Bio Solar Reactor for Pond Water Treatment

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Approval Sheet

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ABSTRACT

We have developed Bio-Solar Reactor (BSR), an innovative treatment technology for harvested rainwater in ponds, dams, lakes and bio degradations in septic tanks. BSR is a fully automated self-contained system; it is a combination of biological treatment powered by solar energy. It uses microbial consortium in addition to alum as coagulant, aeration for treatment of wastewater and solar power micro- controller to operate this system-meeting energy requirements in remote areas. Bio Solar Reactor (BSR) was designed collectively by IESE and PAKOSWISS technologies as joint venture and is functioning perfectly. The algal bloom and odor which appears at the surface of the pond water is cleared. When bacterial consortium becomes active in the pond, the COD reduction up to 85% was observed within 10-15 days with maximum rate after 4th day. The system can be successfully installed at any remote pond site to treat its COD and nutrient load for further use after disinfection.

The pond is located at the back side of IESE. Three phases of treatment were conducted in IESE-NUST to check the improvement in the quality of waste water via removal of COD, nitrates, phosphates, turbidity, DO and other parameters on sewage water from three different sources. Time durations of the treatment in three phases are given:

Phase	Date
Winter Phase	19th December, 2015 - 15th January, 2016
Spring Phase	23rd February, 2016 - 5th April, 2016
Summer Phase	19th April, 2016 - 10th May, 201

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

Access to water and sanitation is a fundamental human right that is supported by international law and declarations. In fact, 21st century is witnessing high population growth accompanied with industrialization and urbanization. These two phenomena have led to an unbalanced situation between water demand and natural recharge. Global availability of clean portable water is becoming a big threat to the habitat of human kind. Over 2.6 billion people around the globe are living without adequate sanitation facilities and nearly 900 million people doesn't have access to drinking water from improved water resources (UN-Water, 2010). Worldwide 2.4 million lives could be saved if adequate water and reliable sanitation is made available along with the practice of appropriate hygiene (Prüss-Üstün*et al.*, 2008). It is well understood that in this situation the cost for rectifying is high, so the only way is to provide at least some degree of treated water and economically sound and sustainable sanitation solutions (Tebbutt, 1998).

The fresh water consumption has increased many folds from start and the end of the 20th century. At present, the world population is roughly about 6.8 Billion, around one third of the countries are considered to be in water emergency, which is when to demand is more than 10% of supply. If this situation continued, globally two third of the population will be living in water scarce regions (Macedonio*et al.,* 2012).

The situation is alarming and getting worse in developing countries like Pakistan, which suffer from lack of proper Surface wastewater treatment systems in the rural and peri-urban areas. It is very often that the quality of available water is deteriorated and compromised due to lack of collection and treatment.

In developing countries, the centralized treatment option is expensive and not feasible in large urban areas due to complexity of sewerage network, whereas many houses cluster of houses, and small communities even lack sewer systems (Crites and Tchobanoglous, 1998). In this context, it is preferred to adopt on-site treatment options based upon the situation, locality and environment (Lens *et al.,* 2001, Luostarinen and Rintala, 2005).

Pakistan being victim of poor water and sanitation situation is losing 4% of its economy to bad sanitation and water supplies. The urban (36%) and rural (64%) population has 72% and 34% access to water and sanitation respectively. There is a dire need to provide on-site domestic wastewater treatment solutions that treats domestic wastewater up to the

National Environmental Quality Standards (NEQS), Pakistan Environmental Protection Agency (PEPA) and is safe for disposal or use in landscaping, horticulture and irrigation.

Source: 92 News

Waste water from residential areas which lack proper wastewater treatment system is collected in ponds where can be treated effectively by using Bio Solar Reactor developed by us Bio solar reactor can be installed in pond having wastewater collected from houses, cluster of residences, or small commercial units .

The floods in Pakistan have adversely affected the water quality mostly in rural areas. Water from such sources are often contaminated with nitrogenous compounds, ammonia, algae bloom, eutrophication and high turbidity. Conventional treatments Oxidation ponds, ASP, Trickling filters etc. are not effective and are difficult to apply in remote areas.

1.2. CHARACTERISTICS OF POND WATER

Pond water is mainly comprised of Domestic waste water and rain harvested water which consists of (99.9%) water together with relatively small concentrations of suspended and dissolved organic and inorganic solids. Among the organic substances present in waste water are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as there is high concentration of phosphates, nitrates and other various other nutrients. Increased nutrient concentrations potentially lead to eutrophication. In modeling eutrophication, the rate of water renewal plays a critical role. Stagnant water is allowed to collect more nutrients than bodies with replenished water supplies. It has also been shown that excess of nutrients cause algal bloom in the pond.

Table 1 shows the levels of the major constituents of strong, medium and weak domestic wastewaters.

Concentration, Constituent mg/l

Constituents	**Strong**	**Medium**	**Weak**
Total solids	1200	700	350
Dissolved solids	850	500	250
COD	600	400	200
Suspended solids	350	200	100
Nitrogen	85	40	20
Phosphorus	20	10	6
Chloride	100	50	30
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50
BOD_5	300	200	100

Source: UN Department of Technical Cooperation for Development (1985)

Municipal wastewater also contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc. Even if toxic materials are not present in concentrations likely to affect humans, they might well be at phototoxic levels, which would limit their agricultural use. Direct use of untreated waste water in agricultural can have some serious health issues. Other related concerns are

- Microbiological contamination risks for surface and ground water
- Transfer of chemical and biological contaminants to crops
- Accumulation of bio available forms of heavy metals and fate of organics in soil

However, from the point of view of health, a very important consideration in agricultural use of wastewater, the contaminants of greatest concern are the pathogenic micro- and macro-organisms.

1.3. SCOPE OF THE STUDY

Our Focus is the Development of innovative water treatment solution for rain harvested water ponds, municipal waste water ponds, water in dams, lakes, agricultural ponds, bio degradation in septic tanks. Pakistan is facing worst energy crisis in present times so our objective is to develop such innovative technology which Powered by solar energy.

This technology does not need any land or energy like other treatment plants to run. Treated pond wastewater can be used for agricultural and horticulture purposes.

BSR is a self-contained system primarily developed for the treatment of grey water through microbes (Aqua fit), by Using Coagulant (Alum) for sedimentation of suspended particles, which is operated by microcontrollers for aeration and mixing this whole system is fully automated driven by solar Power.

1.4. OBJECTIVES

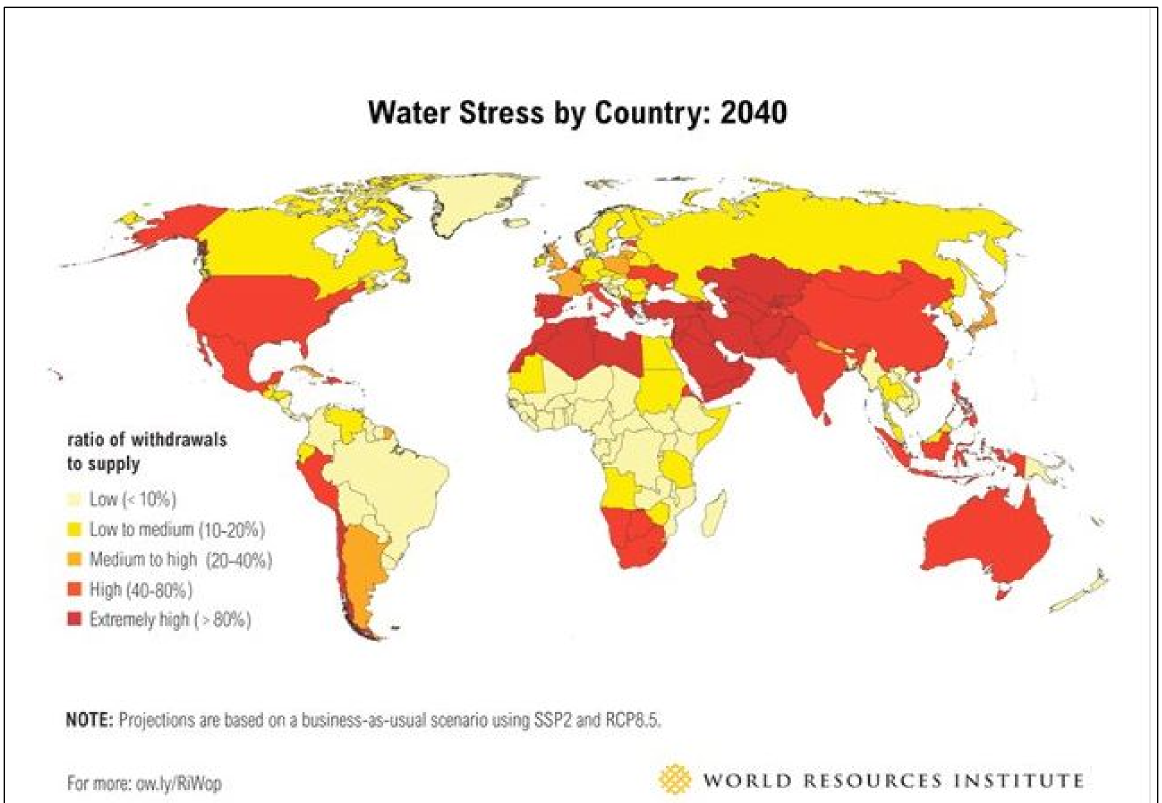
- Designing and assembling of different components of BSR
- installation and operation / validation of BSR
- Prototype testing & performance evaluation of BSR for treatment of pond water

CHAPTER 2

LITERATURE REVIEW

2.1. World Water Availability

The two third surface of earth is covered by water, so it is obviously clear that water is one of the most vital components in charge of life on earth It is not only vital for sustenance of life but equally essential for the socioeconomic development. Globally a billion people, or one in seven people on the planet, don't have access to water; it is due to the increasing demand from agriculture, an expanding population, energy production and climate change. It is believed that the next world war would be fought on the water issue. Water stress and water scarcity conditions for an area are set by United Nations, which are defined as having annual water supplies bellow 1700 m^3 and 1000 m^3 per capita respectively (UNEP, 2005).



Source: World Resource institute

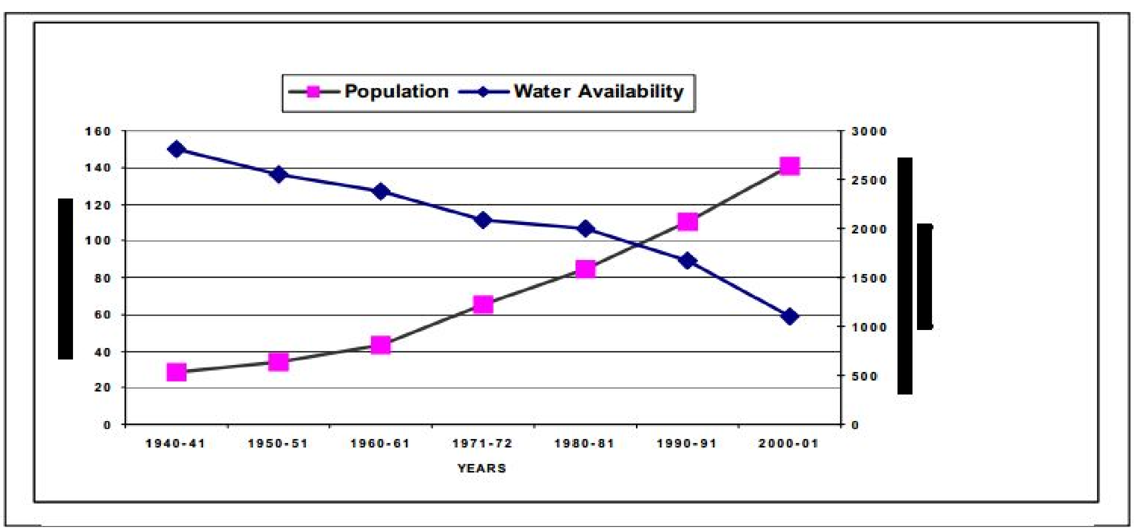
2.2. Pakistan's Scenario

Pakistan once was a water-surplus country, is now a water deficit country. The rainfall is neither sufficient nor regular, to meet the growing needs of water. The main water consumption sectors of Pakistan are Agriculture, domestic and Industrial, which accounts for 96%, 2% and 2% of available freshwater respectively. Surface and ground water in all large cities is polluted by the human activities and are not recommended for consumption. Pakistan Council of Research in Water Resources (PCRWR) conducted a study in all provinces from 2002 to 2006, concluded that around 90% of the water sources cannot be recommended for human consumption.

