg/L. Most of the organic phosphorus comes from human waste as a result of impaired protein and nucleic acid metabolism and the elimination of phosphorus in the urine. The most important role in the manufacture of detergents is formed for household activities, most of which consist of 12-13 percent phosphorus or more than 50 percent consist of polyphosphates. The use of this material as a substitute for soap greatly increases the phosphorus content of domestic waste (Loganathan, Paripurnanda & Vigneswaran, Saravanamuth & Kandasamy, Jaya & Bolan, Nanthi,2014).

2.9 POLLUTION LOAD CAPACITY

Water pollution load capacity is the ability of water in a water source to receive input from the pollution load without causing the water to become polluted. Determination of capacity is the implementation of water pollution control using a water quality approach. This approach aims to control pollutants originating from various pollutant sources that enter the water source by considering the intrinsic conditions of the water source and the established water quality standards. Calculation of the pollution load according to Lestari, Handayani & Haribowo, Riyanto & Yuliani, Emma, 2019, the pollution load or load (L) is the concentration of pollutants (C) multiplied by the capacity of water flow or water discharge (Q) containing pollutants in equation (2.2)

$$\mathbf{L = C.\ Q} \qquad \mathbf{(2.2)}$$

With:

C = Concentration of pollution load

Cr = average concentration of constituents for combined flow;

Ci = concentration of constituent b in the i-th stream;

Qi = flow rate of the i-th stream;

Mi = mass of constituents in the i-th stream.

Determination of the pollution load capacity according to the Delhi Pollution Control Board scientifically there are several methods including:

a. Mass balance method: A mathematical model that uses mass balance calculations can be used to determine the average concentration of downstream flow (downstream) originating from point sources and non-point sources of pollutant sources, this calculation can also be used to determine the percentage change in flow rate or pollutant load. If several streams converge to produce a final flow, or if the quantity of water and the mass of the constituents are calculated separately, it is necessary to carry out a mass balance analysis to determine the quality of the final flow by calculation in equation (2.3).

$$\boldsymbol{C_R} = \frac{\sum \boldsymbol{C_i}\,\boldsymbol{Q_i}}{\sum \boldsymbol{Q_i}} = \frac{\sum \boldsymbol{M_i}}{\sum \boldsymbol{Q_i}} \qquad (\mathbf{2.3})$$

Where:

C_R: mean constituent concentration for the combined flow;

C_i : constituent concentration in the i-th stream;

Q_i : flow rate of the i-th stream;

M_i : mass of constituents in the i-th stream

This mass balance method can also be used to determine the effect of erosion on water quality that occurs during the construction or operational phase of a project, and can also be used for a flow segment, a cell in lakes, and oceans. However, this mass balance method is only appropriate for conservative components, namely components that do not undergo changes (not degraded, not lost due to precipitation, not lost due to evaporation, or due to other activities) during the mixing process such as salts.

b. Streeter-Phelps Method Modeling of river water quality has progressed significantly since the introduction of the DOSAG1 software in 1970 (Novita, Elida & Afifah, Nahda. ,2020). The basic principle of this modeling is the application of mass balance to the river with the assumption of dimension 1 and steady condition. The consideration used in the modeling is the need for oxygen in the aquatic life (BOD) to measure the occurrence of pollution in water bodies. River modeling was introduced by Streeter and Phelps in 1925 using the oxygen sag curve equation in which the water quality management method is determined on the basis of critical oxygen deficit Dc. Streeter and Phelps modeling is only limited to two phenomena, namely the process of reducing dissolved oxygen (deoxygenation) due to bacterial activity in degrading organic matter in water and the process of increasing dissolved oxygen (reaeration) caused by turbulence that occurs in the river flow. Streeter-

Phelps stated that the rate of biochemical oxidation of organic compounds is determined by the concentration of residual organic compounds in equation (2.4).

$$dL/dt = - K'. L \qquad (2.4)$$

Where,

L: concentration of organic compounds (mg/L);

t: time (days);

K’: first-order reaction constant (day^{-1});

If the initial concentration of organic compounds as BOD is L_o which is expressed as ultimate BOD and L_t is BOD at time t, then equation (2.4), The result of the integration of equation (2.4) during the deoxygenation period is:

$$Lt = L_o. e^{(K'.t)} \qquad (2.5)$$

Determination of K' can be done by:

(1) the method of logarithmic difference,

(2) moment method (Moore et al. method), and

(3) Thomas method.

The rate of deoxygenation due to organic compounds can be expressed by the equation (2.6).

$$r_D=-K'.L \qquad (2.6)$$

Where,

K’: first-order reaction rate constant, day^{-1};

L: BOD at the point requested, mg/L; If L is replaced with $L_o\ e^{-K't,}$ then equation (2.7) becomes:

$$r_D = -K'. Lo\ e^{-K'.t} \qquad (2.7)$$

Where,

L_o: The ultimate BOD at the discharge point (after mixing), mg/L The oxidation process is divided into two namely.

a) Dissolved Oxygen Increase Process (Reaeration) The oxygen content in the water will receive additional due to turbulence so that the transfer of oxygen from air to water and this process is the process of reaeration. This oxygen transfer is expressed by the reaeration rate equation (2.8)

$$r_R = K`_2 (Cs - C) \qquad (2.8)$$

with,

$K`_2$: constant of reaeration, day-1 (natural number basis);

C_s: saturated dissolved oxygen concentration, mg/L;

C: dissolved oxygen concentration, mg/L.

Reaeration constant can be estimated by determining the flow characteristics and using one of the empirical equations. The O'Conner and Dobbins equations are commonly used equations to calculate reaeration constant in equation (2.9).

$$K'2 = 294 (D_L. U)^{1/2} x H^{3/2} \qquad (2.9)$$

with

D_L: molecular diffusion coefficient for oxygen, m^2/day;

U: average flow rate, m/sec;

H: mean flow depth, m;

b) Oxygen sag curve

If the two processes above are channeled with dissolved oxygen concentration as the vertical axis and time or distance as the flat axis, then the cumulative flow result that states the interaction between the deoxygenation and reaeration processes is the curve of dissolved oxygen content in the water body. This curve is known as the oxygen sag curve. If it is assumed that the river and sewage are completely mixed at the discharge point, then the concentration of the constituents in the water-waste mixture at x = 0 at equation (2.10).

$$C_O = \frac{Qr\ Cr + Qw\ Cw}{Qr + Qw} \quad (2.10)$$

Where,

Co = initial constituent concentration at the discharge point after mixing, mg/L;

Qr = river flow rate, m3/second;

Cr = constituent concentration in the river before mixing, mg/L;

Cw = concentration of constituents in wastewater, mg/L.

Changes in oxygen levels in the river can be modeled by assuming the river as a plug flow reactor.

