

**POTENTIALITY OF TURAG RIVER AS A DRINKING
SOURCE**

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POTENTIALITY OF TURAG RIVER AS A DRINKING SOURCE

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APPROVAL

The thesis titled "Potentiality of Turag River As A Drinking Source" submitted by Rafat Tanvir Ahmed (Student ID 115420), Md. Wassim Sazzad (Student ID 115428), M. Taofiqur-Rahman (Student ID 115436) of Academic Year 2011-12 has been found as satisfactory and accepted as partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering.

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DECLARATION

It is hereby declared that this thesis/project report or any part of it has not been submitted elsewhere for the award of any Degree or Diploma (except for publication).

November, 2015

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**DEDICATED TO
OUR BELOVED PARENTS**

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Chapter 1: Introduction

1.1 General Introduction

Water is the most essential substance for all forms of life. Among them Human use it the most. The most prominent theories claim that origin of life on this planet first developed in the surface layer of the prehistoric oceans approximately three billion years ago. Humans spend the first nine months of their development completely surrounded by water and during an early phase of the growth of the fetus, it develops rudimentary gills. The human body consists of approximately 64 % water and requires 2–3 liters of drinking water daily to maintain a healthy balance within the body (during normal conditions). The immense quantity of water, covering 71 % of the earth's surface to a mean depth of 3.8 km, measures in volume about $1.4 \cdot 10^9 \text{ km}^3$. But only a maximum of about 0.3 % of the world's total water resources is available for human usage. Among them surface water holds a good percentage. But all the surface water cannot be used for the actual purpose such as drinking, irrigation, pisciculture etc. due to surface water pollution. Lot of cities depend on surface water to fulfill their daily demands using different types of treatment process.

Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005). The existing tendency of industrialization and urbanization may contribute greatly to the poor quality of water through indiscriminate disposal of solid waste, industrial effluents and other toxic wastes which are the major environmental issues posing threats to the existence of human being (Furtado *et al.*, 1998; Chindah *et al.*, 2004; Ugochukwu, 2004; Emongor *et al.*, 2005; Rahman *et al.*, 2008). Generally municipal solid waste is collected and dumped in a mixed form in an unscientific manner on open waste land or low lying areas even near rivers, ponds and other ecological sensitive regions, which resulting in the pollution of water whereby the quality of the water deteriorates (Sahu, 2007). The waste dump sites virtually become a breeding ground for all kinds of diseases (Sahu, 2007). Solid waste leachate is the greatest threat to

groundwater which possesses various chemical and biological contaminants (Bidhendi *et al.*, 2010).

In terms of quantity industry is a small user of water, but has a significant impact on quality (Mukherjee and Nellyat, 2006). Over three-fourth of fresh water draw by the domestic and industrial sectors, return as domestic sewage and industrial effluents which inevitably end up in surface water bodies or in the groundwater, affecting water quality (Mukherjee and Nellyat, 2006). Due to lack of properly equipped plants and sanitary dumping sites operated within the required standards, the industrial wastes are released in an adhoc manner to the environment (Satter and Islam, 2005). Presently 10% of waste water generated is being treated; the rest is discharged as it into the water bodies (Satter and Islam, 2005). When the waste stream contains a complex mixture of toxic substances predominantly natural and synthetic organic substances, metals, and trace elements, as well as pathogens from domestic and industrial sectors enter into streams, rivers and other water bodies, they get dissolved or suspended or deposited on the bed resulted in the pollution of water quality About 80% of the diseases in developing countries are related to contaminated water and the resulting death toll is as much as 10 million per year.

1.2 Overall Water Treatment Process

Clean, safe water is vital for every day life. Water is essential for health, hygiene and the productivity of our community. The water treatment process may vary slightly at different locations, depending on the technology of the plant and the water it needs to process, but the basic principles are largely the same. This section describes standard water treatment process.

Coagulation / Flocculation

During coagulation, liquid Aluminium Sulfate (alum) and/or polymer is added to untreated (raw) water. When mixed with the water, this causes the tiny particles of dirt in the water to stick together or coagulate. Next, groups of dirt particles stick together to

form larger, heavier particles called flocs which are easier to remove by settling or filtration.

Sedimentation

As the water and the floc particles progress through the treatment process, they move into sedimentation basins where the water moves slowly, causing the heavy floc particles to settle to the bottom. Floc which collects on the bottom of the basin is called sludge, and is piped to drying lagoons. In Direct Filtration, the sedimentation step is not included, and the floc is removed by filtration only.

Filtration

Water flows through a filter designed to remove particles in the water. The filters are made of layers of sand and gravel, and in some cases, crushed anthracite. Filtration collects the suspended impurities in water and enhances the effectiveness of disinfection. The filters are routinely cleaned by backwashing.

Disinfection

Water is disinfected before it enters the distribution system to ensure that any disease-causing bacteria, viruses, and parasites are destroyed. Chlorine is used because it is a very effective disinfectant, and residual concentrations can be maintained to guard against possible biological contamination in the water distribution system.

Sludge Drying

Solids that are collected and settled out of the water by sedimentation and filtration are removed to drying lagoons.

Fluoridation

Water fluoridation is the treatment of community water supplies for the purpose of adjusting the concentration of the free fluoride ion to the optimum level sufficient to reduce dental caries. Hunter Water is required to fluoridate water in accordance with the NSW Fluoridation of Public Water Supplies Act 1957.

pH Correction

Lime is added to the filtered water to adjust the pH and stabilize the naturally soft water in order to minimize corrosion in the distribution system, and within customers' plumbing.

1.3 Water Condition of Dhaka City

Dhaka is one of the mega cities in the world. It is a highly populated city with a population about 12 million. About 19.4% of the total population of Dhaka city lives in the slum and squatter areas. Being the capital city and due to faster growth of Dhaka city, people from all over the country are gathering here day by day for their betterment. Dhaka Water Supply and Sewerage Authority (Dhaka WASA) is the only water supplier to this huge and growing population. But the Dhaka WASA can only produce 1900 million liters of water per day against Dhaka city's daily demand of 2200 million liters. The source of this supplied water is mainly the ground water. About 87% of total water supply by Dhaka WASA comes from deep tube wells, and rest of the supply comes from surface water treatment. Until 2002, there was a shortfall of about 350 million liters per day in the command area of Dhaka Water and Supply Authority (DWASA); in fact, the shortfall may be even greater, due to leakage in the water supply network. Thus it imposes a great impact to the ground water and causing the lowering of ground water table. The declination in groundwater table is 2.81 meter per year (m/y) whereas the groundwater recharge is only 1.33 m/y. So in near future we are going to face scarcity of water. To avoid this dilemma, it is high time to find alternative sources.

Dhaka city is surrounded by a number of rivers and canals of which *Turag*, *Buriganga*, *Dholeshwari*, *Baluand* and *Lakhya* are the important ones. These rivers could be potential source from where water could be extracted for drinking purpose. But these rivers receive partially treated and untreated sewage effluent, sewage polluted surface run-off and untreated industrial effluent from nearby residence and industrial areas. The rivers are further polluted by indiscriminate throwing of household, clinical, pathological & commercial wastes and discharge of spent fuel and human excreta. In fact, the river has become a dumping ground of all kinds of solid, liquid and chemical waste of bank-side population. So after selecting the proper promising source, some treatments needed to be introduced to reduce the pollutants and make the water potable. In this study we have highlighted Turagriver to find out its potentiality as a drinking surface water source and thus it could supply water to the northern part of Dhaka city. To evaluate its potentiality we have done some quality test of Turag water to determine the pollutants level and quality of the water and thus determining the treatment process.

1.4 Objective of The Study

The overall objective of this study was to evaluate the water quality of Turag River around Dhaka city. The specific Objectives of this study is to

- Collection and analyze sample from Turag River.
- Compilation of available data on river quality of Turag.

Present experimental data to find present status and trends of water quality of Turag River:

- Comparison of water quality between Summer & Winter season.
- Operate Coagulation process on different sources on Turag River.
- Identifies locations along the Turag River from where river water of acceptable quality may be available for the treatment plant throughout the year, including the dry season.

CHAPTER 2: LITERATURE REVIEW

Moayedi et al, developed an environmentally safe fluid waste stream and a solid waste suitable for disposal or reuse (usually as farm fertilizer). They used an advanced technology which is now possible to reuse sewage effluent for drinking water. They also informed that Singapore is the only country to implement such technology on a production scale. On the other hand, wastewater treatment and re-use engineers need a good understanding of wastewater microbiology for two reasons: firstly, because most wastewater treatment processes are microbiological & secondly, because wastewaters contain microorganisms that can cause human disease. Wastewater treatment engineers also need to understand the effect of fully treated, partially treated, and untreated wastewaters on the biology of the receiving watercourses. Their study provides an introduction to the most famous raw water treatment method. It concludes with a brief description of a simplified technique for the biological assessment of tropical freshwater quality using aquatic micro-invertebrates.

Pasha et al (2012), performed a study to assess the water quality of Turag river and to study the impact of industrial and domestic wastes on water quality. They also made a comparison of various parameters on water quality based on the existing standards for water quality. They informed that residential areas around Turag river must have a well defined and well maintained waste disposal system. So, a well defined sanitary system should be developed in the Turag river adjacent to slum areas as they are significant source of fecal contamination & Efficient solid waste management should be implemented in residential areas around Uttara and Tongi.

Dalwar & Hadiuzzaman (2005) provided an assessment of the present status of water quality of Balu and Shitalakhya River based on analysis of water sample collected from these two rivers during February 2005 by a review of the available data on the water quality of the two rivers. It also identifies locations along the Shitalakhya River from where river water of acceptable quality may be available for the treatment plant throughout the year, including the dry season. Their study estimates pollution loading on

Balu and Shitalakhya River and BOD load is projected using the estimated BOD load in 1998. And an equation has been developed using the projected BOD loads by which we can easily predict the BOD load at different year if population of that year is known. They also Identifies locations along the Shitalakhya & Balu River from where river water of acceptable quality may be available for the treatment plant throughout the year, including the dry season.

Aslam & W.K.Chow et al(2013), performed a study where surface waters in South Australia (River Murray) are extended dry and wet climate conditions, the water quality had changed markedly from low to high DOC (and turbidity), requiring reassessment and adjustment of treatment conditions of these waters for potable supply using DAX-8 resin before and after coagulation with alum and HPAC. HPAC is mainly a novel composite Polyaluminum chloride coagulant. Investigation was conducted on the character and treatability of NOM through fractionation. Alum was found to have high efficiency for removal of very hydrophobic, sorbed DAX-8 fraction (SDF) compounds in these waters. Several tests were conducted in order to assess the treatability of organics present in River Murray waters over the 5 months study period of January to May when the DOC concentrations were high in the river. Alum treatment resulted in higher (average 65%) removals of DOC than HPAC (average 58%). Moreover, Rainfall events had changed River Murray water quality and its organic constituents over the study period of five months during a high rainfall climate cycle.

Trinh & Kang (2011), provides an assessment on the Response surface methodological approach to optimize the coagulation–flocculation process in drinking water treatment. They performed jar tests often requires carrying out a time consuming iteration procedure to find out the right amount of chemical for coagulation–flocculation process in water treatment plants. Applying the response surface method (RSM) in jar tests as an alternative to the conventional methods was investigated in this study. Their purpose is finding out the optimum combination of coagulant dose and pH with respect to the highest removal efficiency of turbidity and dissolved organic carbon (DOC). The results achieved

using poly-aluminum chlorides (PACl) were compared to those achieved using conventional coagulant such as alum. They found the optimum conditions to be PACl concentration of 0.11mM at pH 7.4 and alum concentration of 0.15mM at pH 6.6. Compromising to simultaneously optimize the two responses resulted in 91.4% turbidity removal and 31.2% DOC removal using PACl whereas 86.3% turbidity and 34.3% DOC were removed using alum. Their study reveals that PACl is more efficient than alum for removal of turbidity. PACl is recommended for the coagulation–flocculation of high turbidity water. For water treatment in which DOC is a significant concern, both PACl and alum should be considered, with a compromise between the removal efficiencies of turbidity and DOC, along with the dose required, and other factors, such as the chemical used to adjust pH, the temperature of water, and the cost of coagulants.