Like any other developing and populous country Pakistan is also facing shortage of water. Pakistan is now classified as water scare country in the world (World Bank, 2006). The water resources are continuously being exhausted and polluted. Water from lakes and rivers is diminishing at a very fast rate and this problem is increased by the help of long droughts and poor water management. The water per capita availability of from 5600 m^3 in 1951 dropped to 1100 m^3 in the year 2006; currently it has dropped further.Now Pakistan is classified as water stressed country. With increase in population and no further development of water resources this problem will get worse with time. (Khair et al., 2012).

Water pollution has worsened the existing water scarcity situation. The water quality of rivers and lakes is no longer safe for human consumption. Even the ground water quality is affected and aquifers in the country are polluted (Azizullah et al., 2011). According to national figures, about half of the population doesn't have access to safe potable water.

Fig: Per-capita water availability of Pakistan



Source :(Muhammad Akram Kahlown and Abdul Majeed 2000)

2.3. Wastewater Generation

Wastewater is used water generated from various activities in our daily lives around the communities from residential and non-residential sources. Domestic wastewater is composed of black and grey water, according to their generation at source. The black water is generated from toilets and grey water from baths, kitchens and washing places (Henze and Ledin, 2001). It is reported that majority of the pathogenic bacteria, nutrients and organic matter is present in black water (Terpstra, 1999) which magnifies the importance of black water treatment.

Table shows the characteristics of domestic wastewater, black water and grey water.

Factor (mg/1)	**Domestic Wastewater**	**Black Water**	**Grey Water**
BOD	110–410	310–610	110–410
COD	200–750	910–1500	210–710
N	21–81	120–320	9–31
P	5–22	45–95	3–8

Source: (Henze and Ledin, 2001)

2.4. Wastewater treatment

Wastewater is harmful to public health and can pollute the environment unless properly treated. Apart from potential threat to public health and the environment, the wastewater has the potential of affecting the local economy, residential, business development, and other aspects of our daily lives. Before mid-18th century, there were no proper treatment concepts for wastewater, therefor wastewater and other wastes were dumped or supplied to nearby water bodies, which later, resulted in epidemics of cholera, dysentery, typhoid and many other water borne diseases. Wastewater treatment is one of the strategies to cope with the water crisis around the globe. In many parts of the world reuse of wastewater is of great interest including both industrial and developing nations. (Zeng et al.,2013).

Pakistan is a low-income country, where only 8% of the wastewater generated is treated (Sato et al., 2007). Wastewater is directly discharged into drain which is ultimately received by natural water bodies causing water pollution. There is no biological treatment system in Pakistan, except for Islamabad and Karachi, which too treat less than 8 % of wastewater generated. (Murtaza & Zia, 2012).

As discussed earlier by the year 2040, at least 19 countries including Pakistan will be declared as water stressed countries. This will influence life of the people directly. According to a report 43% of the population in these areas live in rural areas and about 70% of this rural population lives below the poverty line with almost no proper water and sanitation set-up. (El Kharraz et al.,2012).

2.5. The Treatment Process

Sewage treatment or domestic wastewater treatment is the process of removing contaminants from wastewater and household sewage. It includes physical, chemical, and biological processes to remove the respective contaminants. The objective of sewage treatment is to produce an environmentally-safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse. Conventional sewage treatment may involve below mentioned three stages.

• **Primary treatment:** It consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.

• **Secondary treatment**: It removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne microorganisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.

• **Tertiary treatment**: The purpose of tertiary treatment is to provide a final treatment stage to raise the effluent quality before it is discharged to the receiving environment (sea, river, lake, ground, etc.). (Sumaira et al., 2009)

2.6. WASTEWATER TREATMENT BY BIOLOGICAL PROCESS

The use of biological (aerobic and anaerobic) treatment process for wastewater treatment can be traced back to the late nineteenth century (Visvanathan et al., 2010). Since then, these aerobic and anaerobic biological processes have been commonly used to treat wastewater. Biological methods are very effective for wastewater treatment and during various treatment stages, approximately all harmful chemical materials become dissociated. In these processes, the organic matters (exists mainly in soluble form) is converted into

CO_2, H_2O, NH_4, NO_2, NO_3, CH_4 and biological cells. The end products are dependent on the presence of oxygen (Visvanathan et al., 2010).

There are several biological methods which can be used for wastewater treatment e.g. Activated sludge, trickling filters, anaerobic degradation etc.

2.7. Types of Biological Processes for Wastewater Treatment

The principal biological processes used for wastewater treatment can be divided into two main categories:

1. Attached growth (or biofilm) processes 2. Suspended growth processes

1. **Attached Growth Processes**

In attached growth processes, the microorganisms responsible for the conversion of organic material or nutrients are attached to an inert packing material. The organic material and nutrients are removed from the wastewater flowing past the attached growth also known as biofilm. Packing materials used in attached growth processes include rock, gravel, slag, sand, redwood, and a wide range of plastic and other synthetic materials. Attached growth processes can also be operated as aerobic or anaerobic processes. The packing can be submerged completely in liquid or not submerged, with air or gas space above the biofilm liquid layer. The most common aerobic attached growth process used is trickling filter.

2. **Suspended Growth Processes**

In suspended growth processes, microorganisms responsible for treatment are maintained in liquid suspension by appropriate mixing methods. The most common suspended growth process used for municipal wastewater treatment is the activated sludge process.

2.8. Activated Sludge Process

The activated sludge process is the most widely applied biological wastewater treatment process (Doorn et al., 2006 and Okoh et al., 2007). In the activated sludge process, a bacterial biomass suspension (the activated sludge) is responsible for the removal of pollutants. Activated sludge system has been widely used throughout the world. (Healey, 1989) reported that there are 9000 US, 501 UK and over 60 French wastewater treatment plants employing activated sludge process.

The activated sludge process involves blending settled primary effluent wastewater with a culture of microorganisms into a fluid termed "mixed liquor". This mixed liquor is passed through aeration tank which provides an adequate oxygen source for the microorganisms to break down the organic pollutants. In all activated sludge plants, once the wastewater has received sufficient treatment, excess mixed liquor is discharged into settling tanks and the treated supernatant undergoes further treatment before discharge. Part of the settled material, the sludge, is returned to the head of the aeration system to re-seed the new wastewater entering the tank. This fraction of the sludge is called return activated sludge (RAS.). Excess sludge is called surplus activated sludge (SAS) or waste activated sludge (WAS). WAS is removed from the treatment process to keep the ratio of biomass to food supplied in the wastewater in balance. WAS is stored in sludge tanks and is further treated by digestion, either under anaerobic or aerobic conditions before disposal.

2.9. Septic Tank

A septic tank consists of a tank and a soil absorption field that is constructed to allow treated effluent to penetrate into the soil. A septic tank in its simple format is primary treatment solution which is efficient in removing pollutants to reduce environmental risks to surrounding (Christopher et al., 2005). the 1st reported application of domestic use of septic tank was in France in 1860 that was a ‘box’ located among the house and the cesspool trapped excrement, which reduced the solids and generate clean water which entered to the soil more quickly. In the America, household septic tank was 1st used in 1883 which have two-section tank design. After that the septic tank use increases rapidly and now it is implemented in many parts of the world (Buttler et al., 1995).

Table: Problems and their sources for septic tanks

Problems	Sources
Odor	Insufficient ventilation ,Blockage inside tank within chambers, Inadequate area for biodegradation
Backflow	Blockage of inlet drainage field area deficiency overfilling of tank
Solids flow out from tank	Insufficient biodegradation overfilling of tank
Groundwater	Pollution Blockage of absorption zone Drainage field insufficient area overfilling of tank leakage within the walls of septic tank
Groundwater penetration to the tank	Inappropriate location Elevated water table

Source: (Butler,et al., 1995)

2.10. MBR for wastewater treatment

Membrane bioreactor (MBR) is an advance technology for wastewater treatment, which combines both activated sludge process and separation by membrane filtration unit. Wastewater is supplied to the reactor where microorganisms use this as a substrate for growth, maintenance and metabolism. Biologically treated water is separated by membrane either MF or UF.

Activated biomass is recycled back to aeration tank (Drews, 2010; Poostchi et al., 2012; Trussell et al., 2006). The first full scale MBR was established in North America in 1970 and after that in Japan in 1980. This process consists on combination of membranes and the biological reactor system. The function of membrane is defined as a thin wall which has processing capability by selective resistance to transfer of different constituents of a fluid through it. The material of membranes should be of reasonable mechanical strength which can maintain a high through put of desired permeate with the high degree of selectivity (Ben et al., 2010). MBR is gaining attention for treating domestic as well as industrial wastewaters with advantages of better effluent quality for reuse as compared to conventional activated sludge process, small foot print, lower waste sludge production, more flexibility and high robustness (Cosenza et al., 2013; Masse et al., 2006; Wang et al., 2007; Yan et al., 2012).

Table : Advantages and disadvantages of MBR

Advantages of MBR	**Disadvantages of MBR**
Small footprint	Membrane surface fouling
No settlement problems	Membrane channel clogging
No further polishing required for disinfection/clarification	High capital and operational cost
No equalization of hydraulic and organic loadings required	Process complexity

Source: (Rousseau, 2011)

Table demonstrates the advantages and disadvantages of different biological wastewater treatment methods.

Technology	**Applications**	**Advantages**	**Disadvantages**
Activated sludge	Low conc. organics, Some inorganics	• Removal of dissolved constituents • Low maintenance • Destruction process	• Volatile emissions • Waste sludge disposal area • High energy costs • Requires technically skilled manpower
Trickling filters, Fixed-film reactors	Low conc. organics, Some inorganics	• Low maintenance • Destruction process • Relatively safe • Reduced sludge generation	• Volatile emissions • Susceptible to shocks and toxins • Susceptible to seasonal changes • Relatively high capital and operating cost
Aerated lagoons, Stabilization ponds	Low conc. organics, Some inorganics	• Removal of dissolved Constituents • Low maintenance • Destruction process • Relatively safe • Low capital costs	• Produce effluent with a high suspended solids concentration • Volatile emissions • Susceptible to shocks and toxins • High land requirement • No operational control
Anaerobic degradation (septic systems)	Low conc. organics, Chlorinated organics, Inorganics	• Removal of dissolved constituents • Treatment of chlorinated wastes	• Susceptible to shocks and toxins • Susceptible to seasonal changes • Relatively high capital and running cost

Source: (Nazaroff and Alvarez, 2001)

2.11. Microorganisms in Wastewater Treatment

Wastewater is mostly discharged into streams without treatment thinking that the self - purification ability would take care of it. But most of the receiving bodies are already overcharged. Therefore, effluent treatment must be done before discharge, so that the physico-chemical parameters of receiving water body are not harmed. Major microorganisms present in wastewater are bacteria, protozoa, metazoan, algae and fungi but bacteria makeup (95%) most of all the wastewater microorganisms in activated sludge and have important role in wastewater treatment (Gerardi, 2006).

Nutrient removal is done through two major processes

- Fixed film processes
- Suspended growth processes

The fixed films processes are based on ability of microorganisms to grow on surfaces because of availability of food, protection from high velocity currents and other environmental conditions. Physical forces such as adhesion and adsorption etc. might also be responsible for attached growth. As the adsorbed microorganisms grow and reproduce.

In suspended growth the bacterial flocs are in continuous contact with wastewater. Bacteria, protozoa and metazoan dominate suspended growth processes (Curtis, 2003). Most of the bacteria are Gram negative hetrotrophic rod shaped in aerobic conditions including Pseudomonas, Chromobacter, Achromobacter, Alcaligenes and Flavobacterium. Coliforms are said to enter wastewater from influent and are not considered indigenous. Nitrifying bacteria as well as filamentous bacteria (Beggiatoa, Thiothrix and Sphaerotilus) are also present in wastewater and form biofilms.Various kinds of bacteria play their role in treating wastewater and the important of them are filamentous bacteria, methanogenic bacteria, poly phosphate accumulating bacteria, sulfate reducing bacteria, nitrifying bacteria, denitrifying . (Yang et al., 2010).

2.12. Microbial Consortia

It is a group of different species of microorganisms that act together as a community. Consortia can perform more complex tasks and can survive in more changeable environments than can uniform populations. Microbial consortia are ubiquitous in nature and are implicated in processes of great importance to humans, from environmental remediation and wastewater treatment to assistance in food digestion. Synthetic biologists are honing their ability to program the behavior of individual microbial populations, forcing the microbes to focus on specific applications, such as the production of drugs and fuels. The microbial consortia can perform even more complicated tasks and endure more changeable environments than monocultures can; they represent an important new frontier for synthetic biology. (Katie Brenner, et al., 2008)

The degradation of organic wastes by the bacterial consortia is highly significant. It reduces the time span of degradation and produces no foul odor. The use of microbial consortium generated through natural selection or improvement of the performance of these microorganisms in organic kitchen waste degradation through genetic manipulation, may be the best option for the efficient treatment of organic kitchen waste or domestic wastewater. The pretreatment of food waste can be used for biological solubilization and mineralization in garbage disposal system which is a novel approach. (Payel Sarkar, Mukesh et al., 2011)

2.13. Aqua Fit

The Aqua fit series is a product made through over 20 years of our research of various types of bacteria not only in Japan but in other countries, The series offers a lineup of products suitable for improvement and purification of water in sea, dams, lakes, agricultural ponds, biodegradation in septic tanks, and for improvement of soil for agricultural use and rice fields.

