A COMPARATIVE STUDY OF BIOCHEMICAL COMPOSITION OF WASTE IN THE STREAM THALAGALA OYA AND LAKE GREGORY, NUWARA-ELIYA.

By

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This Thesis is submitted in partial fulfillment of the requirement of the Bachelor of Science Special Degree (Applied Sciences) in Chemical Technology

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DECLARATION

The work described in this thesis was carried out by me at the Department of Physical Sciences, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, under the supervision of Dr.C.P.Udawatte, Head of the Department, Department of Physical Sciences, Faculty of Applied Sciences, Sabaragamuwa University of SriLanka & Mr.Wasantha Liyanage, President, Land Owner's Restore Rain Forest in Sri Lanka, No 244A, Vystwyke Rd, Colombo-3. A report on this has not been submitted to any other university for another degree.

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Affectionately

Dedicated

To

My Parents, Teachers and Supporters

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ABSTRACT

Nuwara Eliya city has been very attractive due to the scenic beauty of Lake Gregory. But during the last two decades its beauty has lost due to the waste added. Because the land use pattern around the lake has changed a lot with the cultivation increased. This was carried out to determine the polluted areas of the stream Talagala Oya and Lake Gregory observing the parameters BOD, COD, PH, TS, TDS, Phosphate concentration and Nitrate concentration.

Here DO and BOD were measured using the Winkler method. COD was measured using the Potassium dichromate titration method and pH was measured using the P^H meter. Phosphate concentration and Nitrate concentration were measured using UV Absorption Spectrophotometer. TS, TDS and TSS were measured using the weight difference.

According to the results, The DO level has decreased from upstream to downstream. BOD and COD values have increased from the first points to the middle and have decreased again when going to last points. Here the Nitrate concentration has been more than the phosphate concentration and increases from upstream to downstream. Most of the occasions P^H value was in between 5 and 7. It is in the standard range. TS, TSS and TDS values have also increased from first points to the middle and then have decreased when going to the last.

According to the above results, it can be concluded that the lot of waste is added to the lake when going from upstream to the downstream and some places have diluted up to the lake. And the large amounts of acids and bases are also not added. Further it can be concluded that water is not dissolved with much heavy metals and toxicity of cyanides and sulfides is also less. Normally P^H becomes to that range due to organic acids produced by decaying of organic matter. It is concluded that the water in those places is more polluted. Therefore the necessary actions should have been taken to stop the ways of adding wastes to the lake and protect it.

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LIST OF ABBREVIATIONS

DO	Dissolved Oxygen
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
TS	Total Solids
TSS	Total Suspended Solids
Conc	Concentrated
Dis	Distilled
ppm	Parts per Million
ppb	Parts per Billion
UDA	Urban Development Authority
CEA	Central Environmental Authority
CTB	Ceylon Tourist Board

CHAPTER 1

INTRODUCTION

1.1. Background

Lake Gregory is a man-made tank, named after Sir William Gregory, Governer of then Ceylon from 1872 to 1877. The swamp, which existed at this location, was converted into the water body of the Lake Gregory by damming Thalagala Oya stream. This is a unique artificial wetland created in the heart of the high altitude city of Nuwara Eliya. It is located just 610 m below the Pidurutalagala peak, which is the highest peak in Sri Lanka. The Lake is bounded on all sides by roads, and the surrounding area has been severely altered by agricultural expansion, and urban sprawl. Because of the Lake's aesthetic value and scenic attraction, many holiday homes (IWMI, 2009).

Location: 60 57' 0 N and 800 45' 0 E to 60 56' 0 N and 800 48' 0 E; 768229 N and 472384 E to 766384 N and 477907 E; within the municipality area of (IWMI, 2009).

Area: The area of the Gregory's Lake is 0.4 km^2 with a perimeter of about 3.5 km.

Altitude: 1,914 m above MSL

A major tributary of this Lake is the Thalagala Oya stream that originates from the Pidurutalagala Peak. Thalagala Oya receives many small tributaries on its downhill journey to the Lake. Most of the streams in the catchment area have been changed over the years for commercial agriculture developments. These agriculture developments and tourist expansions are threatening the future of the present day Lake. Lake Gregory receives an average annual rainfall of 2,000-2,500 mm, and a mean annual temperature of approximately 160^{0}C. The underlying area of the Lake consists of highly crystalline charnockitic genesis rocks of Precambrian age (IWMI, 2009).

Major habitat types around the Lake area include freshwater marshes, streams, degraded montane forests and agricultural lands (tea plantations, vegetables cultivations etc.). The

aquatic vegetation in the Lake consists of phytoplankton, and rooted macrophytes. The fauna recorded from the Lake environs include 11 species of invertebrates and 77 species of vertebrates (IWMI, 2009).

The freshwater fish populations in the Lake consist entirely of exotics, dominated by *Oreochromis spp.* and *Cyprinus spp.* Among the aquatic amphibians, the endemic *Polypedates eques* and *Lankanectus corrugata* inhabit the streams and marshes around the Lake. Aquatic birds that visit the Lake include cormorants (*Phalacrocorax niger*), egrets (*Egretta garzetta, Mesophoyx intermedia*), herons (*Ardeola grayii*) and kingfishers (*Alcedo atthis, Halcyon smyrnensis)*, while raptors include Elanus caeruleus and Circus spp. Among the mammals, *Lutra lutra* and *Prionailurus viverrinus* inhabit the surrounding environs. The riparian areas and associated streams harbour several endemic crab species (*Perbrinkia spp.* and *Ceylonthelphusa spp.*) (IWMI, 2009).

The phytoplankton communities are dominated by Myxophyceae (blue green algae). The floating macrophytes in the Lake are dominated by two exotic species; *Salvinia molesta*, and *Pistia stratiotes*. The other rooted aquatic plants that are common in the Lake include *Hydrilla verticillata*, *Nymphaea spp.*, and *Cabomba sp.* Predominant plant species in the Lake bank include *Aristea eckloni*, *Pogostemon reflexus*, *Eriocaulon brownianum*, and *Osbeckia parvilolia* (IWMI, 2009).

Land tenure:

The Lake is state owned while the surroundings are both privately owned and state owned (IWMI, 2009).

Land use:

The surrounding environs consist of marshes, home gardens, vegetable cultivations, tea plantations, hotels and commercial centers (IWMI, 2009).

Possible changes in land use:

Reclamation of the lake area for commercial agricultural expansion, and human settlements are the major land use changes expected.

Lakes can be divided in to two groups, namely the deep lakes and shallow lakes .Sri Lanka mainly has shallow lakes which were constructed by man. Sri Lanka is a tropical country where rainfall gets periodically depending on monsoon wind. Therefore lakes were constructed for collected rain water, mainly for agriculture activities (Kooragama, 2004).

Gregory Lake is a shallow and is one of the largest tanks in Nuwara-Eliya district. It is situated in the Nuwara-Eliya municipal zone. There are agricultural lands surround the lake. The fertilizer which is added to these lands washed away and can contaminate the Gregory Lake's ecosystem. Talagala Oya is the main water stream which brings a lot of waste to Lake Gregory.

Lot of fecal matters, inorganic fertilizers, pesticides and other wastes are released to Talagala Oya from Hotels, Industies, Houses and Agricultural lands situated around the stream's premise. And there are some direct releases of above waste materials to Lake Gregory too.

Change of nutrient level in the lake affects both fauna and flora of a water body. It also has detrimental effects on water quality, making it unsuitable for human and animal's use. Sometimes it might even lead to toxicity. On the long run, the whole ecosystem can be collapsed. Therefore this study is aiming to do a comparative study of biochemical composition of waste in Thalagala oya and Lake Gregory to know that how far they have been polluted.

1.2. Overall Objectives:

- ✓ To do a comparative study of biochemical composition of waste in Thalagala Oya and Lake Gregory.
- ✓ To know that the variation of been waste when going from upstream of Thalagala Oya to Lake Gregory.

CHAPTER 2

LITERATURE REVIEW

2.1. The Lake Gregory and Thalagala Oya

The Lake Gregory was constructed by Governor Gregory in 1874, by damming the stream Thalagala oya from the mount Piduruthalagala. Central Environmental Authority by regulation of the National Environmental Act no. 47 of 1980 (Gazette 05-03-2007) named this as a Lake Environmental Protection Area. Central Environmental Authority and Nature Exploration and Protection Society of Sri Lanka have planned to construct a Biodiversity park in this protection area. Still no any studies have been done to understand the current status of the protection area. Gregory Lake and Thalagala Oya have been subjected to pollution under the unplanned urbanization, improper use of chemicals and Agricultural practices. Therefore spread invasive plant can be seen at the bank and in the lake due to the above reasons (C.E.A, 2009).

Figure 2.1 Present state of the Lake

Due to the high altitude, Nuwara Eliya has a much cooler climate than the lowlands of Sri Lanka, with a mean annual temperature of 16 °C. But the temperature changes and sometimes it can be like 3°C. In the winter months it is quite cold at night, and there can even be frost. Although it rapidly warms up as the tropical sun climbs higher during the day (WIKIPEDIA, 2009).

Hydrological and biophysical values

The water from Lake Gregory is predominantly used for irrigating green houses and other horticultural activities, particularly during the dry season. The general perception of the local community is that the water in the lake is not very clean as a result of stagnation and due to the large amount of dissolved agro chemicals (IWMI, 2009).

Social and cultural values:

The Lake serves as an aesthetic and recreational site for visitors to Nuwara Eliya. The water within the lake acts mainly as a supply for the surrounding agricultural lands during the dry season and not as a source of potable water for the town residents. Domestic tourism is an important component of the local economy (IWMI, 2009).

Disturbances and threats:

Management authority and jurisdiction:

The Lake falls under the jurisdiction of the Nuwara Eliya Municipal Council while the UDA is responsible for zoning and for the development of regulations, and has prepared a Recreation Master Plan for this wetland and its surrounds. Although a major dredging programme was carried out by the UDA some years ago, responsibilities related to its maintenance lie with the Municipal Council (IWMI, 2009).

Scientific research and monitoring:

No research facility exists at present.

Conservation education:

University students are taken to this site for courses on water quality testing.

Recreation and tourism:

Although there are many tourist hotels in the area surrounding the lake, it is not the sole attraction for visitors to the area. The municipal council leases out permits for boat operators to make boating available to visitors. The CTB in its Tourism Master Plan proposes to introduce recreational facilities at the Lake Gregory (IWMI, 2009).

Conservation measures taken:

The CEA produced a conservation management plan for this site in 1997. Additionally, a small patch of forest bordering the Lake was recently declared as a protected area under the DWC. In the Nuwara Eliya Urban Development Plan, unsuitable agricultural activities on slopes have been prohibited in order to reduce erosion and subsequent silting of the lake (IWMI, 2009).

Conservation measures proposed:

Major threats to Lake Gregory include the reclamation of the Lake area for commercial agricultural expansion, expansion of human settlements and the subsequent increase in pollution. The rapid and uncontrolled increase in invasive plant species (e.g. Salvinia molesta, Pistia stratiotes, Eichhornia crassipes) is also threatening the beauty and ecological value of the lake. The unregulated application of agrochemical and organic manure has already changed the water quality of the lake. Accumulation of heavy metal in the Lake is inevitable unless regular flushing is carried out. Need urgent actions to mitigate existing threats (IWMI, 2009).

2.2. pH measurement

pH represents the effective concentration (activity) of hydrogen ions (H^+) in water. This concentration could be expressed in the same kind of units as other dissolved species, but H^+ concentrations are much smaller than other species in most waters. The activity of hydrogen ions can be expressed most conveniently in logarithmic units. pH is defined as the negative logarithm of the activity of H^+ ions:

$$pH = -\log [H^+]$$

Where $[H^+]$ is the concentration of H^+ ions in moles per liter (a mole is a unit of measurement, equal to 6.022×10^{23} atoms). Because H^+ ions associate with water molecules to form

hydronium (H_3O^+) ions, pH is often expressed in terms of the concentration of hydronium ions. In pure water at 22° C (72° F), H_3O^+ and hydroxyl (OH^-) ions exist in equal quantities; the concentration of each is 1.0×10^{-7} moles per liter (mol/L). Therefore, pH of pure water = $-\log (1.0 \times 10^{-7}) = -(-7.00) = 7.00$. Because pH is defined as $-\log [H^+]$, pH decreases as $[H^+]$ increases (which will happen if acid is added to the water). Since pH is a log scale based on 10, the pH changes by 1 for every power of 10 change in $[H^+]$. A solution of pH 3 has an H^+ concentration 10 times that of a solution of pH 4. The pH scale ranges from 0 to 14. However, pH values less than 0 and greater than 14 have been observed in very rare concentrated solutions (Murphy, 2009).