2.10 QUAL2KW MODELS

The QUAL2Kw model is a development of the Qual2E model using the Virtual Basic for Application (VBA) programming language that can be run with the Microsoft Excel program (Mohammadi, Maryam & Qaderi, Kourosh & Ahmadi, M.M. 2017). In doing the modeling, the QUAL2Kw version 5.1 model is usually used. This model is able to simulate water quality parameters including temperature, conductivity, inorganic solids, Dissolved Oxygen (DO), CBODslow, CBODfast, organic nitrogen, ammonia (NH_4^+), nitrite (NO2 -), nitrate (NO3 -), organic phosphorus, inorganic phosphorus (SRP), phytoplankton, detritus (POM), pathogens, Alkalinity, pH (Ghorbani, Zienab & Amanipoor, Hakimeh & Battaleb-Looie, Sedigheh., 2020) QUAL2Kw is a model for simulating water quality in rivers using a one-dimensional flow approach with a steady pattern. QUAL2Kw is the latest version of the QUAL2E model using the Visual Basic of Application (VBA) programming language that can be run with the Microsoft Excel program. This model can stimulate the transport and presence of pollutants in the waters. This model simulates a river in a one-dimensional form with non-uniform flow, fixed flow and represents a river based on the impact of two sources, namely those from point sources and non-point sources. This model is able to stimulate water quality parameters as follows:

i. pH

ii. Alkalinity

iii. Inorganic suspended solids

iv. Pathogenic bacteria

v. Algae

vi. Temperature

vii. Carbon

viii. Biochemical oxygen demand (BOD)

ix. Dissolved oxygen, phytoplankton

x. Organic and inorganic phosphorus

xi. NH4 –Nitrogen

xii. NH3 –Nitrogen, conductivity

xiii. Pathogenic bacteria

xiv. Alkalinity

The data requirements needed for QUAL2Kw modeling according to Kh, Shemeera. (2018) are as follows:

i. Air Temperature;

ii. Cloud covers;

iii. Wind speed;

iv. Elevation and coordinates of each end of the river segment;

v. The width of the river, the slope of the river and the river bank;

vi. River flow resistance coefficient;

vii. Time zone of sunshine;

viii. Length and discharge of the main river;

ix. Location of river water quality monitoring (kilometers);

x. Details of incoming and outgoing river flows along with their flow rates and locations;

xi. Location of each pollutant source along with flow rate and water quality;

xii. Monitoring the quality of wastewater with parameters adjusted to the pollutant source.

The QUAL2Kw (Q2K) framework provides new elements that are not present in QUAL2E (Q2E). Pelletier and Chapra (2008) mention these elements as follow:

1. Display interface and software environment, Q2Kw is implemented with Microsoft windows environment. This software is programmed in the Windows macro programming language: Visual Basic for Applications (VBA). Excel used as a graphical user interface (GUI).

2. Model segment. Q2E divides the system into river reaches consisting of elements that have the same space. As a comparison, Q2Kw uses river sections that do not have the same space. In addition, double loading for incoming and outgoing loads can be inserted into any section.

3. Anoxia Q2Kw supports anoxic conditions by reducing the oxidation reaction to zero at low oxygen levels.

4. Water deposition interactions. The flux of water deposition on dissolved oxygen and nutrients is simulated internally. Automatic calibration, a generic algorithm is included to determine the optimum value of the kinetic rate parameter to maximize the good fit of the model compared to the measured data. The use of the QUAL2Kw program can estimate the value of the pollution load on each river segment. Modeling using QUAL2Kw software is done first by dividing the reach, distance and river boundaries. The QUAL2Kw program also presents a river based on the impact of two sources, namely point sources and diffuse sources.

2.11 MIKE 21

MIKE 21 DHI software is a software used for 2D free-surface flows. Mike 21 can be applied to hydraulics simulations and related simulations in rivers, lakes, estuaries, piers, bays, beaches and oceans. This program was developed by DHI Water & Environment MIKE 21 which consists of several modules, including the following:

i. Hydrodynamic Module

ii. Sand Transport Module

iii. Transport Module

iv. Mud transport module

v. ECO lab module

vi. Particle Tracking Module

For the purposes of hydrodynamic simulation and water quality modeling carried out in this study, the modules used are two modules, namely Hydrodynamic and ECO Lab. While the modeling stage consists of 3 stages, namely bathymetry modeling of the study area, modeling of water level elevation and calibration and finally water quality modeling. For a detailed explanation, see MIKE (2007).

a. Hydrodynamics Module

The Hydrodynamic (HD) module is a mathematical model to calculate the hydrodynamic behavior of water with respect to various force functions, such as certain wind conditions and water levels. The hydrodynamic module is used to simulate differences in water levels and currents in response to various force functions in lakes, rivers, estuaries and beaches. This model simulates two-dimensional flow in a single layer fluid (vertically homogeneous). This model simulates two-dimensional flow in a single layer fluid (vertically homogeneous).

b. ECO Lab Module

The ECO Lab module is a powerful application that can be used for modeling ecosystem ecology in 2D and 3D. ECO Lab makes it possible to transform aquatic ecosystems into reliable numerical models for accurate predictions.

ECO Lab applications include: Water quality and related ecological studies in rivers, wetlands, lakes, reservoirs, estuaries, coastal waters, and oceans

i. Spatial prediction of each ecosystem response

ii. Simple research or complex research on water quality

iii. Impact and recovery studies

iv. Water quality planning and forecasting studies.

2.12 MODELING OF WATER QUALITY ANALYSIS SIMULATION PROGRAM (WASP)

In a body of water, a complex process occurs, both chemical, biological and physical processes. The process can be simplified by using modeling. The Water Quality Analysis Simulation Program (WASP) is one of the air quality modeling software that can be used to determine the pollutant load capacity. WASP modeling is a dynamic, flexible model that can be used to analyze various air quality problems in various water bodies such as ponds, rivers, lakes, reservoirs, estuaries, and coastal waters based on the main principle of mass conservation. This principle states that the mass of each part of the air quality to be carried out must be considered in one part. The WASP model examines each section of air quality based on spatial and temporal inputs from the beginning to the end point of the displacement, based on the principle of mass balance in space and time (Ambrose, 2009). WASP can be applied from one to three dimensions. Based on Amborse, (2009) input data for mass conservation calculations are in the form of simulations and outputs, segmentation models, advection and dispersion controls, concentration limits, point and non-point pollutant load sources, kinetic parameters, constants, and functions of time and initial concentration. WASP can simulate transport and transformation reactions for fourteen variables, one of which is BOD. The mass balance equation for substances dissolved in water must take into account all materials that enter and leave through direct and diffuse loading; displacement by advection and dispersion, and physical transformations, chemistry, and biology. The use of a coordinate system as shown in the general equation of mass balance, where the x and y coordinates are in the horizontal plane, and the z-coordinate is in the vertical plane Figure 2.1.

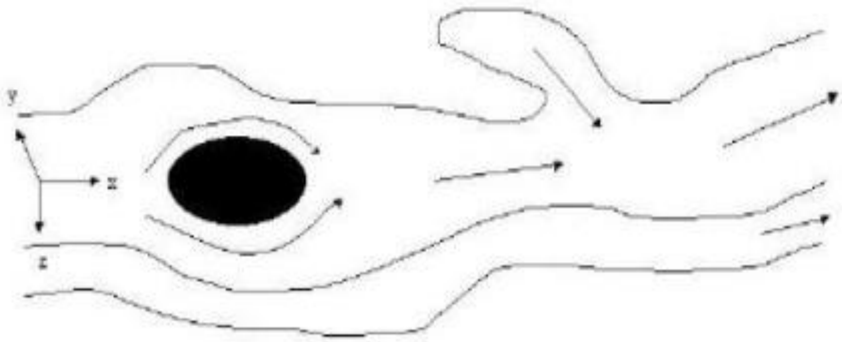

Figure 2.1: Coordinate System of Mass Balance Equations General equation

The conservation of mass is shown in the following equation.

$$\frac{\partial C}{\partial t} = -\frac{\partial}{\partial x}(U_x C) - \frac{\partial}{\partial y}(U_y C) - \frac{\partial}{\partial z}(U_z C) - \frac{\partial}{\partial x}\left(E_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(E_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(E_z \frac{\partial C}{\partial z}\right) + S_L + S_B + S_k \qquad (2.12)$$

Information:

C = concentration of pollutant load (mg/L or g/m^3),

T = time (days),

E_x E_y E_z: longitudinal, transverse, and vertical diffusive coefficients (m^2/day)

U_x, Uy, Uz = longitudinal, lateral, and vertical advection speed (m/day),

S_L= direct and diffuse load rate (g/m^3-day),

S_B = loading limit rate (including upstream, downstream, benthic, and atmospheric) (g/m^3-day),

S_K = total kinetic transformation rate (g/m^3-day)

2.13 QUAL2E

QUAL2E method is a very comprehensive river water quality modeling program and the most widely used today. QUAL2E was developed by the US Environmental Protection Agency. The purpose of using a model is to simplify an event so that the behavior of the event can be known. In QUAL2E, conditions along the river can be known (DO and BOD), so that further actions can be taken such as industries along the river are only allowed to dispose of their waste at a certain load. The determination of the capacity according to the Regulation of the Minister of the Environment No. 01 of 2010 states that the determination of the carrying capacity of the water pollution load must take into account:

a. Hydrological and morphological conditions of water sources including the status of quality and/or trophic status of water sources which are determined by their capacity to accommodate pollution loads;

b. Water quality standards for rivers and estuaries; c. water quality standards and water trophic status criteria for lakes, lakes and reservoirs;

c. Pollution load on each water pollutant source. The steps for determining the carrying capacity of the pollution load according to the Pollution Control Board Delhi.

