Optimization Techniques Used In Waste Water Treatment

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Abstract : Waste-water is the combination of liquid or water-carried wastes originated from the sanitary conveniences of dwellings, commercial or industrial facilities and institutions, in addition to any ground water, surface water and storm water that may be present. Untreated wastewater generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socioeconomic concerns. Wastewater treatment is becoming even more critical due to diminishing water resources, increasing wastewater disposal costs. The municipal sector consumes significant volumes of water, and consequently generates considerable amounts of wastewater discharge. This review paper addresses the utilization of some eco-friendly and low cost technologies for sustainable development, with special reference to duckweed and algae technology. Studying the economics of different wastewater treatments is an essential prerequisite to the identification of cost-effective solutions.

1.0 INTRODUCTION

Water is one of the most important commodities which man has exploited than any other resource for the sustenance of life. Though evaporation and precipitation continuously purify water, pollution of water has emerged as one of the most significant environmental problems of recent times. The unique properties of water, which make it a universal solvent and a renewable resource, also make it a substance with greater tendency to get polluted. Water can be regarded as polluted when it changes its quality or composition either naturally or as a result of human activities, becoming less suitable for drinking, domestic, agricultural, industrial, recreational and any other uses for which it would have been otherwise suitable.

The overall aquatic environment is deteriorating both qualitatively and quantitatively owing to rapid urbanisation, industrialisation and growing population. Billions of liters of wastewater are generated everyday from various sources such as domestic sewage, industrial wastes, agricultural discharges containing detergents, toxic metals, thermal pollutants and radioactive materials in water. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose off these wastewaters safely. In the absence of suitable technology and facilities for treatment, they are inevitably discharged into fresh and &e waters. According to Trivedy (1998), about 7006.74 million litres of wastewater is generated per day in class I cities in India, out of which 59 percentage is collected and gets any kind of treatment while in class 11 cities about 1226.32 million litres of wastewater is generated per day and only 15.54 percentage of which is collected and 5.44 percentage gets any kind of treatment. Most of the smaller towns and cities do not have any treatment facilities. In Kerala, about 51.5 percent of the population is completely without any sanitary provision . Due . to the lack of proper sewerage and sanitation facilities and very often, the lack of sense of social responsibility, large quantities of wastewater of domestic and industrial origin are discharged directly into roadside drains, gullies, canals, and rivers or into the soil. The effects of these practices are clearly observable - surface waters in and nearby such areas are seriously polluted and cause repulsive stench. Groundwater sources are contaminated chemically and bacteriologically and are not utilisable for domestic purposes. Groundwater pollution is particularly serious as eighty percent of the domestic needs are met from this source.

Nature, by virtue of its self-purification capacity can assimilate pollutants to a large extent. In using an aquatic system as a receiving water body for wastewater dilution, its ability to assimilate the waste materials and restore its own quality is relied upon. The capacity of any water body to accomplish this is dependent on a number of factors including the volume, strength of the waste, hydrography of the receiving body, flow and amount of waste dispersion, climate, temperature and efficiency of the reoxygenation process (Schmitz, 1996). However the global increase in wastewater produced annually warrants treatment measures before discharge. Wastewater treatment although has great concern in public health, ecological, aesthetic and other points of view has a low priority, particularly in the developing countries whether are many competing demands on the limited mounts of funds available for development. The high cost of construction and operation of sewage effluent treatment plants is always a deterrent factor. Thus, within these limits, wastewater technology must be selected such that it has a bearrtag on local conditions such as climate, availability of land, equipment, power, skilled personnel and facilities for operation and maintenance of installations. Inappropriate transfer of technology from developed to developing countries can be avoided if the ability of simpler methods to obtain reliable and high quality treatment is recognized.

1.1 BACKGROUND OF THE STUDY

Wastewater generated from domestic sources is the principal source of water pollution in the country. Increasing production and disposal of wastewater have accelerated eutrophication of surface waters and contamination of ground water sources. The characteristics of wastewater discharge vary depending on the population, land use and per capita water consumption. These wastewaters must be treated prior to disposal so that they do not degrade the quality of receiving

water bodies. Conventional treatment systems include a combination of physical, chemical and biological processes to remove solids, organic matter, nutrients, heavy metals and pathogens from wastewater. These treatment processes are therefore not very attractive or economically justifiable especially in cash strapped third world countries. The total cost of such plants are generally greater than those of comparable biological systems primarily due to cost of automatic

control systems, sludge and chemical handling system and their Whence. The addition of chemicals to remove phosphorous and heavy metals as well as disinfection of water by chlorination has several af€er effects. The formation of carcinogenic trihalomethanes on chlorination poses health risks to man. The above factors have revived an interest in the use of eco-friendly alternatives for waste treatment.

Heavy metals are among the most toxic contaminants in the environment and are non-biodegradable. The world consumption of metals has shown an upward trend during the last century. Although the heavy metal content in urban drainage systems generally does not reach the proportions found in industrial effluents, the problems caused by their presence, particularly in areas with dense population are of public concern. Metal containing effluents have unfavorable effects on wastewater treatment such as the inhibition of nitrification and interference in biological oxidation, thus lowering the rate of biodegradation. In

addition, present technologies for metal removal from water, especially in low concentrations are highly expensive and cannot be afforded by third world countries. The emergence of biological systems for wastewater treatment represents an alternative, ecologically safe approach for the removal of pollutants. Biological treatment systems are living systems, which make use of aquatic flora and fauna to either directly consume the waste materials or breaking them down w and then removing it from solutions. Nature, by its delicately hctioning systems;offers the best example of bio-treatment. In any mtcr body, autotrophs take up nutrients and make themselves available for organisms higher in the food chain. The capacity of ecosystems that are dominated by aquatic filter feeders and plants to assimilate inputs of nutrients and organic matter has resulted in the use of such systems to wastewater treatment. Aquatic treatment systems utilise several species of plants, invertebrate zooplankton as well as fishes in monoculture and plyculture operations. Aquatic macrophytes are capable of very high rates of growth associated with high levels of nutrient uptake especially of nitrogen, phosphorous and also metals. This process can be enhanced with a regulated harvesting regime and encouraging new growth. The concept of using fishes to treat polluted waters is very recent, although treated sewage had been used to fertilize fishponds and increase production. The application of filter feeding invertebrates and fishes to consume organic matter in wastewater results in water quality improvement along with production of biomass, which can have alternative versatile uses.

A review of the work done during the past four decades on the utilization of aquatic weeds for wastewater renovation or pollution abatement reveals that, very little work has been done in India. Although there is a vague idea about the bioremediation ability of some aquatic flora and fauna, there has been very little studies carried out on the potential of individual plant and animal species. Screening of metal tolerant macrophytes is highly essential for low cost and efficient treatment of toxic wastewaters. The selection of appropriate species for treatment process is necessary for effective field application. This study therefore has been attempted to evaluate the potential of some aquatic flora and fauna as receptors and bioreactors or processors of waste. Investigations were mainly focussed on the efficiency of test species to remove the pollutants from water. These studies on natural systems to combat water pollution may be of vital interest to sanitary engineers and wastewater treatment managers.

1.2 WASTEWATER CHARACTERISTICS

Wastewater is the flow of used water from a community. The characteristics of wastewater discharges vary from location to location depending upon the population and industrial sector served, land uses and degree of separation between storm water and sanitary wastes. Domestic wastewater comprises spent water from kitchen, lavatory and bathroom as well as any other wastes that people may accidentally or intentionally pour down the drain. Daily per capita water use, quality of water supply and habits of the people also affect wastewater strength. Characterisation of wastewater is essential for an effective and economic waste management program. It helps in the choice of treatment methods, deciding the extent of treatment, assessing the beneficial uses of wastes and utilising the waste purification capacity of natural bodies in a planned and con~lledm anner, Physically, wastewater is usually characterised by a grey colour, musty odour, a solids content of about 0.1 percent and 99 percent water content. With the passage of time sewage becomes stale, dark in colour with a pronounced smell due to microbial activity. The solids can be suspended as well as dissolved. Dissolved solids can be precipitated by chemical and biological process. Suspended solids can lead to the development of sludge deposits and anaerobic conditions when discharged into the receiving waters. Temperature of sewage is use M in indicating the solubility of oxygen, which affects the rate of biological activity. Extremely low temperature adversely affects the efficiency of sedimentation. Usually sewage has higher temperature than that of the water supply. The hydrogen ion concentration of sewage is a valuable parameter in the operation of biological units. The pH of fresh domestic sewage is slightly more than the water supply to the community. However, onset of septic conditions may lower the pH while industrial wastes produce extreme fluctuations. Chemically, wastewater is composed of organic and inorganic compounds, as well as various gases. Organic components consist of carbohydrates, proteins, fats and greases, surfactants, oils, pesticides and phenols. Inorganic components consist of heavy metals, nitrogen, phosphorous, sulphur, chlorides, alkalinity and toxic compounds. In domestic wastewater, the organic and inorganic portion is approximately 50 percent respectively. Gases commonly dissolved in wastewater are hydrogen sulphide, methane, ammonia, oxygen, carbon dioxide and nitrogen. Biologically, wastewater contains various microorganisms, but the ones of concern are those classified as protista including bacteria, fungi, protozoa and algae. These are important in terms of wastewater treatment. Wastewater also contains many pathogenic organisms that generally originate from humans infected with disease or are carriers.