Aqua fit is a blend of natural aerobic and anaerobic active bacteria. It can survive under water or underground where there is less oxygen. The bacteria used in Aqua fit degrade organic and hazardous materials which produce odor such as ammonia, methane and hydrosulfide and purifies the water. It co-exists with active sludge bacteria in septic tanks, improves the purification levels. It lowers the levels of BOD (COD), sulfide, nitrogen, and total phosphorus. As it degrades sludge, its volume decreases and therefore the volume and frequency of vacuum and collection also decrease. (Aqua Service Co., Ltd.)

Source: (Aqua Service Co., Ltd.)

CHAPTER 3

MATERIALS AND METHODS

Following steps were taken to complete our research

- Selection/Renovation of Pond and filling it with waste water
- Design and Development of different components of BSR
- Installation of BSR in Pond- IESE
- Daily and weekly collection and testing of Waste water samples for various parameters
- Analysis of results using statistics
- Comparison with control samples

3.1. Selection/Renovation of Pond and filling it with wastewater

A pond located in the eastern side of IESE was selected and repaired whose dimensions are

Volume = 22000 l

Depth = 1.8 m

Width =3.66 m

Length = 4 m

And filled it with waste water collected from three different places; Nust lake,I-9 waste water Treatment plant, Nust Membrane Bioreactor Plant respectively to analyze our technology in three separate phases . We developed a BSR reactor with certain components.

3.2 BSR COMPONENTS

- **Floater**
  The floater-casing is made of non-corrosive PVC in an innovative design that provides robust structure and good floating balance. The electronic-controller is housed in a well-designed casing which integrates with the floater structure and also provides weather resistance. There is a flush cleaning mechanism of the solar panel which is a unique innovation. The electronic circuit is a purpose designed microprocessor which regulates the operation of several pumps used for various water treatment processes. Solar panel‘s dimension are .5×1 meter and angle is 45·.

- **Submersible unit**

  It is made of a 120 litres plastic drum. It provides housing to Effective Microbes and mechanical filtrations. The media design is our innovation that is inexpensive and provides high surface area for microbes growth. The media contains inoculum of Effective Microbes (EM) that gets activated when in contact with water. The media also contains nutrients for EM's initial needs for proliferation. The submersible unit also contains a reservoir of precipitant/coagulant, which is innovatively dosed in the pool controlled by the microprocessor.

  EM bacteria housed in submersible BSR unit which provides safe heaven Bacteria proliferate in BSR unit and soon colonize the pond consuming N, P, and COD etc.

- **DC Pumps/Electronics**

  Energy is used for operating 6 micro DC 5.6 V pumps through micro-controller.

  - 2 pumps for aeration whichh circulates 400 L/h.
  - 2 pumps for aluminum sulphate coagulant dosage (100ml/day)
  - 1 pump for mechanical filtration which circulates 8000L/h
  - 1 pump for washing of solar panel which is done2-3 times/day for 10 sec. The purpose of this washing is just to remove soil on solar panel so that it can work effectively.

Function of Electronic power-controller (EPC)

The EPC regulates DC power from 40W Solar PV Panel and operates 6 micro DC water pumps for various functions. These functions require 4 sets of logic.

Logic-set 1:

Function: Early in the morning when the power from PV panels starts from 0+ and reaches the required power (6WATTS) then a water pump starts for 5-15 minutes to flush-clean solar panels. According to International recommendations the panels should not be washed when they are hot, therefore early morning hours' operation is desired

Programming Logic:

Start: When the power reaches from Minimum (0+) to 6WATTS

Stop: After 5-15 minutes. The time duration will be decided with experience and will be fixed in the software.

Logic-set 2:

Function: When during early morning the power becomes sufficient to operate two pumps of each 6WATTS (total 12 WATTS) then power is provided to second relay. It should continue to operate till the evening when sun light diminishes to produce less than 12 WATTS. One of these two pumps is in the submersible unit to create water jet/flux. The second pump is in the Solar-Panel Floater for making fountain to add oxygen in the water.

Programming Logic:

Start: When the power reaches from Minimum (0+) to 12WATTS

Stop: When power is reduced to less than 12 WATTS (in the evening or due to clouds)

Logic-set 3:

Function: After Logic-set two in operation when the power becomes sufficient to operate four pumps of each 6WATTS (total 24 WATTS) then power is also provided to 3rd relay. It should continue to operate till the evening when sun light diminishes to produce less than 24WATTS. The idea is that on full power more than 23 WATTS all four pumps should operate (2 for jets and 2 for fountains); and when the power it is less than 24 WATTS only two pumps should operate.

Programming Logic:

Start: When the power reaches from 12 WATTS to 24WATTS and more

Stop: When power is reduced to less than 24 WATTS (in the evening or due to clouds)

Logic-set 4:

Function: This function controls operation of the 6th pump, which is connected to a reservoir of coagulant solution. The pump injects the coagulant into the water jets. The dosing of the coagulant is time controlled (1-60 seconds) with the help of variable switch and 7 segment display. The pump should operate once a day for the preset set duration when all 4 pumps are fully operating.

Programming Logic:

Start: When the power reaches from 0+WATTS to 28WATTS (once a day only)

Stop: After adjustable preset number of seconds.

- **Aqua Fit (Effective Microbes)**
  The Aqua Fit (Consortium of Effective microbes) made through over 20 years of research of various types of bacteria mainly in Japan & other countries. It is a blend of natural aerobic and anaerobic active bacteria. It can survive under water or underground where there is less oxygen. The bacteria used in Aqua fit degrade organic and hazardous materials which produce odor such as ammonia, methane and hydrosulfide and purifies the water (or soil). It co-exists with active sludge bacteria in septic tanks, improves the purification levels. It lowers the levels of BOD (COD), sulfide, nitrogen, and total phosphorus.

- **Media for microbes' growth**

We used media for microbes growth which can’t be degraded by microbes .we also used macaroni to feed microbes initially .Microbes was kept in capsule just to provide safe house .

Media for microbes along with macaroni

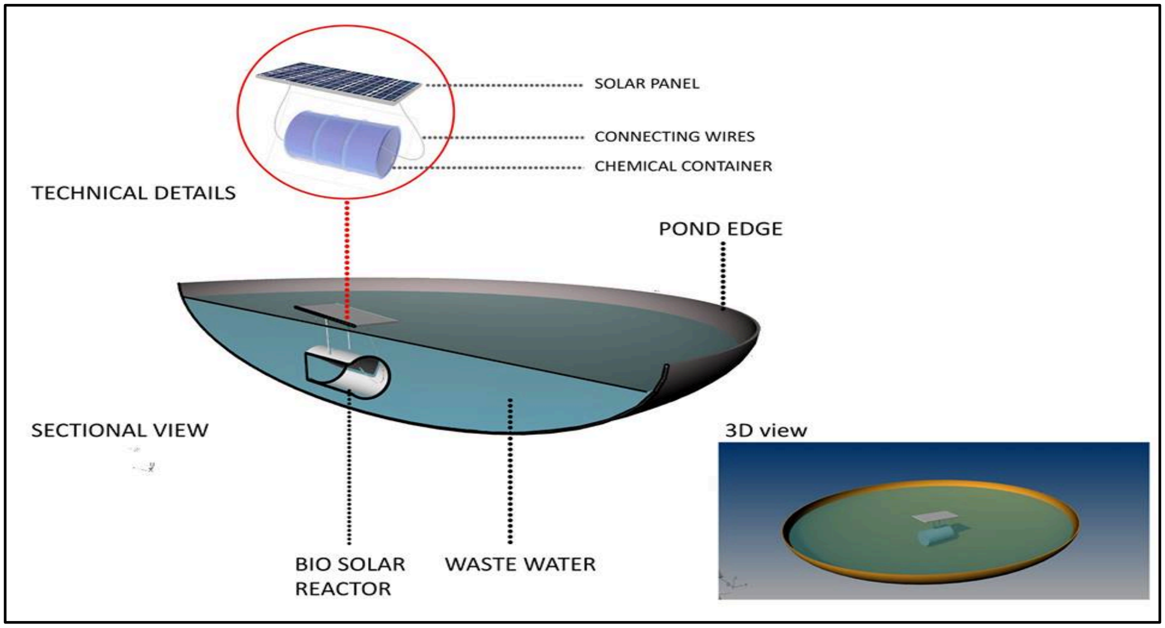
3.3. Working of BSR

BSR starts in every day morning with sunrise. It washes solar panel by using solar panel pump. This happens twice or thrice a day. Mechanical pump with flow rate of 8000L/hr circulate 22000L of whole pond water in 4 days. While whole pond water gets aerated by two pumps with flow rate of 60ml/sec in approximately 8.5 days.

The Floater unit pumps water jets into the pond surface. The ripples caused by water jets increase dissolved oxygen (Do) and removed suffocating pellicle layers on ponds surface caused by micro-algal bloom, scum or Filamentous Bacteria. The oxygen-dissolved water at the top of the pond keeps the anaerobic digestion away from the water surface.

The BSR submersible unit has a provision to inject a prescribed dose of Precipitant for aggregation process. The water jets in the submersible BSR unit maintain flux in water which helps improving precipitant/aggregation process. At night when the jets are stopped, the organic pollution in water settles down to the bottom.

The inoculum of the consortium of effective microbes gets activated as soon as the BSR unit is submersed in water and the capsuled microbes contact with water. The Bio media provides housing and nutrients to the microbes for proliferation in a safe environment. The bacteria digest organic pollutants getting trapped to the **media** (100 in2 of surface area).We used **macaroni** as supplement which has all the essential nutrients such as fats and proteins and carbohydrates. The bacteria then get out of the BSR submersible unit and colonize the pond water. The aerated pond surface and aggregation of organic sludge at the bottom of the pond the pond.keeps the anaerobic digestion to the bottomm.This helps reducing the smell.



BSR Assembly

3.4. INSTALLATION OF BSR

After development of BSR and renovation of pond BSR was installed in pond water .To check BSR efficiencyfollowing tests were performed on Daily & weekly basis:

- COD
- Tempreture
- PH
- E.C
- Turbidity
- Nitrates & Phosphates
- Dissolved Oxygen

3.5. PROCEDURE FOR DETERMINATION OF CHEMICAL OXYGEN DEMAND (COD)

Following reagents were prepared first for the measurement of COD

Distilled water:

Special precautions should be taken to insure that distilled water used in this test be low in organic matter.

Standard potassium dichromate solution (0.250 N):

Dissolve 12.259 g $K_2Cr_2O_7$, primary standard grade, previously dried at 103°C for two hours, in distilled water and dilute to 1000 mL.

Sulfuric acid reagent:

Conc. H_2SO_4 containing 23.5 g silver sulfate, Ag_2SO_4, per 4.09 kg bottle. With continuous stirring, the silver sulfate may be dissolved in about 30 minutes.

Standard ferrous ammonium sulfate (0.25 N):

Dissolve 98.0 g of $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$ in distilled water. Add 20 mL of conc. H_2SO_4 (6.8), cool and dilute to 1 liter. This solution must be standardized daily against standard $K_2Cr_2O_7$ solution (6.2).

Standardization:

To approximately 200 mL of distilled water add 25.0 mL of 0.25 N $K_2Cr_2O_7$ (6.2) solution. Add 20 mL of H_2SO_4 (6.8) and cool. Titrate with ferrous ammonium sulfate (6.4) using 3 drops of ferroin indicator (6.6). The color change is sharp, going from blue-green to reddish-brown.

Mercuric sulfate:

Powdered $HgSO_4$.

Phenanthroline ferrous sulfate (ferroin) indicator solution:

Dissolve 1.48 g of 1-10 (ortho) phenanthroline monohydrate, together with 0.70 g of $FeSO_4 \cdot 7H_2O$ in 100 mL of water. This indicator may be purchased already prepared.

Silver sulfate: Powdered Ag_2SO_4.

Sulfuric acid (sp.gr. 1.84): Concentrated H_2SO_4.