Measurement of pH

The pH of water can be measured with a pH meter, which is an electronic device with a probe. The probe contains an acidic aqueous solution enclosed by a glass membrane that allows migration of H^+ ions. The electrical potential of the glass electrode depends on the difference in $[H^+]$ between the reference solution and the solution into which the electrode is dipped. pH can also be measured with pH paper or by adding a reagent (indicator solution) to the water sample and recording the color change (Murphy, 2009).

Factors Affecting pH:

The concentration of *carbon dioxide* in the water

Carbon dioxide (CO_2) enters a water body from a variety of sources, including the atmosphere, runoff from land, release from bacteria in the water, and respiration by aquatic organisms. This dissolved CO_2 forms a weak acid. Natural, unpolluted rainwater can be as acidic as pH 5.6, because it absorbs CO_2 as it falls through the air. Because plants take in CO_2 during the day and release it during the night, pH levels in water can change from daytime to night (Murphy, 2009).

Geology and Soils of the watershed

Acidic and alkaline compounds can be released into water from different types of rock and soil. When calcite ($CaCO_3$) is present, carbonates (HCO_3, CO_3^{-2}) can be released, increasing the alkalinity of the water, which raises the pH. When sulfide minerals, such as pyrite, or "fool's gold," (FeS_2) are present, water and oxygen interact with the minerals to form sulfuric

acid (H_2SO_4). This can significantly drop the pH of the water. Drainage water from forests and marshes is often slightly acidic, due to the presence of organic acids produced by decaying vegetation (Murphy, 2009).

Drainage from Mine Sites

Mining for gold, silver, and other metals often involves the removal of sulfide minerals buried in the ground. When water flows over or through sulfidic waste rock or tailings exposed at a mine site, this water can become acidic from the formation of sulfuric acid. In the absence of buffering material, such as calcareous rocks, streams that receive drainage from mine sites can have low pH levels (Murphy, 2009).

Air Pollution

Air pollution from car exhaust and power plant emissions increases the concentrations of nitrogen oxides (NO_2, NO_3) and sulfur dioxide (SO_2) in the air. These pollutants can travel far from their place of origin, and react in the atmosphere to form nitric acid (HNO_3) and sulfuric acid (H_2SO_4). These acids can affect the pH of streams by combining with moisture in the air and falling to the earth as acid rain or snow (Murphy, 2009).

Water Quality Standards and Other Criteria regarding pH

The U.S. Environmental Protection Agency (U.S. EPA) sets a secondary standard for pH levels in drinking water: the water should be between pH 6.5 and 8.5 Secondary standards are unenforceable, but recommended, guidelines.

Colorado Department of Public Health and Environment Water Quality Control Division (CDPHE-WQCD) regulations (5 CCR 1002-31) state that waters to be used for domestic water supply should have pH values between 5.0 and 9.0 (Reg. 31 - Basic Standards and Methodologies for Surface Water) (Murphy, 2009).

CDPHE-WQCD regulations state that waters used for primary recreation (including such activities as swimming, rafting, and kayaking) should have pH values between 6.5 and 9.0.

CDPHE-WQCD regulations state that waters classified as "Class 1 Cold Water Aquatic Life" or "Class 1 Warm Water Aquatic Life" should have pH values between 6.5 and 9.0.

Very high (greater than 9.5) or very low (less than 4.5) pH values are unsuitable for most aquatic organisms. Young fish and immature stages of aquatic insects are extremely sensitive to pH levels below 5 and may die at these low pH values. High pH levels (9-14) can harm fish by denaturing cellular membranes (Murphy, 2009).

Changes in pH can also affect aquatic life indirectly by altering other aspects of water chemistry. Low pH levels accelerate the release of metals from rocks or sediments in the stream. These metals can affect a fish's metabolism and the fish's ability to take water in through the gills, and can kill fish fry (Murphy, 2009).

Other Information about pH

The term "pH" was originally derived from the French term "pouvoir hydrogène," in English, this means "hydrogen power." The term pH is always written with a lower case p and an upper case H (Murphy, 2009).

2.3 Dissolved Oxygen

While precipitate of manganese hydroxide is generated in the sample which absorbed any Oxygen to a brown manganese dioxide of uncertain composition. Dissolved oxygen (DO) is a significant factor in water quality, pollution control and several pretreatment processes. Biological decomposition of organic matter uses dissolved oxygen .DO levels significantly below to saturation value often occur in polluted surface waters. Since fish and most aquatic life are stifled by a lack of oxygen, dissolved oxygen determination is a principle measurement in pollution surveys. The rate of air supply to aerobic treatment processes is monitored by dissolved oxygen testing to maintain aerobic conditions and to prevent waste of power by excessive aeration .DO tests are used in the determination of biological oxygen demand of waste water. Here Small samples of waste water are mixed with dilution water and placed in BOD Bottle for dissolved oxygen testing at various intervals of time .oxygen is a significant factor in corrosion of piping systems. Removal of oxygen from boiler feed water is common practice, and the DO test is the means of control (Hammer and Hammer J. r, 1996).

for measuring Dissolved oxygen. The standard test uses a 300ml BOD bottle for containing the water sample. The chemical reagents used in the tests are manganese sulphate solution, alkali- iodide – azide reagent, conc. H_2SO_4 starch indicator and standardized sodium thiosulphate titrant (Hammer and Hammer J. r, 1996).

After adding the first two reagents to the BOD bottle, if no oxygen is present, the manganous (Mn^{++}) reacts only with the hydroxide ion to form a pure white precipitate of $Mn(OH)_2$. if oxygen is present ,some of the Mn^{+2} ion is oxidized to higher valance Mn^{+4} and precipitates as a brown colored oxide (MnO_2) (Hammer and Hammer J .r, 1996).

$Mn^{++} + 2OH^- = Mn(OH)_2$

$2Mn^{++} + 4OH^- + O_2 = 2MnO_2 + 2H_2O$ (Hammer and Hammer J. r, 1996).

After the bottle has been shaken and sufficient time has been allowed for all the oxygen to react, the chemical precipitates are allowed to settle leaving clear liquid in the upper portion. After adding conc.sulphuric acid, bottle is restoppered and mixed by inverting until the suspension is completely dissolved and the yellow color is uniform throughout the bottle. The reaction that takes place with the addition of acid is as follows.

$MnO_2 + 2I + 4H^+ + Mn^{++} = I_2 + 2H_2O$ (Hammer and HammerJ.r, 1996).

The manganic oxide is reduced to mangananous while and equalent amount of iodide ion is converted to free iodine .The quantity of iodine (I_2) is equivalent to the dissolved oxygen in the original sample.In the titration with 0.025 N thiosulfate solution, thiosulfate is the titrant and it is oxidized to tetrathionate while the free iodine is converted back to iodide ion as in the following reaction (Hammer and Hammer J. r, 1996).

$2S_2O_3^{2-} + I_2 = S_4O_6^{-} + 2I^-$

Since it is impossible to titrate accurately the yellow colored iodine solution to a colorless liquid, an end point indicator is needed. Soluble starch in the presence of free iodine produces a blue color. Therefore after titration to a pale straw color, a few drops of starch solution are added and titration is continued to the first disappearance of the blue color. If 0.025 N is used to measure the dissolved oxygen in a volume equal to 200 ml of original sample, 1 ml of titrant is equivalent to 1.0 mg/l DO (Hammer and Hammer J. r, 1996).

Membrane electrodes are available for measurement of dissolved oxygen without chemical treatment of a sample. A dissolved oxygen probe is composed of two solid metal electrodes

in a contact with a salt solution that is separated from the water sample by a selective membrane (Hammer and Hammer J. r, 1996).

The recessed end of the probe containing the metal electrodes is filled with potassium chloride solution and is covered with a polythene or Teflon membrane held in a place by a rubber O-ring. The probe also has a sensor for measuring temperature. The unit inserted in the bottle is designed specifically for measuring dissolved oxygen in non destructive BOD testing; the same bottle can be measured for oxygen depletion at various time intervals, restoppering between readings. The field probe as shown on the right is submersible and can be lowered into water for DO and temperature measurements in lakes and streams. The same unit attached to long rod can record dissolved oxygen in aeration tanks. Meters used with the probes have both temperature and dissolved oxygen scales and can be operated by line power in the laboratory or battery operated in the field. Membrane electrodes may be calibrated by reading against air saturated with moisture or a water sample of known DO concentration determined by the iodometric method (Hammer and Hammer J. r, 1996).

2.4. Biochemical oxygen demand

The Biochemical oxygen demand determination (BOD) is an empirical test in which standardized laboratories are used to determine the relative oxygen requirements of wastewaters, effluents, and polluted waters. The test has its widest application in measuring waste loadings to treatment plants and in evaluating the BOD removal efficiency of such treatment systems. The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulfides and ferrous ion. It also may the oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless their oxidation is prevented by an inhibitor. The seeding dilution procedures provide an estimate of the BOD at pH 6.5 to 7.5 (Clesceri et.al, 1986).

Many variations of oxygen demand measurements exit. These include using shorter and longer incubation periods, tests to determine rates of oxygen uptake and continuous oxygen-uptake measurements by respirometric techniques. Alternative seeding, dilution, and incubation conditions can be chosen to mimic receiving-water conditions, thereby providing an estimate of the environmental effects of waste water and effluents. Natural sources of organic matter include plant decay and leaf fall. However, plant growth and decay may be unnaturally accelerated when nutrients and sunlight are overly abundant due to human

influence. Urban runoff carries pet wastes from streets and sidewalks; nutrients from lawn fertilizers; leaves, grass clippings, and paper from residential areas, which increase oxygen demand. Oxygen consumed in the decomposition process robs other aquatic organisms of the oxygen they need to live. Organisms that are more tolerant of lower dissolved oxygen levels may replace a diversity of natural water systems contain bacteria, which need oxygen (aerobic) to survive. Most of them feed on dead algae and other dead organisms and are part of the decomposition cycle. Algae and other producers in the water take up inorganic nutrients (Clesceri et.al, 1986).

Consumers like fish and other aquatic animals eat some of the producers, and the nutrients move up the food chain. When these organisms die, bacteria decompose the organic compounds and release into the water inorganic nutrients such as nitrate, phosphate, calcium, and others. Some of these nutrients end up downstream or in sediments, but most of them recycle again and again. Most of the bacteria in the aquatic water column are aerobic. That means that they use oxygen to perform their metabolic activities of decomposition. Remember that we learned in other related exercises that under normal conditions, dissolved oxygen exists in very low concentrations. Natural levels of oxygen in aquatic systems are always somewhat depleted by normal levels of aerobic bacterial activity. In most cases, if dissolved oxygen concentrations drop below 5 parts per million (ppm), fish will be unable to live for very long. All clean water species such as trout or salmon will die well above this level and even low oxygen fish such as catfish and carp will be at risk below 5 ppm (Clesceri et.al, 1986).

When abnormally high levels of aerobic bacterial activity takes place, however, the level of dissolved oxygen can drop dramatically. Under what circumstances does this happen? Generally, this occurs when there is some sort of abnormal "pollution" introduced into the system. This can occur in the form of organic pollution for sources such as domestic sewage, septic tank leakage, and fertilizer runoff, or could be in the form of inorganics from domestic or industrial sources. Natural sources of organic compounds can also come into aquatic systems by means of floods, landslides, and erosion (Clesceri et.al, 1986).