1.3 HISTORY OF WASTEWATER TREATMENT

Man's progress is interlinked with the history of water pollution. With the growth of civilisations, large settlements and towns began to appear giving rise to the problem of waste disposal. Several ancient cities developed elaborate sewer systems. Mohenjodaro and Harappa had drains for collection of wastewater. Wastewater disposal on land became a common practice almost throughout the world upto the seventeenth century. In the eighteenth century, as cities and towns

began to grow, their condition womned as garbage and wastes accumulated on the streets. Though the development of sewers in early nineteenth century cleared the streets, it increased the load on the rivers as wastewaters were directly discharged into them. This initiated its conversion (treatment) by natural chemical and biological processes into substances that could be cycled in the environment, thereby returning the resources to these ecosystems. Pollution problems only occurred when wastes that were generated from resources collected over a large area were returned into a small area of the environment, so that it was ecologically overloaded (Mitchell, et al. 1990). ' At the beginning of the twentieth century, it was realised that direct discharge of wastewater into streams caused health problems and must be treated to check pollution. The new engineering developments in handling and treating sewage remove organic matter, convert nitrogen, phosphorous and other chemicals to soluble forms. The reticulation of large amounts of waste to a single treatment work and the use of water as medium for disposal causes the carriage of immense quantities of biologically available nutrients into aquatic ecosystems, which, as a result often become eutrophicated.

1.4 CONVENTIONAL WASTEWATER TREATMENT PROCESS

Conventional wastewater treatment consists of a combination of physical, chemical and biological operations to remove solids, organic matter and nutrients from wastewater. The general terms used to describe different degrees of treatment, in order of increasing treatment levels are preliminary, primary, secondary and tertiary or advariced wastewater treatment. Disinfection to remove pathogens sometimes follows the last treatment step.

Preliminary Treatment

The objective of preliminary treatment is removal of coarse solids and other large materials often found in raw wastewaters, to enhance the operation and maintenance of subsequent treatment units. Preliminary treatment typically include coarse screening, grit removal and in some case comminution of large objects.

Primary Treatment

Primary treatment involves removal of settleable organic and inorganic solids by sedimentation, and removal of materials that float (scum) by skimming. Approximately 25-50 percent of the incoming BOD, 50-70 percent of the total suspended solids and *65* percent of the oil and pease are removed during primary treatment. Some organic nitrogen, organic phosphorous, and heavy metals associated with solids are also removed during primary sedimentation but colloidal and dissolved constituents is not affected. Primary sedimentation tanks or clarifiers may be round or rectangular basins, 3-5 meter deep, with hydraulic retention time between 2-3 hours. Settled solids (primary sludge) are normally removed from the bottom of tanks by sludge rakes to central well from where it is pumped to sludge processing units in small sewage plants. Sludge is processed in a variety of ways including aerobic digestion, storage in sludge lagoons, direct application to sludge drying beds and land application.

Secondary Treatment

Secondary treatment is the further treatment of the effluent from primary treatment to remove residual organic and suspended solids. In most cases, it follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matters using aerobic biological treatment processes by 'aerobic microorganisms (principally bacteria). These microorganisms metabolise the organic matter in the wastewater, thereby producing more microorganisms and inorganic end products (COz, NH, and H20). Several aerobic biological processes are used for secondary treatment differing primarily in the manner in which oxygen is supplied and rate at which organisms metabolise the organic matter. High rate biological processes are characterised by relatively small reactor volumes and high concentrations of microorganisms compared with low rate processes. High-rate processes include activated sludge processes, trickling filters or biofilters, oxidation ditches, and rotating biological contractors. Microorganisms must be separated from the treated wastewater by sedimentation to produce clarified secondary emuent. Secondary clarifiers (sedimentation tanks) remove the secondary sludge, which are contained with primary sludge for processing.

Tertiary Treatment

Tertiary or advanced wastewater treatment is employed when specific wastewater constituents that cannot be removed by secondary treatment must be removed. Individual treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals and dissolved solids.

1.5 CONVENTIONAL METAL TREATMENT PROCESS

Major objectives for removal of metals from aqueous solutions are toxicity removal that entails an environmental aspect and recovery of valuable metals, which involves a technological aspect. Various methods are available for heavy ' metal waste management. The commonly used methods include precipitation, ion exchange, adsorption, reverse osmosis, electrodialysis and evaporation. Apart from these methods others like foam floatation, liquid membrane techniques, solvent extraction and crystallisation can also be used for heavy metal removal. Metals can be precipitated either as hydroxides, carbonates or sulphides by adding the appropriate chemical to the aqueous metal solutions. Co-precipitation as well as adsorption onto flocculating agents, added to aid in settling the precipitates, appear to play a significant role in reducing the aqueous concentrations of the metal ions. Main limitations of this method are poor filterability of gelatinous sludge formed, production of large volumes of solid sludge requiring safe disposal and difficulty in achieving the permissible metal concentrations in the effluent especially in the presence of metal complexing agents in the wastewater. Ion exchange methods are employed for recovery of precious metals from effluents having very low metal concentrations. The most essential component of this process is an ion exchange resin, which can exchange H+ or ~aio+ns in lieu of the metal ions to be removed from the effluent. The effluent and resin are generally contacted in a packed bed reactor. The transfer of the toxic metal from liquid phase to solid phase is achieved within the bed, which gets exhausted in time and must be regenerated with acid or brine solution and reused for next cycle of metal removal. The major drawback of ion exchange process is its prohibitive cost.

Evaporation is a concentration process whereby water is evaporated from a solution, increasing the concentration of solute in the remaining solution. It was reported by Stenson (1978) that evaporation was used for separation of chromium acid from wastewater. Reverse osmosis is a pressure driven membrane separation process using membranes such as cellulose acetate and polyamide. The main advantage of reverse osmosis is its low energy requirement. .This is mainly used in plating industry for the treatment of rinse waters (Stenson, 1978). Electrodialysis is a membrane process where separation is accomplished

by the selective transport of ions through ion exchange membranes under the influence of an electrical potential applied across the membrane. It is a suitable technique for recovery of ionised species such as metal salts, cyanides or chromate from metal finishing wastewaters. Adsorption, which involves interaction of heavy metals with the sorbent surface, is one of the preferred methods for heavy metal removal. Main advantages of the process are sludge free operation, recovery of sorbed metal and reuse of sorbent, which makes the process economical.

1.6 NATURAL WASTEWATER TREATMENT SYSTEMS

As energy and construction costs have increased, new methods of wastewater treatment with potentially lower energy and capital costs have become increasingly attractive. Relatively simple wastewater technologies can be designed to provide low cost sanitation and environmental protection while providing additional benefits from the reuse of water. Effluents from conventional treatment kilities not only contain some unstable organic matter but also nutrients, which represent potential energy. It is therefore illogical to utilise external energy sources to dissipate energy stored within the wastewater. A natural treatment system makes use of aquatic animals and plants to improve the water quality and reclaim nutrients. In addition, persistent toxic environmental contaminants such as pesticides, aromatic hydrocarbons and metals can be removed from wastewater through biological treatment process. Natural wastewater treatment systems include algal mass culture, macrophyte treatment systems (including constructed wetlands) and aquaculture. Natural systems may be utilised to treat agricultural, domestic and industrial wastewater. Climate, soil conditions, space, waste characteristics and other factors relate to its applicability.

1.7 Algal Mass Culture

Algae are a diverse group of microorganisms that can perform photosynthesis. Of these, unicellular algae *(e.g.* green algae, blue green algae) are of interest in wastewater treatment and recycling process. They are tolerant to changes in environmental conditions. The biological reactions occurring in algal ponds reduce the organic content and nutrients of wastewater by bacterial decomposition and convert them into algal biomass. The algae utilise solar energy and nutrients (or by-products) from bacterial oxidation, perform photosynthesis and synthesise new algal biomass. The excess algae and bacteria need to be regularly removed from the system for efficient performance. Algal cells have high protein value and harvesting for animal and human consumption could be a financial incentive for wastewater treatment. Almost dl the organic wastes such as municipal wastewater, agricultural and human wastes can be treated by algal systems. The main attraction of algal mass cultures is their great versatility for integration into multi-use systems. Sewage and some industrial wastewaters *can* be used as culture medium for algae, without the addition of external nutrients, resulting in wastewater treatment. Algae that are commonly used include *Spirulina, ChZoreNa, Scenedesmus* and *Micractinm* Algae utilise ammonia as the principal source of nitrogen to build their proteinaceous cell material. About 80 percent of nitrogen in the waste is recovered in the algal cells. Phosphorous is not expected to become a limiting factor because of increased use of detergents in home and industry. Other nutrients are present in sufficient quantities in wastewater. The only constraint in algal technology is harvesting the small sized algae and it can be overcome by biological grazing using fish.