- Pipette 20 ml of sample in 250 ml of refluxing flask.
- Add approximately 400 mg (a pinch) of mercuric sulphate.
- Add 10 ml of potassium dichromate by pipette.
- 30 ml of conc.sulphuric acid reagent by measuring cylinder. Acid should be added in controlled manner with mixing of the sample.
- If the sample color changes to green, dilute the sample and repeat the procedure for diluted sample.
- Connect the reflux flask through the condenser and reflux for a minimum period of 2hrs at 150°C.
- Add 80 ml distilled water through condenser cool it to room temp and titrated with standard sulphate using 2 to 4 drops of ferrion indicator.
- End point is the sharp color change from blue green to brick red, even though blue green reappear within minutes. Let the titrate value be 'V' ml
- Reflux in same manner a blank with distilled water 20ml and follow the procedure from previously. Let the titrate value be 'B' ml.
- Calculate the COD (mg/lt) as follows
- COD= ((B-V) ×N (FAS)×8000)/vol of sample(ml).

3.6. PROCEDURE TO MEASURE PH AND E.C

PH meter was used to measure PH. Firstly PH meter is calibrated and Make sure that the meter is set to the pH Mode and adjust the temperature to 25°C.and then placed the electrode in the sample to be tested. The pH of the solution appears in the display. Allow the display to stabilize before taking your reading. Rinse the pH electrode and place it back in the storage solution Similarly E.C meter was used to measure E.C.

3.7. PROCEDURE TO MEASURE TURBIDITY

Turbidimeter was used to find turbidity of the waste water

- Switch on the power supply and check the battery of the turbidimeter,
- Press the 1 N.T.U button and concide the scale with zero by using focusing template.
- Again press 1 N.T.U button and concide the scale with zero using the focusing template.
- A Standard formazine solution of N.T.U is placed on tubidimeter in the path of rays and scale is brought 9 n.t.u
- The Water sample is taken in a test and is placed in turbidimeter.
- Use A Cell rise if the turbidity is more than 100 N.T.U and get the turbidity dilution factor.

3.8. Testing phases of BSR

Three experiments were performed on BSR in winter, spring and summer seasons. In winter Phase, Pond was filled with NUST waste water and BSR was run from15th Dec 2015-13th Jan, 2016.In Spring Phase, pond was filled with I9 waste water treatment plant influent & BSR was run from 26th February, 2016 – 5th April, 2016.In Summer Phase, pond was filled with NUST waste water and BSR was installed in 19th April 2016 -10th May, 2016.

- **Winter Experiment**

  In the winter phase of experiment, NUST H-12 Islamabad waste water was used as a sample. Bio-Solar Reactor was installed on 19th December, 2015 and focused parameters were analyzed on weekly basis. This phase continued till 15th January, 2016 and the functioning of Bio-Solar Reactor was terminated after the required results were attained. During these 40 days, the coagulant dosage pumps were run for 3 sec/day and 23 mg/L of alum dose was added as a coagulant.

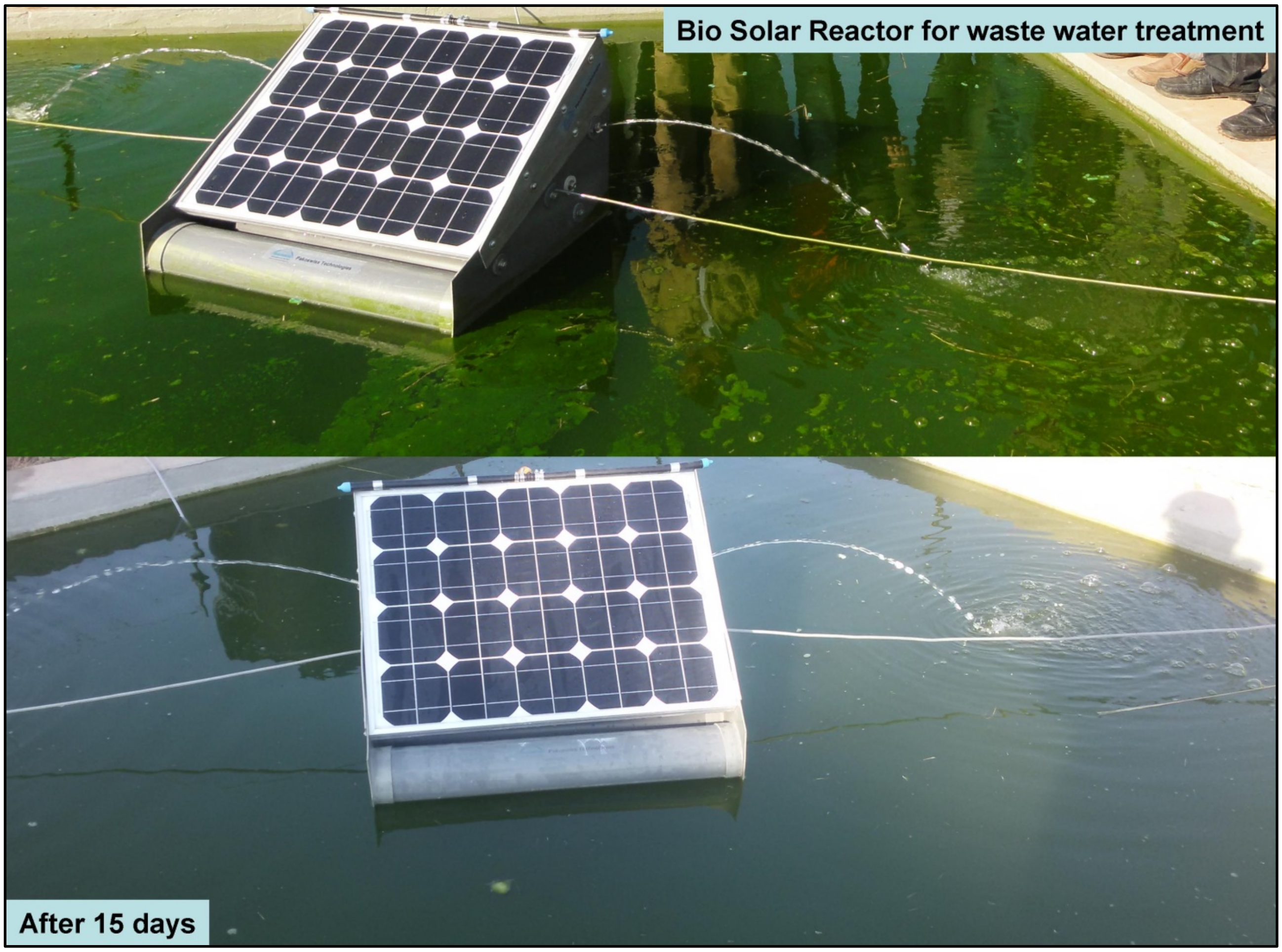
- **Spring Experiment**

  The whole system was installed and run again to counter-check the working of BSR. In the spring phase of experiment, waste water influent from I-9 Water Treatment Plant was used as a sample. Bio-Solar Reactor was re-installed on 23rd February, 2016. The testing frequency was increased and same parameters were analyzed on daily basis. 50g of additional microbial dose was added on 19th April, 2016 to increase the efficiency of Bio-Solar Reactor and to speed-up the treatment process. The coagulant dosage pumps were run for 3sec/day to add 23 mg/L of alum dosage in the pond. The testing continued till 5th April, 2016. Working of BSR stopped when the required results were achieved. Control sample was also considered under observation.

- **Summer Experiment**

  Summer Phase testing was performed for the confirmation of the efficiency of Bio-Solar Reactor obtained in the first two phases. In the summer phase of the experiment conducted, NUST H-12 Islamabad waste water was used as a sample again. BSR was installed on 19th April, 2016. Testing of parameters was continued on daily basis. The coagulant dosage was increased from 3 sec/day to 5 sec/day. Better and faster results were achieved by this increment in the dose of coagulant. Additional microbes were added on 29th April, 2016 to accelerate the treatment process. The required results were obtained till 10th May, 2016 and the BSR functioning was stopped.

We observed that the water quality was getting better rapidly. The below pictures shows the water conditions at the day of installation and after two weeks of installation.


Bio Solar Reactor for waste water treatment
After 15 days

CHAPTER 4

Results and Discussion

4.1. Scope

This chapter presents and discusses the results of analyzed parameters obtained by the treatment of pond water from Bio-Solar Reactor (BSR).

4.2. Experimentation

The pond is located at the back side of IESE. Three phases of treatment were conducted in IESE-NUST to check the improvement in the quality of waste water via removal of COD, nitrates, phosphates, turbidity, DO and other parameters on sewage water from three different sources. Time durations of the treatment in three phases are given in the table 4.1.

Phase	Date
Winter Phase	19th December, 2015 - 15th January, 2016
Spring Phase	23rd February, 2016 - 5th April, 2016
Summer Phase	19th April, 2016 - 10th May, 201

Table: 4.1 Time durations of the treatment in three phases

4.3. Parameters analyzed:

Following parameters were tested and analyzed during the treatment of pond water by Bio-Solar Reactor.

Parameters analyzed on daily basis are:

- Chemical Oxygen Demand (COD)
- pH
- Electrical Conductivity (E.C.)
- Turbidity
- Temperature

Whereas following parameters were analyzed once during start and end of each phase:

- Dissolved Oxygen (DO)
- Nitrates

- Phosphates

The results have been compared with NEQS and US EPA is also applicable shown in table 4.2.

Sr no.	Parameters	Allowable Limit	Standard Guidelines
1	Chemical Oxygen Demand	80 mg/L and less	NEQS
2	pH	6-10	NEQS
3	Electrical Conductivity	Depends upon type of dissolved species	EPA
4	Turbidity	<25 NTU	US EPA Vermont
5	Temperature	40 ^{o}C	NEQS
6	Dissolved Oxygen	>5.5 mg/L	US EPA
7	Biological Oxygen Demand	80 mg/L	NEQS
8	Nitrates & Nitrites	<10 mg/L	EPA
9	Phosphates	<0.1 mg/L	US EPA (1986)

Table 4.2 Standard Limits of Analyzed Parameters

4.4. Control Sample

A controlled sample of 100 L was placed in a tank under observation to compare with the treated water. The same natural conditions of all the parameters i.e. temperature and weather were maintained as of pond water. All the test parameters were analyzed and then compared with the pond samples to find out the efficiency of BSR.

4.5. Average Temperature Profile

Data regarding ambient temperature is shown in figure 4.1 for the study duration. In winter Phase average temperature remained 11 degree Celsius. In spring phase, the average temperature rose to 18.17 ^{o}Cwhereas in summer phase, average temperature reached 25 degree Celsius. This increase in temperature affect the removal efficiency of COD, turbidity, nitrates and phosphates. As the temperature increases, the percentage removal efficiency also increases.

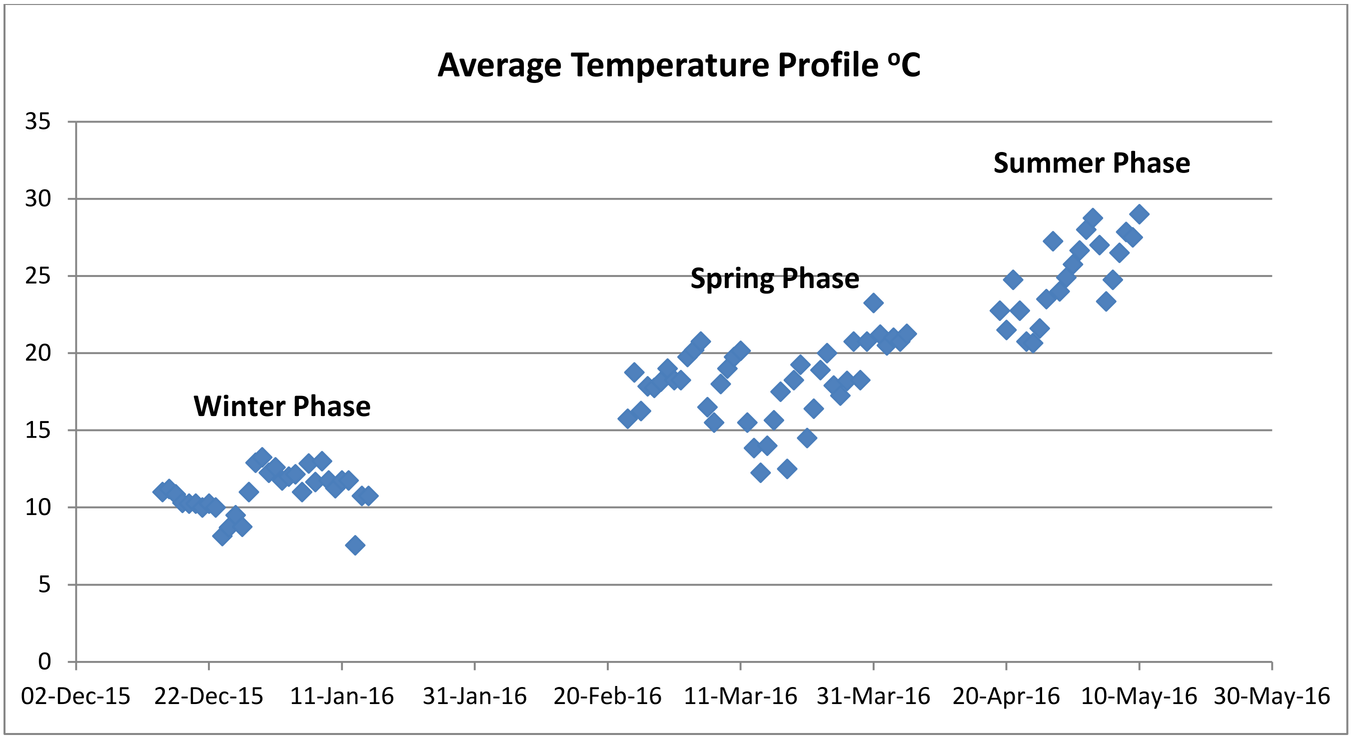


Figure 4.1 Average Temperature Profile °C

4.6. COD

The values of COD in each phase is shown in table 4.3.Whereas control sample COD is shown in red colored dotted line in each figure.