One of the most important nutrients, which affected BOD in aquatic systems in the recent past is phosphate pollution from American households. It was discovered decades ago that the addition of phosphorous to soaps and detergents made them clean better. By the 1960's, millions of households and businesses were dumping tons and tons of phosphate down the drain. Eventually, much of this important nutrient made its way to the watercourses of

America. Because phosphorous is one of the most important limiting factors (necessary nutrients) in aquatic systems, there began numerous and widespread algal blooms. Algal blooms are dramatic population outbursts of growth in which often one or two species of algae suddenly find the conditions right for rapid growth. Because most unicellular algae reproduce asexually by rapid cell division, it doesn't take long for a species of algae to suddenly and literally turn the water green with billions and billions of new cells. Because the conditions necessary to these algal blooms are sometimes temporary or because the algae exceed the threshold level of some other limiting factor, the blooms are only temporary. They often last only a few days. What happens when the bloom is over? The algal cells don't have enough nutrients and most of them die. At this point, the aerobic bacteria become important and start to decompose the algae. Because there is so much food for them, they also experience a sort of bloom, and they literally suck the oxygen out of the water. When the oxygen is gone, the bacteria and most other aerobic creatures in the aquatic system start to die (Clesceri et.al, 1986).

During the 1960's and the 1970's, this phenomenon was widespread with dramatic fish kills and large segments of slow-moving rivers and lakes becoming almost abiotic (lifeless) because of high BOD caused by pollution. The procedures followed in this exercise involve the collection of water and the measurement of dissolved oxygen and pH at the time of the collection. The samples are placed in bottles full to the brim and sealed off by a lid. The sample bottles are covered completely with aluminum foil and placed in a dark place. This limits the photosynthesis, which could happen with captured algae. After five days, the bottles are uncorked and the dissolved oxygen is probed. The difference between the first and the last of the samples is called the BOD. A low number generally means little pollution and/or little aerobic activity. A high BOD means the opposite (Clesceri et.al, 1986).

2.5 .Chemical oxygen demand

The chemical oxygen demand (COD) is used as the measure of oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. For samples from a specific source, COD can be related empirically to BOD, organic carbon, or organic matter. The test is useful for monitoring and control after correlation has been established. The dichromate reflux method is preferred over procedures using other oxidants because of superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation. Oxidation of most organic compounds is 95 to 100% of the theoretical

value. Pyridine and related compounds resist oxidation and volatile organic compounds are oxidized only to the extent that they remain in contact with the oxidant. Ammonia, present either in waste liberated from nitrogen containing matter, is not oxidized in the absence of significant concentration of free chloride ions. The open reflux method is suitable for wide range of waste water where a large sample size is preferred. The closed reflux methods are more economical in the use of metallic salt reagents, but require homogenization of samples containing suspended solids to obtain reproducible results. Ampules and culture tubes with premeasured reagents are available commercially. Follow instructions furnished by the manufacturer (Clesceri et.al, 1986).

2.5.1. Interference and limitations

Volatile straight-chain aliphatic compounds are not oxidized to any appreciable extent. This failure occurs partly because volatile organics are present in the vapor space do not come in contact with the oxidizing liquid. Straight chain aliphatic compounds are oxidized more effectively when silver sulphate is added as a catalyst. However silver sulphate reacts with chloride, bromide, and iodide to produce precipitates that are oxidized only partially. The difficulties caused by the presence of halides can be overcome largely, though not completely, by complexing with mercuric sulphate before the refluxing procedure (Clesceri et.al, 1986).

2.5.2. Sampling and storage

Preferably collect samples in glass bottles. Test unstable samples without delay. If delay before analysis is unavoidable, preserve sample by acidification to pH<2 using con H_2SO_4. Blend samples containing settle able solids with a homogenizer to permit representative sampling. Make preliminary dilutions for wastes containing a high COD to reduce the error inherent in measuring small sample volumes (Clesceri et.al, 1986).

2.6. Solids

The terms "solids", "suspended" and "dissolved" as used herein, replace the terms "residue, "nonfiltrable" and "filterable" of editions previous to the 16th. Solids refer to matter suspended or dissolved in water or waste water. Solids may affect water or effluent quality adversely in a number of ways .Waters with high dissolved solids generally are inferior palatability and may induce an unfavorable physiological reaction in the transient consumer. For these reasons, a limit of 500 mg dissolved solids/L is desirable for drinking waters.

Highly mineralized waters are also unsuitable for many industrial applications. Waters high in suspended solids may be esthetically unsatisfactory for such purposes as bathing. Solids analyses are important in the control of biological and physical wastewater treatment processes and for assessing compliance with regulatory agency waste water effluent limitation (Clesceri et.al, 1986).

2.6.1. Total Solids

The term "total solids" refers to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity. Total solids (also referred to as total residue) are the term used for material left in a container after evaporation and drying of a water sample. Total Solids includes both total suspended solids, the portion of total solids retained by a filter (Murphy, 2007).

Total solids can be measured by evaporating a water sample in a weighed dish, and then drying the residue in an oven at 103 to 105° C. The increase in weight of the dish represents the total solids. Instead of total solids, laboratories often measure total suspended solids and/or total dissolved solids (Murphy, 2007).

2.6.2. Total Suspended Solids (TSS)

Total Suspended Solids (TSS) is solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO) (Murphy, 2007).

The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to

disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes.

High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with storm water. In the water, the pollutants may be released from the sediment or travel farther downstream

High TSS can cause problems for industrial use, because the solids may clog or scour pipes and machinery (Murphy, 2007).

2.6.2.1. Measurement of Total Suspended Solids

To measure TSS, the water sample is filtered through a pre-weighed filter. The residue retained on the filter is dried in an oven at 103 to 105° C until the weight of the filter no longer changes. The increase in weight of the filter represents the total suspended solids.TSS can also be measured by analyzing for total solids (Murphy, 2007).

2.6.2.2 Factors Affecting Total Suspended Solids

The flow rate of the water body is a primary factor in TSS concentrations. Fast running water can carry more particles and larger-sized sediment. Heavy rains can pick up sand, silt, clay, and organic particles (such as leaves, soil, and tire particles) from the land and carry it to surface water. A change in flow rate can also affect TSS; if the speed or direction of the water current increases (Murphy, 2007).

2.6.2.2.1 Soil Erosion

Soil erosion is caused by disturbance of a land surface. Soil erosion can be caused by Building and Road Construction, Forest Fires, Logging, and Mining. The eroded soil particles can be carried by storm water to surface water (Murphy, 2007).

2.6.2.2.2. Urban Runoff

During storm events, soil particles and debris from streets and industrial, commercial, and residential areas can be washed into streams. Because of the large amount of pavement in urban areas, infiltration is decreased, velocity increases, and natural settling areas have been removed (Murphy, 2007).

2.6.2.2.4. Wastewater and Septic System Effluent

The effluent from Wastewater Treatment Plants can add suspended solids to a stream. The wastewater from our houses contains food residue, human waste, and other solid material that we put down our drains. Most of the solids are removed from the water at the WWTP before being discharged to the stream, but treatment can't eliminate everything (Murphy, 2007).

2.6.2.2.5. Decaying Plants and Animals

As plants and animals decay, suspended organic particles are released and can contribute to the TSS concentration.

2.6.2.2.6. Bottom-Feeding Fish

Bottom-feeding fish (such as carp) can stir up sediments as they remove vegetation. These sediments can contribute to TSS.

2.6.2.2.7. Water Quality Standards Regarding Total Suspended Solids

Neither the U.S. Environmental Protection Agency (EPA) nor the State of Colorado provides a standard for TSS in drinking water. Colorado Department of Public Health and Environment Water Quality Control Division (CDPHE-WQCD) regulations (5 CCR 1002-31) state that suspended solid levels will be controlled by Effluent Limitation Regulations, Basic Standards, and Best Management Practices (BMPs) (Murphy, 2007).

2.6.3. Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) are solids in water that can pass through a filter (usually with a pore size of 0.45 micrometers). TDS is a measure of the amount of material dissolved in water. This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells (Mitchell and Stapp, 1992). However, if TDS concentrations are too high or too low, the growth of many aquatic lives can be limited, and death may occur. Similar to TSS, high concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature (Murphy, 2007).

TDS is used to estimate the quality of drinking water, because it represents the amount of ions in the water. Water with high TDS often has a bad taste and/or high water hardness, and could result in a laxative effect.

2.6.3.1. Measurement of Total Dissolved Solids

To measure TDS, the water sample is filtered, and then the filtrate (the water that passes through the filter) is evaporated in a pre-weighed dish and dried in an oven at 180° C, until the weight of the dish no longer changes. The increase in weight of the dish represents the total dissolved solids, and is reported in milligrams per liter (mg/l). The TDS concentration of a water sample can be estimated from specific conductance if a linear correlation between the two parameters is first established. Depending on the chemistry of the water, TDS (in mg/l) can be estimated by multiplying specific conductance (in micromhos/cm) by a factor between 0.55 and 0.75 (Murphy, 2007).

2.6.3.2. Factors Affecting Total Dissolved Solids

2.6.3.3. Geology and Soil in the Watershed

Some rock and soil release ions very easily when water flows over them; for example, if acidic water flows over rocks containing calcite ($CaCO_3$), such as calcareous shales, calcium (Ca^{2+}) and carbonate (CO_3^{2-}) ions will dissolve into the water. Therefore, TDS will increase. However, some rocks, such as quartz-rich granite, are very resistant to dissolution, and don't dissolve easily when water flows over them. TDS of waters draining areas where the geology only consists of granite or other resistant rocks will below (unless other factors are involved).

During storm events, pollutants such as salts from streets, fertilizers from lawns, and other material can be washed into streams and rivers. Because of the large amount of pavement in urban areas, natural settling areas have been removed, and dissolved solids are carried through storm drains to creeks and rivers.

Fertilizer can dissolve in storm water and be carried to surface water during storms, and contribute to TDS (Murphy, 2007).

2.6.3.4. Wastewater and Septic System Effluent

The effluent from Wastewater Treatment Plants (WWTPs) adds dissolved solids to a stream. The wastewater from our houses contains both suspended and dissolved solids that we put down our drain. Most of the suspended solids are removed from the water at the WWTP

before being discharged to the stream, but WWTPs only remove some of the TDS. Important components of the TDS load from WWTPs include phosphorus, nitrogen (Murphy, 2007).

2.6.3.5. Soil Erosion

Soil erosion is caused by disturbance of a land surface. Soil erosion can be caused by Building and Road Construction, Forest Fires, Logging, and Mining. The eroded soil particles may contain soluble components that can dissolve and be carried by storm water to surface water. This will increase the TDS of the water body (Murphy, 2007).

2.6.3.6. Decaying Plants and Animals

As plants and animals decay, dissolved organic particles are released and can contribute to the TDS concentration (Murphy, 2007).

2.6.3.7. Water Quality Standards Regarding Total Dissolved Solids

The U.S. Environmental Protection Agency (U.S. EPA) sets a secondary standard of 500 mg/l TDS in drinking water. Secondary standards are unenforceable, but recommended, guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water. High TDS concentrations can produce laxative effects and can give an unpleasant mineral taste to (Murphy, 2007).

2.7. Nitrate/Nitrite

Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow, and to reproduce. Nitrogen is very common and found in many forms in the environment. Inorganic forms include nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and nitrogen gas (N_2). Organic nitrogen is found in the cells of all living things and is a component of proteins, peptides, and amino acids. Nitrogen is most abundant in Earth's environment as N_2 gas, which makes up about 78 percent of the air we breathe (Murphy, 2007).

Common Forms of Nitrogen in Water

Nitrate and Nitrite

Nitrate (NO_3) is highly soluble (dissolves easily) in water and is stable over a wide range of environmental conditions. It is easily transported in streams and groundwater. Nitrates feed plankton (microscopic plants and animals that live in water), aquatic plants, and algae, which are then eaten by fish. **Nitrite** (NO_2) is relatively short-lived in water because it is quickly converted to nitrate by bacteria (Murphy, 2007).

Excessive concentrations of nitrate and/or nitrite can be harmful to humans and wildlife. Nitrate is of most concern for humans. Nitrate is broken down in our intestines to become nitrite. Nitrite reacts with hemoglobin in human blood to produce methemoglobin, which limits the ability of red blood cells to carry oxygen. This condition is called methemoglobinemia or "blue baby" syndrome (because the nose and tips of ears can appear blue from lack of oxygen). It is especially serious for infants, because they lack the enzyme necessary to correct this condition. Wells contaminated by sewage or agricultural runoff are a major concern in some areas, because of the possibility of water high in nitrite/nitrates and the subsequent increased risk of blue baby disease. High nitrate and nitrite levels can also cause methemoglobinemia in livestock and other animals (Murphy, 2007).

