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TREATMENT OF WASTEWATER USING SOLAR BIOREACTOR

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ABSTRACT

An innovative treatment technology Bio-Solar Reactor (BSR), for harvested rainwater in ponds, mini dams, lakes and bio degradations in septic tanks was developed. BSR is a fully automated self-contained system; 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 requirement 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, gets 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. In a present study tests were run in the pond. Three phases of treatment were conducted to check the improvement in the quality of wastewater and significant removal of COD, nitrates, phosphates, turbidity, DO and other parameters applied on sewage water from three different sources, collected in spring & summer seasons were found.

Key Words: Harvested rain water, water treatment, bio solar reactor, pond water

INTRODUCTION

Access to water and sanitation is a fundamental human right that is supported by international law and declarations. 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 do not have access to drinking water from improved water resources (Hartley and Meter, 2011). 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 (Johnstone, 2014). And situation is alarming and getting worse in developing countries like Pakistan, which suffering 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 (Corcoran, 2010).

In developing countries, the centralized treatment option is expensive and not feasible in large urban areas due to complexity of sewerage network, whereas many cluster of houses, and small communities even lack sewer systems (Langergraber and Muellegger, 2005). Therefore, it is preferred to adopt on-site treatment options based upon the situation, locality and environment (Rolland, N. 2004). Pakistan being victim of poor water and sanitation situation is losing 4% of its economy to bad sanitation and

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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 (Florini & Sovacool, 2011).

The floods in Pakistan have adversely affected the water quality mostly in rural areas. Water from such sources is 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. Wastewater from residential areas which lack proper wastewater treatment system is collected in ponds where can be treated effectively by using Bio Solar Reactor. Bio solar reactor can be installed in pond having wastewater collected from houses, cluster of residences, or small commercial units. In a present study focus was, development of innovative water treatment solution for rain harvested water ponds, municipal wastewater ponds, water in dams, lakes, agricultural ponds, bio degradation in septic tanks. Pakistan is facing worst energy crisis in present times so study aimed to develop such innovative technology which powered by solar energy. 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. Main objectives of the study were installation and operation of BSR in pond filled with domestic wastewater and prototype testing and performance evaluation of BSR for treatment of pond water

METHOD AND MATERIAL

Research was carried in IESE (NUST). Where pond water was treated by BSR provided by Pakoswiss following the steps (Fig,1).

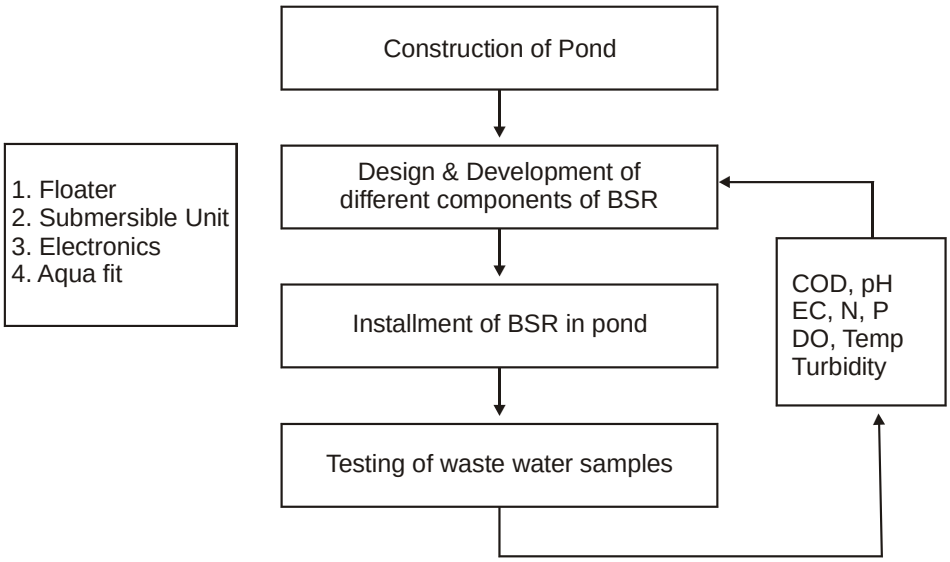


Figure 1: Experimental design for the treatment of waste water.

A pond was constructed having volume 22000 L, depth 1.8 m, width 3.66 m and 4m length. The floater-casing of BSR was made of non-corrosive PVC in an innovative design that provides robust structure and good floating balance. The electronic-controller was housed in a floater. Submersible unit was made of a 120litres plastic drum. Submersible unit also contained a reservoir of precipitant/coagulant, which was innovatively dosed in the pool controlled by the microprocessor. The Aqua Fit (Consortium of Effective microbes) is a blend of natural aerobic and anaerobic active bacteria. 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. Outline of BSR is given in figure 2.