Calculation of the load carrying capacity of source pollution water can be done by various methods, one of which is using computerized numerical modeling (computerized numerical modeling). Computational method is a simulation method with the help of a computer program. This method is more comprehensive in water quality modeling river. Basically, this model applies Streeter Phelps theory by accommodating the many sources of pollution into the river system, the hydraulic characteristics of the river, and climatological conditions. Simulation methods that can be used namely the Qual2E model and the QUAL2Kw model (Carmo, Maria & Gastaldini, Cauduro & Paz, Márcio, 2021).

CHAPTER 3

PROPOSED METHODOLOGY

The research phase contains the steps that will be carried out during the implementation of the research. The research stages include literature study, data collection, research implementation, data analysis and discussion, as well as conclusions and suggestions. The idea of this scheme is the magnitude of the pollution load on Yamuna River water, the raw water of Delhi (NCR). Therefore, water quality management of river needs to be carried out properly, especially minimizing the pollution load discharged into Yamuna River from domestic and industrial waste.

The first thing to do before field observation is to analyze ideal conditions and existing conditions so that differences are found and problems arise. On In this study, it was found a problem where the quality of Yamuna River which should be used as raw water in Delhi city o does not meet the class I water quality standards the existence of these problems, then the research idea is obtained namely the determination of the capacity of the Yamuna pollution load with QUAL2Kw modeling. Field observation which aims to determine the condition around the river so that the point can be determined as a source of pollution (point sources and diffuse sources).

3.1 STUDY AREA

The study area of Yamuna River in Delhi has a stretch of about 22.9KM length that runs from Wazirabad barrage to Okhla barrage. It has 16 drains point that end discharging into the river. Below is the image that showing the river Yamuna’s study area having google earth image in figure-3.1.

Figure-3.1: Google earth Image of study area

3.2 CLASSIFICATION OF WATER QUALITY CLASSES

According to Government Regulation, concerning Water Quality Management and Water Pollution Control in the third section (water quality classification and criteria) it is said that the water quality classification is assigned to 5 classes (Magara, 2021;US, 2004) as shown in below table 3.1.

Table 3.1: Classification of classes of river water quality

S. No	Class	Purpose
i.	Class A	A class, used for drinking water raw water and other same purpose
ii.	Class B	B class, water assigned for water amusement framework/offices, freshwater fish cultivating, creature farming, water for inundating crops, and/or different assignments requiring a similar water quality as the said use
iii.	Class C	C class, water whose assignment can be utilized for the development of freshwater fish, domesticated animals, water for

		flooding crops, and additionally different assignments requiring a similar water quality as the said use
iv.	Class D	D Class, water whose designation can be used to irrigate plantations and / or other designations that require the same water quality as this use
v.	Class E	E class, Suitable only for Industrial cooling and irrigation

3.3. QUAL2KW SOFTWARE AND CHARACTERISTICS

The Qual2Kw is a water flow and river quality model created with the aim of presenting a modern version of the Qual2E model (Brown and Barnwell). The characteristics of Qual2Kw are the same as those of Qual2E in the following aspects:

i. The Qual2Kw model is a one-dimensional model. Channels are well-mixed, both vertical and lateral.

ii. The Qual2Kw model can accommodate types of rivers that have branching. The model has steady-state hydraulics characteristics. The simulated water flow is non-uniform and steady-state, where the flow rate is constant with time. The Qual2KW framework includes new elements, which among others can be explained as follows:

   ii.i. Software Environment and Interface. Qual2KW is implemented in a Microsoft Windows environment. In Fortran 90, a numerical computing programme is written. As a graphical user interface, Excel is used. The Microsoft Office macro language is used for all programmable interface operations: VBA stands for Visual Basic for Applications.

   ii.ii. Segmentation of models. The system is divided into a river by Q2E, which is segmented into equal-sized elements. The structure is also divided into reaches and components by Q2Kw. The only difference is that, unlike Qual2E, the element sizes for Qual2Kw will vary from one to the next. In addition, any aspect may have multiple loadings (multiple loads) and withdrawals.

3.3.1 Qual2Kw Segmentation

Qual2Kw presents a river as an arrangement of several reaches. This arrangement represents any part of the river that has constant hydraulic characteristics, such as the slope and width of the river bed. The reaches of tributary systems are numbered sequentially, beginning with reach 1 at the main river's headwater. The numbering begins when a tributary is encountered until the tributary's headwater is reached. Both headwaters and tributaries are often numbered consecutively, similar to how reaches are numbered. The system's big repercussions (the main stream and any tributaries) are often labelled as segments. This distinction is important in practice since the programme plots the model output on a segment-by-segment basis, and it produces individual plots for the main stem and each tributary. In summary, the nomenclature used to clarify the method by which Qual2Kw organizes the river topology are as follows (Barnwell, 1987 ; Shushobhit Chaudhary, 2018 ; Sarda, 2013):

i. Reach, namely the length of a river with constant hydraulic characteristics.
ii. Element, namely the fundamental model computation unit consisting of subdivisions with the equivalent length of a reach.
iii. Segment, which is a collection of several reaches that represent a branch of the system. The segment consists of the main stem as well as any existing tributaries.
iv. Headwater, which is the upper limit of a model segment.

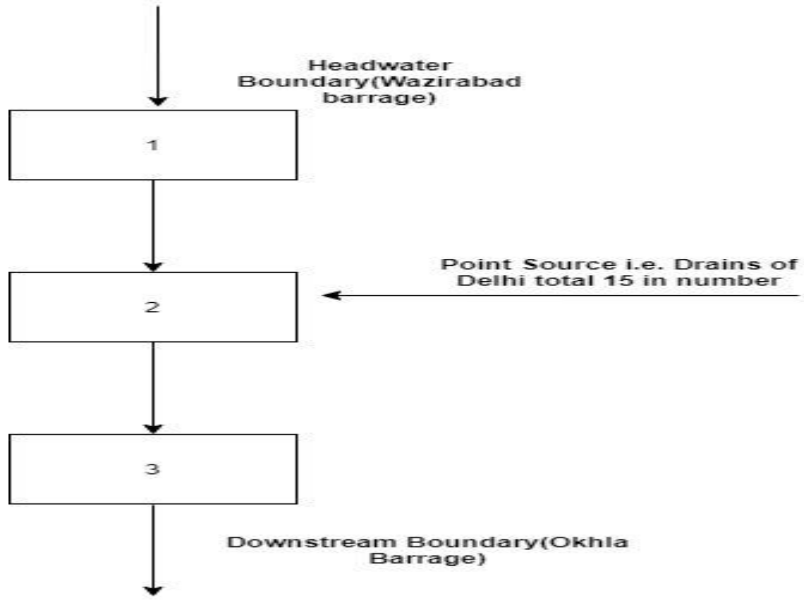

Figure-3.2: Segments of Qual2KW model

To evaluate the fit of each of the parameters in the model calibration QUAL2Kw the function recommended by Pelletier et. to the. (2006), is an equation robust that represents all the variables of the model. This setting function is the reciprocal of the average weight (with which the variables that most influence the process) of normalization of the square root of the error of the difference between the data obtained with the model and the field data and represents in equation below. The reciprocal of this function was taken because it is It is important to mention that the genetic algorithm maximizes the objective function. A characteristic that a fitting function must have for a genetic algorithm: it must be able to "punish" the bad solutions, and to "reward" the good, so that the latter are the ones that spread the most speed.