High concentrations of nitrate and/or nitrite can produce "brown blood disease" in fish. Nitrite enters the bloodstream through the gills and turns the blood a chocolate-brown color. As in humans, nitrite reacts with hemoglobin to form methemoglobin. Brown blood cannot carry sufficient amounts of oxygen, and affected fish can suffocate despite adequate oxygen concentration in the water. This accounts for the gasping behavior often observed in fish with brown blood disease, even when oxygen levels are relatively high (Mississippi State University, 1998).

If excessive amounts of phosphorus and nitrates are added to the water, algae and aquatic plants can be produced in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This process is called eutrophication. Dissolved oxygen concentrations can drop too low for fish to breathe, leading to fish kills (Murphy, 2007).

Ammonia

Ammonia, another inorganic form of nitrogen, is the least stable form of nitrogen in water. Ammonia is easily transformed to nitrate in waters that contain oxygen and can be transformed to nitrogen gas in waters that are low in oxygen. Ammonia is found in water in two forms - the ammonium ion (NH_4^+), and dissolved, unionized (no electrical charge) ammonia gas (NH_3). Total ammonia is the sum of ammonium and unionized ammonia. The dominant form depends on the pH and temperature of the water. The reaction between the two forms is shown by this equation:

$NH_3 + H_2O \ll NH_4^+ + OH^-$

The form of ammonia changes easily when pH changes. As pH increases, H^+ concentration decreases, and OH^- concentrations increase. This makes the equation above move left, increasing the amount of aqueous NH_3. When the pH is below 8.75, NH_4^+ predominates. At pH 9.24, about half of aqueous NH_3 is transformed to NH_4^+. Above pH 9.75, NH_3 predominates (Hem, 1985). Unionized ammonia (NH_3) is much more toxic to aquatic organisms than the ammonium ion (NH_4^+) (Murphy, 2007).

Toxic concentrations of ammonia in humans may cause loss of equilibrium, convulsions, coma, and death. Ammonia concentrations can affect hatching and growth rates of fish; changes in tissues of gills, liver, and kidneys may occur during structural development.

Measurement of Nitrogen Forms

There are many ways of measuring nitrogen forms. Total nitrogen can be determined by adding chemicals to convert all of the nitrogen forms in a sample to nitrate, and then measuring nitrate concentration. Nitrate and nitrite can be measured together or separately. Nitrate and nitrite are most often measured using a colorimetric method, which means the color of treated sample reflects the concentration of the parameter. A chemical is added to the water sample and the darker the color of the sample, the more nitrate and/or nitrite present. This test can be done visually, comparing the treated sample to a set of reference colors. However, it is more accurate to use an electronic colorimeter, which uses a light source and a photodetector to find the concentration based on how much light is absorbed by the sample. If nitrate and nitrite are reported separately, concentrations are given as nitrite as nitrogen (NO_2-

N) and nitrate as nitrogen (NO_3-N). If they are reported together, concentrations are given as nitrite plus nitrate as nitrogen (NO_2 + NO_3 -N). Nitrate and nitrite can be measured in the field using a portable colorimeter, such as a Hach© kit (Murphy, 2007).

Total ammonia (ammonium ion (NH_4^+) plus unionized ammonia gas (NH_3)) is often measured in a laboratory by titration. Ammonia and organic nitrogen compounds are separated by distillation, and then an acid (the titrant) is added to a volume of the ammonia portion. The volume of acid required to change the color of the sample reflects the ammonia concentration of the sample. The more acid needed the more ammonia in the sample. Ammonia is the least stable form of nitrogen, so it can be difficult to measure accurately. The proportion of unionized ammonia can be calculated, using formulas that contain factors for pH and temperature (Murphy, 2007).

Factors Affecting Nitrate+Nitrite Concentrations

Wastewater and Septic System Effluent

Human waste is significant contributor of nitrogen to water. Ammonia, nitrite, and nitrate are decomposition products from urea and protein, which are in human waste. Ammonia is an ingredient in many household cleaning products and is sometimes used to remove carbonate from hard water. Therefore, these nitrogen species go down the drains in our houses and businesses, and can enter streams from wastewater treatment plant (WWTPs) effluent, illegal sanitary sewer connections, and poorly functioning septic systems (Murphy, 2007).

Nutrients in sewage effluent have been among the primary targets of pollution-control legislation, beginning with the Clean Water Act in 1972. Organic forms of nitrogen have largely been controlled by upgrading treatment plants, and advanced treatment processes have been used to decrease ammonia discharge. However, these processes result in an increase in nitrate discharge, so the total nitrogen discharge does not change. Therefore, concerns about fish toxicity have decreased, but the potential for eutrophication has not changed (Mueller and Helsel, 1999).

Fertilizer Runoff

Fertilizer is a major influence on nitrogen concentrations in the environment. Commercial nitrogen fertilizers are applied either as ammonia or nitrate, but ammonia is rapidly converted

to nitrate in the soil. Animal manure is also used as a nitrogen fertilizer in some areas. Organic nitrogen and urea in the manure are converted to ammonia and, ultimately, to nitrate in the soil (Murphy, 2007).

Animal Waste

A significant amount of nitrogen is released in the wastes produced by animals. This can be a serious problem in waters near cattle feedlots, hog farms, dairies, and barnyards. Ducks and geese contribute a heavy load of nitrogen if they are present in large numbers. Excretions of aquatic organisms are very rich in ammonia, a decay product of animal proteins, but the amount of nitrogen they add to waters is usually small. Through the process of nitrification, ammonia is oxidized to nitrite and then to nitrate in water (Murphy, 2007).

Fossil Fuels

The burning of fossil fuels such as gasoline and coal in cars, trucks, and power plants produces many by-products. Coal and petroleum generally contain about 1 percent nitrogen (Hem, 1985). Part of the nitrogen is converted to the gas nitric oxide (NO) during the burning of the fuel. Nitric oxide is converted by sunlight and photochemical processes in air to nitrogen oxide gases (NO and NO_2, which are commonly referred together as NO_x), which are a major component of smog. Nitrogen oxide gases are a major contributor to acid rain.

Industrial Discharge

Many industries use nitrogen during processing. Nitrite is sometimes used as a corrosion inhibitor in industrial process water. Ammonia is used in the production of nitric acid, urea and other nitrogen compounds, and in the production of ice and in refrigerating plants. Ammonia is also used in cleaning supplies and to remove carbonate from hard water. Water from industries is usually discharged to a wastewater treatment plant (WWTP), and may end up in a downstream water body if not completely removed in the WWTP (Murphy, 2007).

2.8. Phosphates

Phosphorus is a nutrient required by all organisms for the basic processes of life. Phosphorus is a natural element found in rocks, soils and organic material. Phosphorus clings tightly to soil particles and is used by plants, so its concentrations in clean waters are generally very

low. However, phosphorus is used extensively in fertilizer and other chemicals, so it can be found in higher concentrations in areas of human activity. Many seemingly harmless activities added together can cause phosphorus overloads (Murphy, 2007).

Phosphorus exists in water in either a particulate phase or a dissolved phase. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus adsorbed to particulates, and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus. Phosphorus in natural waters is usually found in the form of phosphates (PO_4^{-3}). Phosphates can be in inorganic form (including orthophosphates and polyphosphates), or organic form (organically-bound phosphates) (Murphy, 2007).

Organic phosphate is phosphate that is bound to plant or animal tissue. Organic phosphates are formed primarily by biological processes. They are contributed to sewage by body waste and food residues, and also may be formed from orthophosphates in biological treatment processes or by receiving water biota. Organic phosphates may occur as a result of the breakdown of organic pesticides which contain phosphates. They may exist in solution, as loose fragments, or in the bodies of aquatic organisms (Murphy, 2007).

Inorganic phosphate is phosphate that is not associated with organic material. Types of inorganic phosphate include orthophosphate and polyphosphates. **Orthophosphate** is sometimes referred to as "reactive phosphorus." Orthophosphate is the most stable kind of phosphate, and is the form used by plants. Orthophosphate is produced by natural processes and is found in sewage. **Polyphosphates** (also known as metaphosphates or condensed phosphates) are strong complexing agents for some metal ions. Polyphosphates are used for treating boiler waters and in detergents. In water, polyphosphates are unstable and will eventually convert to orthophosphate (Murphy, 2007).

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate.

In freshwater lakes and rivers, phosphorus is often found to be the growth-limiting nutrient, because it occurs in the least amount relative to the needs of plants. If excessive amounts of phosphorus and nitrogen are added to the water, algae and aquatic plants can be produced in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This

process is called eutrophication. Dissolved oxygen concentrations can drop too low for fish to breathe, leading to fish kills (Murphy, 2007).

Measurement of Phosphorus

There are several forms of phosphorus which can be measured. Total phosphorus (TP) is a measure of all the forms of phosphorus, dissolved or particulate, those are found in a sample. Soluble reactive phosphorus (SRP) is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells.

Both phosphorus and orthophosphate are often measured using a colorimetric method, which means the color of treated sample reflects the concentration of the parameter. If total phosphorus is being measured, all forms of phosphorus are converted to dissolved orthophosphate with acid, persulfate, and heat. A chemical is then added to the water sample. The darker the color of the sample becomes, the more phosphorus present. This test can be done visually, comparing the treated sample to a set of reference colors. However, it is more accurate to use an electronic colorimeter, which uses a light source and a photodetector to find the concentration based on how much light is absorbed by the sample (Murphy, 2007).

2.9. Statistical evaluation of data

Here I have used one way ANOVA to interpret my results. A One-Way Analysis of Variance is a way to test the equality of three or more means at one time by using variances.

Assumptions

- The populations from which the samples were obtained must be normally or approximately normally distributed.
- The samples must be independent.
- The variances of the populations must be equal (John, 2009).

Hypotheses

- The null hypothesis will be that all population means are equal; the alternative hypothesis is that at least one mean is different (John, 2009).

P- Value

P value is associated with a test statistic. It is "the probability, if the test statistic really were distributed as it would be under the null hypothesis, of observing a test statistic [as extreme as, or more extreme than] the one actually observed."

The smaller the P value, the more strongly the test rejects the null hypothesis, that is, the hypothesis being tested.

A p-value of .05 or less rejects the null hypothesis "at the 5% level" that is, the statistical assumptions used imply that only 5% of the time would the supposed statistical process produce a finding this extreme if the null hypothesis were true (Economics, 2002).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1. Sampling procedure

Water samples were taken to the sample bottles after reaching to the water body. Fifteen Water samples from fifteen places in one time were taken into DO bottles and they were fixed at the sample points. Another fifteen water samples were also collected from same points in to drinking water bottles for other parameters. Like this same number of samples were collected from same places in five times. All sample bottles were taken to the lab within a period of less than 3 hours. Then other parameters were started to test immediately soon after bringing to the lab. The selected sampling points are mentioned in the following map (Clesceri et.al, 1986).