Material used In purification

- Algae
- Duckweed plants

Algae

Algae are photosynthetic organisms that occur in most habitats. They vary from small, single-celled forms to complex multicellular forms, such as the giant kelps that grow to 65 meters in length. There are five types of algae

1. Bacillariophyta
2. Chloropyta
3. Rhodophyta

Chlorophyta: division of the kingdom of protista consisting of the photosyntetic organism commonly known as *green algae*. The various species can be unicellular, multi-cellular, coenocytic (having more than one nucleus in a cell), or colonial. Chlorophyta are largely aguatic or marine, a few types are terrestrial, occurring on moist soil, on the trunks of trees, on moist rocks and in snow banks. Various species are highly specialized.

BACILLARIOPHYTA (diatoms) : Bacillariophyta are unicellular organisms that are important components of phytoplankton as primary sources of food for zooplankton in both marine and freshwater habitats. Most diatoms are planktonic, but some are bottom dwellers or grow on other algae or plants.

Rhodophyta: Rhodophyta , phylum (division) of the kingdom Protista consisting of the photosynthetic organisms commonly known as red algae. Most of the world's seaweeds belong to this group. Members of the division have a characteristic clear red or purplish color imparted by accessory pigments called phycobilins, unique to the red algae and the cyanobacteria. The chloroplasts of red algae are believed to be derived from cyanobacteria that formed an ancient symbiotic relationship with the algae. Of the approximately 4,000 known species of red algae, nearly all are marine; a few species occur in freshwater. Although red algae are found in all oceans, they are most common in warm-temperate and tropical climates, where they may occur at greater depths than any other photosynthetic organisms. The red algae are multicellular and are characterized by a great deal of branching, but without differentiation into complex tissues.

Duckweed

The duckweeds (genus *Lemna*) and related genera of the duckweed family (Lemnaceae) are the smallest flowering plants known. Individual plants consist of a single, flat oval leaf (technically a modified stem) no more than ¼ of an inch long that floats on the surface of still-moving ponds, lakes, and sloughs. The duckweed inflorescence, consisting of two microscopic staminate flowers and one tiny pistillate flower in a pouch-like sac, is almost never seen. Taxonomists believe the duckweed flowers are modified versions of the familiar leafy spathe and club-like spadix of the skunk cabbages, Jack-in-the-pulpit, calla lilies, and other members of the Arum family (Araceae), and indeed recent genetic studies suggest that duckweeds probably belong in an expanded version of the Arum family. Despite their diminutive size, the flowers of duckweeds can attract flies, mites, small spiders, and even bees that can spread the plant's pollen after being attracted by sticky secretions from the stigma. Duckweeds can also be "contact pollinated" through the collision of adjacent floating stems that jars pollen loose and on to the receptive stigma.

However, sexual reproduction is the exception rather than the rule in duckweeds. More often, species propagate asexually by forming chains of new stems from vegetative buds. Some duckweed can also produce specialized buds called turions that break off the parental stem and sink to the bottom of a lake or pond to over-winter. In spring, the starch-filled turions rapidly begin to metabolize, causing the structure to float back to the surface and grow into a typical duckweed stem.

Duckweeds grow quickly and produce new offshoots rapidly. Dense populations are an important food source for aquatic waterfowl and fish, but can become a nuisance to humans. Scientists have recently come to appreciate the fast growth rate of duckweeds, however, and the plants are being used for bioremediation of waterways with excessive amounts of phosphorus and nitrogen from agricultural runoff. Harvesting duckweeds as a crop can remove these pollutants and provide valuable livestock feed or fertilizer. Researchers are also developing techniques to use genetically modified duckweeds to synthesize insulin and other commercially valuable proteins (being plants, duckweeds are immune to animal viruses, making them invaluable in creating new biomedicines).

Nine duckweed species occur in North America. Common duckweed (*L. minor*) is the most widespread species, ranging across Canada and reported for all states except Hawaii and South Carolina. Identifying duckweeds to species can be tricky due to their minute size and absence of showy floral characters. Stem size and the number of roots (if any) distinguish other genera in the duckweefamily.

COMPARISON BETWEEN CONVENTIONAL AND NATURAL TREATMENT SYSTEMS

Conventional wastewater treatment relies on large scale plants. It is the preferred form of wastewater treatment in developed countries to a large extent because it is a well known technology in which civil engineers throughout the world are trained. It also minimises the area required for treatment per capita, which is an important consideration in urban areas, where space h at a premium. Conventional treatment also shortens the period that the wastewater effluent remgns in retention ponds and w can eeat more effluent over a period of time. However it has some disadvantages.

+ High capital and maintenance costs for plants and supporting infrastructure.
+ Retrofit or replacement of piping is labour and resource intensive
+ Not easily adaptable to new technologies or to varying scales
+ No alternative in the event of a disaster
+ Does not promote water conservation
+ Intensive use of nutrients and reuse of water is not optimised
+ Water quality benefits are inconclusive

Ecological alternatives to wastewater treatment are newer technologies often unknown and resisted by the engineering and public works committees. Their land requirements are greater than conventional plants and therefore can be feasible in sub-urban and rural areas. These systems are effective options in developing countries, which would like to keep mechanisation to minimum and use innovative methods appropriate to local conditions. Like conventional centralised treatment facilities, natural biological treatment systems can help reduce the level of biological oxygen demand and disease causing organisms in water bodies. In spite of land constraints, where feasible, ecological alternatives provide the following advantages:

+ Reclamation of nutrients
+ May be built on any scale
+ Flexible and adaptable to a variety of sites
+ Are more transparent
+ Provide useable open space for recreation
+ Low capital and maintenance costs
+ Little or no chemical use
+ Decentralised locations
+ Educational value

2.0 METHODOLOGY

2.1 Introduction

Evaluating the reliability of treatment processes and treatment facilities should be an important part of planning and design process for water resource, wastewater treatment and particularly wastewater reuse project. With the recent development in technology, particularly the development of membrane process and alternative disinfection process for water and wastewater treatment, there is an increasing need for a common methodology to evaluate the reliability of alternative processes and treatment facility that utilize different combination of those processes. To assess to reliability of a treatment facility, several aspect of treatment facility, several aspect of treatment must be considered including a methodical evaluation of both mechanical reliability and plant performance. A straightforward method for conducting this type of analysis is described herein along with description of application of this methodology. A discussion is provided highlighting the value of such a methodology for both the water quality engineer and risk manager. Some test perform during water treatment process are as follows.

- pH
- Suspended solids
- Turbidity
- Total Dissolved solid
- Total Phosphorus
- Kjeldahl Method
- Biological Oxygen Demand (BOD)
- Chemical oxygen demand
- Oil and Grease
- Dissolved Oxygen
- Total solids
- Total Coliform
- Faecal coliform
- Nitrite

2.1.1 pH

pH indicates the sample's acidity but is actually a measurement of the potential activity of hydrogen ions (H+) in the sample. pH measurements run on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids. Solutions with a pH above 7.0, up to 14.0 are considered bases. All organisms are subject to the amount of acidity of stream water and function best within a given range.

The technical definition of pH is that it is a measure of the activity of the hydrogen ion (H+) and is reported as the reciprocal of the logarithm of the hydrogen ion activity. Therefore, a water with a pH of 7 has 10-7 moles per liter of hydrogen ions; whereas, a pH of 6 is 10-6 moles per liter. The pH scale ranges from 0 to 14.

pH Value

0	7	14
Acidic	Neutral	Basic

2.1.2 Suspended solids

Suspended solids refer to small solid particle which remain in suspended in water as a colloid or due to the motion of the water. It is used as one indicator of water quality. Suspended solids are important as pollutants and pathogens are carried on the surface of particle. The smaller the particle in grams, and so the higher the pollutant load that is likely to be carried.

2.1.3 Turbidity

Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.

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 (the settable solids), 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.

DIGITAL TURBIDITY METER

2.1.4 Total Dissolved Solids

Total dissolved solids definition is that the solids must be small enough to survive filtration through a filter with two-micrometer (nominal size, or smaller) pores. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects) it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants.

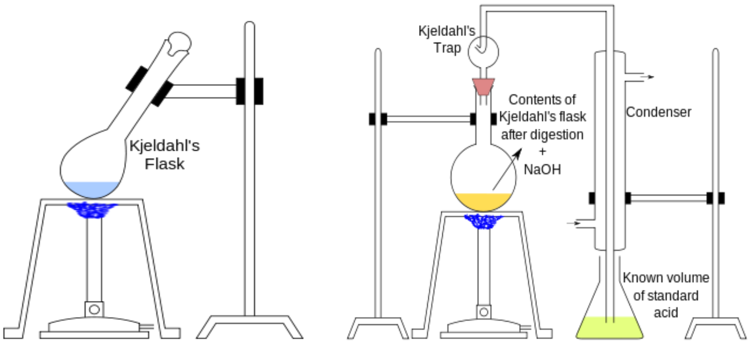
2.1.5 Total Phosphorus

Total Phosphorus is the sum of reactive, condensed and organic phosphorous. A significant fraction of condensed and organic phosphorous in treated wastewater represents phosphorous after chemical or biological treatment, available for removal by sedimentation or filtration.