$$\mathbf{f(x)} = \left[\sum_{i=1}^{q} W_i\right]\left[\left[\sum_{i=1}^{q}\frac{1}{W_i}\right]\left[\frac{\frac{\sum_{j=1}^{m} O_{i,j}}{m}}{\frac{\sum_{j=1}^{m}(P_{i,j}-O_{i,j})^2}{m}}\right]^{1/2}\right] \qquad \textbf{(3.1)}$$

Where:

$O_{i,j}$ = Observed Value

$P_{i,j}$ = Value predicted by the model

m = Number of pairs of observed and predicted values

W_i= Weight factor

$O_{i,j}$= Number of state variables

Various formulas used under the scheme are as under: -

- Flow Balance

$$Q_i = Q_{i-1} + Q_{in,i} - Q_{ab,i} \qquad (3.2)$$

Where,

Q_i = Outgoing flow from i into i + 1 segment in [m^3/d],

Q_{i-1} = Incoming flow from the upper side segment i –1 [m^3/d],

$Q_{in,i}$ is the total incoming flow into the reach from point source [m3/d], and

$Q_{ab,i}$ is the total outgoing flow from the reach due to point source [m^3/d].

3.4 RESEARCH FRAMEWORK

This study discusses the identification and prediction of the quality of water bodies in Yamuna River using 5 scenarios and dividing them into 16 segments. In this case, identification uses sampling and prediction of water quality using modeling with the Qual2Kw application. This research needs to be done so that the water in Yamuna River gets special attention in maintaining the quality and quantity of water bodies that aim for water conservation. Identification of water quality can be seen from the parameters pH, BOD, COD, DO and TSS.

This research method is structured in the form of a research framework, namely the flow or procedure in the research to be carried out. This research framework aims to:

i. As an illustration of the initial stages of research so that it can facilitate research and report writing.

ii. Can find out things related to research so that research objectives are achieved and make it easier for readers to understand the research to be carried out.

iii. As an initial guideline in conducting research, so that risky errors can be minimized.

This research framework is a basic general description of conducting research because there is no study or research regarding the prediction of water quality in Yamuna River using Qual2K. The research stages start from the research idea, direct observation and determining the source of the pollutant (point source and / or non-point source) until the sections or segments that can be researched are obtained. This research is supported by a literature study, primary and secondary data which will later be processed by the Qual2Kw method with several scenarios for modeling. Based on this, it can be seen that the framework and research flow diagram are arranged in Figure 3.3.

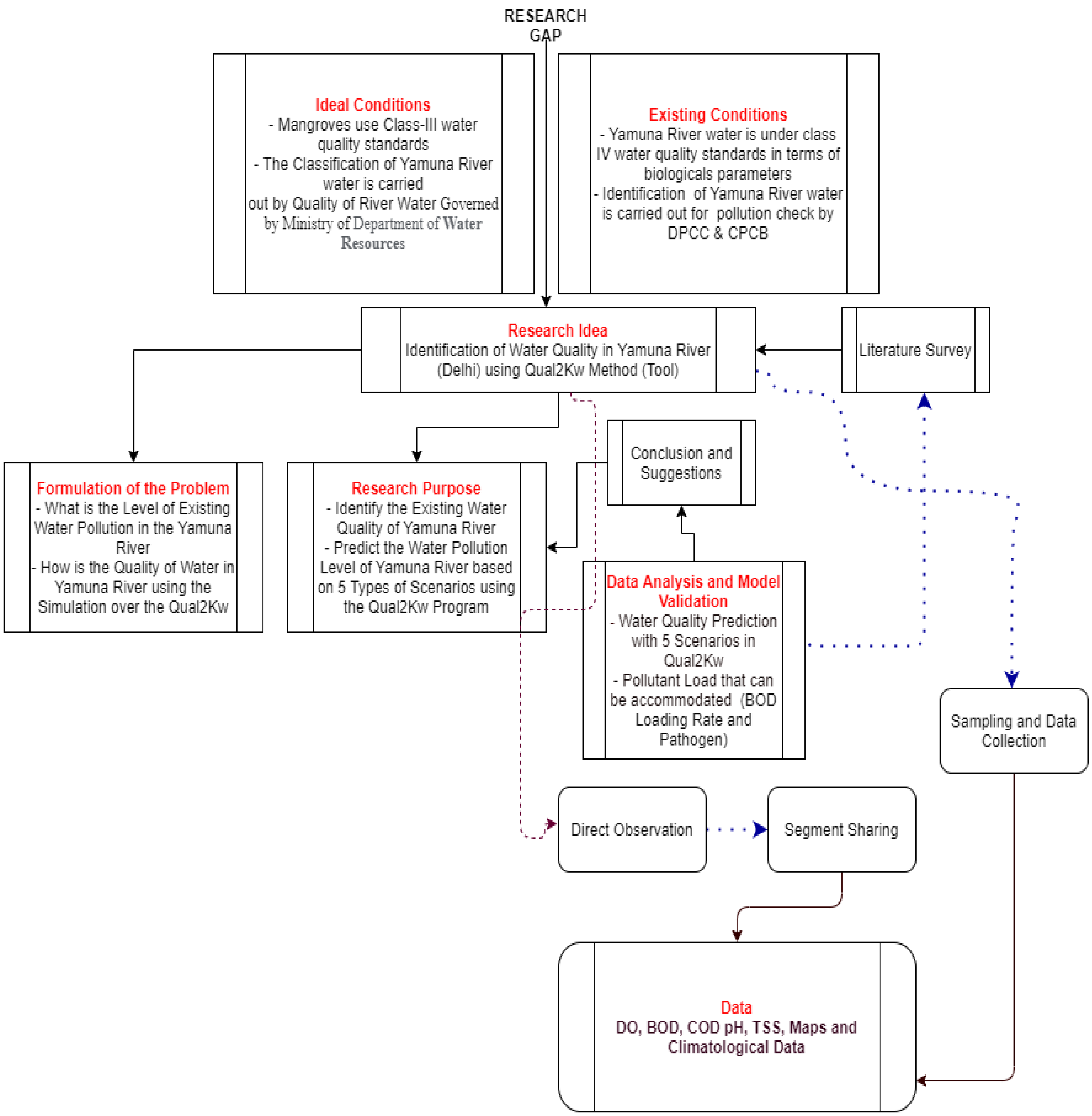

Figure 3.3: Research Methodology

3.4.1 Determination of Sampling Points (Drainage Points)

The research segment was determined as the basis for taking sample points to determine changes in water quality that occurred in the Yamuna River. Based on the river water sampling point is determined based on the river water discharge on 16 various drainage points. The water discharge of the river is 21.97 m^3 / second at Wazirabad Barrage (Station 1) which subsequently declines gradually, details mentioned in Table 3.2.