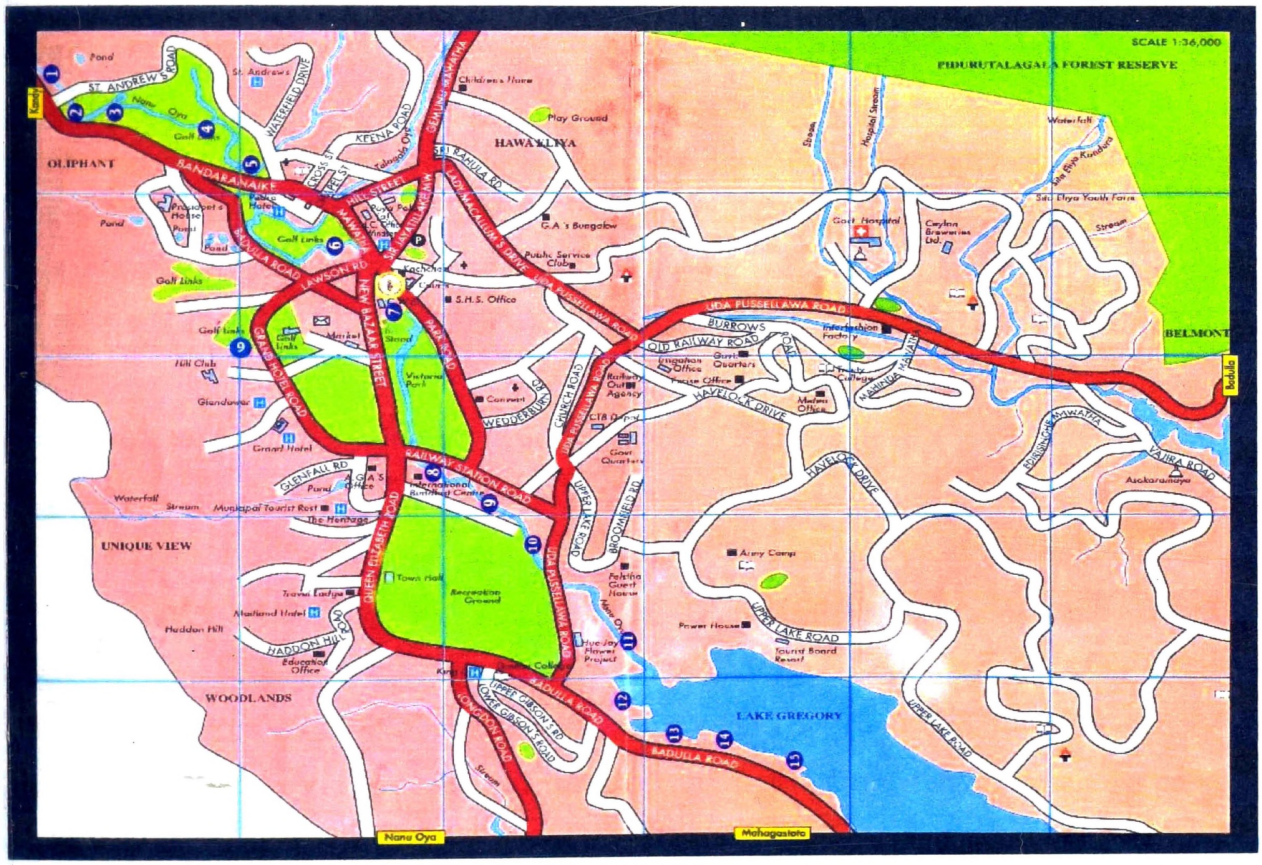

Figure 3.1.Sampling points of Lake Gregory and Thalagala Oya

3.2. Material and Methodology

Relevant experiments were done according to the standard methods.

3.2.1. pH (Standard Electrode Method)

The electrode was rinsed well in deionized water. The pH meter electrode was placed into the sample. The temperature and pH were read and recorded. The electrode was rinsed well with deionized water. pH of 4.0 and 7.0 buffer were measured periodically to ensure that the meter is not drifting off calibration. The pH meter electrode was placed into the samples and the pH was read (Silva, 1996).

3.2.2. Dissolved Oxygen. (Winkler's Method)

Preparation of reagents

480g of manganous sulphate was dissolved in 1000 ml dis. Water. Then500 g of NaOH and 135 g of NaI were dissolved in 1000 ml dis. Water and 10 g of sodium azide dissolved in 40 ml dis Water were added. Next an emulsion of 10 g soluble starch and 0.2 g salicylic acid were prepared in 1000 ml dis Water and boiled for few minutes and it was let to settle. Then 3.1025 g of sodium thiosulphate was dissolved in 1000 ml dis. Water and it was preserved by 5 ml chloroform (0.0125 N solution) (Clesceri et.al, 1986).

Procedure

Sodium thiosulphate solution was standardized. Then 2 ml of manganous sulphate solution was added immediately to the sample collected in BOD incubation bottle. After that2 ml of alkaline potassium iodide (reagent 2) solution was added. Next air bubbles were excluded and stoppered by inverting the bottle several times. Then it was shaken again when the precipitate was settled. Next Sample bottle was transferred to the laboratory fully dipped in a water bath. Then 2 ml of con H_2SO_4 was added at laboratory and mixed well by inverting the bottle.100 ml of the bottle content was transferred into 250 ml titration flask and Titrated with 0.0125 N sodium thiosulphate solutions to pale straw color.1-2 ml starch solution was added and the titration was continued to the first disappearance of the blue color (Clesceri et.al, 1986).

Calculation

Dissolved Oxygen (mg/l) = (ml of 0.0125 N sodium thiosulphate Used for titration Used for titration)*3.188

Where:

3.188=Dilution factor (Clesceri et.al, 1986).

3.2.3 .Biological Oxygen Demand

Preparation of reagents

For dilution of water

0.85 g of potassium dihydrogen phosphate, 2.175 g of potassium hydrogen phosphate, 3.34 g of sodium hydrogen phosphate and 0.17 g of ammonium chloride were in dissolved in 100 ml dis. Water.2.25 g of magnesium sulphate was dissolved in 100 ml of dis water.2.75 g of calcium chloride was dissolved in 100 ml dis water. 0.025 g of ferric chloride was dissolved in 100 ml dis. water. All the reagents given for DO were made (Clesceri et.al, 1986).

Procedure

Preparation of dilution water

1 ml of each reagents 1, 2, 3 & 4 was added to dis water and diluted to 1000 ml. Temperature was brought to 25°C. Saturated with DO by aerating .It was Stored in aluminum wrapped bottle (Clesceri et.al, 1986).

Determination of DO

Sample was saturated the sample by aerating. Bottles were filled up to the neck to displace all air. Two bottles filled with sample covered with aluminium foil were incubated at 25^0C dipped in a water bath for three days. The procedure for DO was followed using the original sample. After 3 days, the procedure for Do was followed using the two incubated samples to determine final DO (Clesceri et.al, 1986).

Calculation

Biological Oxygen Demand (mg/L) = V1 – V2

Where:

V1=Initial DO (mg/L)

V2=Final DO (mg/L)

(CLESCERI et.al, 1986)

3.2.4 Chemical Oxygen Demand

Preparation of reagents

12.259 g of potassium dichromate (dried at 103oC for 2 hours) was dissolved in dis water and diluted to 1liter. Well ground 5.04 g silver sulphate was added in 500 ml con H_2SO_4. (kept two days to dissolve)98 g of ferrous ammonium sulphate was dissolved in dis water,20 ml of con H_2SO_4 was added , cooled and diluted to 1 liter(0.25N).1.48 g of 1-10(ortho)phenanthroline monohydrate was dissolved with 0.70 g of ferrous sulphate in 100 ml dis water (Clesceri et.al, 1986).

Procedure

50 ml of the sample was transferred into a reflux flask with new glass beads and 1g of $HgSO_4$.5 ml of con H_2SO_4 was added very slowly while mixing to dissolve mercuric sulphate. (Cooled while mixing).Reflux flask was placed in an ice bath and 25 ml of 0.25N $K_2Cr_2O_7$ (reagent 1) was added slowly. Flask was connected to the condenser and water cooler was turned on.70 ml of Sulphuric/silver sulphate solution (reagent 2) was added through the opened end of the condenser and mixed well. Open end of the condenser was covered and started heating and refluxed for 2hours.The flask was allowed to cool and washed down the condenser with about 25 ml of dis. water. The solution was transferred to a 500 ml Erlenmeyer flask, the solution was diluted to about 300 ml with dis. Water and allowed to cool.8 to 10 drops of ferroin indicator (reagent 4) were added and titrated with 0.25N ferrous ammonium sulphate (reagent 3) solution. A blank determination was run using dis. water in place of the sample simultaneously (Clesceri et.al, 1986).

Calculation

$$\text{Chemical Oxygen Demand (mg/l)} = \frac{(V1-V2)\ N*8000}{V3}$$

Where:

V1= Volume titrant required for titration of blank

V2= Volume of titrant required for titration of sample

V3= Volume of original sample

N= Normality of titrant (Clesceri et.al, 1986).

3.2.5. Nitrite.

pH of the sample was adjusted to 8 with HCl (1:3 HCl to water).The sample was filtered through 0.45μm pore size filter paper.50 ml of the filtered sample was placed in a volumetric flask.2 ml of the buffer was added, mixed well and color was allowed to develop at least for 15 minutes. The absorbance was read at 543 nm (Clesceri et.al, 1986).

3.2.6. Nitrate.

Preparation of reduction column.

Cadmium granules were washed with dilute HCL and rinsed with distilled water.25g acid washed cadmium granules were washed in 100 ml copper sulfate solution (reagent 3) for 5 minutes till blue color was partially faded and then it was decant and repeated with fresh copper sulfate solution Until a brown colloidal precipitate was formed. The copper cadmium colloid was washed with dis water to remove all the precipitated copper. The color of the granules was black. A glass column was used with a stopcock and 25ml burette. A glass wool plug was inserted to the bottom of the column filled with dis water. Sufficient copper-cadmium granules were added to produce a column 18.5cm long (the water level was maintained above the granules) The column was washed with 200ml dilute NH_4Cl/EDTA solution (reagent 2).The column was activated by passing 100ml of mixture of 1mg/; nitrate standard and 75 ml of diluteNH_4Cl/EDTA solution (Merck and Darmstadt, 2004).

Determination of nitrate

pH of the sample was adjusted between .5 and 9 with con. HCL.75 ml of NH_4Cl/EDTA (reagentl) was added to 25 ml of the sample and mixed well. Sample was poured in to the column and eluent was collected at a rate of 7-10 ml/min. The first 25 ml was discarded and the rest of the sample was collected in original ample flask.2 ml of the buffer developing reagent was added immediately to 50 ml of sample passed through the column. Color was allowed to develop for 15 minutes. Absorbance was measured at 543 nm within two hours. Nitrate concentration was determined (Merck and Darmstadt, 2004).

Calibration

A series of standards as required was prepared by diluting the working solution. The reduction of standards was carried out as described for the samples (see the procedure).A

calibration curve; absorbance versus the concentration of nitrate of the standards was plotted. for 1hr in a muffle furnace (Merck and Darmstadt, 2004).

3.2.7 Phosphate

50 ml of the filtered sample was pipette into a125 ml Erlenmeyer flask. A drop of phenolphthalein solution was added.5N H_2SO_4 solution was added drop wise to just discharge the color developed.10 ml of combined reagent was added and mixed well. Absorbance was measured at 880 nm. Phosphate concentration was determined from the calibration curve (Clesceri et.al, 1986).

Calibration

A series of slandered was prepared by diluting working solution. The standards were treated as given in the procedure. The calibration curve, between phosphorus content and absorbance was plotted (Clesceri et.al, 1986).

3.2.8. Total solids

Preparation of evaporating dishes

Clean evaporating dishes were heated at 103-105°C for 1hr in an oven .Those were cooled in desiccators, weighted and stirred in desiccators until ready for use (Clesceri et.al, 1986).

Sample analysis

The sample was stirred to homogenous, placed 25-50g in a prepared evaporating dish and weighed .It was evaporated to dryness on a water bath ,dried at 103-105°C for 1hr,cooled to balance the temperature in an individual desiccators containing fresh desiccant and weighed (Clesceri et.al, 1986).

3.2.9. Total Suspended Solids

Preparation of glass fiber filter

The glass fiber filter was placed on the membrane filter apparatus with the wrinkled surface upward. While vacuum was applied, the disc was washed with three successive 20 ml volumes of dis water .After water had passed through, all the traces of water was removed by continuous application of vacuum. The filter was removed from membrane filter apparatus and dried in oven at 103-105°C for 1 hour. The filter was cooled in desiccators and weighed. Drying cycle was repeated until a constant weight was obtained. Same procedure was repeated for other fiber filters (Clesceri et.al, 1986).

Selection of sample volume

100 ml of the sample was taken for filtration. Filtering apparatus was assembled. Prepared glass fiber filter was placed on the filter support and was in suction(filter was wet with a small amount of dis water first)The sample was shaken vigorously and predetermined sample volume was taken into a graduated cylinder then it was transferred quantitatively to the filter. The graduated cylinder, the filter containing non filterable residue and the filter funnel wall were washed with three volume portion of dis water allowing complete drainage between washings. The filter was removed from the filter support and dried at least for twelve hours at 103-105°C.It was cooled in a desiccator and weighed. It was repeated until a constant weighed was obtained (Clesceri et.al, 1986).

$$\text{Total suspended solids (mg/l)} = \frac{(A-B)*100}{V}$$

Where:

A= Weight of filter + residue (mg)

B= Weight of filter (mg)

V= Volume of the sample filtered (ml)

(Clesceri et.al, 1986)

3.2.10. Total Dissolved Solids

The amount of the suspended solid was subtracted from the amount of total solids (Clesceri et.al, 1986).