2.1.6 Kjeldahl Method

Total Kjeldahl nitrogen or TKN is the sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+) in the chemical analysis of soil, water, or wastewater (e.g. sewage treatment plant effluent). The Kjeldahl method or Kjeldahl digestion (Danish pronunciation) in analytical chemistry is a method for the quantitative determination of organic nitrogen in chemical substances like ammonia developed by Johan Kjeldahl in 1883.

Kjeldahl Flask.



2.1.7 Biological Oxygen Demand (BOD)

Standard method for indirect measurement of the amount of organic pollution (that can be oxidized biologically) in a sample of water. BOD test procedure is based on the activities of bacteria and other aerobic microorganisms (microbes), which feed on organic matter in presence of oxygen. The result of a BOD test indicates the amount of water-dissolved oxygen (expressed as parts per million or milligrams per liter of water) consumed by microbes incubated in darkness for five days at an ambient temperature of 20°C. Higher the BOD, higher the amount of pollution in the test sample.

2.1.8 Chemical oxygen demand

In environment chemistry the COD test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers) or wastewater, making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution.

2.1.9 Oil and Grease

Oil and grease are mainly contributed from kitchen wastes, because they are major components of food stuffs such as butter, lard, margarine, and vegetable oils and fats. Fats are also commonly found in meats, seeds, nuts, and some fruits. Grease and oils are also discharged from industries like garages, workshops, factories etc. fats and oils are compounds of alcohol and glycerol with fatty acids. Such matter floats on top of the sedimentation tanks, often choke pipes in the winter, and clog filters. They thus interfere with functioning of normal treatment plants. The particles interfere with biological action and cause maintenance problems. Fats are among the more stable of organic compound and are not easily decomposed by bacteria. It is therefore necessary to detect and remove these from wastewater.

2.1.10 Dissolved Oxygen

Dissolved oxygen tests are performed during sewage disposal treatment processes. DO test performed on sewage before treatment, helps in indicating the condition of sewage. Its only very fresh sewage contains some DO, which is soon depleted by aerobic decomposition. Also, the DO in fresh sewage depends upon temp. If the temp. of sewage is more, the DO contain will be less. The Solubility of oxygen in sewage is 95% of that distilled water. The determination of D.O present in sewage is very important, because while discharging treated sewage into some river stream. It is necessary at least 4 ppm of DO in it.

2.1.11 Total Solids

Sewage normally contains very small amount of solid in relation to the huge quantity of water (99.9%). It only contains about 0.05 to 0.1% of total solids. Solids present in sewage may be in any of the four forms: Suspended solids, Dissolved solids, colloidal solids and settleable solids. The solids present in sewage comprise of both the organic as well as in organic solids.

Suspended solids are those solid which remain floating in sewage. Dissolved solids are those which remain dissolved in sewage just as salt in water. Colloidal solids are finally divided solids are that portion of solid matter which settles out, if sewage is allow to remain undistributed for period of 2 hours. Particles more than 1 micron in size are classified as suspended solids, particles less than 1 micron and up to 10^{-3} micron are classified as colloidal solids and particles smaller than 10^{-3} micron are considered as dissolved solids.

2.1.12 Coliform Bacteria

Coliform Bacteria defined as rod-shaped Gram-negative non-spore forming and motile or non-motile bacteria which can ferment lactose with the production of acid and gas when incubated at 35–37°C. Coliforms can be found in the aquatic environment, in soil and on vegetation; they are universally present in large numbers in the feces of warm-blooded animals. While coliforms themselves are not normally causes of serious illness, they are easy to culture, and their presence is used to indicate that other pathogenic organisms of fecal origin may be present.

2.1.13 Faecal Coliform

A Faecal coliform is a facultative anaerobic, rod-shaped, Gram-negative, non-sporulating bacterium. These bacteria generally originate in the intestines of warm blooded animals. Faecal coliform are capable of growth in the presence of bile salts or similar surface agents are oxidase negative and produce acid and gas from lactose within 48hours at 44 degree C. The term thermotolerant coliform is more correct and gaining acceptance over faecal colifirm. In general increased levels of faecal coliform provide a warning of failure in water treatment, a break in the integrity of the distribution system, possible contamination with pathogens.

2.1.14 Nitrite

Nitrite ion which has the chemical formula NO_2 is a symmetric anion with equal N-O bond lengths. Upon protonation the unstable weak acid nitrous acid is produced. Nitrite can be oxidized or reduced, with the product somewhat dependent on the oxidizing reducing agent and its strength. The nitrite ion is an ambidentate ligand, and is known to bond to metal centers in at least five different ways. Nitrite is also important in biochemically as a source of potent vasodilator nitric oxide. In organic chemistry the NO_2 group is present in nitrous acid esters and nitro compound. Nitrite is also used in the food production industry for curing meat.

2.2 Design Criteria For Waste Stabilization Pond

Elevation

MSL of Nagpur = 247.4

Waste stabilization Pond Design Criteria

Major Parameter	Types of ponds			
	Aerobic	Facultative	Anaerobic	Maturation
Depth (M)	0.3 -1.5	1.0-3.0	2.5-5	1-1.4
Detention (D)	4 – 40	5-30	15-50	5-18
Organic Loading (Kg/Ha/Day)	40 -160	15-150	200-500	0-15
BOD Removal Efficiency (%)	80 – 95	80-95	50-80	60-80
Algal Concentration (Mg/L)	40- 260	10-80	0-10	5-15

Table No 2.2

Aerial Loading OR Organic Loading

In India organic loading varying from 150 Kg/ha/Day to 325 Kg/ha/Day for latitude of 36 º N to 8 º N respectively are following **(IS 5611)**

Yield of photo synthetic O_2 and recommendation BOD loading

Latitude (N)	Yield of photo synthetic O_2 (Kg/ha/Day)	Aerial BOD loading (Kg/ha/Day)
36	150	150
32	175	175
28	200	200
24	225	225
20	250	250
16	275	275
12	300	300
8	325	325

Table No 2.3

Correction factor for Elevation = 1+0.003EL

Correction factor for Sky Elevation = 100/(100 + (3x (15/10)))

Detention Period

$$P_T = P_{20} (1.047^{T-20})$$

P_T = BOD removal rate constant for the pond at temp ^{0}C

La = influent BOD

Le = BOD removed in the effluent

$$t = (1 / P_T) \log_{10} (La/Le)$$

t = Detention Period in Days

Assume Design

Population = 56 No

Influent of BOD_5 =300 mg/l

Total BOD load applied = 300 x10^{-6} x 56x 135 x 56 = 2.268 kg/day

Total BOD load applied =2.268 kg/day

Aerial Loading OR Organic Loading
Areal BOD loading at 21 º N latitude (from table 2) = 238.88 kg/ha/day
Correction Factor for Elevation = 1+0.003EL
EL= Elevation
Correction Factor for Elevation = 1+0.00x (247.5/100) = 1.0075
Correction Factor for Sky Elevation =100/ (100 + (3x (14/10)))= 100/104.5
Corrected Aerial loading OR Organic loading = (238.88/1.0075) x (100/104.5)
= 226.91 kg/ha/day

Corrected Aerial loading OR Organic loading = 226.91 kg/ha/day

Pond Area = Total BOD load applied/ Corrected Aerial loading OR Organic loading
= (2.268 kg/day) / (226.91 kg/ha/day)
= 0.0091 Ha
= 99 m^2
Detention Period (t) = (1 / $P_{T)}$ log $_{10}$ (La/Le)
= (1 / 0.126) Log $_{10}$ (300 /30)
= 7.93 day = 8 days

Pond Area = 99 m^2

Detention Period (t) =8 days

Pond Volume and Pond Depth
Total inflow = 56 x 135 x 8 = 60.48 m^2
Depth (d) = Total inflow / Pond Area
= 60.48 / 99
= 0.61 m
Depth (d) =0.61 + F.B.
=0.61 + 0.2
Depth (d) =0.8 mt.

Depth (d) =0.8 mt.