Jiang (2015), presented the role of coagulation in water treatment. He declared that recent researches have explored other metal based salts (not Al or Fe salts) to prepare coagulants for drinking water treatment. Examples of such coagulants are titanium tetrachloride (TiCl_4), titanium sulfate ($\text{Ti}(\text{SO}_4)_2$) and zirconium tetrachloride (ZrCl_4). Performance of TiCl_4 and ZrCl_4 for drinking water treatment were studied and compared with alum [23]. He indicates that ZrCl_4 has the highest DOC removal at near its isoelectric point, at pH 4.5; the residual concentrations of aromatic protein II (P2), the fulvic acid (FA), soluble microbial protein (SMP) and humic acid (HA) for ZrCl_4 were lowest in comparison with that for alum and TiCl_4 . Their study results also demonstrated that ZrCl_4 was more efficient for the removal of low to medium MW range organic compounds (<2000 Da) than TiCl_4 or alum. In contrast, the removal of these components at pH 6 and 8 was much less for ZrCl_4 than for the other two coagulants. These findings further demonstrate that zirconium and titanium tetrachlorides are effective for the removal of humic substances (HA and FA) at near their isoelectric points, normally at lower pH conditions. He mentioned that, the performance of coagulation process is one of major factors in improving overall efficiency and cost effectiveness of water treatment. Future research needs are suggested to pay particular attention to the aspects of developing and using more effective coagulants/flocculants; optimizing unit configurations and process design, dose

control and sludge handling; and more fundamental studies of the properties and behavior of coagulating chemicals.

Yang & Gao et al (2010), investigated The effect of pH and coagulant dosage on the coagulation performance of aluminum Sulphate and Polyaluminum Chloride (PAC) with respect to the treatment of Yellow River water in this paper. The separation and measurement of residual aluminum (Al) speciation were also conducted. The results indicated that PAC showed superior coagulation performance compared to that of $\text{Al}_2(\text{SO}_4)_3$ in most cases during the Yellow River water treatment. At a dosage of 15 mg/L, PAC achieved an optimum removal efficiency of turbidity, UV_{254} and DOC of 96.3, 57.1, 32.7%, respectively, and $\text{Al}_2(\text{SO}_4)_3$ also achieved an optimum removal efficiency of turbidity, UV_{254} and DOC of 94.5, 53.5 34.8%, respectively. For PAC and $\text{Al}_2(\text{SO}_4)_3$, the optimum pH during the treatment of Yellow River water could be determined at 6.0. At initial pH 6.0 and the dosage of 15 mg/L (Al_2O_3), for PAC and $\text{Al}_2(\text{SO}_4)_3$, the turbidity removal efficiency could reach about 85.7 and 85.0%, UV_{254} removal efficiency about 55% and 52%, and the DOC removal efficiency could reach about 45 and 38%. For the two coagulants, no matter under different dosage or pH, the majority of residual total Al existed in dissolved form, among which, dissolved organically bound Al was the predominant speciation. And, dissolved inorganically bound monomeric Al was the main component in the dissolved monomeric Al. PAC exhibited lower concentration for each kind of residual Al species, except the concentration of dissolved organically bound Al; and PAC could effectively reduce the concentration of dissolved monomeric Al.

Konieczny & S kol et al (2009), investigated the ‘in-line’ coagulation-ultrafiltration hybrid process using three different coagulants- viz. FeCl_3 , $\text{Fe}_2(\text{SO}_4)_3$ and $\text{Al}_2(\text{SO}_4)_3$. The coagulants were dosed in the amounts of 2.4 mg Fe/dm³, 2.8 mg Fe/dm³ and 2.9 mg Al/dm³, respectively. Surface water from the Czarna Przemsza river (Silesia region, Poland) was used as raw water. The ultrafiltration membrane module with capillary polyether sulphone membranes was applied. It has been shown that the application of coagulant “in-line” contributes to the improvement of the quality of water as a result of

growth of the removal of organic matter. It has also been statistically proven that the proper choice of the coagulant is of significant importance for the degree of removal of organic matter from the water. The highest efficiency of the process was achieved when the aluminum coagulant was used. Furthermore, it has been shown that the application of “in-line” coagulation and ultrafiltration with the most proper coagulant restricts the fouling of the membranes, so that contaminations deposited on the membrane can easily be removed using deionized water.

CHAPTER 3: METHODOLOGY

3.1 Study Area:

We selected four locations for sample collection. We used Global Positioning System (GPS) to determine latitude and longitude of the locations. Latitude and longitude of the locations were noted down to ensure the same location for our next sample collection date for seasonal variation. The name with GPS locations were tabled below.

Table 3.1: Name of the locations and their position (latitude and longitude)

Sample ID	Name of the location	Position	
		Latitude	Longitude
T 1	Rupnagar	23.81840	90.33895611
T 2	Ashulia Station	23.890453	90.33972
T 3	Pubail	23.8951470	90.45514136
T 4	Gacha Union	23.9433781	90.34654878

Location Map

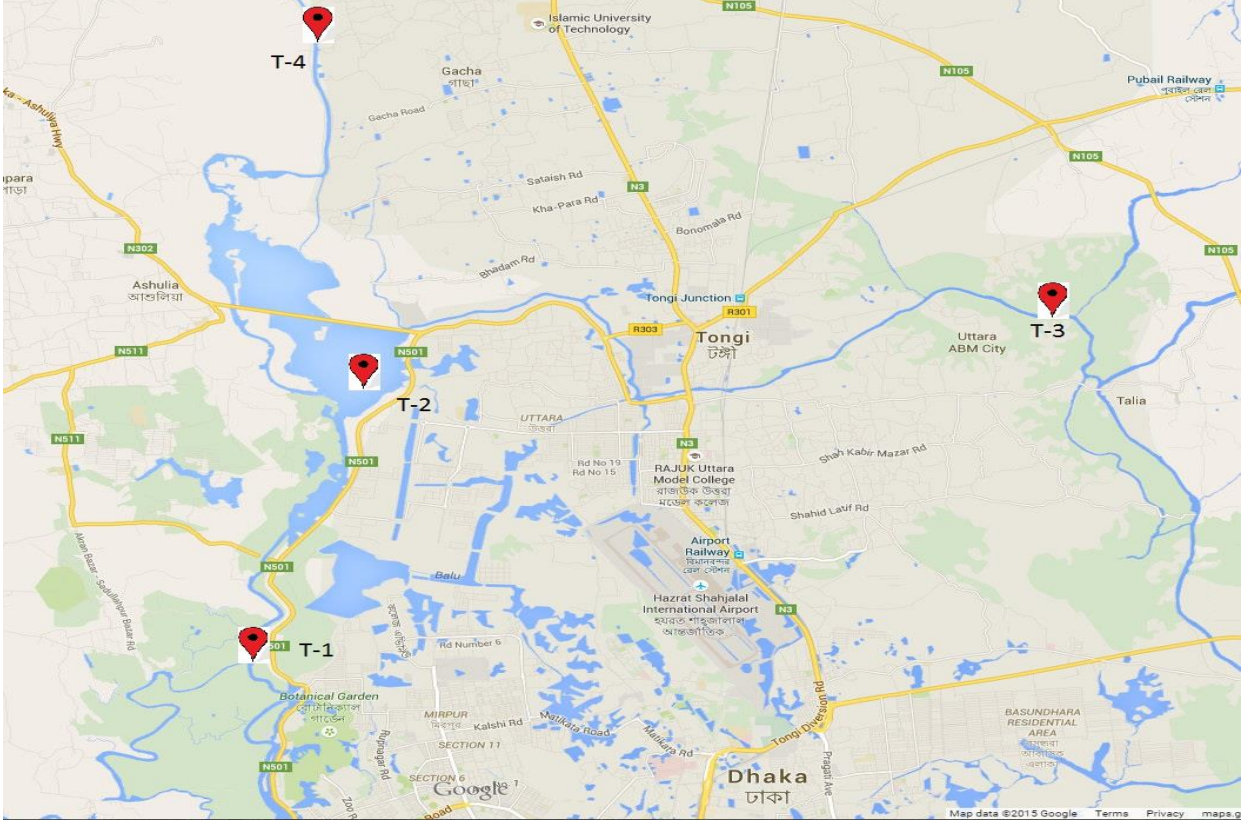


Fig. 3.1: Location map (satellite view)

Site View



Photo 3.1: Rupnagar



Photo 3.2: Ashulia station



Photo 3.3: Pubail



Photo 3.4: Gacha union

3.2 Sample Collection and Preservation:

Water sampling depth:

Water sample were collected at the stations at a depth of 1-1.5 ft. from the river surface.

Sample labels:

We used labels to prevent sample misidentification. After collecting the sample labeling tape was attached to the sampling bottle and then short information like location number, sample number etc. was written in the label. We used waterproof ink to provide the label information.

Field log book:

While collecting the samples, we recorded all the information about the location in the field log book. Sampling date, time, location, informative notes, water physical condition etc. was jotted down in the log book with a view to making the analysis process easier.

Water Preservation:

We use 600ml plastic water bottle for collection of sample. The samples were bottled carefully to avoid entrance of floating pollutants. Sample bottles were kept in ice box with ice while transporting them. In the laboratory the samples were placed inside the refrigerator for preservation.



Photo 3.5: Plastic bottle for sample collection (600ml plastic bottle)



Photo 3.6: Ice box for preserving sample while travelling



Photo 3.7: Sample preserved in refrigerator

3.3 Analysis of Water Sample

We have analyzed the water sample for the following parameters:

- pH
- Turbidity
- Color
- Hardness
- Electric Conductivity (EC)
- Total dissolved solids (TDS)
- Total suspended solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Free CO₂
- Chloride
- Mn
- Iron

3.3.1 pH

pH is the measurement of alkalinity or acidity. Solutions with a pH less than 7 are acidic and solutions with a pH greater than 7 are alkaline or basic. Pure water is neutral, being neither an acid nor a base. pH measurements are important in medicine, biology, chemistry, agriculture, forestry, food science, science, oceanography, civil engineering, chemical engineering, nutrition, water treatment & water purification, and many other applications. The pH of water affects the aquatic life as pH affects the solubility of many toxic chemicals.

3.3.2 Turbidity

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. Fluids can contain suspended solid matter

consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand, very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid. Turbidity is considered as a good measure of the quality of water.

3.3.3 Color

Color in water is primarily a concern of water quality for aesthetic reason. Colored water gives the appearance of being unfit to drink, even though the water may be perfectly safe for public use. On the other hand, color can indicate the presence of organic substances, such as algae or humic compounds. More recently, color has been used as a quantitative assessment of the presence of potentially hazardous or toxic organic materials in water. Highly colored water has significant effects on aquatic plants and algal growth. Light is very critical for the growth of aquatic plants and colored water can limit the penetration of light. Thus a highly colored body of water could not sustain aquatic life which could lead to the long term impairment of the ecosystem. Very high algal growth that stays suspended in a water body can almost totally block light penetration as well as use up the dissolved oxygen in the water body, causing a eutrophic condition that can drastically reduce all life in the water body. At home, colored water may stain textile and fixtures and can cause permanent damage, as the picture of the sink above shows.