In winter phase,the sample had an initial COD value of 224 mg/L. As the BSR started working, the value of COD of pond water started to decrease. This decrease was due to the microbial activity. As the microbes grew in the submersible unit, they started consuming COD of the pond water as their nutrition. COD reached its final value of 44.8 mg/L after which no further change in the COD was observed within a month. Figure 4.2 shows the trend of COD in the first phase of experiment.

In spring phase, two samples were considered under observation: control sample and pond sample under treatment. The results of both the samples were then compared to find out the pollutants removal efficiency. I-9 waste water with initial COD of 220 mg/L was used for winter phase experimentation in the pond. As soon as the BSR started working, the value of COD of pond water started to decrease due to microbial COD consumption. COD reached its final value of 32 mg/L. No further change in the COD was observed after 45 days. Figure 4.3 shows the trend of COD in the first phase of experiment.

In summer phase,two samples: control sample and the pond sample were considered under examination and the test parameters were analyzed. NUST waste water was used as a sample with an initial COD of 166.4 mg/L. Tests were performed on the samples after every 12 hours on the pond sample. COD dropped down up to 96.8 mg/L and then unexpectedly started increasing until it reached 184.8 mg/L. This abnormal behavior was due to the malfunctioning of BSR unit. The pumps providing coagulant dosage were temporarily stopped and the microbes died due to unavailability of favorable conditions. Additional 50 g of microbial dose was introduced on 29th April, 2016 after which a drastic decrease in the COD value was observed. The BSR was stopped after the value reached to 36mg/L and no further change in the COD was observed. These results were achieved in only 10 days because of the optimum temperature (35° C) of water for microbial growth shown in figure 4.4.

Winter Phase	**Date**	Day-1	Day-2	Day-6	Day-12	Day-16	Day-22	Day-29
	COD mg/L	224	BSR-Installed	179.2	147.6	106.2	60.8	44.8
Spring Phase	**Date**		Day-1		Day-4	Day-8	Day-15	Day-18
	COD mg/L	Sample Changed	220	BSR-Installed	197.8	199	192.4	176
	Date	Day-21	Day-25	Day-26	Day-27	Day-30	Day-31	Day-32
	COD mg/L	176	184	167	160	94	79.2	74.8
	Date	Day-33	Day-35	Day-37	Day-38	Day-39	Day-40	Day-41
	COD mg/L	70.4	61.6	46.4	70.4	32	32	32
Summer Phase	**Date**	Day-1	Day-3	Day-5	Day-7	Day-8	Day-9	
	COD mg/L	166.4	128	112	105	96.8	114.4	
	Date	Day-11		Day-14	Day-17	Day-20	Day-21	
	COD mg/L	105.6	BSR-Re-installed	82	48	36	32	

Table 4.3 Pond Sample COD in different phases

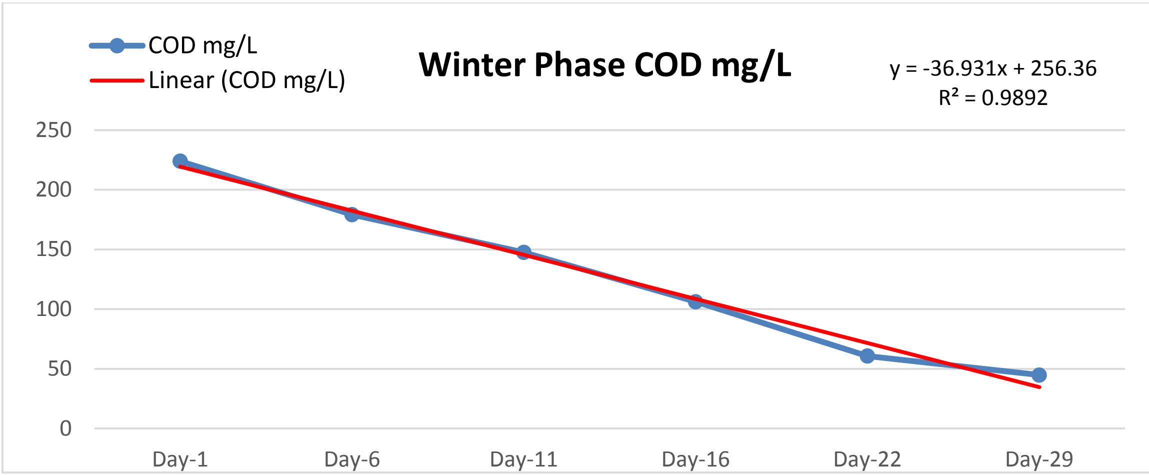


Figure 3.2 Winter Phase Pond Sample COD

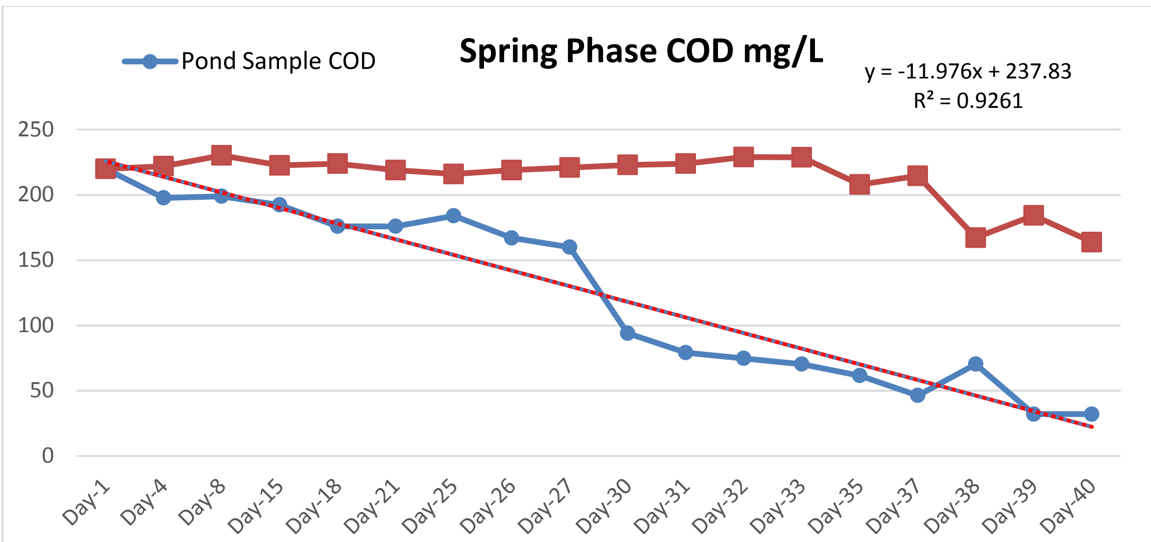


Figure 4.3 Spring Phase Pond Sample COD

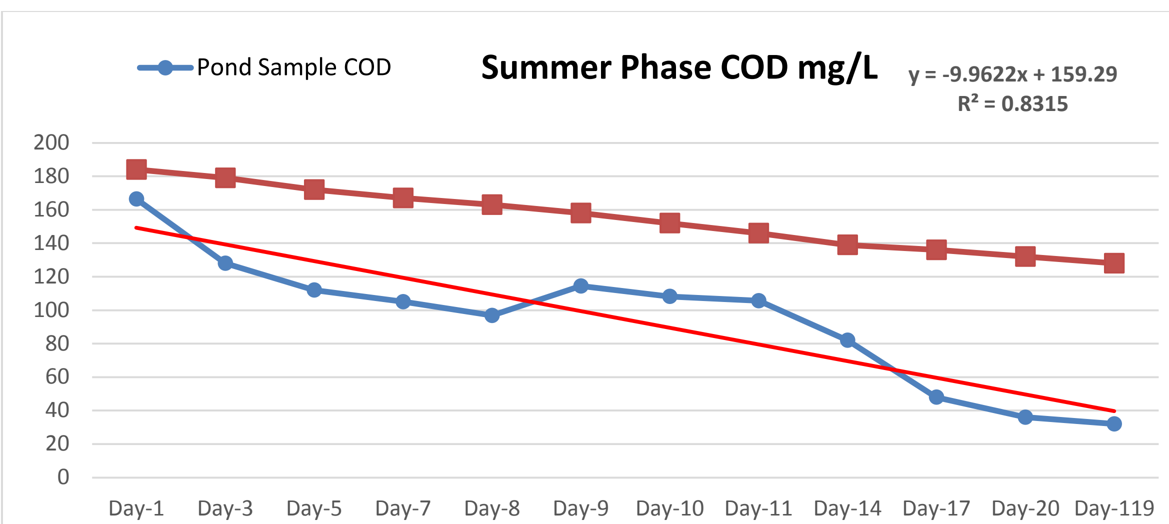


Figure 4.4 Summer Phase Pond Sample COD

4.6.4. Percentage Removal Efficiency of COD

The percentage removal of COD in the three phases is given in table 4.6 and figure 4.5 below.

Phase	Winter Phase	Spring Phase	Summer Phase
COD Removal Percentage	80	85.4	80.51

Table 4.6 Percentage Removal of COD in the three phases

Percentage removal is calculated as follows:

$$\text{Mean Value of Percentage COD removal} = \frac{80 + 85.4 + 80.51}{3} = 81.97\%$$

Standard Deviation = 2.981%

So, the efficiency of BSR in COD removal can be expressed as 81.97% ± 2.98%.