Pond System
Pond Ratio = L: B Ratio =3:1
3B x B =0.0099
$3B^2$ = 99
B^2 = 99/3 =33
B = 5.74mt.
L = 3 x B = 3 x 5.74=17.23
L =17.23 mt.
Actual Pond Size = 18 x 6 x 0.8 m^3

B = 5.74mt

L = 17.23 mt

Actual Pond Size = 18 x 6 x 0.8 m^3 for Detention Time 8 Days

Flow in Pond = Actual Pond Size / Detention Time
= 18 x 6 x 0.8 / 8
= 10.8 m^3 / day
Flow in Pond = 10.8 l/min

Flow in Pond = 10.8 l/min

Design Summery
Actual Pond Size = 18 x 6 x 0.8 m^3 for Detention Time 8 Days
Corrected Aerial loading OR Organic loading = 226.91 kg/ha/Day
Population = 56 No
Actual pond size= 0.80 x 0.85 x .20 m^3 for Detention Time 8 Days
Velocity of flow is 0.017 l/min

2.3 General Standards For Discharge Of Environmental Pollutants Part-A: Effluents

The Environment (Protection) Rules, 1986 [Schedule – VI]

SR. No	Parameter	Standard			
		Inland surface water	Public sewer	Land for irrigation	Marine Coastal areas
1	Suspended solids mg/l	100	600	200	a)For process waste water- 100
2	Particulate size of suspended solids	Shall pass 850 micron IS sieve	-	-	a)Floatable solids, max 3mm b)Settable solids max. 850 micron
3	pH value	5.5-9.0	5.5-9.0	5.5-9.0	5.5-9.0
4	Oil & Grease mg/l	10	20	10	20
5	K jeldahi Nitrogen	100	-	-	100
6	BOD	30	350	100	100
7	COD	250	-	-	250
8	Nitrate	10 Mg/l	-	-	20mg/l

2.3.1 Load Based Standards - Part-C

Petroleum Oil Refinery

Sr. No.	**Parameter**	**Standard**
		Quantum limit in Kg/l 1,000 tons of crude processed
1	Oil & Grease	2.0
2	BOD 3 days, 27oC	6.0
3	COD	50
4	Suspended Solids	8.0

3.0 RESULT AND DISCUSSION

3.1 BOD

The BOD at the source remained within a following range (80-100) through the study period (fig. no 4.1), while at the outlet, it was in the range of (20-40) (Table No 4.1)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
BOD	90	90	90	60	60	30

Table No 4.1 BOD Parameter Value of Sampling Treatment System

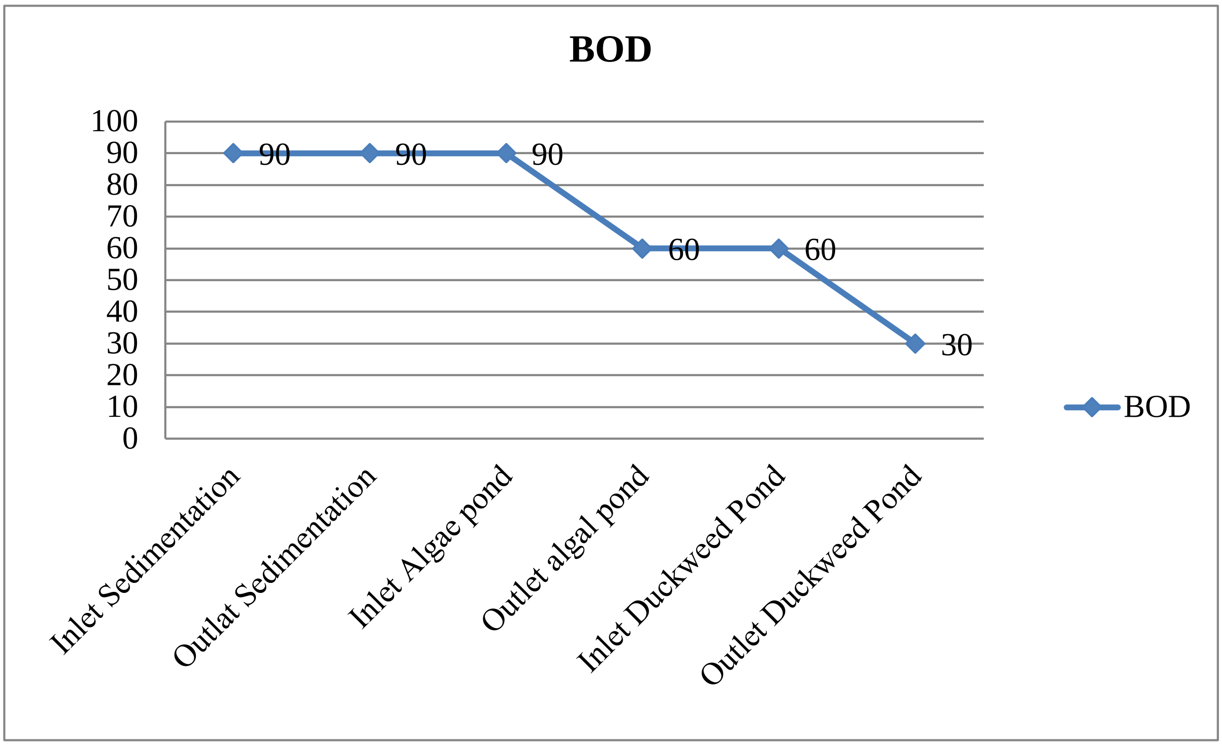


Figure No 3.1 Variation in BOD Content at Sampling Treatment System

3.2 COD

The COD at the source remained within a following range (170-190) through the study period (fig. no 4.2), while at the outlet, it was in the range of (59-79) (Table No 4.2)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
COD	180	180	180	119	119	69

Table No 3.2 COD Parameter Value of Sampling Treatment System

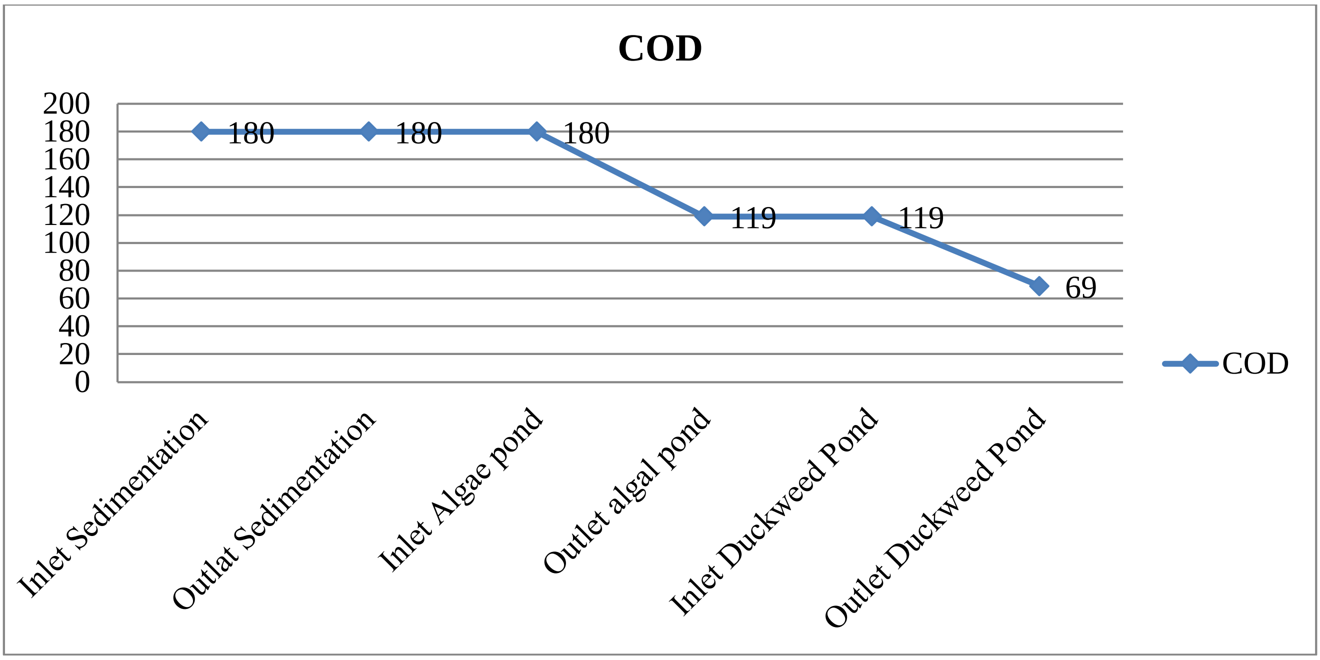


Figure No 3.2 Variation in COD Content at Sampling Treatment System

3.3 pH

The pH at the source remained within a following range (7-9) through the study period (fig. no 4.3), while at the outlet, it was in