3.3.4 Hardness

Hardness is correlated with TDS (Total dissolved solids). It represents total concentration of Ca^{2+} and Mg^{2+} ions, and is reported in equivalent CaCO_3 . Other ions (Fe^{2+}) may also contribute. Hardness expressed as mg/L CaCO_3 is used to classify waters from "soft" to "very hard". This classification is summarized in the table

Table: Relationship of Hardness Concentration and Classification of Natural water (F. Joseph; Jr. Malina)

Table 3.2: Classification of hardness

Hardness as mg/L CaCO₃	Classification
0 - 60	Soft
61 – 120	Moderately hard
121 - 180	Hard
>180	Very hard

Hardness observed for streams and rivers throughout the world ranges between 1 to 1000 mg/L. Typical concentrations are 47 mg/L to 74 mg/l CaCO₃.

Hardness is also an indicator to industry of potential precipitation of calcium carbonates in cooling towers and boilers, interference with soaps and dyes in cleaning and textile industries and with emulsifiers in photographic development. Hard water is less corrosive than soft. Treatment usually left to consumer (domestic, industrial, etc) depending on needs.

3.3.5 Electric Conductivity (EC)

The electrical conductivity of water estimates the total amount of solids dissolved in water -TDS, which stands for Total Dissolved Solids. TDS is measured in ppm (parts per million) or in mg/l. The electrical conductivity of the water depends on the water temperature: the higher the temperature, the higher the electrical conductivity would be. The electrical conductivity of water increases by 2-3% for an increase of 1 degree Celsius of water temperature. Many EC meters nowadays automatically standardize the readings to 25°C.

While the electrical conductivity is a good indicator of the total salinity, it still does not provide any information about the ion composition in the water. The same electrical

conductivity values can be measured in low quality water (e.g. water rich with Sodium, Boron and Fluorides) as well as in high quality irrigation water (e.g. adequately fertilized water with appropriate nutrient concentrations and ratios). The commonly used units for measuring electrical conductivity of water are: $\mu\text{S}/\text{cm}$ (microSiemens/cm) or dS/m (deciSiemens/m); where $1000 \mu\text{S}/\text{cm} = 1 \text{dS}/\text{m}$

3.3.6 TDS

Total dissolved solids (TDS) is a measure of salt dissolved in a water sample after removal of suspended solids. TDS is residue remaining after evaporation of the water. The TDS load carried in streams throughout the world has been estimated by Livingston (1963) to 120 mg/L. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter.

TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing. In the United States, elevated TDS has been due to natural environmental features such as mineral springs, carbonate deposits, salt deposits, and sea water intrusion, but other sources may include: salts used for road de-icing, anti-skid materials, drinking water treatment chemicals, storm water, and agricultural runoff.

In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Therefore, the total dissolved solids test provides a qualitative measure of the amount of dissolved ions but does not tell us the nature or ion relationships. In addition, the test does not provide us insight into the specific water quality issues, such as Elevated Hardness, Salty Taste, or Corrosiveness. Therefore, the total dissolved solids test is used as an indicator test to determine the general quality of the water. The sources of total dissolved solids can

include all of the dissolved cations and anions, but the following table can be used as a generalization of the relationship of TDS to water quality problems.

3.3.7 Alkalinity

Alkalinity is a measure of the acid-neutralizing capacity of water. It is an aggregate measure of the sum of all titratable bases in the sample. Alkalinity in most natural waters is due to the presence of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxyl (OH^-) anions. However, borates, phosphates, silicates, and other bases also contribute to alkalinity if present. This property is important when determining the suitability of water for irrigation and/or mixing some pesticides and when interpreting and controlling wastewater treatment processes. Alkalinity is usually reported as equivalents of calcium carbonate (CaCO_3). Alkalinity is important because it buffers the pH of water within the system. Without this buffering capacity, small additions of acids or bases would result in significant changes of pH, which could be deleterious for aquatic life. Alkalinity also influences the distribution of some organisms within aquatic systems. For example, most freshwater amphipod species are usually limited to low-medium carbonate waters, whereas some species such as *Gammarus lacustris* may be found in high carbonate waters (Pennak 1989).

The associated carbonates and bicarbonates comprising the majority of alkalinity may also impact the bioavailability and toxicity of several metallic environmental contaminants and pesticides to non-target and target organisms. For example, the bioavailability of copper-based, non-chelated pesticides generally decreases as alkalinity increases due to copper's reactions with the oppositely charged bicarbonate/carbonate ions and competition of the counter cations for active sites. The efficacy of these copper-based pesticides decreases as bioavailability decreases. For this reason, always consult the pesticide label for specific instructions regarding alkalinity of makeup water for pesticide

mixing. Failure to follow the recommendations may result in significant waste of material and personnel resources, with no resulting pest control benefits.

3.3.8 BOD₅

Biological oxygen demand (BOD₅), the most widely used parameter, is a measure of the amount of oxygen used by indigenous microbial population in water in response to the introduction of degradable organic material. This parameter depends on water characteristics: dilution, essential nutrients (N, P, K, Fe, etc), and bacteria seed. The 5-day BOD (BOD₅) is most widely used. The BOD₅ of natural water is related to the dissolved oxygen concentration, which is measured at zero time and after 5 days of incubation at 20 °C. The difference is the dissolved oxygen used by the microorganisms in the biochemical oxidation of organic matter. The BOD₅ can be calculated as $BOD_5 = D_0 - D_1$, in which the BOD₅ is in mg/L and D₀ and D₁ are the dissolved oxygen concentration in mg/L at time 0 and 5 days, respectively.

Typical concentration of BOD₅ for streams and rivers throughout the world are < 2 to 15 mg/ L and the observed range is < 2 to 65 mg/L. Biological oxygen demand (BOD), the most widely used parameter, is a measure of the amount of oxygen used by indigenous microbial population in water in response to the introduction of degradable organic material. This parameter depends on water characteristics: dilution, essential nutrients (N, P, K, Fe, etc), and bacteria seed. The 5-day BOD (BOD₅) is most widely used. The BOD₅ of natural water is related to the dissolved oxygen concentration, which is measured at zero time and after 5 days of incubation at 20 °C. The difference is the dissolved oxygen used by the microorganisms in the biochemical oxidation of organic matter. The BOD₅ can be calculated as $BOD_5 = D_0 - D_1$, in which the BOD₅ is in mg/L and D₀ and D₁ are the dissolved oxygen concentration in mg/L at time 0 and 5 days, respectively.

Typical concentration of BOD₅ for streams and rivers throughout the world are < 2 to 15 mg/ L and the observed range is < 2 to 65 mg/L.

3.3.9 Free CO₂

Carbon dioxide is vital in the life of plants and microorganisms. It is produced due to respiration of aquatic organisms. Free CO₂ in the present study was recorded maximum (1.33 mg/l ± 0.61) at Site 2 in comparison to Site 1, which was observed (1.19 mg/l ± 0.52). The lower values of Free CO₂ were observed in the month of Nov to February and higher values were recorded in the month of June to September at Site 2. The increase in carbon dioxide level during these months may be due to decay and decomposition of organic matter due the addition of large amount of sewage, which was the main causal factor for increase in carbon dioxide in the water bodies.

Joshi et al. (2009) reported that free carbon dioxide in the Ganga water was invariably present throughout the year. It fluctuated from 1.15 mg/l in winter season to 5.39 mg/l in rainy season. The free carbon dioxide was found to be maximum in monsoon season and minimum in winter season.

3.3.10 Chloride

Almost all natural waters contain chloride and sulfate ions. Their concentrations vary considerably according to the mineral content of the earth in any given area. In small amounts they are not significant. In large concentrations they present problems. Usually chloride concentrations are low. Sulfates can be more troublesome because they generally occur in greater concentrations. Low to moderate concentrations of both chloride and sulfate ions add palatability to water. In fact, they are desirable for this reason. Excessive concentrations of either, of course, can make water unpleasant to drink. Chloride is commonly found in streams and wastewater. Chloride may get into surface water from several sources including: Wastewater from industries and municipalities, Wastewater from water softening, Road salting, Agricultural runoff, Produced water from gas and oil

wells, The EPA Secondary Drinking Water Regulations recommend a maximum concentration of 250 mg/l for chloride ions and 250 mg/l.

3.3.11 Manganese(Mn)

Manganese occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. However, human activities are also responsible for much of the manganese contamination in water in some areas. Ambient manganese concentrations in seawater have been reported to range from 0.4 to 10 µg/l (ATSDR, 2000), with an average of about 2 µg/l (Barceloux, 1999). Levels in fresh water typically range from 1 to 200 µg/l (Barceloux, 1999). ATSDR (2000) reported that a river water survey in the USA found dissolved manganese levels ranging from <11 to >51 µg/l. The United States Geological Survey's National Water Quality Assessment Program has gathered limited data since 1991 on representative study basins around the USA. These data indicate a median manganese level of 16 µg/l in surface waters, with 99th-percentile concentrations of 400–800 µg/l (Leahy & Thompson, 1994; USGS, 2001). Higher levels in aerobic waters are usually associated with industrial pollution. The reducing conditions found in groundwater and some lakes and reservoirs favour high manganese levels; concentrations up to 1300 µg/l in neutral groundwater and 9600 µg/l in acidic groundwater have been reported (ATSDR, 2000). The National Water Quality Assessment Program data indicate that the 99th-percentile level of manganese in groundwater (5600 µg/l) is generally higher than that in surface waters, but the median level in groundwater (5 µg/l) is lower than that in surface water (USGS, 2001).

3.3.12 Iron(Fe)

The main naturally occurring iron minerals are magnetite, hematite, goethite and siderite. Weathering processes release the element into waters. Both mineral water and drinking water contain iron carbonate. In deep sea areas the water often contains iron fragments the size of a fist, manganese and small amounts of lime, silicon dioxide and organic compounds. Iron is applied worldwide for commercial purposes, and is produced in amounts of 500 million tons annually. Some 300 million tons are recycled. The main

reason is that iron is applicable in more areas than possibly any other metal. Alloys decrease corrosivity of the metal. Steel producers add various amounts of carbon. Iron alloys are eventually processed to containers, cars, laundry machines, bridges, buildings, and even small springs. Iron compounds are applied as pigments in glass and email production, or are processed to pharmaceuticals, chemicals, iron fertilizers, or pesticides. These are also applied in wood impregnation and photography. Aluminum waste products containing iron were discharged on surface water in the earlier days. Today, these are removed and applied as soil fillers. Iron compounds are applied in precipitation reactions, to remove compounds from water in water purification processes. The ^{59}Fe isotope is applied in medical research and nuclear physics.

CHAPTER 4: COAGULATION AND FLOCCULATION

4.1 Introduction

Coagulation and flocculation are essential processes in various disciplines. In potable water treatment, clarification of water using coagulating agents has been practiced from ancient times. As early as 2000 BC the Egyptians used almonds smeared around vessels to clarify river water. The use of alum as a coagulant by the Romans was mentioned in around 77 AD. By 1757, alum was being used for coagulation in municipal water treatment in England.

4.2 Coagulation

Coagulation is the process by which colloidal particles and very fine solid suspensions initially present in a wastewater are combined into larger agglomerates that can be separated via sedimentation, flocculation, filtration, centrifugation or other separation methods. Coagulation is commonly achieved by adding different types of chemicals (coagulants) to the wastewater to promote destabilization of the colloid dispersion and agglomeration of the resulting individual colloidal particles. It is an essential part of drinking water treatment as well as wastewater treatment.