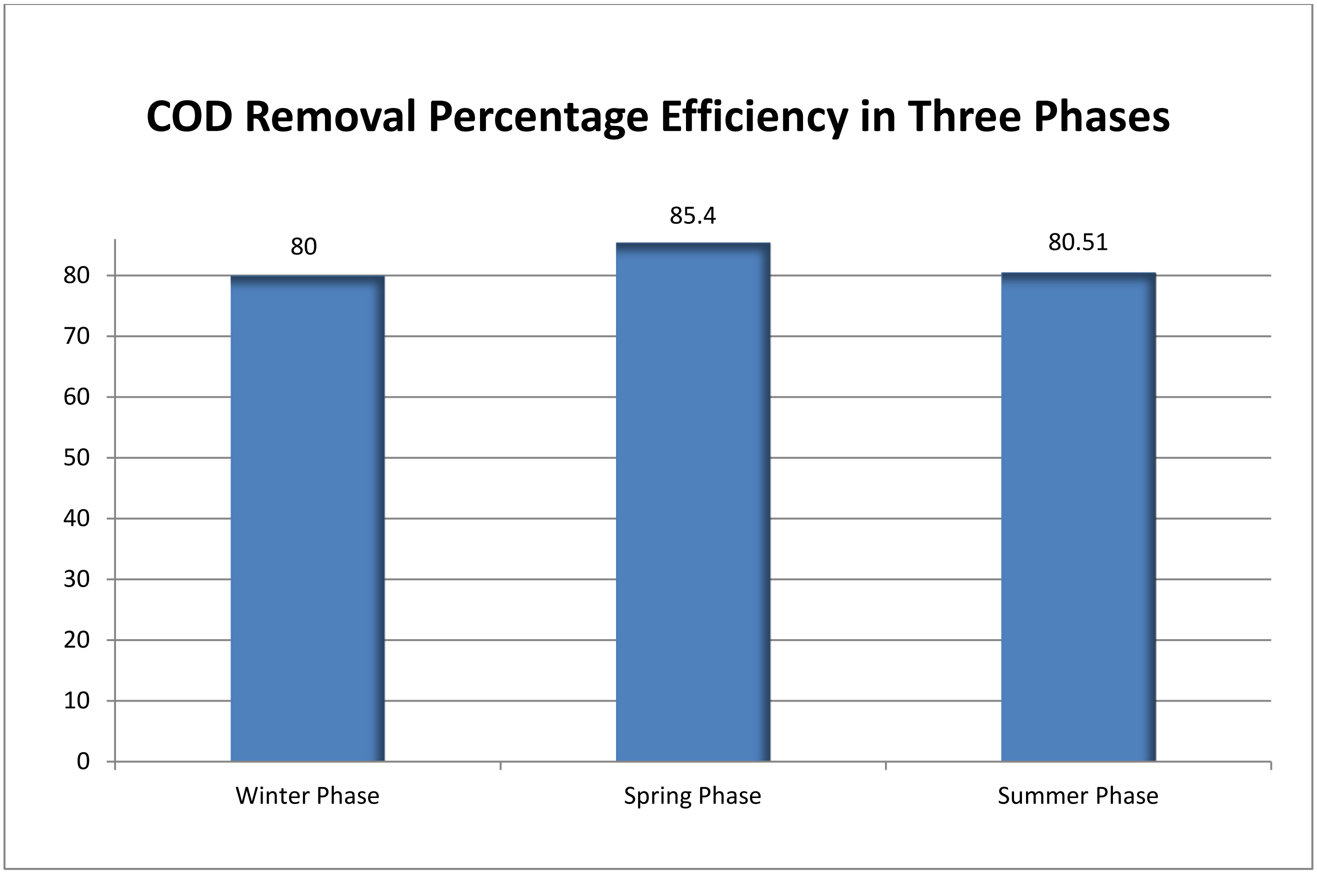


Figure 4.5 Percentage Removal of COD in the three phases

4.7. Turbidity

Turbidity is the muddiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to naked eye. It is the measure of relative clarity of a liquid.

In winter phase,the determination of turbidity is a key test of water quality. Turbidity of pond water was measured on weekly basis by nephelometer. NUST waste water in winter phase with an initial turbidity of 241 NTU was used. Turbidity started decreasing after the installation of BSR and finally dropped to 10.7 NTU at the end of the winter phase. Alum was added as a coagulant which caused the suspended solids in the waste water to agitate and settle down due to its own weight under the action of gravity. The turbidity results of winter phase are shown in figure 4.6.

In springphasethe initial value of I-9 waste water was 32.6 NTU. Turbidity reduced to 8 NTU till the end of the spring phase. Turbid water became clearer after treatment. Turbidity may increase due to the algal growth in pond water. Greenish tint may appear due to the presence of naturally growing algae. Figure 4.7 shows the trend of turbidity removal in spring phase.

In the summer phase, NUST waste water initial turbidity was 68.2 NTU which after treatment changed drastically and dropped to 8.13 within 20 days. The coagulant dosage was increased to 28 mg/Lin summer phase to accelerate the treatment process. The turbidity of control sample did not show evident changes. The only drop in turbidity was due to the settlement of heavy suspended particles. The trendof turbidity removal in summer phase is shown in the figure 4.8.

Following are the turbidity results in different phases are shown in the table 4.4.

Winter Phase	**Date**	Day-1	Day-3	Day-6	Day-11	Day-16	Day-22	Day-29
	Turbidity NTU	241	157	69.8	39.4	22.8	13.2	10.7
Spring Phase	**Date**	Day-1	Day-4	Day-8	Day-15	Day-21	Day-25	
	Turbidity NTU	32.6	24.3	17.3	18.2	18.3	13.4	
	Date	Day-29	Day-32	Day-37	Day-38	Day-39	Day-40	
	Turbidity NTU	12.8	12.2	10.4	9.6	8.1	8	
Summer Phase	**Date**	Day-1	Day-3	Day-5	Day-7	Day-8	Day-9	
	Turbidity NTU	68.2	41.7	21.1	18.2	13.7	13.4	
	Date	Day-10	Day-11	Day-14	Day-17	Day-20	Day-21	
	Turbidity NTU	12.9	11.3	10.7	9.2	8.6	8.13	

Table 4.4 Turbidity results in different phases

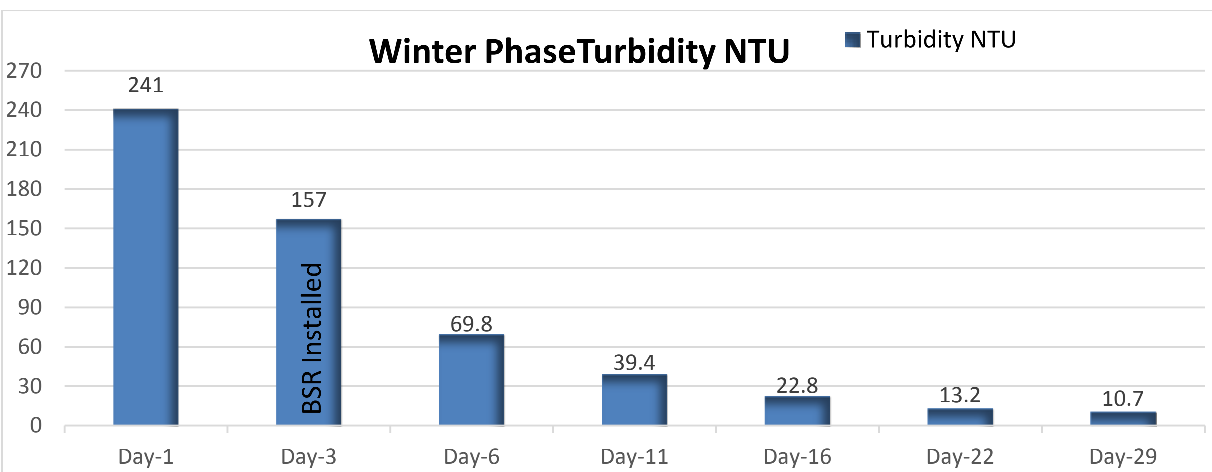


Figure 4.6 Winter Phase Pond Sample Turbidity

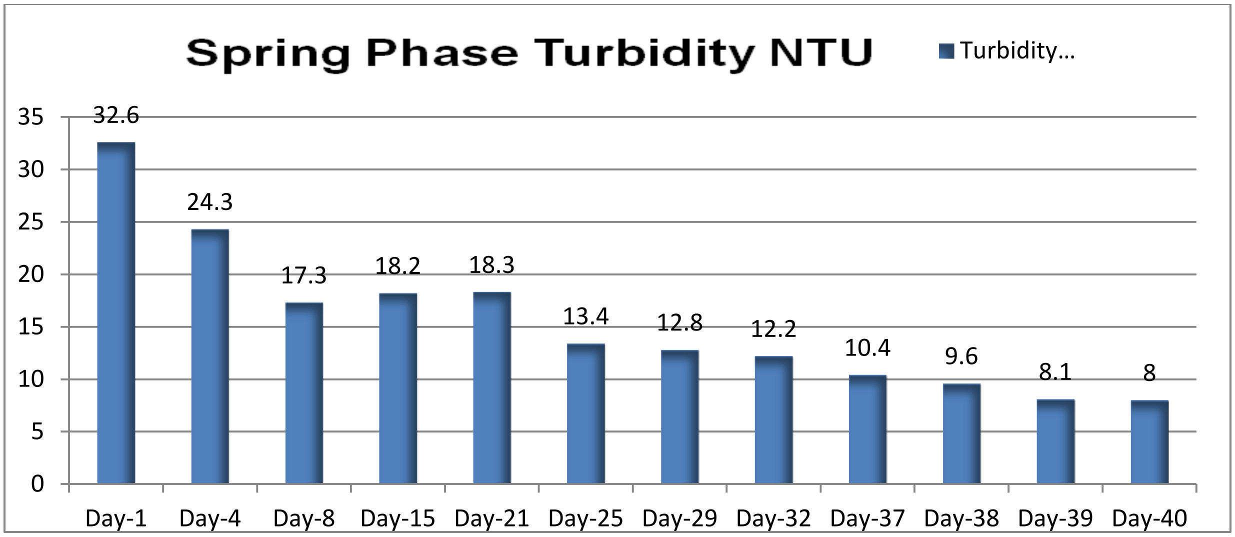


Figure 4.7 Spring Phase Pond Water Turbidity

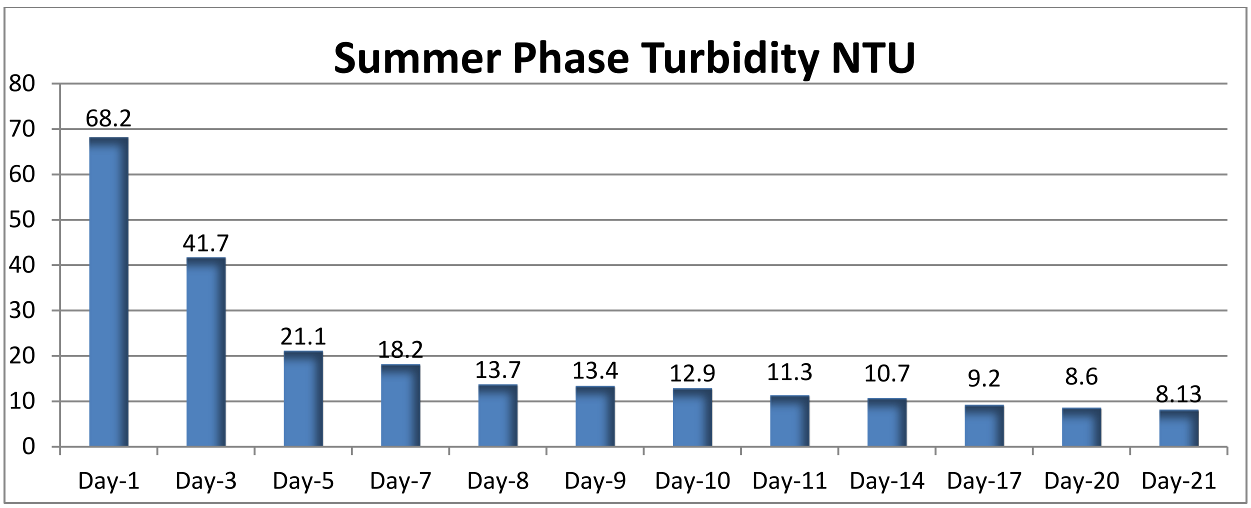


Figure 4.8 Summer Phase Pond Sample Turbidity

4.7.4. Percentage Removal Efficiency of Turbidity

The percentage removal of turbidity in the three phases is given in the table 4.5 and figure 4.9 below.

Phase	Winter phase	Winter phase	Winter phase
Turbidity Removal Percentage	95.56	75	88.3

Table 4.5Percentage Removal of turbidity in the three phases

Percentage turbidity removal is calculated as follows:

Mean Value of Percentage turbidity removal = $\frac{95.56 + 75 + 88.3}{3}$ = 86.286%

Standard Deviation = 10.426%

So, the efficiency of BSR in turbidity removal can be expressed as 86.286% $\pm$10.426%

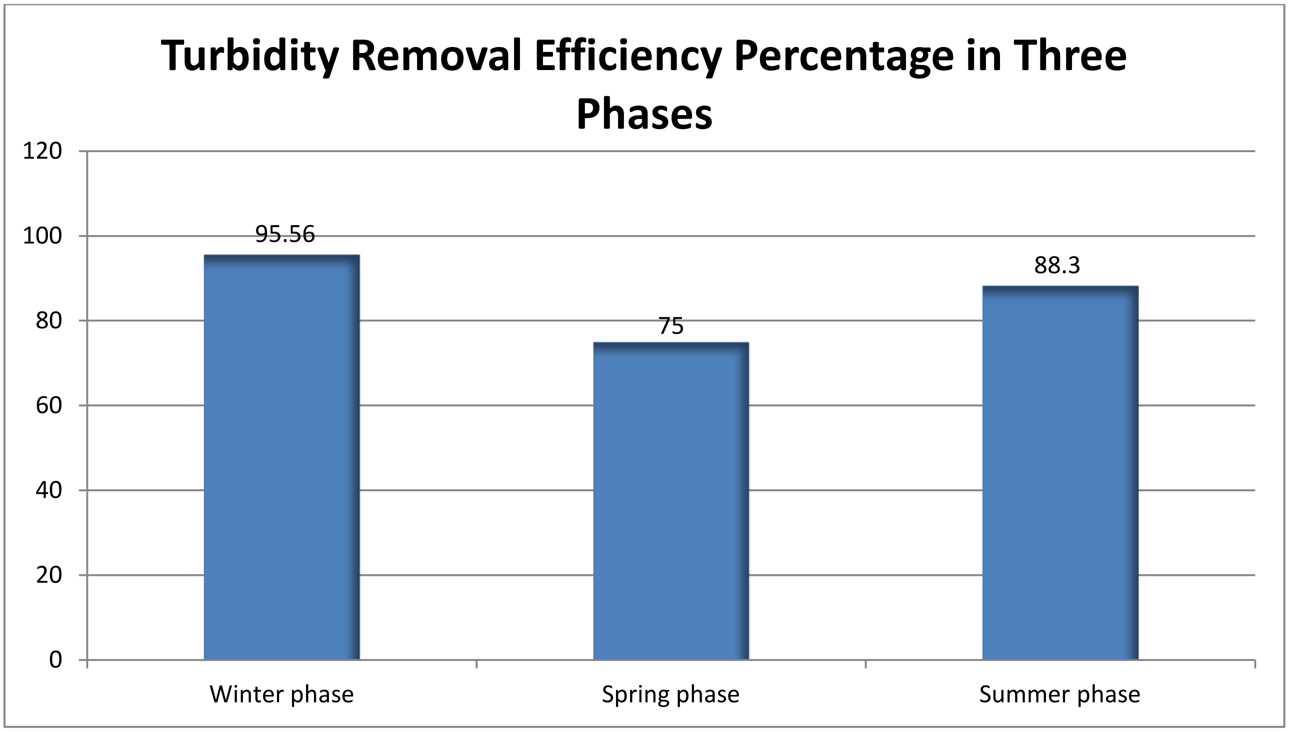


Figure 4.9Percentage Removal of turbidity in the three phases

4.8. pH

pH is the negative of the logarithm to base 10 of hydrogen ion concentration. It is a measure of the acid content in water. As alum is a coagulant formed by a weak base and strong acid so, it decreases the pH of solution.