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
pH	8	8	7.9	7.9	7.9	7.9

Table No 3.3 pH Parameter Value of Sampling Treatment System

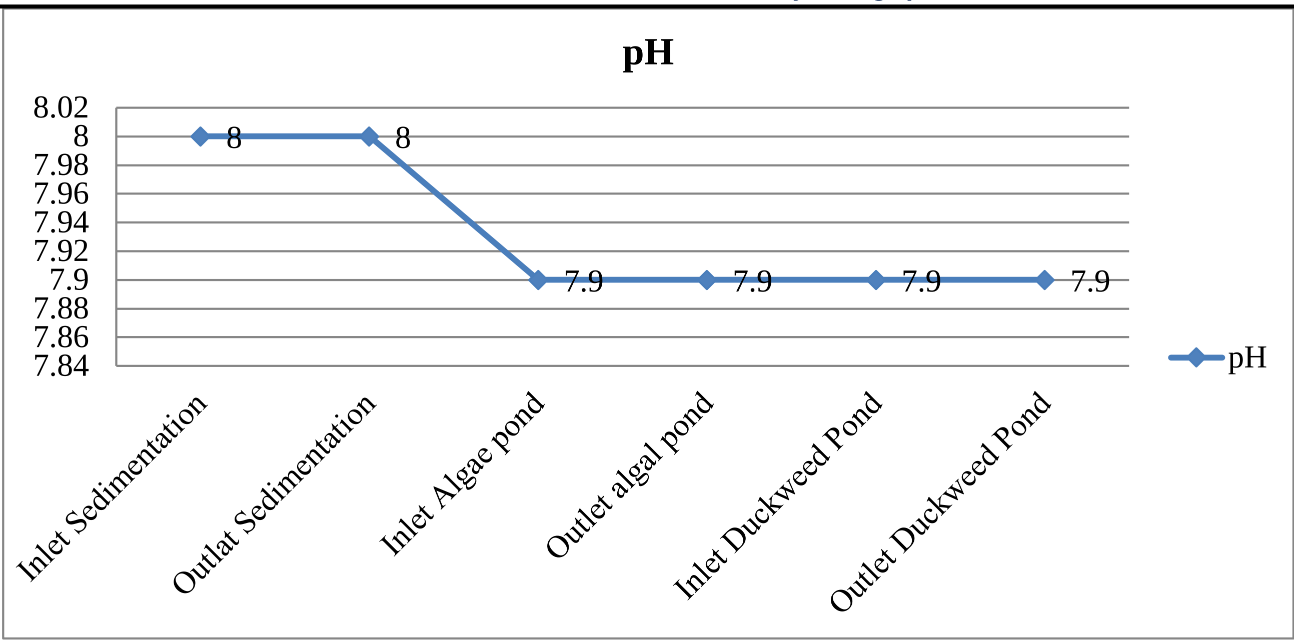


Figure No 3.3 Variation in pH Content at Sampling Treatment System

3.4 Dissolved Oxygen

The Dissolved oxygen at the source remained within a following range (170-190) through the study period (fig. no 4.3), while at the outlet, it was in the range of (59-79) (Table No 4.3)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Dissolved Oxygen	1.2	1.3	1.3	3.6	3.6	4.8

Table No 3.4 Dissolved Oxygen Parameter Value of Sampling Treatment System

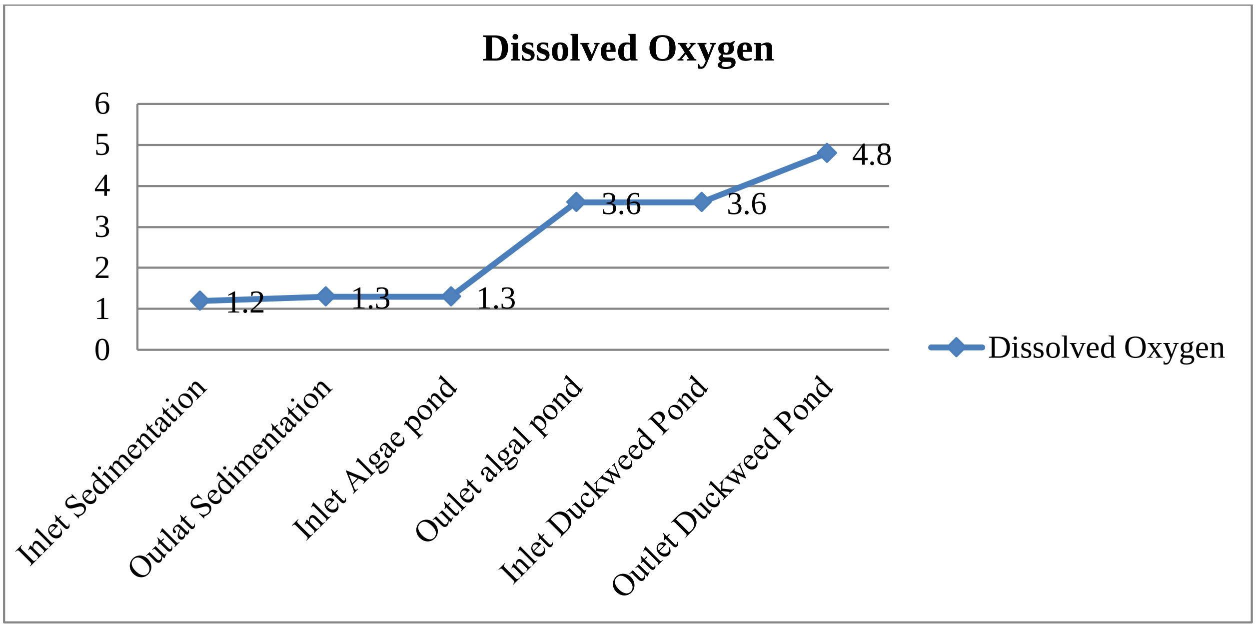


Figure No.3.4 Variation in Dissolved Oxygen Content at Sampling Treatment System

3.5 Suspended Solid

The Suspended solid at the source remained within a following range (130-150) through the study period (fig. no 4.5), while at the outlet, it was in the range of (60-80) (Table No 4.5)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Suspended Solid	140	100	100	90	90	70

Table No 3.5 Suspended Solid Parameter Value of Sampling Treatment System

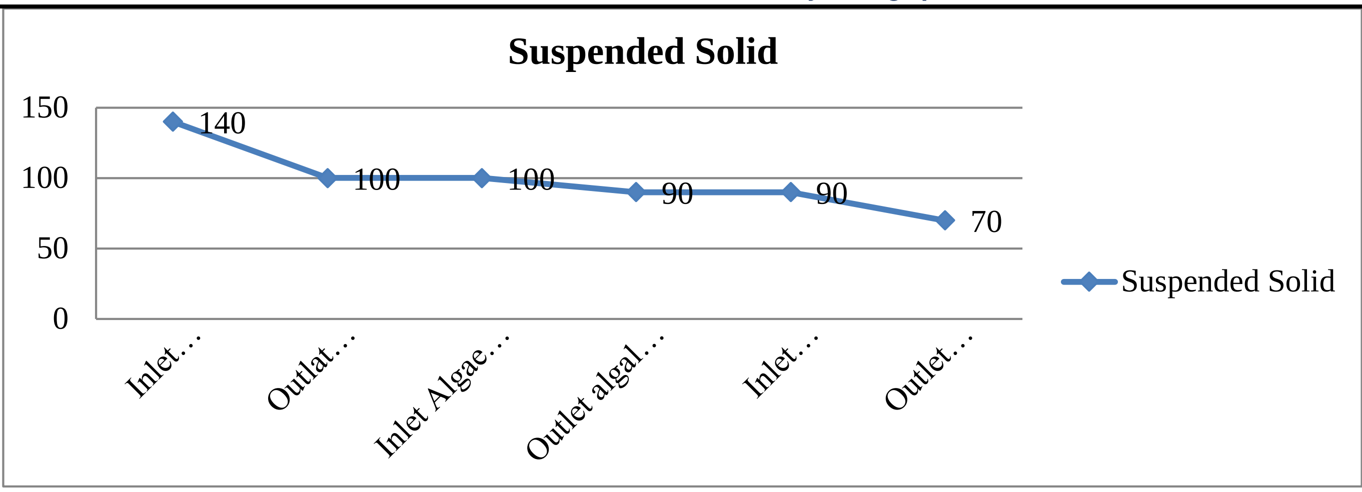


Figure No 3.5 Variation in Suspended Solid Content at Sampling Treatment System

3.6 Total Dissolved Solid

The Total dissolved solid at the source remained within a following range (835-855) through the study period (fig. no 4.6), while at the outlet, it was in the range of (297-317) (Table No 4.6)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Total Dissolved Solid	845	564	564	450	450	307