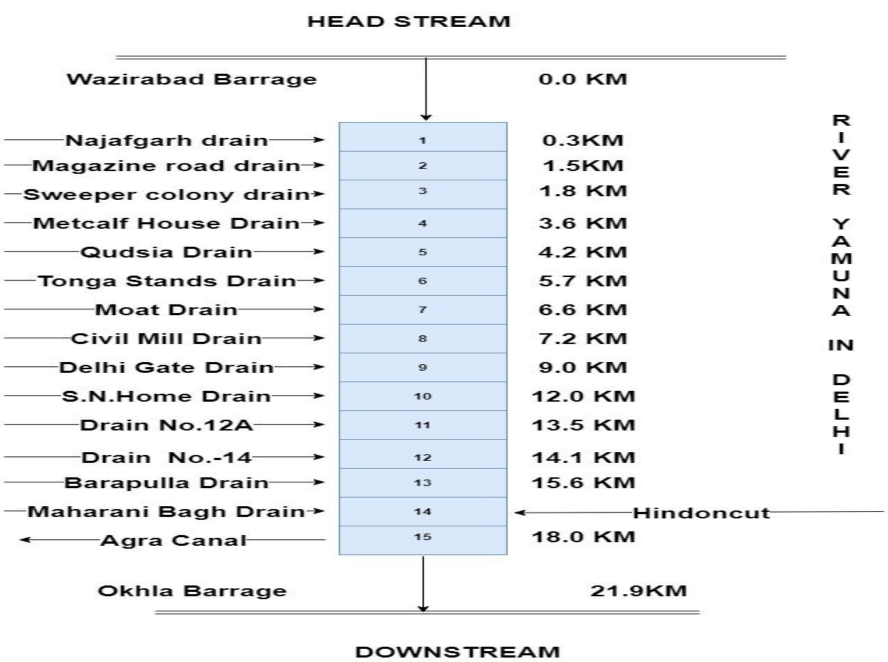

Figure 3.4: Various Drainage Points in Delhi

Before determining the point of sampling, we must first determine the segments of the Yamuna River. In this study, 16 segments were determined starting from the Wazirabad area (upstream) to the Agra canal (downstream) (Table 2). Segment boundary determination is based on the presence of easy sampling sites, forks of tributaries, river bends, and incoming from pollution point sources. The research segment was determined as the basis for taking sample points to determine changes in water quality that occurred in the Yamuna River. Based on the Pollution Control Board, the river water sampling point is determined based on the river water discharge. The water discharge of the Yamuna River varies at differently at different drain points. Thus, sampling is at two points respectively at a distance of 300 meters to 1200 meters respectively the width of the river and at a depth of 0.5 times the depth from the surface. Sampling starts from the upstream of the river at 0.0 Km (Wazirabad barrage) to 21.97(Okhla Barrage) of Flow. This collection is distance based on water use activities throughout the research segment, which are mostly residential areas, offices, Industries and warehousing.

Table.3.2: -Segments of River Yamuna at Delhi, source: (Shushobhit Chaudhary, 2018)

Distance (in K.M)	**Station/Drain name**	**Flow(m^3/s)**
0.0	Wazirabad Barrage (Station 1)	21.97
0.3	Najafgarh Drain (D1)	0.057
1.5	Magazine Road (D2)	0.104
1.8	Sweeper Colony (D3)	0.114
3.6	Khyber Pass (D4)	0.942
4.2	Metcalf House (D5)	0.495
5.7	Qudsia Bagh (D6)	0.077
6.3	Tonga Stands (D7)	0.0001
6.6	Moat Drain(D8)	0.677
7.2	Civil Mill (D9)	1.899
9	Delhi Gate (D10)	0.994
12	S.N. Home Drain(D11)	0.19
13.5	Drain no.12A(D12)	0.19
14.1	Drain no.14 (D13)	1.871
15.6	Barapulla drain(D14)	2
18	Agra canal (D15)	2.1
21.9	Okhla Barrage (Station 2)	-

CHAPTER 4
IMPLEMENTATION AND RESULTS

4.1. MODEL CALIBRATION

Model Calibration After segmentation, it is necessary to calibrate the model. This is done so that the model is closer to the input data that has been entered into the program due to time differences and data variations. An important factor in model calibration is the determination of the model coefficient which includes the reaction coefficient of each parameter. Model calibration is divided into 2, namely hydraulic data calibration and water quality data calibration. Trial and error are carried out by testing the calibration model which aims to compare the predictive data of the model with the results of the observations. In other words, the calibration model approximates the water quality data from observations. In the hydraulic data calibration Trial and error is performed on the manning formula in the reach worksheet, while the water quality data calibration is on the reach rates worksheet is being done.

4.2. DETERMINATION OF YAMUNA RIVER SEGMENT

The length of the Yamuna River used in this study is 21.9 km stretching from the upper (Wazirabad Barrage) to the lower (Okhla Barrage). Upstream to downstream are divided into 16 segments, each bounded by a bridge. These bridges are used to take water samples as shown in Figure 4. The determination of the segments of the Yamuna River aims to facilitate the analysis of changes in water quality along the Yamuna River flow. The use of bridges at the beginning and end of the segment aims to facilitate water sampling and obtain hydraulic data such as velocity and flowrate. Segment determination is not only based on the existence of a place for sampling, but also based on the presence of bends and changes in river dimensions.

4.2.1 Biochemical Oxygen Demand

Analysis of the Hydraulic Conditions of the Yamuna River The hydraulic conditions of the Yamuna River can be seen through the velocity and discharge data of the water. Yamuna river hydraulic data is needed as comparative data on the fluctuations in the concentration of river pollutant parameters. Water discharge data can be obtained through depth measurements using BOD Flow Rate. The flow velocity is then calculated by equation 3.1. The fluctuation of water velocity during measurement can be seen in Table 4.1.

Table.4.1: BOD loading Rate, Source :(BOD data -DPCC website and Flow data- (Shushobit Chaudhary, 2018))

Distance (in K.M)	**Station/Drain name**	**BOD (mg/l)**	**Flow(m 3/s)**	**Current waste loading rate (kg/day)**
0	Wazirabad Barrage	3	21.97	5694.624
0.3	Najafgarh Drain(D1)	30	0.057	147.744
1.5	Magazine Road drain(D2)	30	0.104	269.568
1.8	Sweeper Colony drain(D3)	135	0.114	1329.696
3.6	Khyber Pass drain(D4)	60	0.942	4883.328
4.2	Metcalf House Drain(D5)	NO FLOW	0.495	NO FLOW
5.7	Qudsia Bagh drain(D6)	80	0.077	532.224
6.3	Tonga Stands Drain(D7)	26	0.0001	0.2246
6.6	Moat Drain(D8)	NO FLOW	0.677	NO FLOW
7.2	Civil Mill Drain(D9)	26	1.899	4265.9136
9	Delhi Gate Drain(D10)	68	0.994	5839.9488
12	S.N. Home Drain(D11)	118	0.19	1937.088
13.5	Drain no.12A(D12)	NO FLOW	0.19	NO FLOW
14.1	Drain no.14 (D13)	31	1.871	5011.2864
15.6	Barapulla drain(D14)	63	2	10886.4
18	Agra canal (D15)	40	2.1	7257.7
21.9	Okhla Barrage (station 2)	60	-	

The formulation which to calculate the BOD loading rate is mentioned under for ready reference and perusal.

$$\textit{Waste loading Rate}\left(IN\frac{Tonnes}{Day}\right) = BOD\left(\frac{MG}{L}\right) X\ \textit{Flow Rate}\left(\frac{M3}{S}\right) X\ 1000\ X\ \left(\frac{1}{1000000000}\right) X\ 24\ X\ 60\ X\ 60 \qquad (4.1)$$