4.3 Necessity of Coagulation

- Wastewaters often contain pollutants that are present in colloidal form
- In such cases the colloidal suspension may contain:
 - Organic materials
 - Dissolved and suspended particles
 - Metal oxides

- Insoluble toxic compounds
- Material producing turbidity
- This material must be removed prior to discharge
- Because of the nature of the colloidal suspension these particles will not sediment or be separated with conventional physical methods (such as filtration or settling)
- So to remove these dissolved and suspended particles coagulation process is used.

4.4 Additional Benefits of Coagulation

- The addition of some common coagulants to a wastewater not only produces coagulation of colloids but also typically results in the precipitation of soluble compounds, such as phosphates, that can be present in the wastewater.
- In addition, coagulation can also produce the removal of particles larger than colloidal particles due to the entrapment of such particles in the flocs formed during coagulation

4.5 Effects of Coagulation Treatment of Waste Water

4.5.1 Primary Effect

- Agglomeration and eventual removal of colloids (primarily responsible for wastewater turbidity)

4.5.2 Secondary Effect

- Precipitation of some chemical species in solution
- Agglomeration of larger particles in the floc

4.6 Flocculation

Flocculation, in the field of chemistry, is a process wherein colloids come out of suspension in the form of floc or flake; either spontaneously or due to the addition of a clarifying agent. *Flocculation* refers to the separation of a solution and most commonly, this word is used to describe the removal of a sediment from a fluid. In addition to occurring naturally, it can also be forced through agitation or the addition of flocculating agents. Many manufacturing industries use it as part of their processing techniques, and it is also extensively employed in water treatment.

4.7 Coagulation vs. Flocculation

- Although the words "coagulation" and "flocculation" are often used interchangeably they refer to two distinct processes
- Coagulation indicates the process through which colloidal particles and very fine solid suspensions are *destabilized* so that they can begin to agglomerate if the conditions are appropriate
- Flocculation refers to the process by which destabilized particles actually *conglomerate* into larger aggregates so that they can be separated from the wastewater

4.8 Classification of Coagulants

Coagulants can be classified as two main types,

- 1) Primary Coagulants and
- 2) Coagulant Aids

Primary coagulants neutralize the electrical charges of particles in the water which causes the particles to clump together. **Coagulant aids** add density to slow-settling flocs and add toughness to the flocs so that they will not break up during the mixing and settling processes. Primary coagulants are always used in the coagulation/flocculation

process. Coagulant aids, in contrast, are not always required and are generally used to reduce flocculation time.

Chemically, coagulant chemicals are either metallic salts (such as alum) or polymers. **Polymers** are man-made organic compounds made up of a long chain of smaller molecules. Polymers can be either **cationic** (positively charged), **anionic** (negatively charged), or **nonionic** (neutrally charged.) The table below shows many of the common coagulant chemicals.

Table 4.1: Common coagulant chemicals

Chemical Name	Chemical Formula
Aluminum sulfate (Alum)	$\text{Al}_2(\text{SO}_4)_3 \cdot 14 \text{H}_2\text{O}$
Ferrous sulfate	$\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$
Ferric sulfate	$\text{Fe}_2(\text{SO}_4)_3 \cdot 9 \text{H}_2\text{O}$
Ferric chloride	$\text{FeCl}_3 \cdot 6 \text{H}_2\text{O}$
Cationic polymer	Various
Calcium hydroxide (Lime)	$\text{Ca}(\text{OH})_2$
Calcium oxide (Quicklime)	CaO
Sodium aluminate	$\text{Na}_2\text{Al}_2\text{O}_4$
Bentonite	Clay
Calcium carbonate	CaCO_3
Sodium silicate	Na_2SiO_3
Anionic polymer	Various
Nonionic polymer	Various

4.9 Aluminum Sulphate (Alum)

There are variety of primary coagulants which can be used in a water treatment process. One of the earliest and still most extensively used is Aluminium Sulphate also known as alum. Alum can be bought in liquid form with a concentration of 8.3% or in dry form with a concentration of 17%. When alum is added to water it reacts with the water and results in positively charged ions.

Advantages of alum

- It readily dissolves with water
- It does not cause the unsightly reddish brown staining of floors, walls and equipment like ferric sulphate

Disadvantages of Alum

- It is effective only at certain pH range
- Good flocculation may not be possible with alum in some waters

4.10 Jar Test Procedure

- A wastewater sample is placed in a beaker and magnetically stirred. The pH must be adjusted to a desired valued (typically 6)
- A known amount of coagulant is added and the agitation is maintained at a high value for 1 minute to promote coagulation. Then the sample is agitated slowly for 3 minutes to promote flocculation. New additions are made until a visible floc is obtained;
- Using this concentration of coagulant, the coagulation experiment is now repeated at different pH values using a longer flocculation time (typically about 10 to 40 minutes), followed by settling with no agitation (15-60 minutes)
- The amount of residual pollutant in solution is measured at the end of each pH experiment. The optimal coagulation pH is obtained;

- Using this optimal pH value a new series of experiments is conducted in which the coagulant dosage is changed. The optimal coagulant dosage is obtained;
- Plots of residual pollutant concentration vs. pH and residual pollutant concentration vs. coagulant dosage can be constructed.

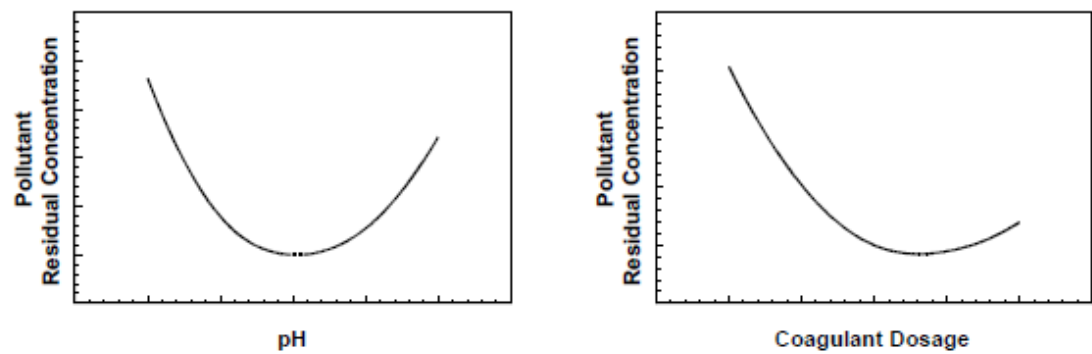


Fig. 4.1: (a) Plots of residual pollutant concentration vs. pH and (b) residual pollutant concentration vs. coagulant dosage

Chapter 5: RESULTS AND DISCUSSION

5.1: Pre-Treatment Test Results

Table 5.1: Pre-treatment test results

Locations	T-1		T-2		T-3		T-4		Standard
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	
Name of The Tests									
pH	7.35	7.89	7.63	8.21	7.66	7.93	6.93	7.79	6.5-8.5
Turbidity (FTU)	76.7	63	112	95	112	89	29.8	17.9	5.00
Color (PtCo)	481	335	681	420	496	300	580	354	0-15
Hardness (mg/l)	90	77	95	78	103	82	81	50	200-500
EC (μ s/cm)	960	325	1470	437	1147	212.7	730	117.8	1000
TDS (mg/L)	590	325	921	607	825	523	738	438	<1000
TSS (mg/L)	200	147	300	259	281	227	260	211	<20
BOD ₅ (mg/L)	24	17	13	11	23	19	13	9	<30
Free CO ₂ (mg/L)	30	22	25	19	40	31	28	23	< 50
Chloride (mg/L)	410.38	290.4	482.8	312	450.6	256.5	431.7	228.2	150-600
Mn (mg/L)	0.117	0.098	0.303	0.301	0.257	0.243	0.051	0.09	0.10
Fe (mg/L)	0.14	0.12	0.20	0.22	0.18	0.25	0.16	0.57	

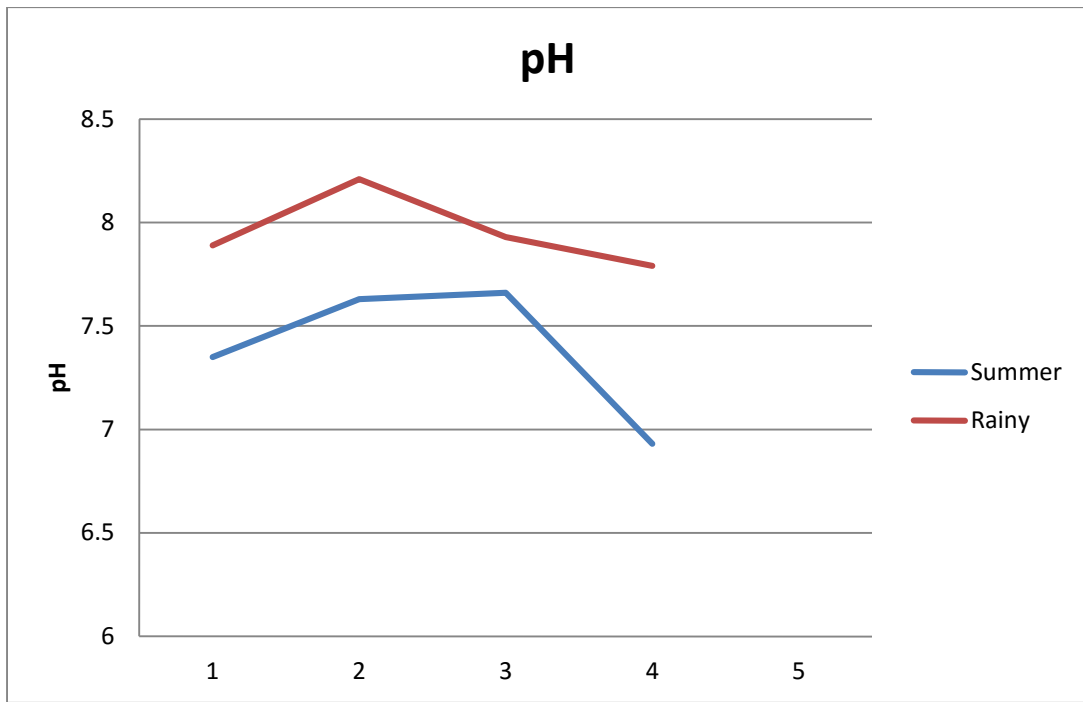


Fig. 5.1: Graph of pH (in summer and rainy season)

From the graph we can see that the pH of Turag river water samples varied from 6.93 to 8.21 which is within standard limit. According to DoE, the standard value of pH is 6 to 9. The normal range for pH in surface water systems is 6.5 to 8.5 and for groundwater systems 6 to 8.5 (Gob, Environment Conservation Rules, 1997). pH greatly affects biological activity. If extremely low or high pH occurs then most of the aquatic life will be dead. It also affects the solubility of many toxic chemicals, so the availability of these substances affects aquatic organisms. Most metal becomes soluble and more toxic when acidity increases. pH greater than 7 indicates water to be alkaline and below 7 indicates it to be acidic. The measurement of alkalinity helps to determine the corrosiveness of water. As the values are within standard limit so it has no negative impact on the water quality of Turag river