Table No 3.6 Total Dissolved Solid Parameter Value of Sampling Treatment System

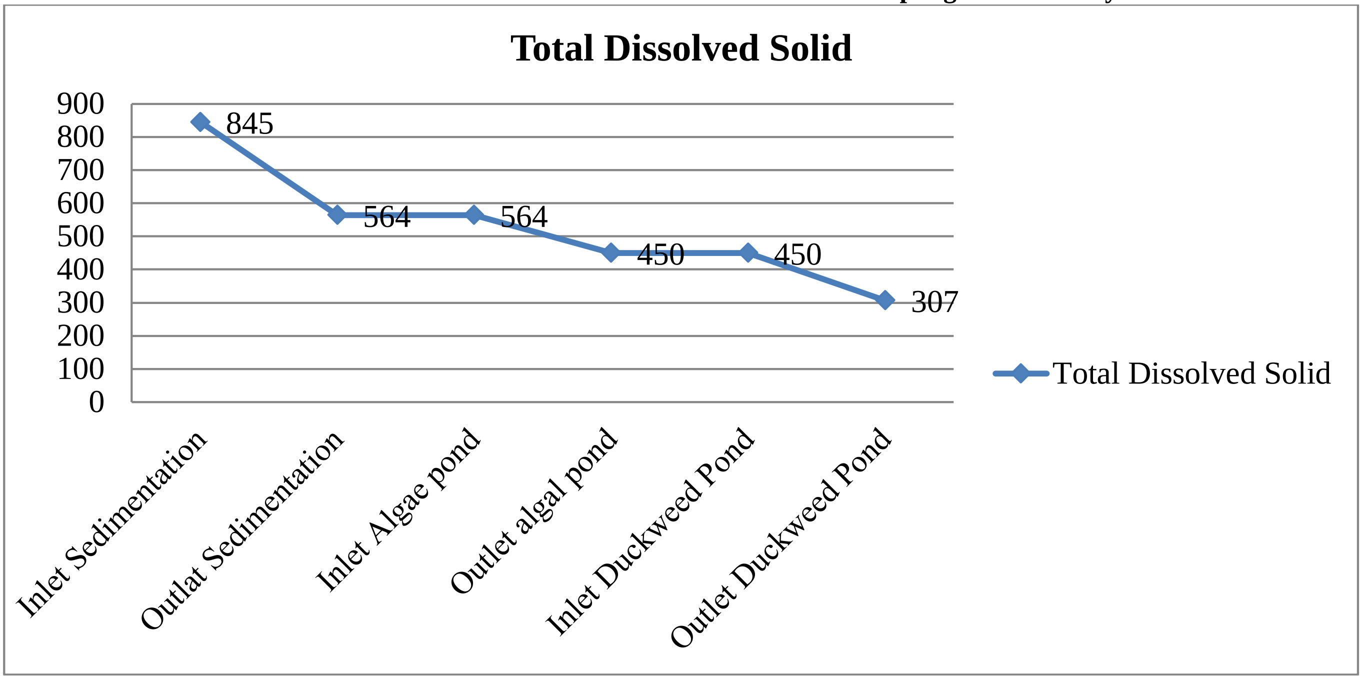


Figure No 3.6 Variation in Total Dissolved Solid Content at Sampling Treatment System

3.7 Total Solids

The Total solid at the source remained within a following range (1040-1060) through the study period (fig. no 4.7), while at the outlet, it was in the range of (650-670) (Table No 4.7)

Parameter	Inlet Sedimentation	Outlat Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Total Solids	1048	1040	1040	878	878	660

Table No 3.7 Total Solids Parameter Value of Sampling Treatment System

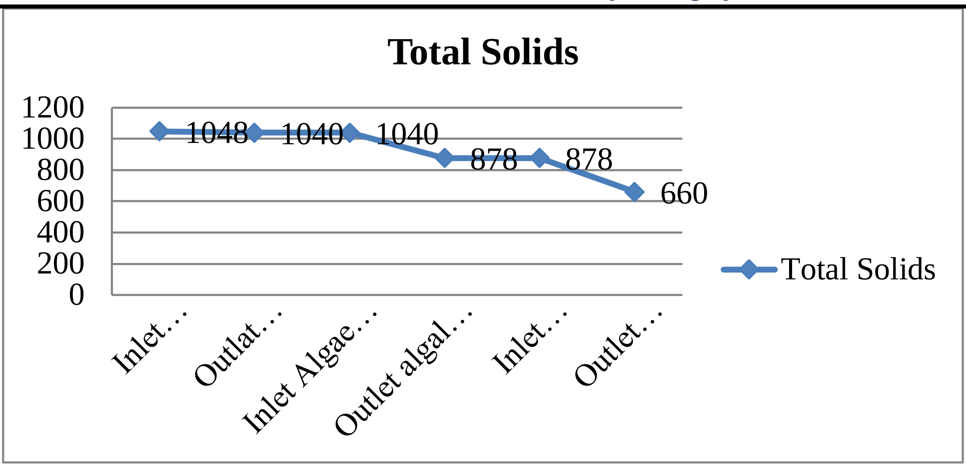


Figure No 3.7 Variation in Total Solids Content at Sampling Treatment System

3.8 Turbidity

The Turbidity at the source remained within a following range (80-100) through the study period (fig. no 4.1), while at the outlet, it was in the range of (20-40) (Table No 4.1)

Parameter	Inlet Sedimentation	Outlat Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Turbidity	11	9	9	7	7	4.6

Table No 3.8 Turbidity Parameter Value of Sampling Treatment System

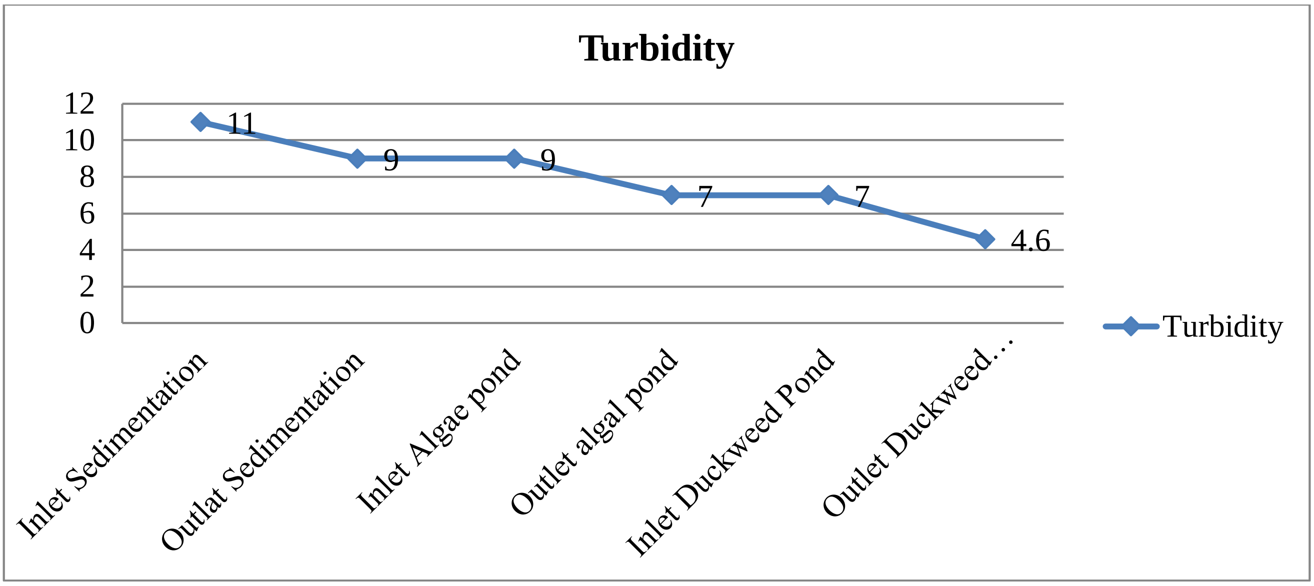


Figure No 3.8 Variation in Turbidity Content at Sampling Treatment System

3.9 Total Phosphorus

The Total phosphorus at the source remained within a following range (1.5-1.7) through the study period (fig. no 4.9), while at the outlet, it was in the range of (1.0-1.5) (Table No 4.9)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Total Phosphorus	1.614	1.614	1.614	1.42	1.42	1.31

Table No 3.9 Total Phosphorus Parameter Value of Sampling Treatment System

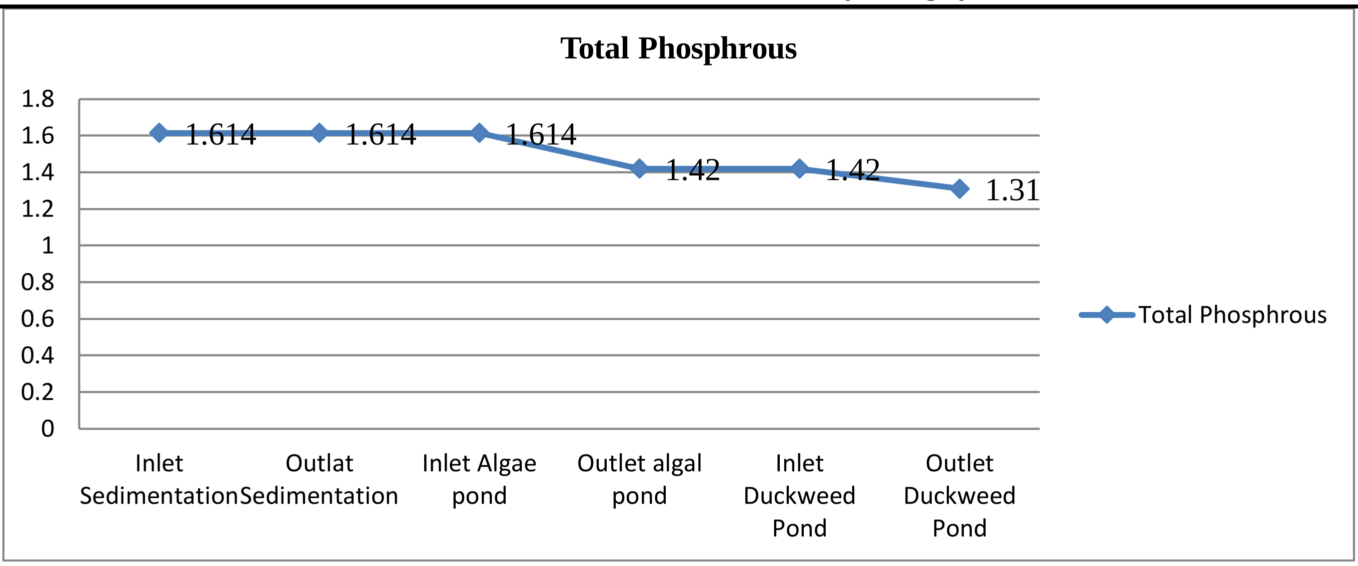


Figure No 3.9 Variation in Total Phosphorus Content at Sampling Treatment System

3.10 Kjeldahl Nitrogen

The Kjeldahl nitrogen at the source remained within a following range (5-25) through the study period (fig. no 4.10), while at the outlet, it was in the range of (5-25) (Table No 4.10)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
kjeldahl Nitrogen	14.3	14.3	14.3	9.11	9.11	6.72