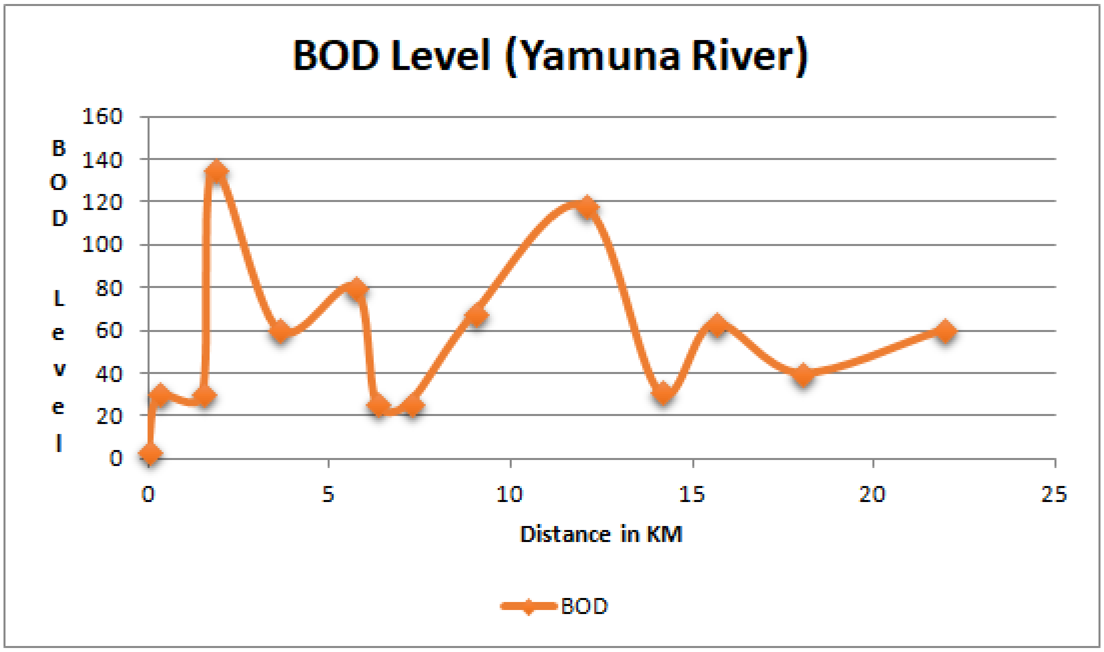

Figure 4.1: Observed BOD on various Segments (Drainage Points as per Table 4.1)

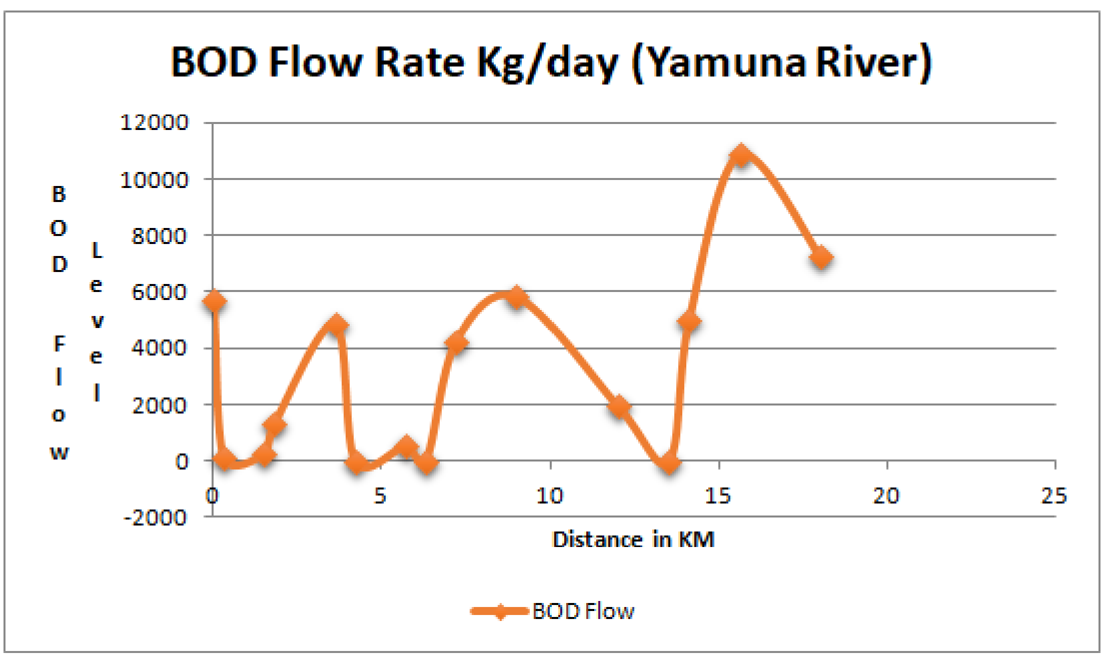

Figure 4.2: BOD flow rate on various Segments (Drainage Points as per Table 4.1)

Table 4.2: DPCC and CPCB Data for Yamuna River (Source DPCC and CPCB website,20-21)

	Data source DPCC and CPCB website					
Distance (in K.M)	**Station/Drain name**	**pH**	**DO (in mg/l)**	**COD (in mg/l)**	**BOD (in mg/l)**	**TSS (in mg/l)**
Headstream	Palla station	7.78	8.7	20	1.8	0
0	Wazirabad Barrage (Station 1)	7.63	7.4	24	3	0
0.3	Najafgarh Drain(D1)	7.26	0	272	30	100
1.5	Magazine Road drain(D2)	6.76	0	144	30	100
1.8	Sweeper Colony drain(D3)	6.31	0	476	135	586
3.6	Khyber Pass drain(D4)	6.43	0	180	60	172
4.2	Metcalf House Drain(D5)		No flow	No flow	No flow	No flow
5.7	Qudsia Bagh drain(D6)	7.38	0	288	80	74
6.3	Tonga Stands Drain(D7)	6.66	0	84	26	72
6.6	Moat Drain(D8)		No flow	No flow	No flow	No flow
7.2	Civil Mill Drain(D9)	6.79	0	80	26	84
9	Delhi Gate Drain(D10)	6.6	0	200	68	162
12	S.N. Home Drain(D11)	6.46	0	480	118	260
13.5	Drain no.12A(D12)		No flow	No flow	No flow	No flow
14.1	Drain no.14 (D13)	6.88	0	86	31	58
15.6	Barapulla drain(D14)	6.88	0	176	63	136
18	Agra canal (D15)	6.84	0	180	40	0
21.9	Okhla Barrage (Station 2)	7.17	0	192	60	0

4.2.1 Dissolved Oxygen (DO)

Lack of oxygen in water can interfere with the life of aquatic biota, including their growth rate. DO parameters are measured directly over the Yamuna River water. The DO concentration of Yamuna River does not meet Class B water quality standards because none of it reaches 5 mg / l. The trend of DO concentration changes from upper to lower is constantly at the value of 0. The highest concentration is at Point 1 (Palla station 1) is 8.7, subsequent Wazirabad Barrage 7.63 is thereafter remaining is 0. The below figures depict the illustration using line graph with data table.