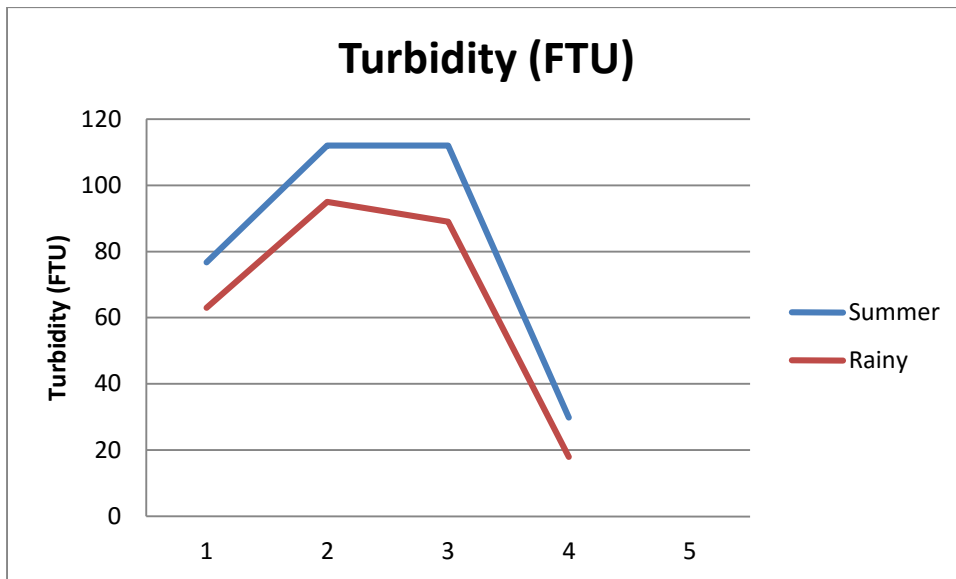


Fig. 5.2: Graph of turbidity (in summer and rainy season)

Turbidity is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. The table reveals that the turbidity value is higher than the standard for all the locations. Although it is less in rainy season but could not meet the standard. The standard value of turbidity is 5 FTU defined by WHO, where the table shows the lowest value is 17.9 FTU in location T-4 (Gacha Union) for rainy season. High turbidity can significantly reduce the aesthetic quality of river sources, having a harmful impact on recreation and tourism. It can harm fish and other aquatic life by reducing food supplies degrading spawning beds, and affecting gill function

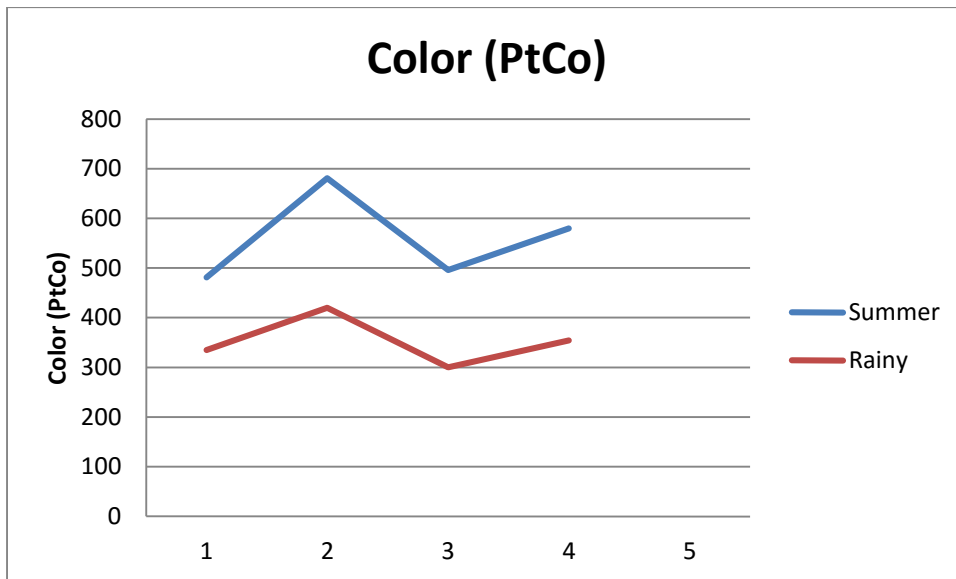


Fig. 5.3: Graph of Color (in summer and rainy season)

Water color is referred as apparent color and true color based on the type of solid material present in it. Apparent color is the color of the whole water sample, and consists of color due to both dissolved and suspended components. The standard limit of Color in surface water is 15 PtCo. From the table we can see that the color of Turag river water varies from 300 PtCo to 681, which is much more higher than the standard limit. Highly colored water has significant effects on aquatic plants and algal growth. Light is very critical for the growth of aquatic plants and colored water can limit the penetration of light. Thus highly a colored body of water could not sustain aquatic life which could lead to the long term impairment of the ecosystem.

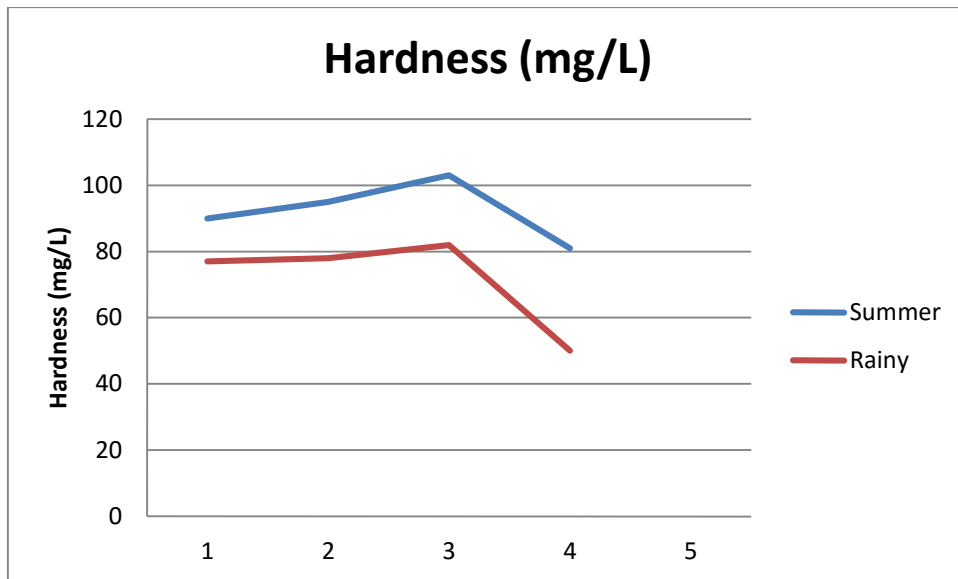


Fig. 5.4: Graph of hardness (in summer and rainy season)

Hardness is not caused by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, although other cations, although other cations (e.g. Aluminium, barium, iron, manganese, strontium and zinc) also contribute. Water containing calcium carbonate at concentrations below 60 mg/L is generally considered as soft; 60-120 mg/L moderately hard; 120-180 mg/L is hard; and more than 180 mg/L very hard(McGowan,2000).

The standard limit of hardness is within 200-500(mg/L). From the table we can see that the hardness of Turag river water varies from 50(mg/L) to 103(mg/L), Which is within the standard limit.

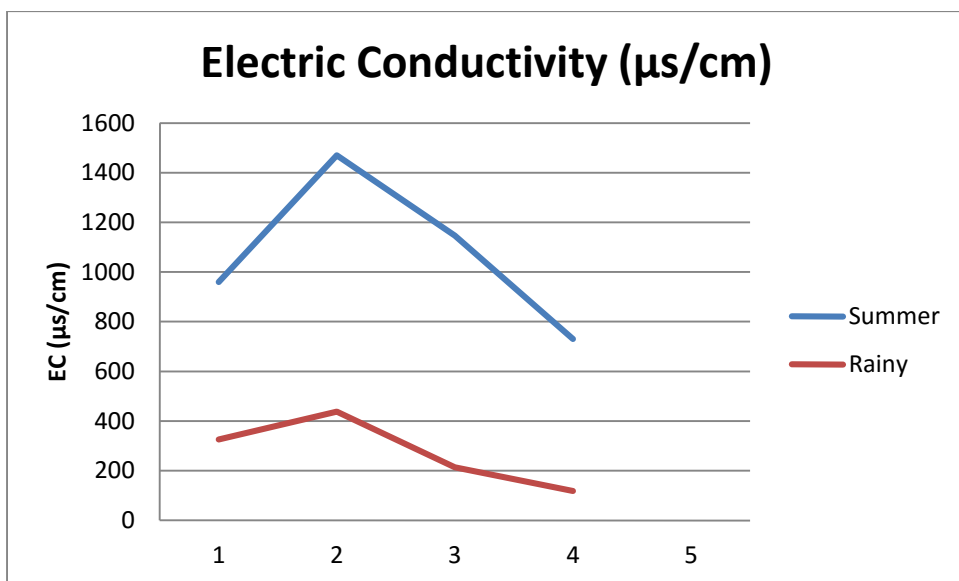


Fig. 5.5: Graph of electric conductivity (in summer and rainy season)

The electrical conductivity (EC) is usually used for indicating the total concentration of charged ionic species in water. All the four locations have shown limited electrical conductivity which is within the standard limit for both summer and rainy season, except two values exceeds the standard. These two values are in Ashulia Station and Pubail for summer season.

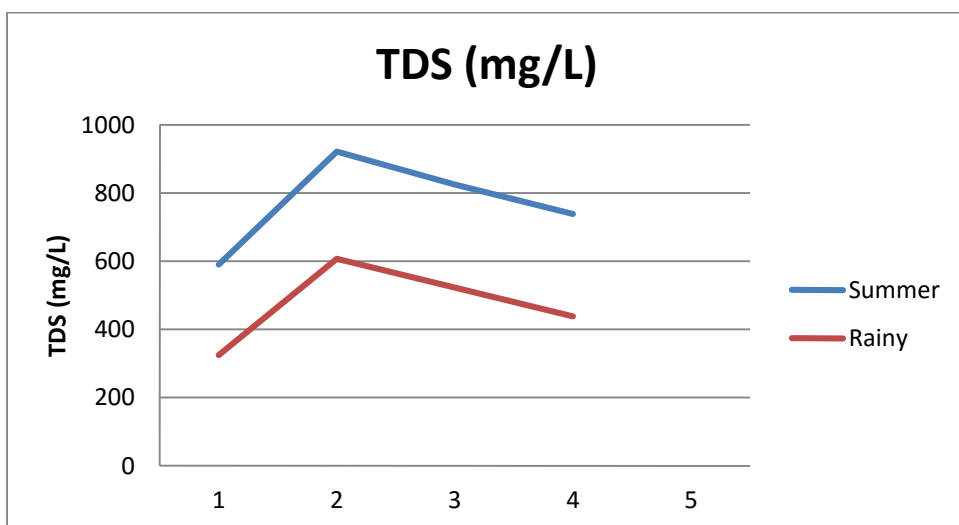


Fig. 5.6: Graph of TDS (in summer and rainy season)

The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/l; good, between 300 and 600 mg/l; fair, between 600 and 900 mg/liter; poor, between 900 and 1200 mg/liter; and unacceptable, greater than 1200 mg/liter (1). Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste. At Rupnagar source, TDS level is good for both summer and rainy season. But, at Ashulia source, TDS level is poor for summer which turns into good at rainy season. For Pubail & Gacha source, TDS level is fair for summer season but turns into good for rainy season.