Table No 3.10 Kjeldahl Nitrogen Parameter Value of Sampling Treatment System

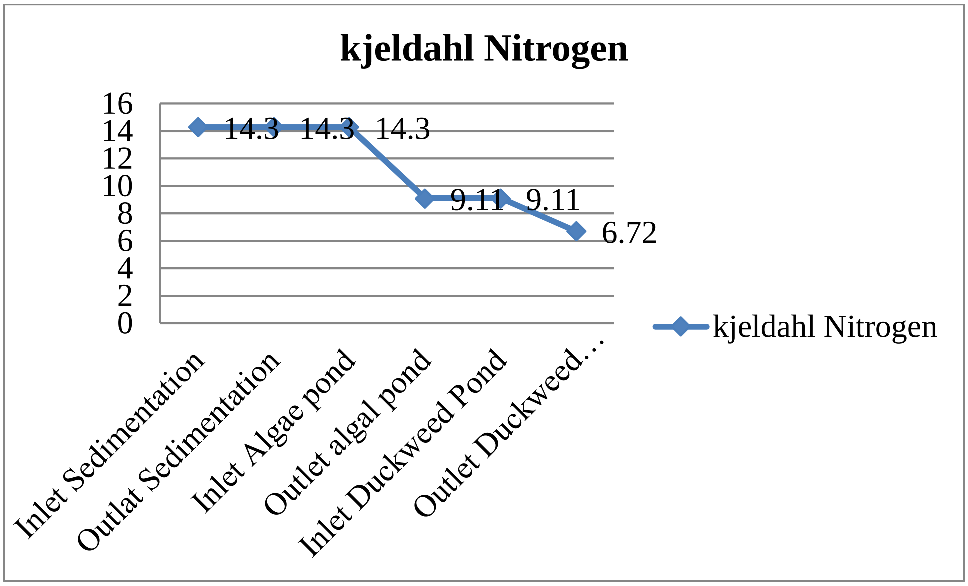


Figure No 3.10 Variation in Kjeldahl Nitrogen Content at Sampling Treatment System

3.11 Oil and Grease

The Oil and grease at the source remained within a following range zero through the study period while at the outlet, it was in the range of Zero

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Oil And Grease	NIL	NIL	NIL	NIL	NIL	NIL

Table No 3.11 Oil and Grease Parameter Value of Sampling Treatment System

3.12 Nitrate-N

The BOD at the source remained within a following range zero through the study period, while at the outlet; it was in the range of zero

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Nitrite-N	0	0	0	0	0	0

Table No 3.12 Nitrate-N Parameter Value of Sampling Treatment System

3.13 Total Colliforms

The Total colliform at the source remained within a following range (270-290) through the study period (fig. no 4.13), while at the outlet, it was in the range of (40-60) (Table No 4.13)

Parameter	Inlet Sedimentation	Outlat Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Total Colliforms	280	280	280	150	150	47

Table No 3.13 Total Colliforms Parameter Value of Sampling Treatment System

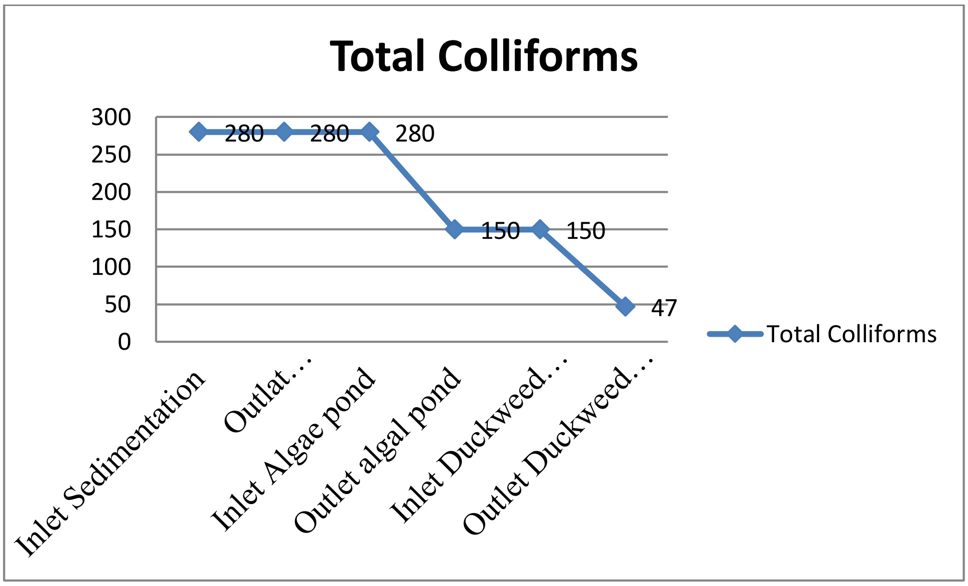


Figure No 3.13 Variation in Total Colliforms Content at Sampling Treatment System

3.14 Faecal Colliform

The Faecal colliform at the source remained within a following range (40-60) through the study period (fig. no 4.14), while at the outlet, it was in the range of (20-40) (Table No 4.14)

Parameter	Inlet Sedimentation	Outlet Sedimentation	Inlet Algae pond	Outlet algal pond	Inlet Duckweed Pond	Outlet Duckweed Pond
Faecal Colliforms	49	45	45	30	30	6.8

Table No 3.14 Faecal Colliform Parameter Value of Sampling Treatment System

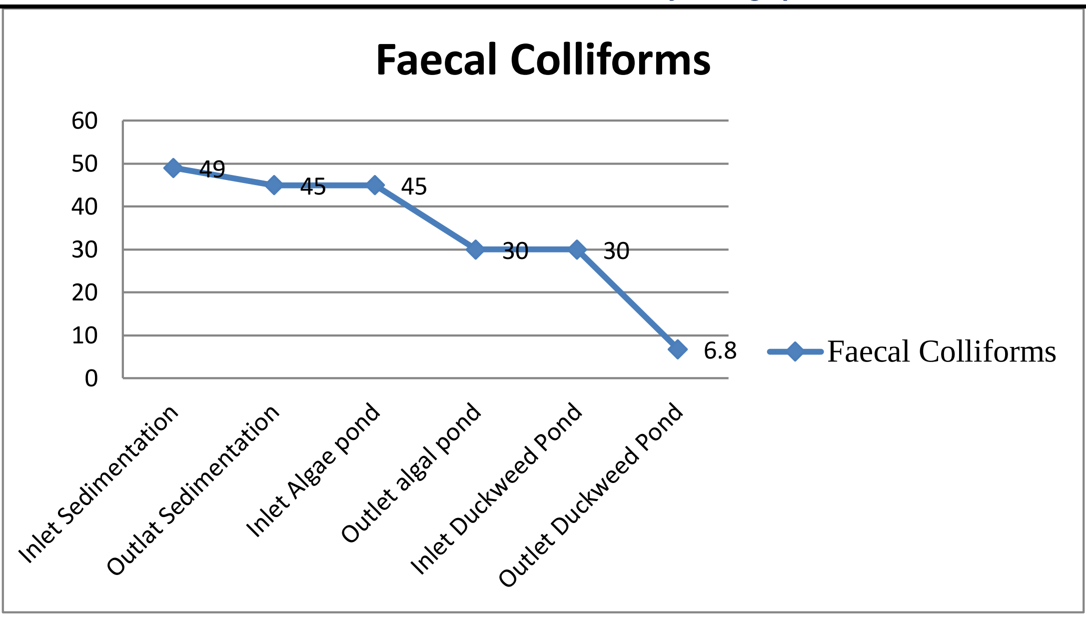


Figure No 3.14 Variation in Faecal Colliform Content at Sampling Treatment System

CONCLUSION

Following conclusion can be made based on the results presented

- Water pH at the source remained within a narrow range through the study period while at the outlet; it was in the range of 7-9 that is in the range.
- Water DO quality and the average dissolved oxygen values of the treatment system registered a gradual increase from source in the range.
- Water BOD and COD while at outlet, it was in the range standard range.
- The growth of Duckweed was lower in presence of algal water due to the consumption of nutrients by both algal and duckweed.
- The present experiment study, on water removed efficiently is 90%-95%