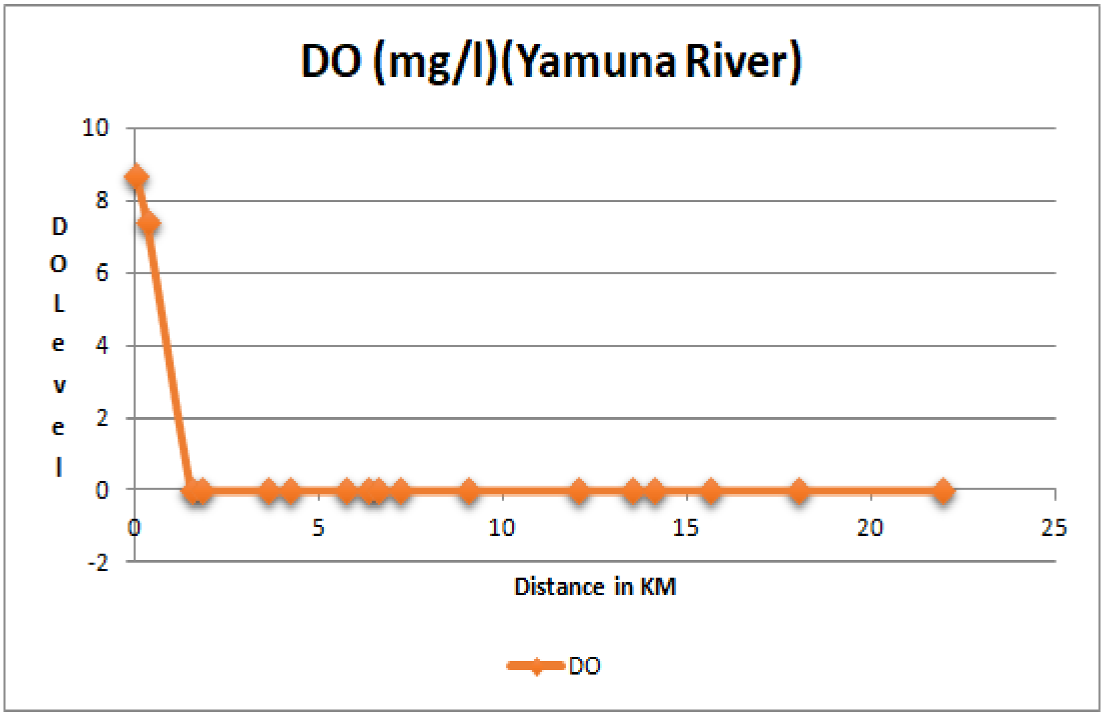

Figure 4.3: Dissolved Oxygen at various Drainage Points in Yamuna River

4.2.2 Chemical Oxygen Demand (COD)

Organic materials measured in COD analysis are biodegradable and non-biodegradable organic. In class B water quality standards, the maximum concentration of COD in water is 25 mg/l. COD concentrations in the Yamuna River for is depicted as under. In the Yamuna River, COD concentration fluctuates vary high on various drainage points. This indicates that organic contaminants were degraded, resulting in lower BOD5 and COD levels. Since BOD5 is a COD attribute, it is the same as COD, which demonstrates the value of biodegradable and non-biodegradable organics.

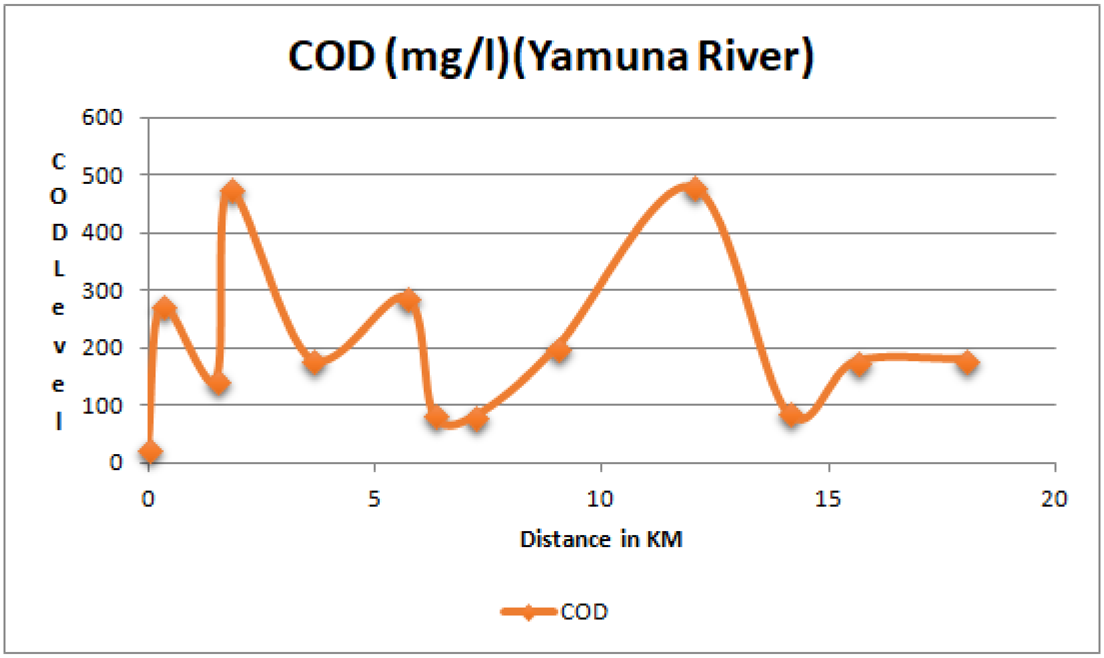

Figure 4.4: Chemical Oxygen Demand at various Drainage Points in Yamuna River

4.2.3 Total Suspended Solid (TSS)

In class B water quality standards, the maximum concentration of TSS in water is 50 mg / l. The TSS concentration in the Yamuna River shown in figure 9 is. However, the increase in TSS concentration is thought to be due to the input of incoming industrial and domestic waste therefore, a decrease in TSS value due to reduced water flow rates so that part of the TSS is deposited and the water flow rate decreases. During the analysis, the TSS concentration in the Yamuna River fluctuated at different drainage points. The TSS concentration in the Yamuna River did not meet the criteria as compared to class B water quality standards, ranging from 69 mg/l to 700 mg/l at different drainage points.

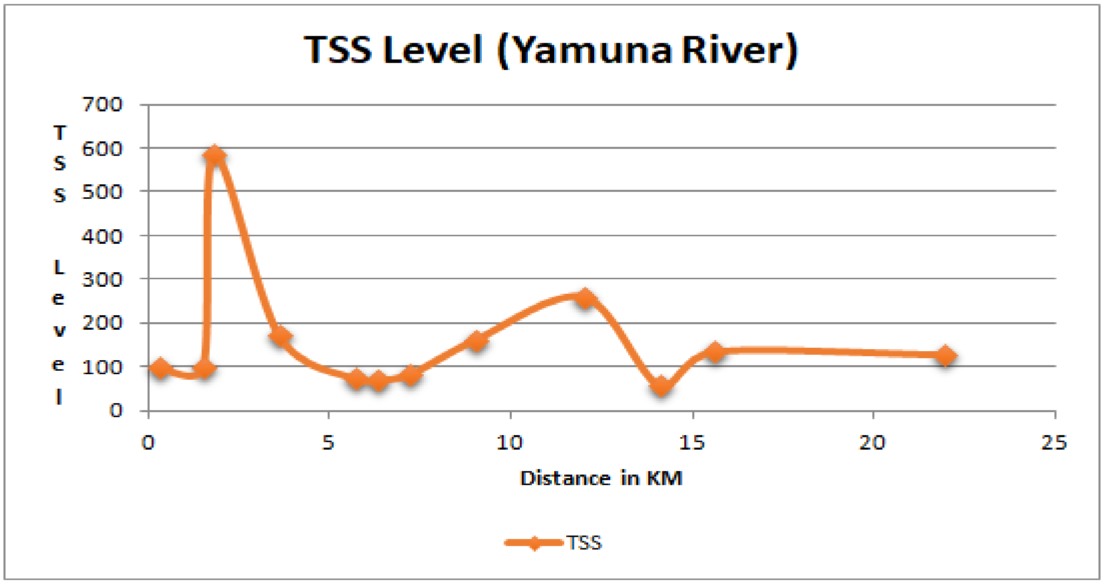

Figure 4.5: Total Suspended Solid along the downward flow of Yamuna River

4.2.4 Degree of acidity (pH)

In class B water quality standards having permissible pH range is 6-5 to 8.5. The pH for Yamuna River water is presented in figure 10. The pH value in many natural waters ranges from 4 to 9. The low pH of water is due to the high sulfuric acid content in the waters. On the other hand, the high pH of waters can be caused by the high amount of lime that enters the water. The degree of acidity of waters is one of the important chemical parameters in monitoring the stability of the waters.