Working of BSR

Pond was filled with waste water collected from three different places (Fig, 3) to evaluate the efficiency of BSR. Research experiment was divided into three phases. 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 and DO increases. The DO 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 bacteria digest organic pollutants getting trapped to the media. A macaroni was used as supplement which had 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 keeps the anaerobic digestion to the bottom. This helps reducing the smell.

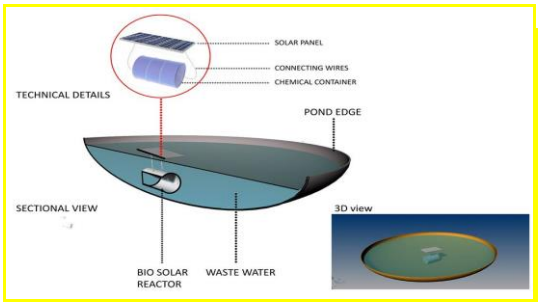


Figure 2: Outlines of BSR Assembly

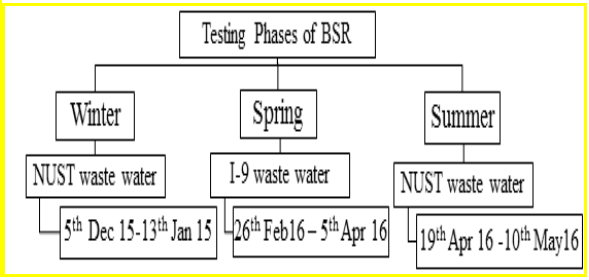


Figure 3: Testing phases of BSR

ANALYTICAL PROCEDURES

Water quality parameters, their units and methods of analysis are summarized in (Table.1). The temperature of pond water samples was measured at the sampling points by mercury thermometer. In laboratory all the samples were analyzed for different physico – chemical parameters. pH, EC, DO and turbidity was measured by pH meter, DO meter EC and turbidity meters respectively. Phosphorus and nitrogen were

measured by using spectrophotometer. COD by closed reflux titrimetric method (APHA, 2005).

Table 1: Water quality parameters associated with their abbreviations, units and analytical methods used.

Variables	Abbreviations	Units	Analytical methods
Temperature	Temp	°C	Thermometer
PH	pH	pH unit	pH meter
Turbidity	-	NTU	Nephlometric
Chemical Oxygen Demand	DO	mg L–1	Closed Reflux Titrimetric Method
Electrical conductivity	EC	µS cm–1	Electrometric
Phosphorus	P	mg L–1	Spectrometer
Nitrogen	N	mg L–1	Spectrometer
Dissolved Oxygen	DO	mg L–1	DO meter

RESULTS AND DISCUSSION

After treatment of waste water, analytical results of water parameters were compared with NEQS and US EPA. And it was found that results were significantly different at initial stage of treatment and at the end of treatment. Table 2 showing the standard limits of analyzed parameters.

Table 2: Standard Limits of Analyzed Parameters.

Parameters	Allowable Limit	Standard Guidelines
Chemical Oxygen Demand	80 mg/L and less	NEQS
PH	6-10	NEQS
Electrical Conductivity	_	EPA
Turbidity	< 25 NTU	US EPA Vermont
Temperature	40 °C	NEQS
Dissolved Oxygen	>5.5 mg/L	US EPA
Biological Oxygen Demand	80 mg/L	NEQS
Nitrates & Nitrites	<10 mg/L	EPA
Phosphates	<0.1 mg/L	US EPA (1986)

Control Sample

A controlled sample of 100 L was placed in a tank under observation to compare with the treated water. It was found that average temperature of pond water was 11, 18.17 and 25 °C in winter, spring and summer respectively. This increase in temperature significantly improve the removal efficiency of COD, turbidity, nitrates and phosphates (Fig, 4).