No considerable change was observed in thepH value of three phases of treated water. Following figure 4.10 shows the trend of pH in all three phases.

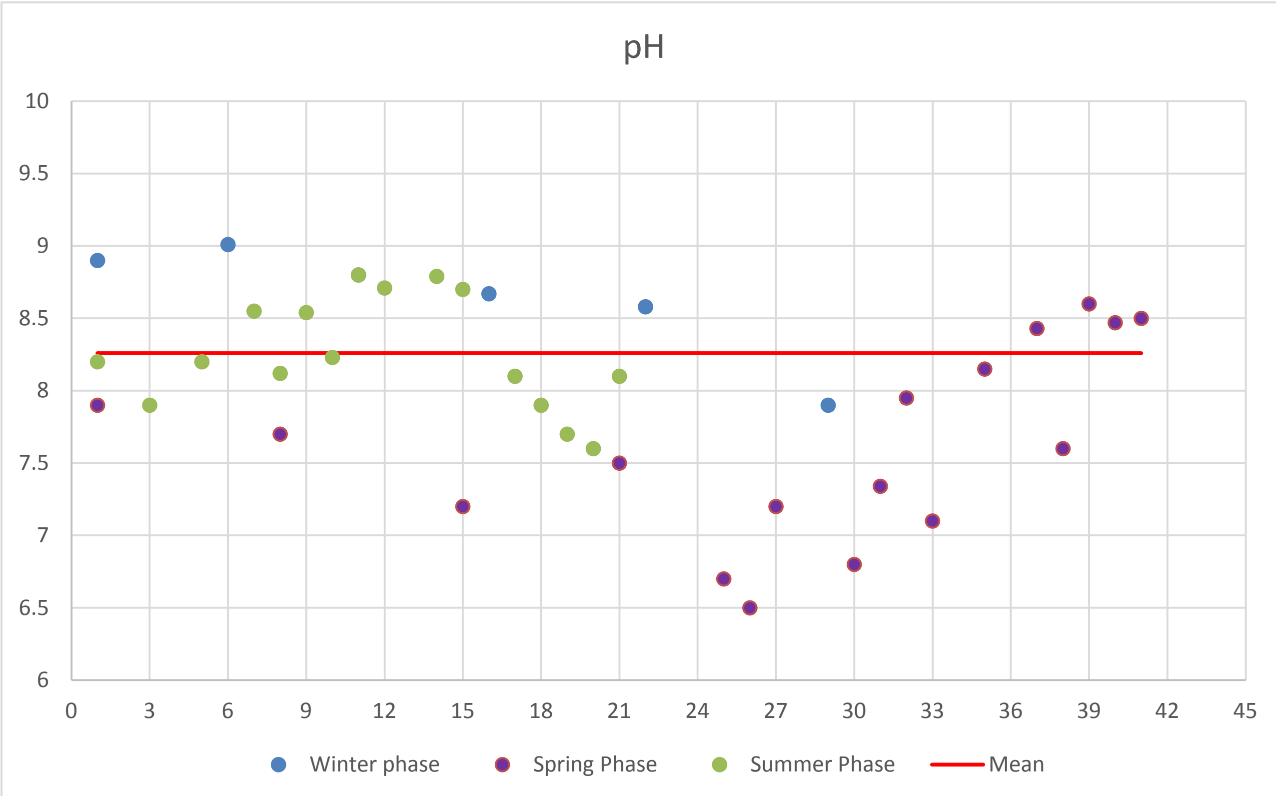


Figure 4.10 pH in different phases

4.9. Electrical Conductivity (E.C.)

Electrical Conductivity is a measure of water's capability to pass electrical current.The electrical conductivity of water estimates the total amount of solids dissolved in water - Total Dissolved Solids. Electrical current is transported by the ions in solution, the conductivity increases as the concentration of ions increases.

The source of NUST waste water is tap water so, the NUST waste water has approximately same E.C. as of tap water available in NUST. This slight increment may be due to the evaporation of the water and the increased concentration of the ions per liter of pond water. The figures 4.11 shows the relatively constant values and trend of E.C. in all three phases.

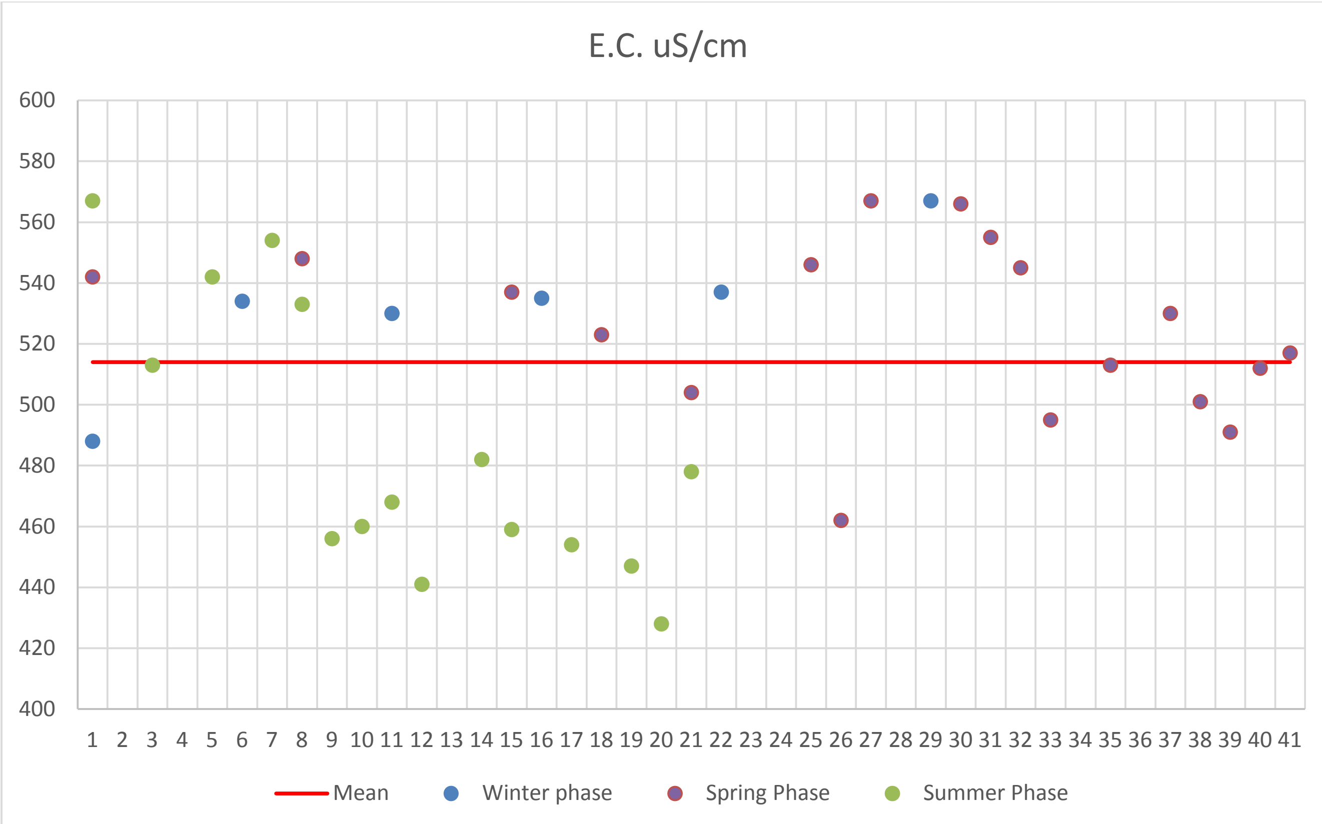


Figure 4.11 E.C. in different phases

4.10. Nitrates & Phosphates

Nitrates and phosphates were determined at the start and end of the three phases shown in table 4.6 and 4.7and figure 4.12 and 4.13. Almost 50% removal of nitrates was obtained.

	Initial Nitrates mg/L	Final Nitrates mg/L
Winter phase	11.89	5.69
Spring phase	15.77	7.31
Summer phase	12.78	6.42

Table 4.6 Nitrates Removed

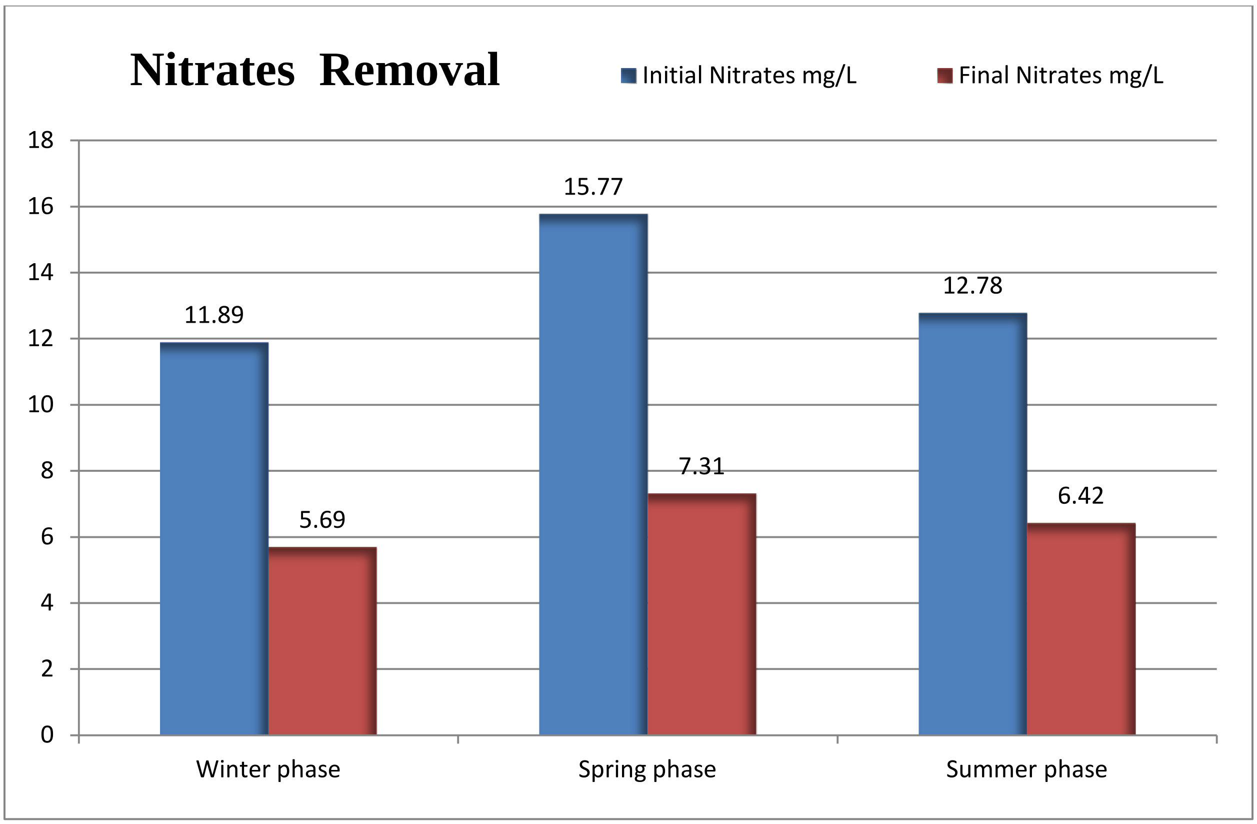


Figure 4.12Nitrates Removal in three phases

	Initial phosphates mg/L	Final phosphates mg/L
Winter phase	12.8	6.12
Spring phase	13.2	6.4
Summer phase	16.71	8.33