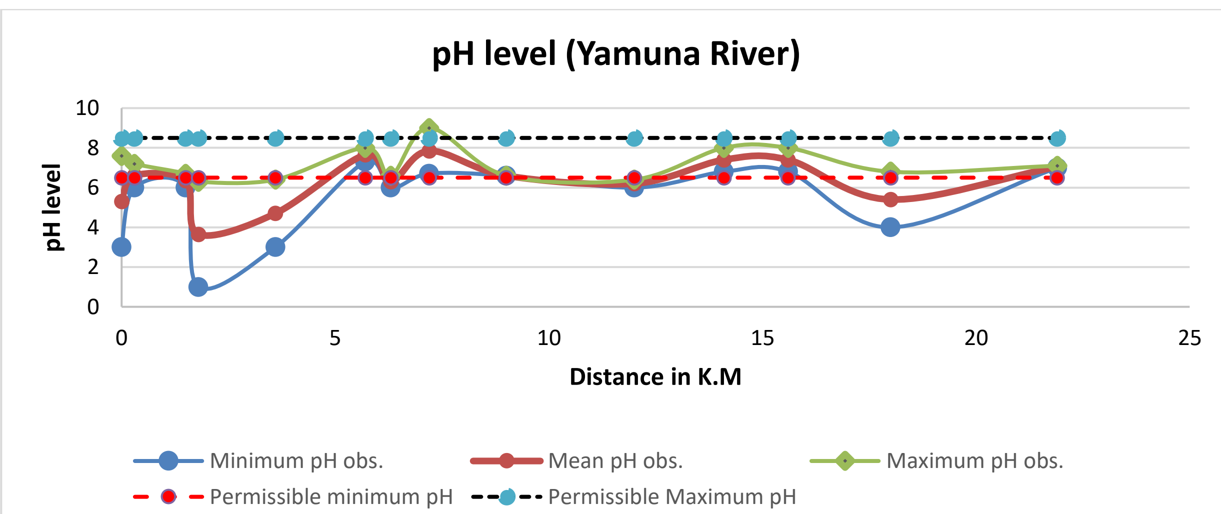

Figure 4.6: The observed degree of acidity (pH) at various Drainage Points in Yamuna River

The above figures are derived from data provided by Delhi Pollution Control Committee in March 2021. Consequently, the below table illustrate the statistics for read reference. The figure 4.7 below, indicates the values for the current and predicted BOD loading rate for the river Yamuna using the tool, which clearly indicate the reason for the pollution of River Yamuna biologically.

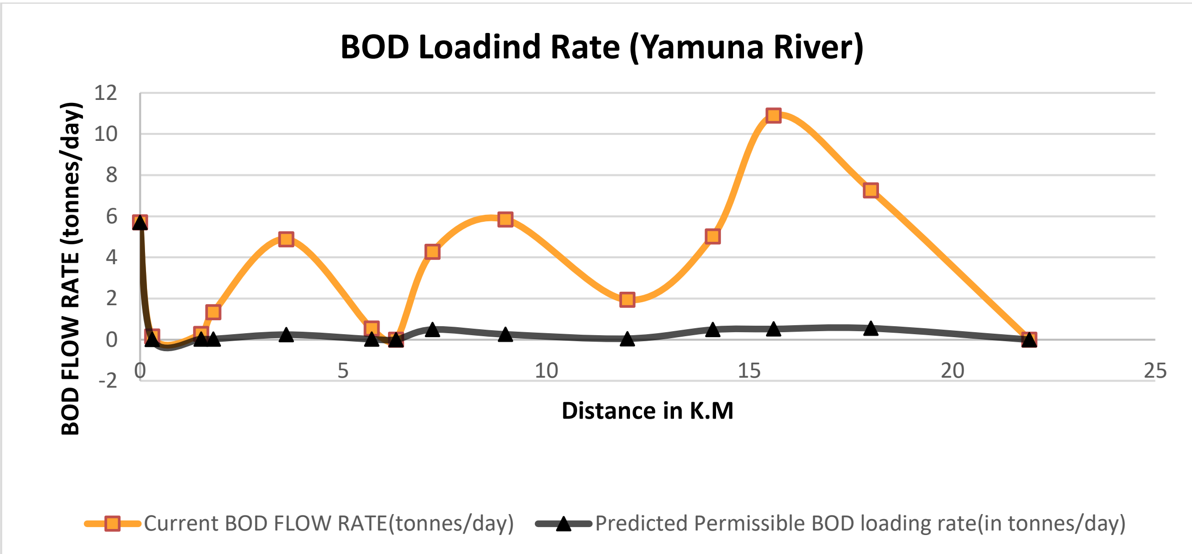

Figure 4.7: BOD loading rate current v/s predicted.

Below in table 4.3, showing the waste load data for current scenario and predicted values for River Yamuna.

Table 4.3: Waste load allocation data with current and predicted values

Distance (in K.M)	Station/Drain name	BOD (mg/l)	Flow(m3/s)	Current waste loading Rate (tonnes/day)	Predicted waste loading Rate (tonnes/day)
0	Wazirabad Barrage	3	21.97	5.695	5.695
0.3	Najafgarh Drain(D1)	30	0.057	0.1477	0.01477
1.5	Magazine Road drain(D2)	30	0.104	0.2695	0.02695
1.8	Sweeper Colony drain(D3)	135	0.114	1.3296	0.029548
3.6	Khyber Pass drain(D4)	60	0.942	4.883	0.2442
4.2	Metcalf House	NO	0.495	NO FLOW	0.128

	Drain(D5)	FLOW			
5.7	Qudsia Bagh drain(D6)	80	0.077	0.5322	0.01996
6.3	Tonga Stands Drain(D7)	26	0.0001	0.000224	2.59E-05
6.6	Moat Drain(D8)	NO FLOW	0.677	NO FLOW	0.17547
7.2	Civil Mill Drain(D9)	26	1.899	4.266	0.49222
9	Delhi Gate Drain(D10)	68	0.994	5.839	0.257644
12	S.N. Home Drain(D11)	118	0.19	1.937	0.049248
13.5	Drain no.12A(D12)	NO FLOW	0.19	NO FLOW	0.049248
14.1	Drain no.14 (D13)	31	1.871	5.011	0.48496
15.6	Barapulla drain(D14)	63	2	10.886	0.5184
18	Agra canal (D15)	40	2.1	7.258	0.55432
21.9	Okhla Barrage (station 2)	60	-		

The calculation of the carrying capacity of this pollution load serves to determine the ability of the Yamuna River water body to accommodate the maximum limit of waste that enters it. The calculation of the carrying capacity is based on simulation. In determining the carrying capacity of the pollution load, the parameters calculated for each segment are TSS, BOD, COD so that it can be seen the ability of the Yamuna River to accommodate the incoming pollutant load in each segment.

CHAPTER 5

CONCLUSION & SUGGESTIONS

Conclusions are drawn from the results of the analysis of the data that has been done. The conclusions made refer to the goals to be achieved. Furthermore, for research suggestions obtained from the limitations of researchers in conducting research so that it can be investigated by further researchers.

5.1 CONCLUSION

On the basis of this study regarding determining the status of the water quality of the Yamuna River by methods based on tool QUAL2KW, it can be concluded that water in the Yamuna River based on the methods vide QUAL2KW depict that River is in a heavily polluted condition. This result based on the overall calculations derived from table 4.1, table 4.2 and table 4.3, whereas the data is provided by Delhi Pollution Control Committee. The BOD loading rate is 8-10 times greater than the calibrated permissible or predicted BOD loading rate, which is main cause of Yamuna River pollution, while the DO level should be more than 5mg/l for sustainability of living organisms especially aquatic but, except Wazirabad barrage and Palla station, rest of the station has DO level below 1 mg/l and the Pathogenic indicator Fecal Coliform should below 2500 MPN/100ml but none of the stations and drain except Palla and wazirabad barrage, have less than 2500 MNP/100ml.,All the existing point source have pathogenic value 30-40 time more than permissible limit.

5.2 SUGGESTIONS

Suggestions that can be given from the final project for calculation of the carrying capacity of the pollution load using the method this QUAL2Kw

1. There is a further study with other scenarios, such as variations in water quality conditions and river discharge.

2. It is possible to do a sufficient preliminary study to study depth to predict non-point source data.

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