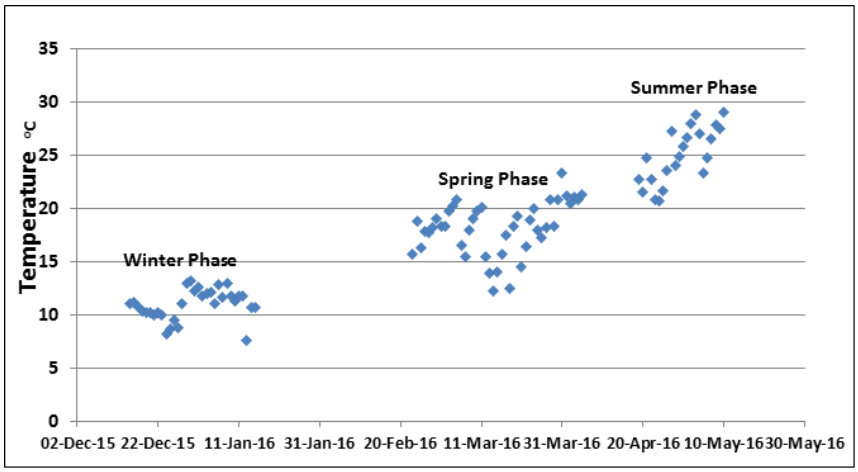
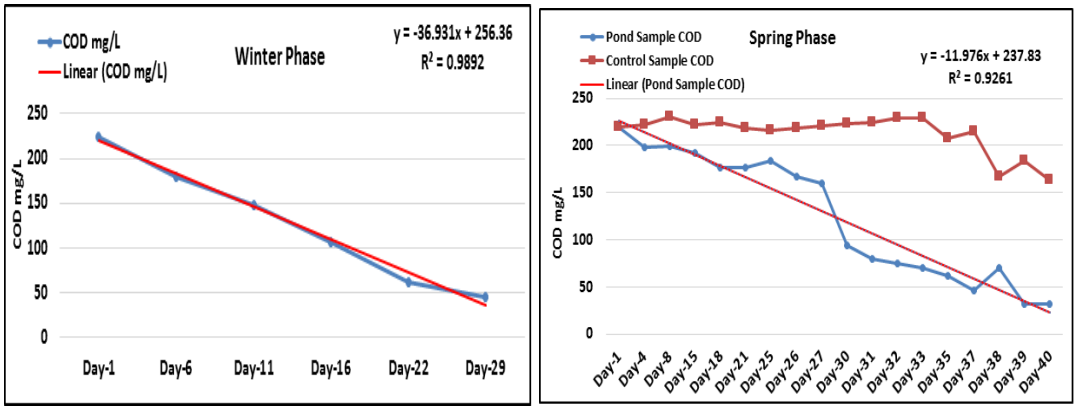


Figure 4: Average Temperature Profile

In winter COD of waste water decreased from 224 mg/L to 44.8 mg/L (Fig, 5a). 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. In spring phase, I-9 waste water with initial COD of 220 mg/L was treated, it was found that BSR removed COD to 32 mg/L ((Fig, 5b). In summer phase, 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 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 5 (c). Figure (5d) shows that BSR efficiently removed COD 80, 85.4 and 80.5 % in winter, spring and summer respectively.

(a) (b)



(c) (d)

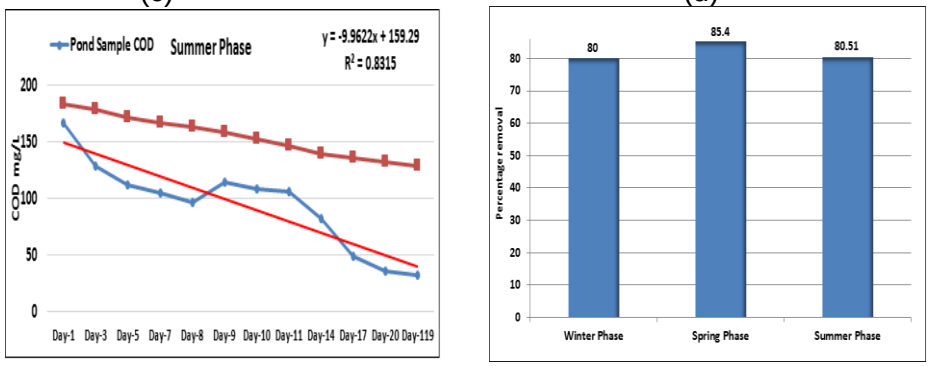
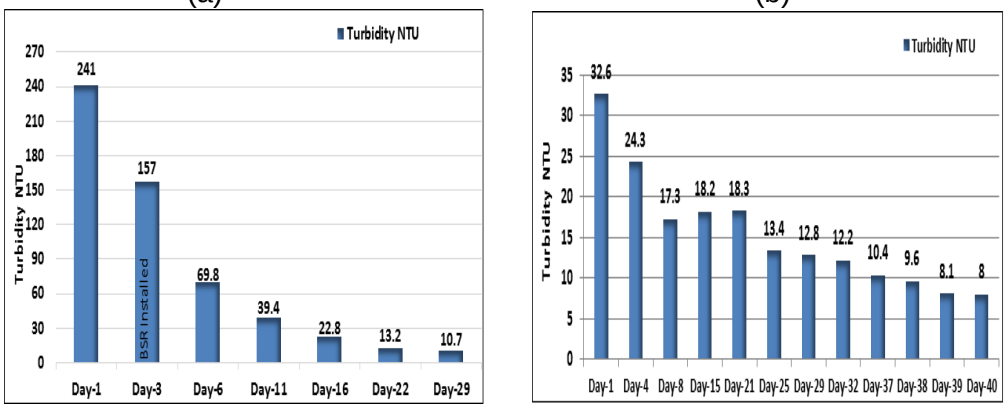