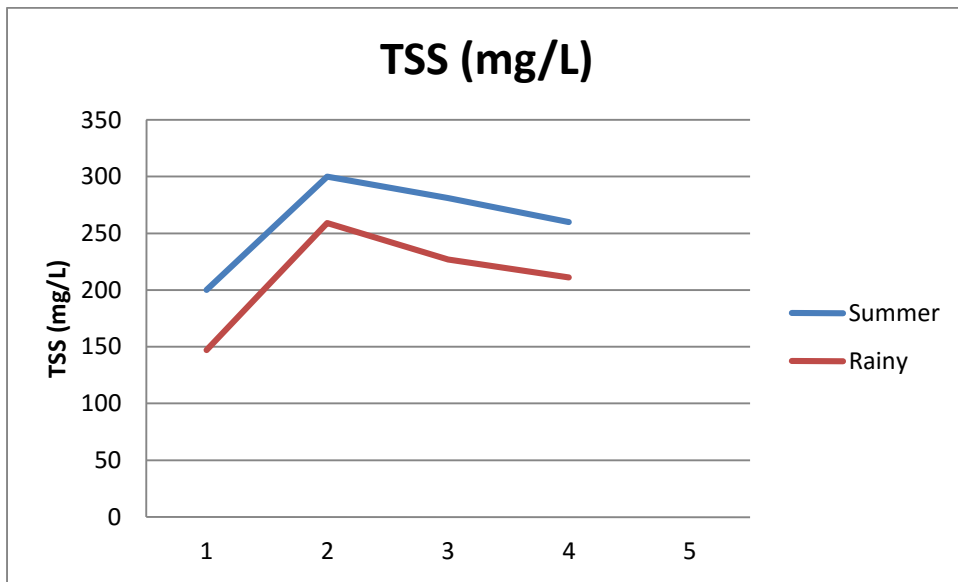


Fig. 5.7: Graph of TSS (in summer and rainy season)

In most situations, a total suspended solids(TSS) concentration below 20 mg/L appears clear, while levels over 40 mg/L may begin to appear cloudy. In this cases, TSS value of all sources exceeds the standard limit.

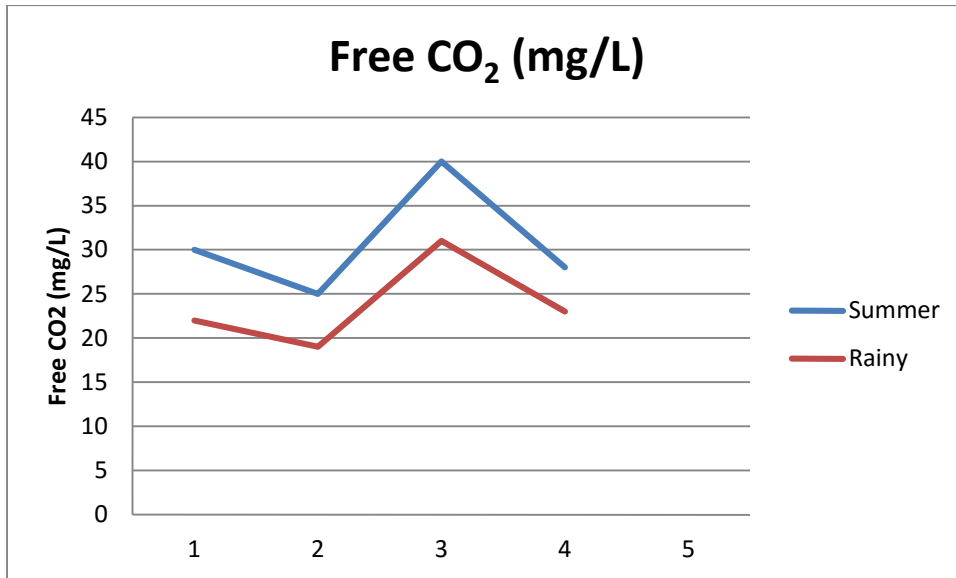


Fig. 5.8: Graph of free CO₂ (in summer and rainy season)

For free CO₂ the concentration is suitable for concentration up to 50 mg/l. From the graph we can see that the concentration is within the limit.

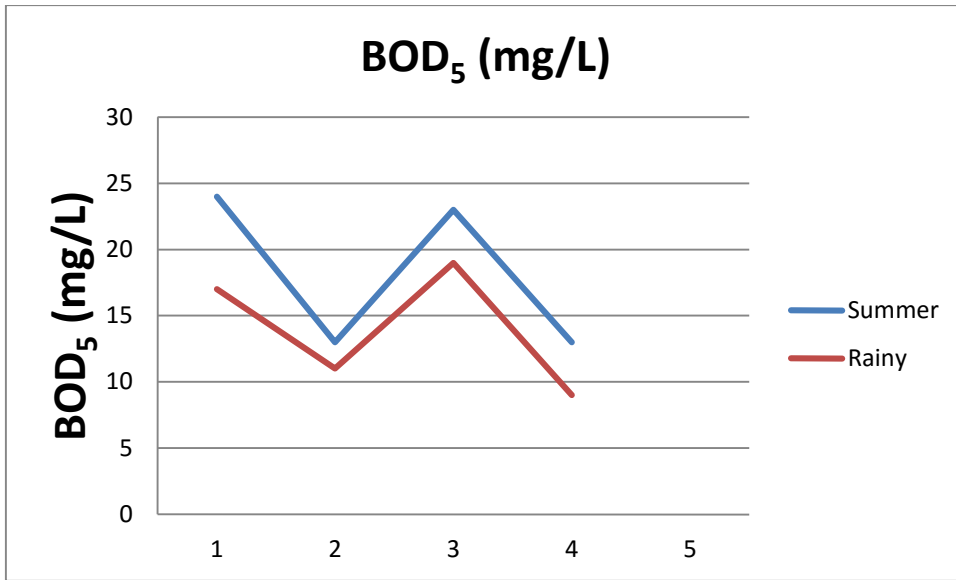


Fig. 5.9: Graph of BOD₅ (in summer and rainy season)

BOD₅ is an important factor and the results that graph is showing is within the limit.

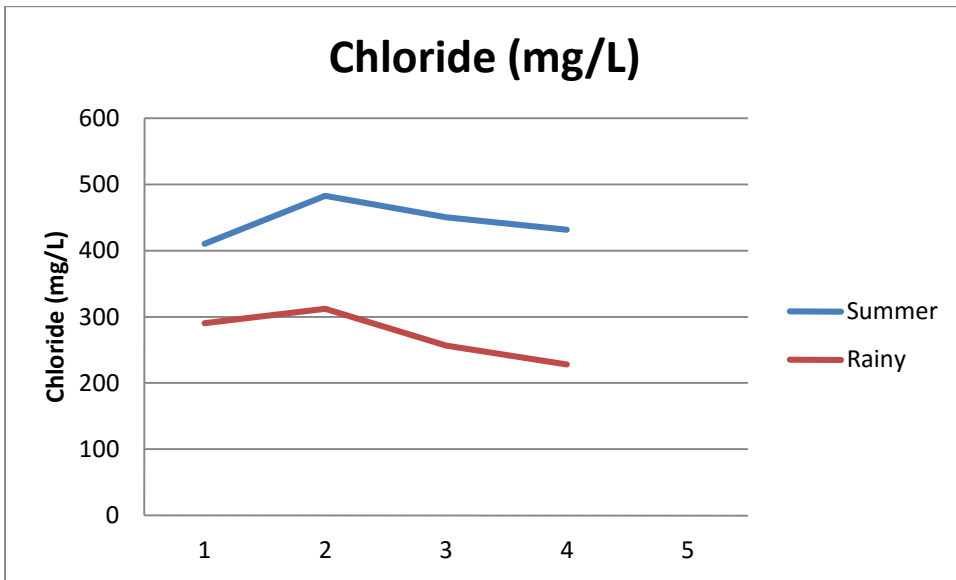


Fig. 5.10: Graph of chloride (in summer and rainy season)

The concentration of chloride found in surface water correlates with the proportion of impervious surfaces in the watershed. Chloride cannot be treated or filtered, so once salt is applied, chloride remains in the watershed until it is flushed downstream. The standard limit for Chloride is 150-600 mg/l and from the graph we can see that amount of chloride in water is within the limit.

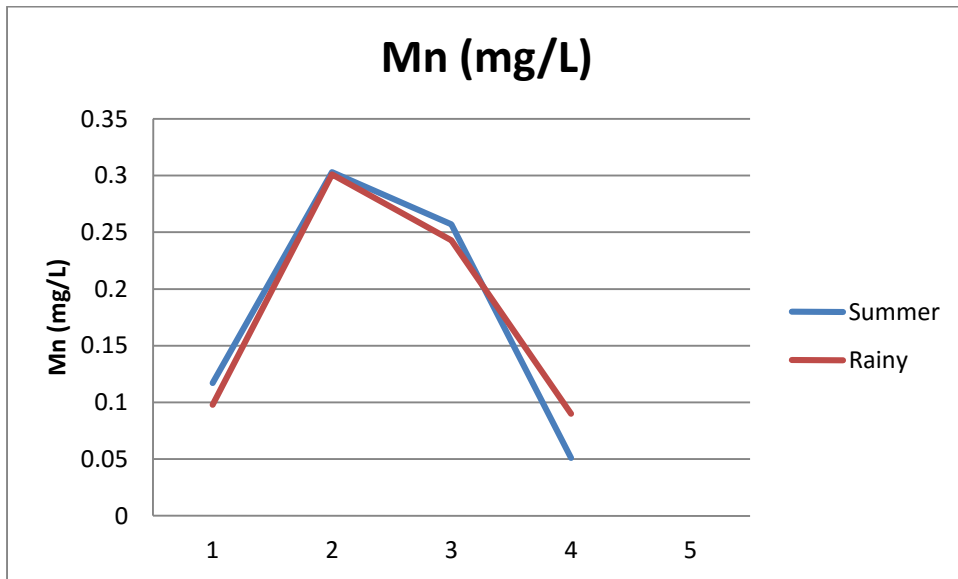


Fig. 5.11: Graph of Mn (in summer and rainy season)

Concentrations of dissolved Mn in natural waters that are essentially free of anthropogenic inputs can range from 0.01 to > 10 mg/L. Higher levels in aerobic waters are usually associated with industrial pollution some lakes and rivers favour high Mn levels. Standard limit for Mn in drinking water is .10 mg/l. The graph is showing that in most of the cases the amount of Mn is higher than the standard.

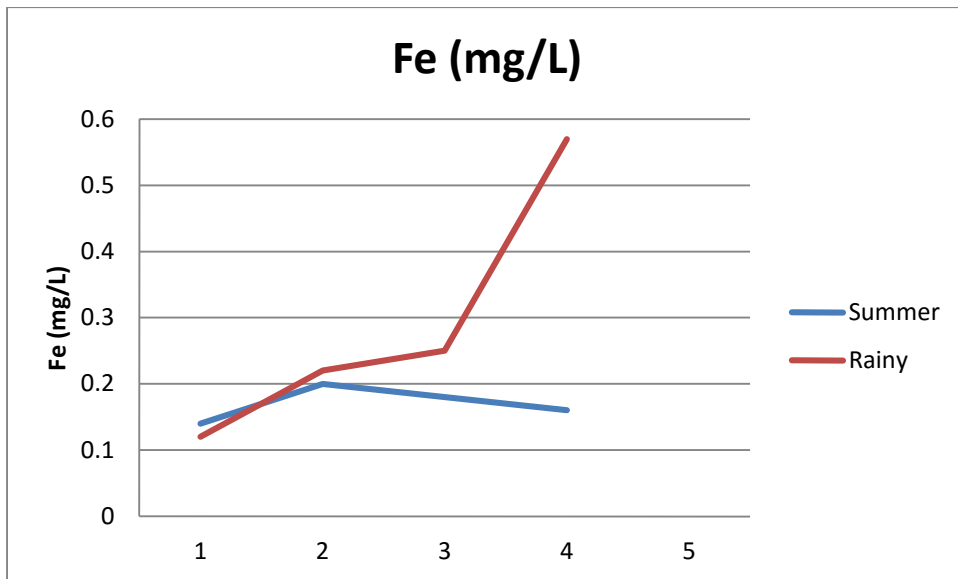


Fig. 5.12: Graph of Fe (in summer and rainy season)

Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day. The standard limit for Fe in Drinking is 0.3-1.0 mg/l. The graph shows that in most of the cases the amount of iron is within the standard limit.