Calculation

Dissolved solids (mg/l) =Total solids – Total suspended solids (Clesceri et.al, 1986)

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Results of the collected water samples

Table 4.1. Results of first sample set

Following two tables show the results of first fifteen samples.

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-} Concentration(ppb)	NO_3^- Concentration(ppm)
2.503	7.9796	6.81	18.071	1.66
1.981	6.3154	7.57	9.804	1.793
1.837	5.8564	8.52	151.1	2.583
1.493	4.7597	11.35	124.38	0.407
1.097	3.4972	11.08	369.49	0.299
0.482	1.5366	11.01	1838	1.634
0.738	2.3527	11.51	188.59	0.194
0.255	0.8129	9.12	8.843	0.045
0.855	2.7257	10.01	38.256	0.269
0.153	0.4878	9.46	36.91	0.1
1.548	4.9350	7.91	11.727	2.834
0.916	2.9202	7.98	21.339	1.025
1.833	5.8436	11.02	19.609	0.872
1.845	5.8819	11.37	12.88	1.661
1.078	3.4367	8.84	12.111	2.368

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.495	1.57806	101	8	93	268
0.763	2.432444	146	52	94	235
0.284	0.905392	1448.6	20	1444.8	252
0.869	2.770372	268.6	14	254.6	225
0.147	0.468636	243.6	12	231.6	216
0.129	0.411252	185.2	44	141.2	208
0.738	2.352744	305.8	40	265.8	596
0.255	0.81294	221	8	213	26
0.603	1.922364	51.4	48	3.4	18
1.548	4.935024	162.8	36	126.8	129
0.287	0.914956	170.2	24	146.2	162
1.036	3.302768	196	44	152	33
0.555	1.76934	220.6	156	64.6	53
0.166	0.529208	176.6	20	156.6	32
0.681	2.171028	156	16	140	367

Table 4.2. Results of second sample set

Following two tables show the results of second fifteen samples.

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-}Concentration(ppb)	NO_3^-Concentration(ppm)
2.537	8.0880	5.93	19.801	1.39
1.777	5.6651	6.01	94.968	1.534
1.686	5.3750	6.17	62.863	1.934
1.343	4.2815	6.24	100.16	1.82
1.012	3.2263	6.4	255.11	0.619
1.159	3.6949	6.3	81.511	1.367
0.343	1.0935	6.82	466.38	0.103
0.197	0.6280	6.55	308.74	0.09
0.366	1.1668	6.51	126.88	0.374
0.192	0.6121	6.41	395.44	0.107
3.873	12.3471	8.34	119.57	0.09
1.883	6.0030	7.78	77.858	0.218
3.304	10.5332	6.88	204.55	3.562
1.962	6.2549	6.71	46.907	6.606
1.798	5.7320	6.56	44.985	7.469

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.754	2.403752	5.6	8	2.4	188
0.806	2.569528	8.2	4	42	334
1.935	6.16878	10.2	10	0.2	262
1.709	5.448292	16.6	14	2.6	355
5.287	16.854956	13.6	4	9.6	170
0.023	0.073324	11.6	10	1.6	185
0.51	1.62588	44	14	30	338
1.117	3.560996	13.2	8	5.2	346
0.267	0.851196	14.4	8	6.4	330
0.866	2.760808	14	10	4	225
0.709	2.260292	22.4	18	4.4	287
0.731	2.330428	15.2	12	3.2	237
3.496	11.145248	24	22	2	229
0.242	0.771496	21	4	17	234
0.948	3.022224	20	5	15	326

Table 4.3. Results of Third sample set

Following two tables show the results of third fifteen samples.

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-}Concentration(ppb)	NO_3^- Concentration(ppm)
2.67	8.5120	6.05	18.071	2.565
1.686	5.3750	6.16	63.248	1.905
1.665	5.3080	6.25	58.249	1.468
1.426	4.5461	6.28	232.04	1.494
0.787	2.5090	6.23	282.02	0.117
1.041	3.3187	6.29	153.02	1.258
0.434	1.3836	6.78	483.49	0.142
0.134	0.4272	6.39	452.35	0.117
0.281	0.8958	6.72	182.44	0.506
0.182	0.5802	6.37	498.29	0.147
3.248	10.3546	8.06	87.662	0.227
3.248	10.3546	8.18	79.78	0.163
2.049	6.5322	7.1	287.59	2.489
1.009	3.2167	6.66	38.064	9.925
1.646	5.2474	6.43	71.706	9.067

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.344	1.096672	12.5	6	6.5	125
1.23	3.92124	8.8	7	1.8	62
0.729	2.324052	8	3	5	173
1.34	4.27192	19	14	5	102
3.521	11.224948	26	10	16	190
0.237	0.755556	8.6	6	2.6	152
1.601	5.103988	30.5	26	4.5	205
2.324	7.408912	17.2	14	3.2	179
2.183	6.959404	36.2	30	6.2	194
2.405	7.66714	19.2	16	3.2	155
1.358	4.329304	24.6	22	2.6	185
1.075	3.4271	34.2	28	6.2	189
0.733	2.336804	39.2	36	3.2	176
0.064	0.204032	14	6	8	135
0.884	2.818192	8.2	4	4.2	150

Table 4.4. Results of Forth sample set

Following two tables show the results of fourth fifteen samples.

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-} Concentration(ppb)	NO_3^- Concentration(ppm)
2.373	7.5651	5.83	331.62	1.695
1.596	5.0880	6.17	223.39	1.372
1.831	5.8372	6.28	70.553	2.285
1.591	5.0721	6.36	117.08	2.047
0.778	2.4803	6.57	223.39	0.529
1.13	3.6024	6.47	113.81	1.244
0.309	0.9851	6.81	622.86	0.131
0.144	0.4591	6.68	449.65	0.108
1.626	5.1837	6.52	721.68	0.122
0.185	0.5898	6.56	603.83	0.127
3.208	10.2271	6.59	91.315	0.116
2.747	8.7574	8.31	111.5	0.098
1.938	6.1783	6.97	161.68	0.106
1.579	5.0339	6.47	35.757	10.076
1.479	4.7151	6.34	46.33	15.681

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.656	2.091328	15	6	9	60
0.137	0.436756	9.4	8	1.4	173
0.468	1.491984	10.8	10	0.8	194
0.579	1.845852	13.8	6	7.8	196
1.222	3.895736	10.8	6	4.8	78
1.5	4.782	20.4	10	10.4	187
0.49	1.56212	20	16	4	123
0.472	1.504736	38.2	20	18.2	73
0.883	2.815004	18	10	8	140
0.543	1.731084	19.2	16	3.2	74
0.513	1.635444	15.8	12	3.8	203
0.562	1.791656	14.2	12	2.2	184
0.124	0.395312	14.2	10	4.2	170
0.596	1.900048	20.8	12	8.8	161
0.589	1.877732	20.2	6	14.2	134

Table 4.5. Results of Fifth sample set

Following two tables show the results of fifth fifteen samples.

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-} Concentration(ppb)	NO_3^- Concentration(ppm)
1.742	5.5535	6.14	19.032	1.903
1.004	3.2008	6.15	66.708	1.631
1.399	4.4600	6.33	58.826	1.539
1.38	4.3994	6.09	110.73	0.955
0.786	2.5058	6.16	519.25	11.608
0.361	1.1509	6.25	116.69	1.111
0.251	0.8002	6.68	765.12	0.154
0.229	0.7301	6.41	329.5	0.116
0.924	2.9457	6.44	199.16	0.099
0.213	0.6790	6.26	329.5	0.113
1.994	6.3569	6.36	99.774	0.108
2.17	6.9180	6.89	92.853	0.211
1.902	6.0636	6.42	148.22	4.268
1.669	5.3208	6.18	147.484	11.877
1.191	3.7969	7.02	58.412	11.716
3.123	9.9561	5.82	8.651	2.428

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.259	0.825692	20.2	16	4.2	144
0.78	2.48664	24.2	16	8.2	175
2.383	7.597004	6	4	2	179
2.475	7.8903	16.4	12	4.4	150
1.901	6.060388	21.2	16	5.2	126
1.087	3.465356	15.2	12	3.2	136
2.051	6.538588	32.8	28	4.8	125
2.07	6.59916	14.2	12	2.2	121
2.257	7.195316	32	27	5	149
2.421	7.718148	14.4	13	1.4	146
1.419	4.523772	37.2	31	6.2	124
1.067	3.401596	30.2	24	8.2	162
2.491	7.941308	17.5	12	5.5	150
0.255	0.81294	16.4	12	4.4	125
1.838	5.859544	26.2	20	6.2	133
0.062	0.197656	28.8	16	12.8	129

4.2. Analysis of data

Table 4.6. Average of the Results compared to the Result of Drinking water sample

Following tables show the average value of the values of tables 4.1, 4.2, 4.3, 4.4 and 4.5 compared to the drinking water sample .This drinking water sample was obtained from a water spring in Nuwara –Eliya town area.

Average DO	Average PH	Average PO_4^{3-}	AverageNO_3^-
7.53962	6.152	81.319	1.8426
5.1288544	6.412	91.6236	1.647
5.3673168	6.71	80.3182	1.9618
4.6117608	7.264	136.878	1.3446
2.843696	7.288	329.852	2.6344
2.6607048	7.264	460.6062	1.3228
1.32302	7.72	505.288	0.1448
0.6114584	7.03	309.8166	0.0952
2.5835552	7.24	253.6832	0.274
0.58978	7.012	372.794	0.1188
8.8441496	7.452	82.0096	0.675
6.9906464	7.828	76.666	0.343
7.0301776	7.678	164.3298	2.2594
5.1416064	7.478	56.2184	8.029
4.5856192	7.038	46.7088	9.2602

For Drinking water sample

5.82	8.651	2.428	0.062

Average BOD	Average TS	Average TSS	Average TDS	Average COD
1.5991008	30.86	8.8	23.02	157
2.3693216	39.32	17.4	29.48	195.8
3.6974424	296.72	9.4	290.56	212
4.4453472	66.88	12	54.88	205.6
7.7009328	63.04	9.6	53.44	156
1.8974976	48.2	16.4	31.8	173.6
3.436664	86.62	24.8	61.82	277.4
3.9773488	60.76	12.4	48.36	149
3.9486568	30.4	24.6	5.8	166.2
4.9624408	45.92	18.2	27.72	145.8
2.7327536	54.04	21.4	32.64	192.2
2.8507096	57.96	24	34.36	161
4.7176024	63.1	47.2	15.9	155.6
0.8435448	49.76	10.8	38.96	137.4
3.149744	46.12	10.2	35.92	222

For Drinking water sample

0.197656	28.8	16	12.8	129

4.2.1. Statistical evaluation of data using one way ANOVA

Table 4.7.Statistical evaluation

Variable	P value	α value	Statistical conclusion
pH	0.002	0.05	Reject H_o
DO	0.000	0.05	Reject H_o
PO_4^3	0.543	0.05	Do not reject H_o
NO_3	0.000	0.05	Reject H_o
BOD	0.018	0.05	Reject H_o
TS	0.835	0.05	Do not reject H_o
TSS	0.177	0.05	Do not reject H_o
TDS	0.760	0.05	Do not reject H_o
COD	0.585	0.05	Do not reject H_o

- Here the drinking water sample was taken as 16th sample
- The following comparison has done with the data of C.E.A obtained from 4th place of Toppaz area, 3rd place of Market area, 1st place of Victoria area and 1st place of Lake Area.

4.3. pH Measurement

Ho: mean pH of each sample point is equal to the pH of drinking water sample

H1: at least one mean pH of each sample point is not equal to the pH of drinking water sample.

Table 4.8. Statistical evaluation of pH

Variable	P value	α value	Statistical conclusion
pH	0.002	0.05	Reject H_o

According to the above table, at least one mean pH of each sample point is not equal to the pH of drinking water sample. This can be happened when collected water is not suitable to the condition of pH of drinking water.