Table 4.7 Phosphates Removal in three phases

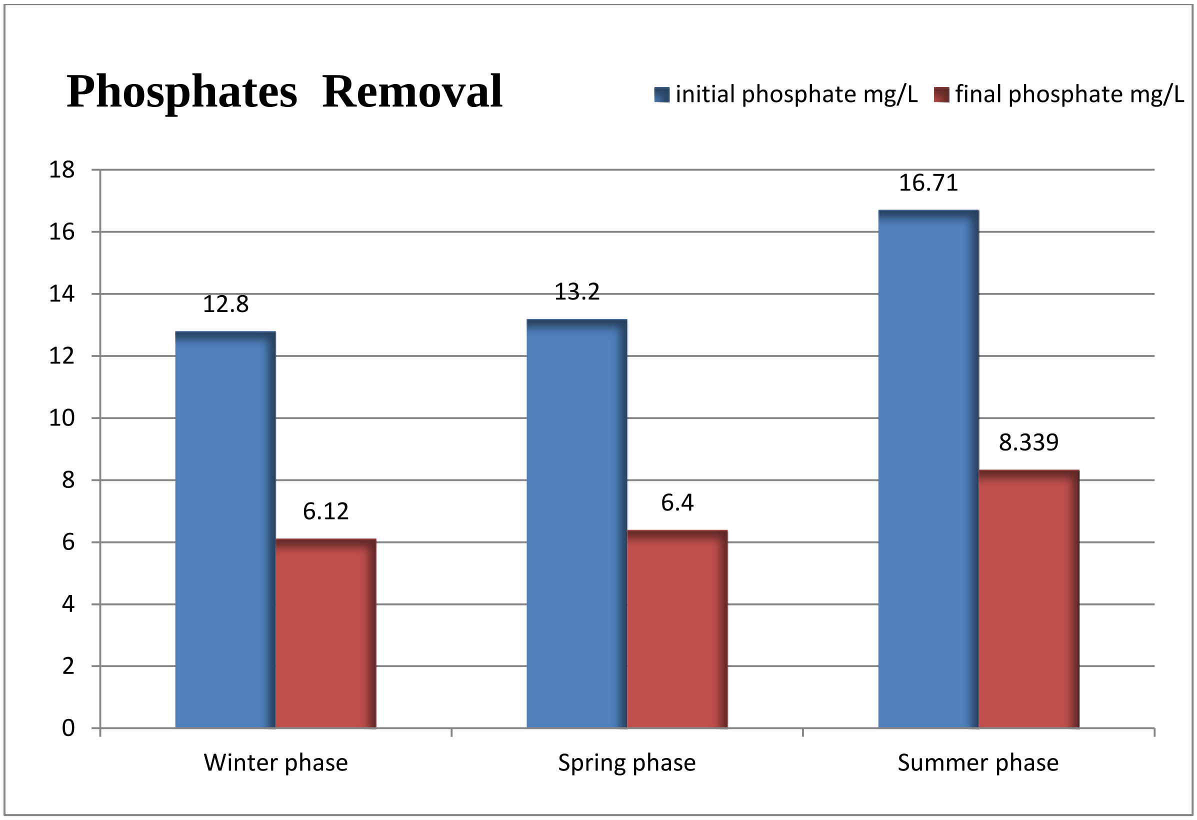


Figure 4.13 Phosphates Removal in three phases

4.10.1. Percentage Removal Efficiency of Nitrates and Phosphates

Almost 50% nitrates as well as phosphates have been removed in all three phases as shown in table 4.8 and figure 4.14.

	Nitrates Removal	Phosphates removal
Winter phase	52.14%	52.18%
Spring phase	53.64%	51.51%
Summer phase	49.76%	50.09%

Table 4.8 Percentage Removal Efficiency of Nitrates and Phosphates

Percentage nitrates and phosphates removal is calculated as follows:

Mean Value of Percentage Nitrates removal =52.14%+ 53.64%+ 49.76% = 51.85%

Standard Deviation = 1.95%

So, the efficiency of BSR in Nitrates removal can be expressed as 51.85% ±1.95%

Mean Value of Percentage Phosphates removal =52.18%+ 51.51%+ 50.09% = 51.26%

Standard Deviation = 1.06%

So, the efficiency of BSR in Nitrates removal can be expressed as 51.26% ±1.06%

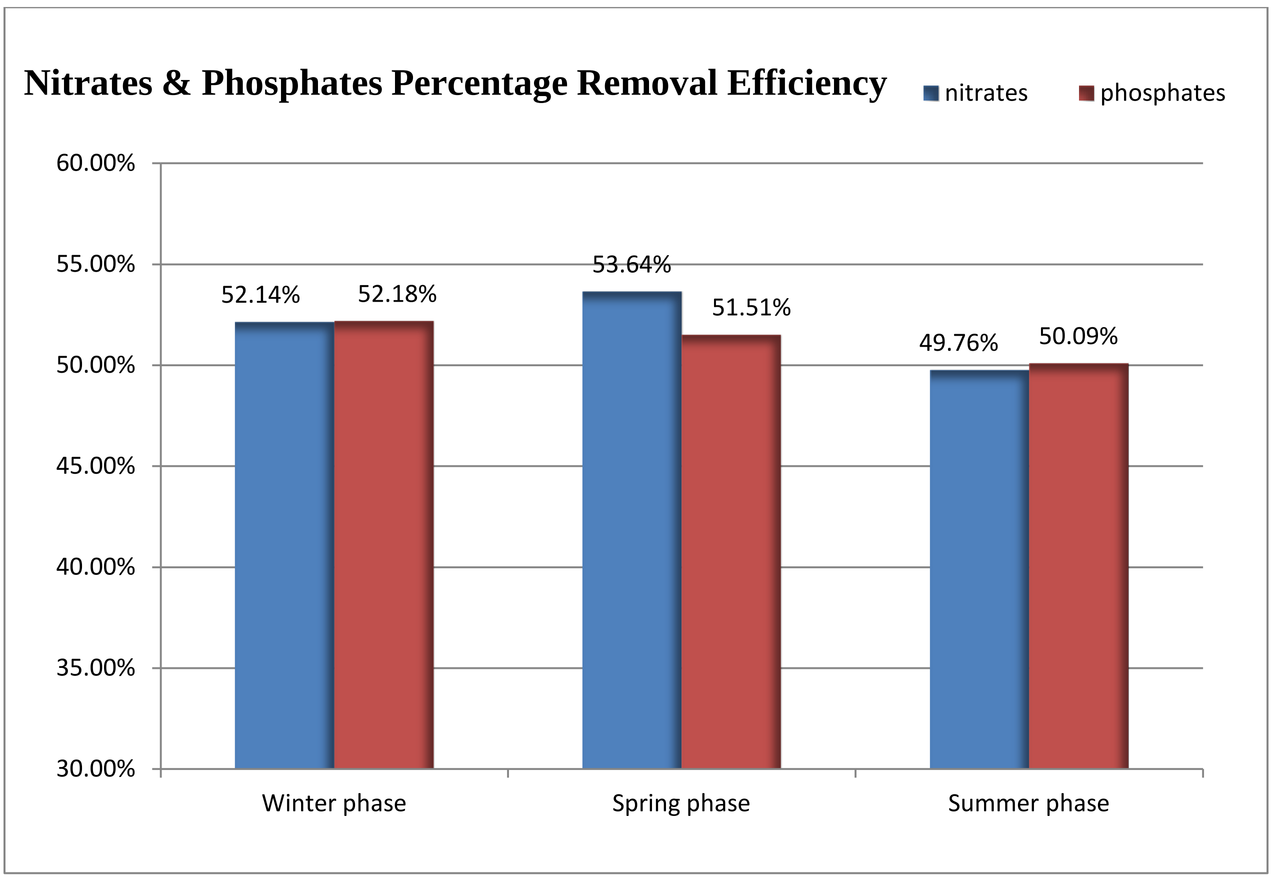


Figure 4.14 Percentage Removal Efficiency of Nitrates and Phosphates

4.11. Dissolved Oxygen

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. Aeration pumps were installed to add Dissolved Oxygen in pond water under treatment. DO tests were performed once in each phase. Initially, no DO was detected and DO up to its maximum of 10 mg/L was observed at the end of spring phase as shown in table 3.9 and figure 3.15. Only 4mg/L of DO is normally required for fish in water. Dissolved oxygen detected in three phases is shown in table 3.9 and figure 3.15.

	initial phosphate mg/L	final phosphate mg/L
Winter phase	0	7.34
Spring phase	0.54	10
Summer phase	0.17	9.86

Table 4.9 DO in three phases

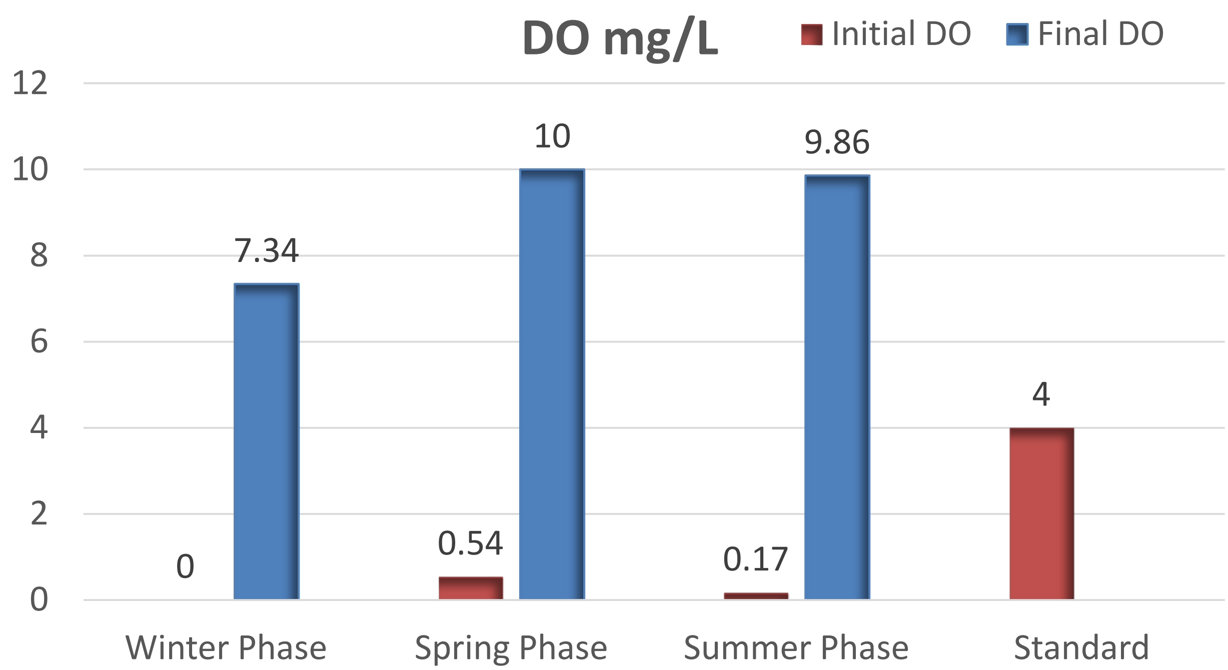


Figure 4.15 DO in three phases

4.12. Conclusion and Recommendations

- Bio- Solar Reactor (SBR) was designed byPAKOSWISS Technologies and tested by IESE and as joint venture and is functioning perfectly.
- Innovative method of feeding microbes using macaroni and plastic fiber was found very effective
- The algal bloom started appearing at the initial stages of test runs and finally cleared when bacterial consortium became active in the pond.
- The COD reduction up to 85 % was observed within 10-15 days with maximum rate after 4th day. Maximum efficiency is observed in spring phase.
- The system can be successfully installed at any remote pond site to treat its COD and nutrient load for further use after disinfection.

All the objectives are achieved successfully. First BSR was designed and assembled. BSR was installed on 15th Dec, 2015, the prototype was tested by running efficiently and the validity of design was confirmed. Continuous tests were conducted and the efficiency of BSR was calculated for the evaluation of its performance.

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