5.2: After Treatment Results

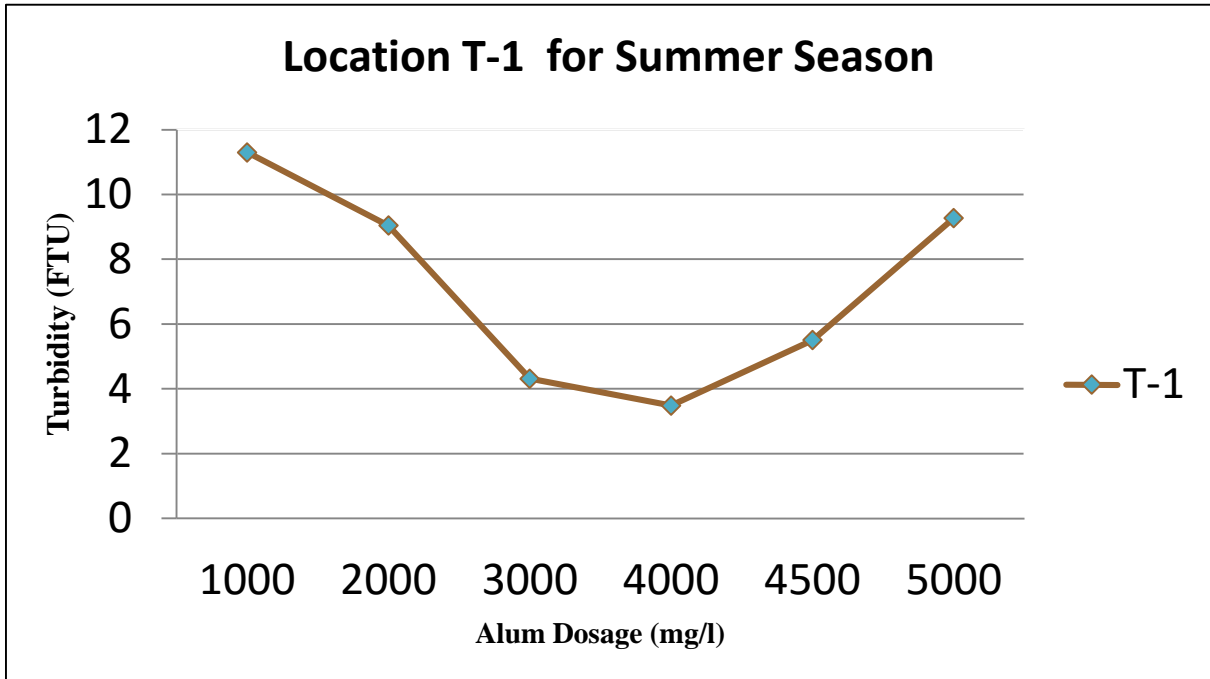


Fig. 5.13: Graph of turbidity after treatment at location T-1 in summer season

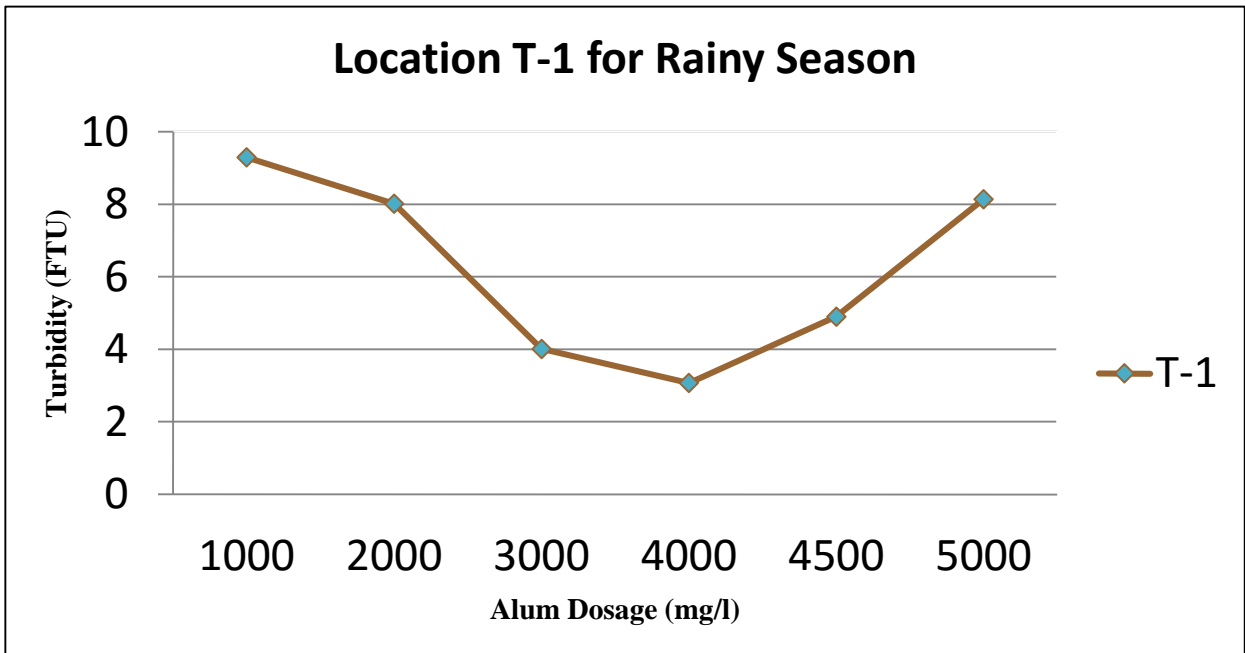


Fig. 5.14: Graph of turbidity after treatment at location T-1 in rainy season

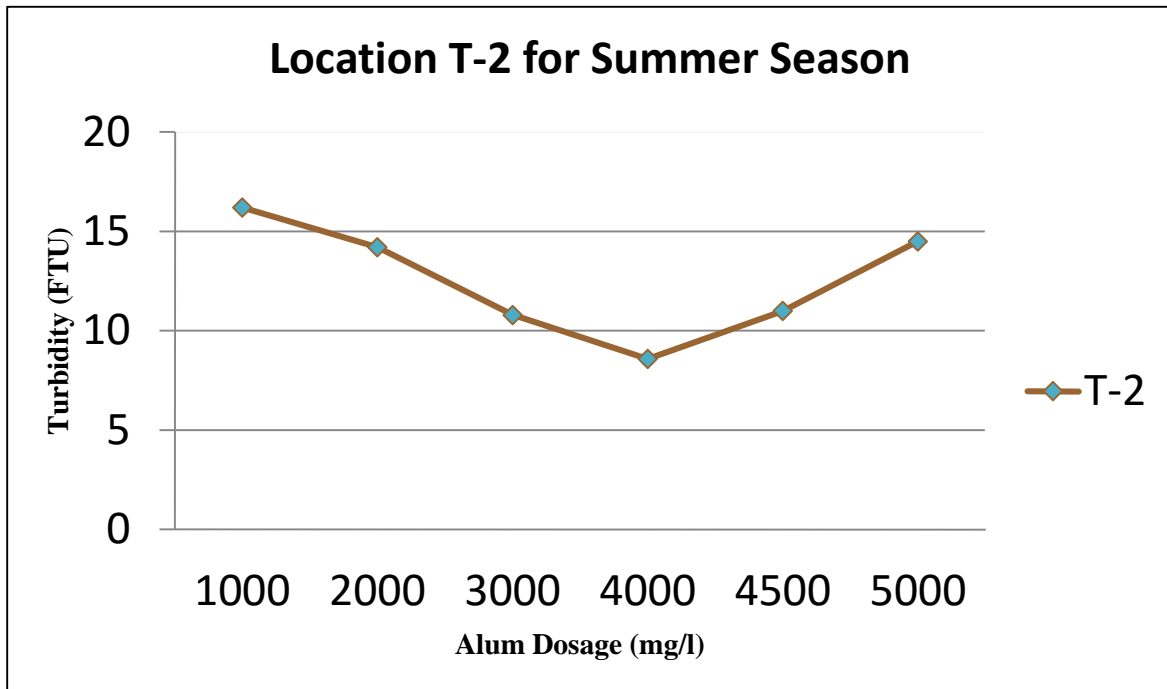


Fig. 5.15: Graph of turbidity after treatment at location T-2 in summer season

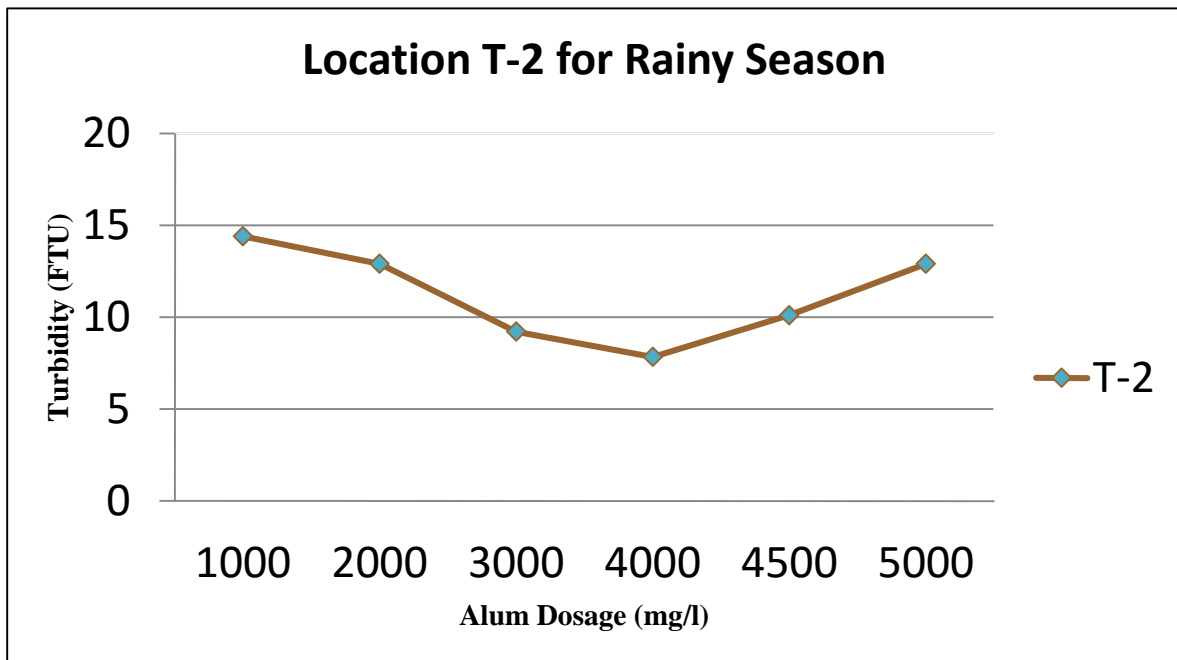


Fig. 5.16: Graph of turbidity after treatment at location T-2 in rainy season

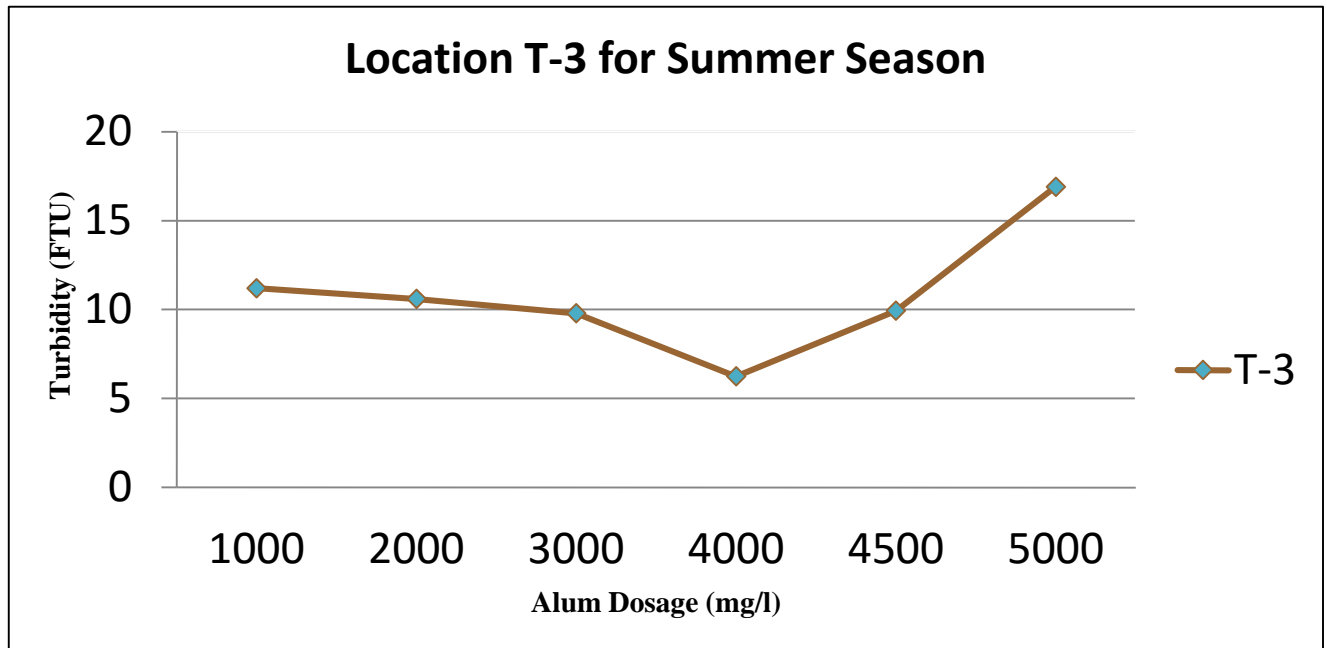


Fig. 5.17: Graph of turbidity after treatment at location T-3 in summer season

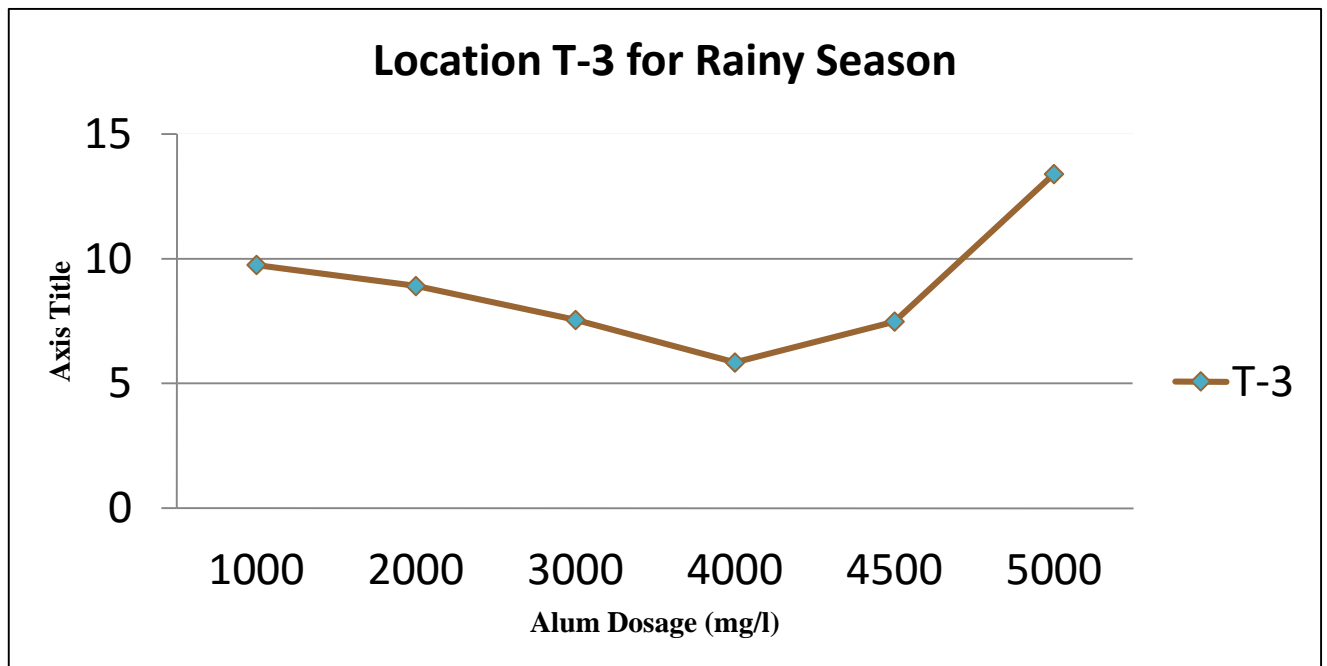


Fig. 5.18: Graph of turbidity after treatment at location T-3 in rainy season

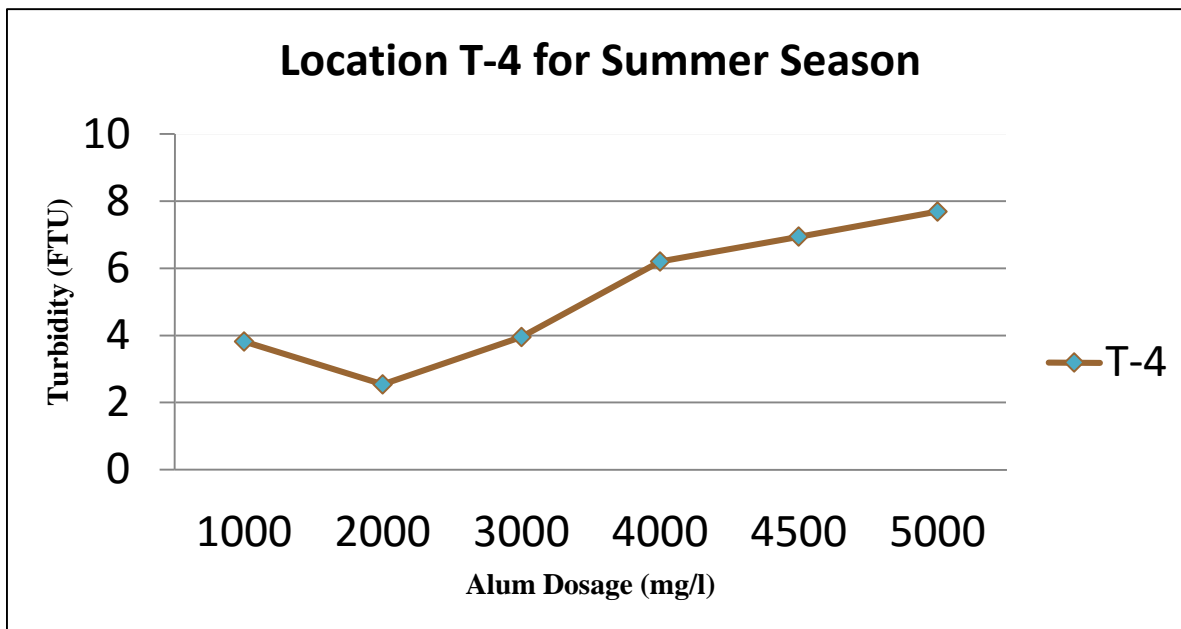


Fig. 5.19: Graph of turbidity after treatment at location T-4 in summer season

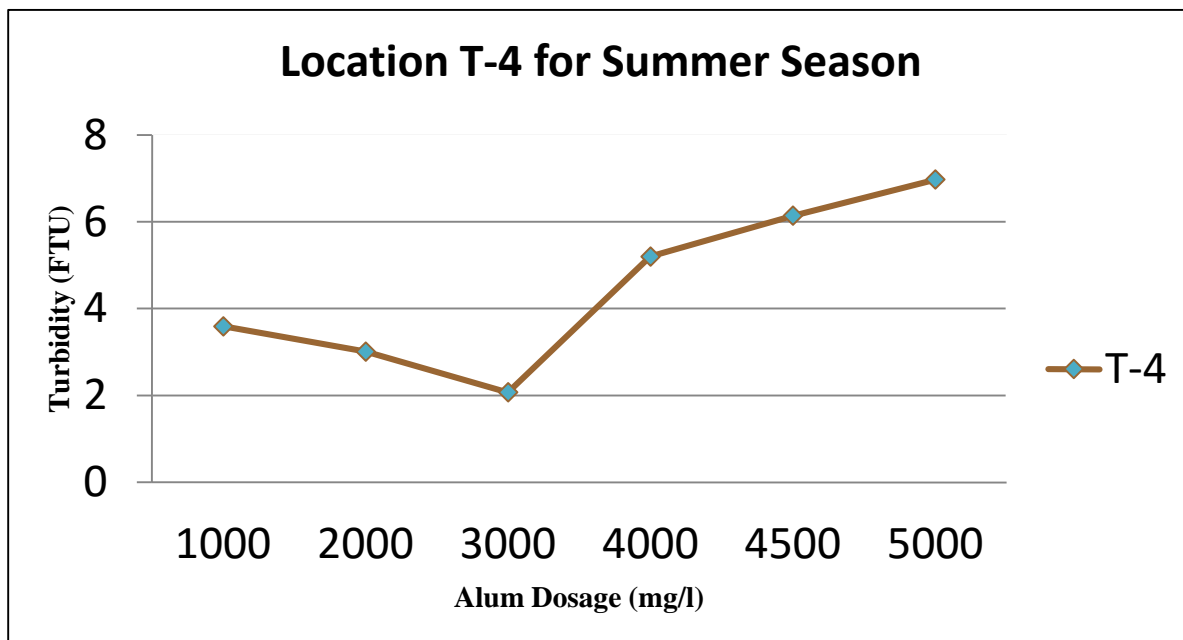


Fig. 5.20: Graph of turbidity after treatment at location T-4 in rainy season

The present paper deals only with the presentation and comparison of the results concerning the most optimum doses of the coagulants applied. Tests were conducted in order to assess the treatability of organics present in Turag River waters for both in summer & rainy season when the Turbidity concentrations were high in the river. Optimum conditions for near-maximum Turbidity removals were found to occur at pH levels between 6.93 and 8.21 and doses of alum is 4000 mg/L, which is very much higher from these graphs, it can be seen that the treatability of the organics generally decreased from March to August which correlated with the source water Turbidity values. Alum treatment resulted in higher (average 80%) removals of Turbidity. The data indicates a general trend towards lower treatability of organics in raw water from the summer to rainy period.

Chapter 5: Conclusions and Recommendations

Rainfall events had changed Turag River water quality and its organic constituents over the study period for summer and rainy season during a high rainfall climate cycle. We did the project find out the best possible site for Treatment. But the initial results showing that the river is too much polluted. And for the treatment of the water it needs a huge amount of Alum to perform Coagulation, although this is a bench scale test. To remove all the pollutants presents in the river water a lot of other tests need to be done to make the water potable. As we were doing initial study about the treatment of Turag River Water, among the four sites, the Gacha Union (T-4) site is more preferable.

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