Table 4.9. Comparison of results of pH with the data of Central Environmental Authority (C.E.A)

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria park**			**Gregory Lake**				
Mean pH(My)	6.15	6.41	6.71	7.26	7.29	7.26	7.72	7.03	7.24	7.01	7.45	7.83	7.68	7.48	7.04
C.E.A Jan .2008				7.6			7.1	5.9			6.2				
C.E.A Feb 2008				7.6			7.1	5.9			7.6				
C.E.A Jan 2009				7.4			7.1	6.9			6.9				
pH of the drinking water sample -8.65															

According to the above table, except three places in Toppas area, the pH of the other points has been nearly equal. This may be due to addition of more organic fertilizer from those places. But almost all the pH values lie in the standard range; 6-9 (Murphy, 2009). And there is a considerable difference in between pH of drinking water and the pH of the sample points. But pH of the drinking water sample has slightly changed than that of standard value. This also can be happened when the organic fertilizer content is high in that area. The standard pH of drinking water is 6.5-8.5 (Murphy, 2007).

Compared to the C.E.A data, except in market area, my data has slightly changed from C.E.A data. This can be happened due to equipmental errors and human errors. And the pH has reduced compared to the past years.

4.4. Dissolved Oxygen

Ho: mean DO of each sample point is equal to that of drinking water sample.

H1: at least one mean DO of each sample point is not equal to that of drinking water sample

Table 4.10.Statistical evaluation of DO

Variable	P value	α value	Statistical conclusion
DO	0.000	0.05	Reject H_o

According to the above table at least one mean DO of each sample point is not equal to that of drinking water sample .This can be happened when the condition of waste water samples is not compatible with drinking water sample. So, it is clear that according to DO values, all the collected water samples are not suitable for drinking.

Table 4.11. Comparison of results of DO with the data of Central Environmental Authority (C.E.A)

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria Park**			**Gregory Lake**				
Mean DO(My)	7.54	5.13	5.37	4.61			1.32	0.611	2.58	0.59	8.84	6.99	7.03	5.14	4.59
C.E.A Jan .2008				8.1			5.9	5.3			8.2				
C.E.A Feb 2008				8.1			5.9	5.3			6.1				
C.E.A Jan 2009				6.1			3.2	1.5			2.6				
DO of drinking water sample 5.82															

According to my DO value, it clearly decreases from Toppaz to the beginning of Lake Gregory. This can be happened when the waste is also increased like that. And DO of the

Lake area is comparatively high than that of other areas. This can be happened when the waste of lake is comparatively low than that of other three areas. DO of Market area and Victoria Park area is very low compared to the other areas. This can be to the presence of lot of waste in those areas. Compared to the data of C.E.A also, it is clear that DO has decreased from Toppaz to the lake throughout the past years.

4.5. Biological Oxygen Demand

Ho: mean BOD of each sample point is equal to that of drinking water sample

H1: at least one mean BOD of each sample point is not equal to that of drinking water sample

Table 4.12.Statistical evaluation of BOD

Variable	P value	α value	Statistical conclusion
BOD	0.018	0.05	Reject H_o

According to the above table at least one mean BOD of each sample point is not equal to that of drinking water sample .This happens when organic material content of the drinking water sample is different from that of waste water samples. Thus, this can also be due to absence of drinking water conditions in waste water samples. That means there is a significant difference between the BOD value of drinking water sample and BOD value of each waste water sample point.

Table 4.13. Comparison of results of BOD with the data of Central Environmental Authority (C.E.A)

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria Park**			**Gregory Lake**				
Mean BOD	1.60	2.37	3.70	4.44	7.70	1.90	3.44	4.00	3.95	4.96	2.73	2.85	4.72	0.84	3.15
C.E.A Jan .2008				1.00			4.00	5.00			2.00				
C.E.A Feb 2008				1.00			4.00	5.00			1.00				
C.E.A Jan 2009				3.00			9.00	5.00			4.00				
BOD of drinking water sample	0.2														

According to my BOD values and other research's values, it is comparatively less in Toppaz area and comparatively high in the places of market area. And it is very high in the first place of Market area as the pollution of that place is very high. If BOD value is normally low, it indicates that pollution is low in those places. Increasing BOD value compared to the past data of C.E.A indicates that pollution also has increased.

4.6. Chemical Oxygen Demand

Ho: mean COD of each sample point is equal to that of drinking water sample

H1: at least one mean COD of each sample point is not equal to that of drinking water sample.

Table 4.14.Statistical evaluation of COD

Variable	P value	α value	Statistical conclusion
COD	0.585	0.05	Do not reject H_o

According to the above results, there is no significant difference among drinking water and each waste water sample points. This can be happened when COD of drinking water sample is equal to that of waste water samples.

Table 4.15. Comparison of results of COD with the data of Central Environmental Authority (C.E.A)

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria**			**Gregory Lake**				
My mean COD	157	196	212	206	156	174	277	149	166	146	192	161	156	137	222
C.E.A Jan .2008				20			10	10			20				
C.E.A Feb 2008				5			10	10			5				
C.E.A Jan 2009				17			33	15			27				
COD of drinking water sample	129														

According to my COD values, it is greater than 150 in most areas. This can be happened when the inorganic content of the water is very high. Normally standard COD value of drinking water is 10(SLS 614, 1983). But it is 129.This also could be, when the nitrate and phosphate fertilizer is added in high amounts to the spring water. But compared to the values of C.E.A, it has been very low. Sometimes this can be happened, if their materials and methodology is completely wrong only. According to the past values, it is clear that COD value has slightly decreased. This can be happened when the addition of the amount of nitrate and phosphate fertilizer is decreased.

4.7. Phosphate concentration

Ho: mean PO_4^{3-} concentration of each sample point is equal to that of drinking water sample.

H1: at least one mean PO_4^{3-} concentration of each sample point is not equal to that of drinking water sample.

Table 4.16.Statistical evaluation of phosphate

Variable	P value	α value	Statistical conclusion
phosphate	0.543	0.05	Do not reject H_o

According to the above results, there is not a significant difference in Phosphate concentration in both drinking water sample and waste water sample. This can be happened as the phosphate and nitrate fertilizers are added from the cultivation areas.

Table 4.17. Comparison of results of phosphate with the data of Central Environmental Authority (C.E.A)

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria Park**			**Gregory Lake**				
My mean phosphate(ppm)	0.08	0.09	0.08	0.14	0.33	0.46	0.50	0.31	0.25	0.37	0.08	0.08	0.16	0.05	0.05
C.E.A Jan .2008				0.01			0.02	0.04			0.01				
C.E.A Feb 2008				0.01			0.02	0.04			0.01				
C.E.A Jan 2009				0.02			0.08	0.15			0.15				
phosphateof drinking water sample	0.002														

According to the above table, phosphate concentration has increased from Toppaz area to Gregory Lake and it is comparatively less in Lake Area. This is due to the addition of higher amount of fertilizers in Toppaz, Market and Victoria Park areas than in Lake Area. Compared to the C.E.A data phosphate concentration has increased during the past years. This can be due to the increase of adding phosphate fertilizer to the water. Normally according to the drinking water standard in Sri Lanka (SLS 614, 1983), phosphate should not contain in drinking water. But here it has been 0.002.This can be due to the addition of phosphate fertilizer to the spring water. Therefore drinking water of this area is not suitable for drinking.

4.8. Nitrate concentration

Ho: mean NO_3-of each sample point is equal to that of drinking water sample

H1: at least one mean NO_3- of each sample point is not equal to that of drinking water sample.

Table 4.18.Statistical evaluation of Nitrate

Variable	P value	α value	Statistical conclusion
Nitrate	0.000	0.05	Reject H_o

According to the above table Nitrate concentration of drinking water sample is not compatible with that of waste water samples. This can be happened when the amount of added nitrate fertilizer is different from that of waste water sample.

Table 4.19. Comparison of results of Nitrate with the data of Central Environmental Authority (C.E.A)

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria Park**			**Gregory Lake**				
My mean Nitrate (ppm)	1.84	1.65	1.96	1.34	2.63	1.32	0.14	0.09	0.27	0.12	0.67	0.34	2.26	8.03	9.26
C.E.A Jan .2008				0.06			0.22	0.20			0.06				
C.E.A Feb 2008				0.06			0.22	0.20			0.06				
C.E.A Jan 2009				0.06			0.21	0.24			1.00				
Nitrate of drinking water sample	0.06														

According to my data, nitrate concentration has been very less in Victoria Park area and it has been more in Lake Areas. This can be happened when the amount of added nitrate fertilizer is less in Victoria area than that of Lake Area. Nitrate concentration of the first place in Victoria Park area is very low. This can be due to no cultivation is present there. But according to the data of C.E.A, the nitrate concentration in Toppaz area hasn't changed in past years while it has increased in other areas. This can be when the amount of adding fertilizer has regulated in Tòpaz area. In the other area it has increased as the amount of adding fertilizer has increased. According to the Sri Lankan drinking water standards (SLS 614, 1983) nitrate should not contain in drinking water. But here it has been 0.06 and it reveals that Nitrate fertilizer is mixed with drinking water in this area.

4.9. Total Solids

Ho: mean TS of each sample point is equal to that of drinking water sample.

H1: at least one mean TS of each sample point is not equal to that of drinking water sample.

Table 4.20.Statistical evaluation of TS

Variable	P value	α value	Statistical conclusion
TS	0.835	0.05	Do not reject H_o

As in above table, amount of TS has been compatible in both drinking water sample and waste water samples. This could be, when the amount of TS is compatible in both drinking water sample and waste water samples.

Table 4.21. Comparison of results of TS with drinking water sample

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria Park**			**Gregory Lake**				
Mean TS	30.86	39.32	296.72	66.88	63.04	48.20	86.62	60.76	30.4	45.92	54.04	57.96	63.10	49.76	46.12
TS of drinking water sample	28.8														

Here, the amount of TS in most areas has been very low compared to that of drinking water standards. This can be, when the amount of suspended solids and dissolved solids is less due to been less of silt, decaying plant, animal matter, industrial waste and sewage in these areas. But TS in the third place of Toppaz area has been very high compared to the other areas. This can be, when the amount of suspended solids and dissolved solids is more due to been more of silt, decaying plant, animal matter, industrial waste and sewage in these areas. According to the Sri Lankan drinking water standards (SLS 614, 1983), Total solids that should contain in drinking water are 500 mg/L. But here as it has been very less in my drinking water

sample, it indicates that the amount of silt particles, decaying plant, animal matter, industrial waste and sewage is less liquefied in spring water of this area.

4.10. Total Suspended Solids

Ho: mean TSS of each sample point is equal to that of drinking water sample.

H1: at least one mean TSS of each sample point is not equal to that of drinking water sample.

Table 4.22.Statistical evaluation of TSS

Variable	P value	α value	Statistical conclusion
TSS	0.177	0.05	Do not reject H_o

Here the total suspended value has been compatible in both drinking water sample and waste water samples. This can be happened as the TS value is also compatible in both.

Table 4.23. Comparison of results of TSS with the drinking water sample

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria Park**			**Gregory Lake**				
Mean TSS	8.8	17.4	9.4	12	9.6	16.4	24.8	12.4	24.6	18.2	21.4	24.0	47.2	10.8	10.2
TSS of drinking water sample	16														

Here TSS value is very high in Gregory Lake. This is because lots of silt, decaying plant, animal matter, industrial waste and sewage has been dissolved there. In Toppaz area it has been comparatively low because less amount of silt, decaying plant, animal matter, industrial waste and sewage have been dissolved there. There is a desirable difference in 2nd place of

Toppaz area, 3rd place of Market area and the 3rd place of Lake Area. This can be due to increase of silt, decaying plant, animal matter, industrial waste and sewage in those places. Here the TSS value of drinking water sample is in between Toppaz and Market area. This is because amount of dissolved silt, decaying plant, animal matter, industrial waste and sewage is also like that.

4.11. Total Dissolved Solids

Ho: mean TDS of each sample point is equal

H1: at least one mean TDS of each sample point is not equal

Table 4.24.Statistical evaluation of TDS

Variable	P value	α value	Statistical conclusion
TDS	0.760	0.05	Do not reject H_o

Here also TDS value in both drinking water sample and waste water samples has been compatible. This is because TS and TSS values were also like that.

Table 4.25. Comparison of results of TDS with drinking water sample

Sample point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Toppaz area				**Market area**			**Victoria Park**			**Gregory Lake**				
MeanTDS	23.0	29..5	290.6	54..9	53.4	31.8	61.82	48..36	5.8	27.7	32.6	34.4	15..9	39.0	35..9
TDS of drinking water sample	12.8														

As in above table, the TDS of 3rd place of the Toppaz area is largely high compared to the other points. This is because of the high solubility of silt, decaying plant, animal matter,

industrial waste and sewage in the particular area. This was same for TS and TSS too. As TDS is calculated from the difference of TS and TSS, same explanation can be given for this as in TS and TSS. In the second point of Victoria Park area, it has been less than 10.This is because of the least solubility of silt, decaying plant, animal matter, industrial waste and sewage in this area. The TDS of drinking water sample is also very less and it indicates the desirability of drinking water.

CHAPTER 05

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

According to the above results, it can be concluded that the lot of wastes are added to the lake when going from upstream to the downstream and some places are getting diluted while going to the lake. Further, collected water is not suitable for drinking because of the deviation of tested parameters from drinking standards. And the pollution of the sample points has increased from past years. It can further be concluded that phosphates and Nitrates have mixed with spring drinking water. Normally PH becomes to that range due to organic acids produced by decaying of organic matter. It is concluded that the water in those places is more polluted. Finally, Gregory Lake and Thalagala Oya have been subjected to pollution under the unplanned urbanization, improper use of chemicals and Agricultural practices.

5.2. Recommendations

The results can be varied according to seasonal variations of Nuwara-Eliya. Therefore it is recommended to do these experiments throughout the year. As the adding of waste is increasing from upstream to downstream, lot of wastes are added from the septic systems of hotels situated in the town areas. Therefore it is recommended that necessary actions should be taken to construct the systematic sewage.

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APPENDIX

Appendix-1.Parameter values of first sample set

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-}Concentration(ppb)	NO_3^- Concentration(ppm)
2.503	7.9796	6.81	18.071	1.66
1.981	6.3154	7.57	9.804	1.793
1.837	5.8564	8.52	151.1	2.583
1.493	4.7597	11.35	124.38	0.407
1.097	3.4972	11.08	369.49	0.299
0.482	1.5366	11.01	1838	1.634
0.738	2.3527	11.51	188.59	0.194
0.255	0.8129	9.12	8.843	0.045
0.855	2.7257	10.01	38.256	0.269
0.153	0.4878	9.46	36.91	0.1
1.548	4.9350	7.91	11.727	2.834
0.916	2.9202	7.98	21.339	1.025
1.833	5.8436	11.02	19.609	0.872
1.845	5.8819	11.37	12.88	1.661
1.078	3.4367	8.84	12.111	2.368

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.495	1.57806	101	8	93	268
0.763	2.432444	146	52	94	235
0.284	0.905392	1448.6	20	1444.8	252
0.869	2.770372	268.6	14	254.6	225
0.147	0.468636	243.6	12	231.6	216
0.129	0.411252	185.2	44	141.2	208
0.738	2.352744	305.8	40	265.8	596
0.255	0.81294	221	8	213	26
0.603	1.922364	51.4	48	3.4	18
1.548	4.935024	162.8	36	126.8	129
0.287	0.914956	170.2	24	146.2	162
1.036	3.302768	196	44	152	33
0.555	1.76934	220.6	156	64.6	53
0.166	0.529208	176.6	20	156.6	32
0.681	2.171028	156	16	140	367

Appendix-2.Parameter Values of second sample set

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-}Concentration(ppb)	NO_3^- Concentration(ppm)
2.537	8.0880	5.93	19.801	1.39
1.777	5.6651	6.01	94.968	1.534
1.686	5.3750	6.17	62.863	1.934
1.343	4.2815	6.24	100.16	1.82
1.012	3.2263	6.4	255.11	0.619
1.159	3.6949	6.3	81.511	1.367
0.343	1.0935	6.82	466.38	0.103
0.197	0.6280	6.55	308.74	0.09
0.366	1.1668	6.51	126.88	0.374
0.192	0.6121	6.41	395.44	0.107
3.873	12.3471	8.34	119.57	0.09
1.883	6.0030	7.78	77.858	0.218
3.304	10.5332	6.88	204.55	3.562
1.962	6.2549	6.71	46.907	6.606
1.798	5.7320	6.56	44.985	7.469

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.754	2.403752	5.6	8	2.4	188
0.806	2.569528	8.2	4	42	334
1.935	6.16878	10.2	10	0.2	262
1.709	5.448292	16.6	14	2.6	355
5.287	16.854956	13.6	4	9.6	170
0.023	0.073324	11.6	10	1.6	185
0.51	1.62588	44	14	30	338
1.117	3.560996	13.2	8	5.2	346
0.267	0.851196	14.4	8	6.4	330
0.866	2.760808	14	10	4	225
0.709	2.260292	22.4	18	4.4	287
0.731	2.330428	15.2	12	3.2	237
3.496	11.145248	24	22	2	229
0.242	0.771496	21	4	17	234
0.948	3.022224	20	5	15	326

Appendix-3.Parameter values of Third sample set

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-}Concentration(ppb)	NO_3^- Concentration(ppm)
2.67	8.5120	6.05	18.071	2.565
1.686	5.3750	6.16	63.248	1.905
1.665	5.3080	6.25	58.249	1.468
1.426	4.5461	6.28	232.04	1.494
0.787	2.5090	6.23	282.02	0.117
1.041	3.3187	6.29	153.02	1.258
0.434	1.3836	6.78	483.49	0.142
0.134	0.4272	6.39	452.35	0.117
0.281	0.8958	6.72	182.44	0.506
0.182	0.5802	6.37	498.29	0.147
3.248	10.3546	8.06	87.662	0.227
3.248	10.3546	8.18	79.78	0.163
2.049	6.5322	7.1	287.59	2.489
1.009	3.2167	6.66	38.064	9.925
1.646	5.2474	6.43	71.706	9.067

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.344	1.096672	12.5	6	6.5	125
1.23	3.92124	8.8	7	1.8	62
0.729	2.324052	8	3	5	173
1.34	4.27192	19	14	5	102
3.521	11.224948	26	10	16	190
0.237	0.755556	8.6	6	2.6	152
1.601	5.103988	30.5	26	4.5	205
2.324	7.408912	17.2	14	3.2	179
2.183	6.959404	36.2	30	6.2	194
2.405	7.66714	19.2	16	3.2	155
1.358	4.329304	24.6	22	2.6	185
1.075	3.4271	34.2	28	6.2	189
0.733	2.336804	39.2	36	3.2	176
0.064	0.204032	14	6	8	135
0.884	2.818192	8.2	4	4.2	150

Appendix-4.Parameter values of Forth sample set

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-}Concentration(ppb)	NO_3^- Concentration(ppm)
2.373	7.5651	5.83	331.62	1.695
1.596	5.0880	6.17	223.39	1.372
1.831	5.8372	6.28	70.553	2.285
1.591	5.0721	6.36	117.08	2.047
0.778	2.4803	6.57	223.39	0.529
1.13	3.6024	6.47	113.81	1.244
0.309	0.9851	6.81	622.86	0.131
0.144	0.4591	6.68	449.65	0.108
1.626	5.1837	6.52	721.68	0.122
0.185	0.5898	6.56	603.83	0.127
3.208	10.2271	6.59	91.315	0.116
2.747	8.7574	8.31	111.5	0.098
1.938	6.1783	6.97	161.68	0.106
1.579	5.0339	6.47	35.757	10.076
1.479	4.7151	6.34	46.33	15.681

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.656	2.091328	15	6	9	60
0.137	0.436756	9.4	8	1.4	173
0.468	1.491984	10.8	10	0.8	194
0.579	1.845852	13.8	6	7.8	196
1.222	3.895736	10.8	6	4.8	78
1.5	4.782	20.4	10	10.4	187
0.49	1.56212	20	16	4	123
0.472	1.504736	38.2	20	18.2	73
0.883	2.815004	18	10	8	140
0.543	1.731084	19.2	16	3.2	74
0.513	1.635444	15.8	12	3.8	203
0.562	1.791656	14.2	12	2.2	184
0.124	0.395312	14.2	10	4.2	170
0.596	1.900048	20.8	12	8.8	161
0.589	1.877732	20.2	6	14.2	134

Appendix-5.Parameter values of Fifth sample set

$Na_2S_2O_3$ Volume(ml)	DO(O_2mg/L)	PH	PO_4^{3-}Concentration(ppb)	NO_3^- Concentration(ppm)
1.742	5.5535	6.14	19.032	1.903
1.004	3.2008	6.15	66.708	1.631
1.399	4.4600	6.33	58.826	1.539
1.38	4.3994	6.09	110.73	0.955
0.786	2.5058	6.16	519.25	11.608
0.361	1.1509	6.25	116.69	1.111
0.251	0.8002	6.68	765.12	0.154
0.229	0.7301	6.41	329.5	0.116
0.924	2.9457	6.44	199.16	0.099
0.213	0.6790	6.26	329.5	0.113
1.994	6.3569	6.36	99.774	0.108
2.17	6.9180	6.89	92.853	0.211
1.902	6.0636	6.42	148.22	4.268
1.669	5.3208	6.18	147.484	11.877
1.191	3.7969	7.02	58.412	11.716
3.123	9.9561	5.82	8.651	2.428

$Na_2S_2O_3$ Volume(i-f)(ml)	BOD_3(mg/l)	TS	TSS	TDS	COD
0.259	0.825692	20.2	16	4.2	144
0.78	2.48664	24.2	16	8.2	175
2.383	7.597004	6	4	2	179
2.475	7.8903	16.4	12	4.4	150
1.901	6.060388	21.2	16	5.2	126
1.087	3.465356	15.2	12	3.2	136
2.051	6.538588	32.8	28	4.8	125
2.07	6.59916	14.2	12	2.2	121
2.257	7.195316	32	27	5	149
2.421	7.718148	14.4	13	1.4	146
1.419	4.523772	37.2	31	6.2	124
1.067	3.401596	30.2	24	8.2	162
2.491	7.941308	17.5	12	5.5	150
0.255	0.81294	16.4	12	4.4	125
1.838	5.859544	26.2	20	6.2	133
0.062	0.197656	28.8	16	12.8	129

Appendix-6.Average Parameter values with Drinking water sample

Average DO	Average PH	Average PO_4^{3-}	AverageNO_3^-
7.53962	6.152	81.319	1.8426
5.1288544	6.412	91.6236	1.647
5.3673168	6.71	80.3182	1.9618
4.6117608	7.264	136.878	1.3446
2.843696	7.288	329.852	2.6344
2.6607048	7.264	460.6062	1.3228
1.32302	7.72	505.288	0.1448
0.6114584	7.03	309.8166	0.0952
2.5835552	7.24	253.6832	0.274
0.58978	7.012	372.794	0.1188
8.8441496	7.452	82.0096	0.675
6.9906464	7.828	76.666	0.343
7.0301776	7.678	164.3298	2.2594
5.1416064	7.478	56.2184	8.029
4.5856192	7.038	46.7088	9.2602
For Drinking water sample			
5.82	8.651	2.428	0.062

Average BOD	Average TS	Average TSS	Average TDS	Average COD
1.5991008	30.86	8.8	23.02	157
2.3693216	39.32	17.4	29.48	195.8
3.6974424	296.72	9.4	290.56	212
4.4453472	66.88	12	54.88	205.6
7.7009328	63.04	9.6	53.44	156
1.8974976	48.2	16.4	31.8	173.6
3.436664	86.62	24.8	61.82	277.4
3.9773488	60.76	12.4	48.36	149
3.9486568	30.4	24.6	5.8	166.2
4.9624408	45.92	18.2	27.72	145.8
2.7327536	54.04	21.4	32.64	192.2
2.8507096	57.96	24	34.36	161
4.7176024	63.1	47.2	15.9	155.6
0.8435448	49.76	10.8	38.96	137.4
3.149744	46.12	10.2	35.92	222
For Drinking water sample				
0.197656	28.8	16	12.8	129

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