Figure 5: (a)(b)(c) observed values of COD in winter, spring and summer treatment phases respectively. (d) Removal of COD observed from waste water

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 (O'Connell, 2013). 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 treated. 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 6 (a). In spring phase the initial value of I-9 waste water was 32.6 NTU which reduced to 8 NTU till the end of the spring phase. Turbidity may increase due to the algal growth in pond water. Greenish tint may appear due to the presence of naturally growing algae. Figure 6 (b) 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 Fig, 6 (c). 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. Complete removal of turbidity is different phases of research are shown in Fig, 6 (d).

(a) (b)



(c) (d)

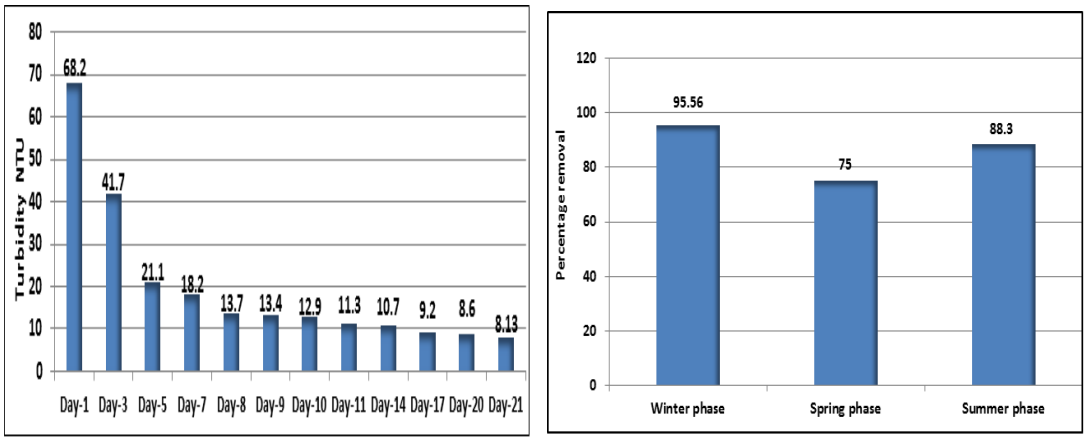


Figure 6: (a)(b)(c) observed values of turbidity in winter, spring and summer treatment phases respectively. (d) Removal of turbidity observed from waste water

pH is the negative of the logarithm to base 10 of hydrogen ion concentration. It is a measure of the acid content in water (McLean, 1982). 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 the pH value of three phases of treated water. Following figure 7 (a) shows the trend of pH in all three phases.

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 (Corwin & Lesch 2003). The figures 7(b) shows the relatively constant values and trend of E.C. in all three phases.

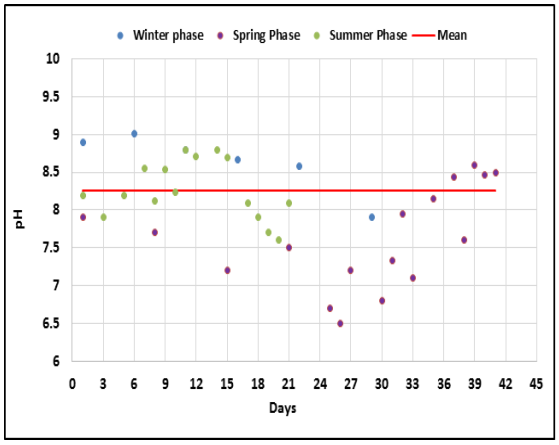


Figure 7(a): pH in different phases of experiment

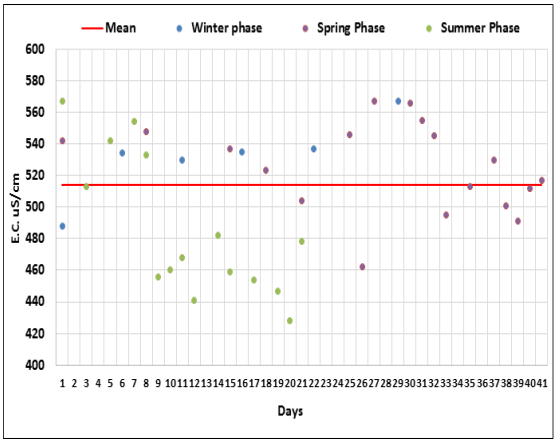


Figure 7(b) EC measured in experiment different phases of experiment

Nitrates and phosphates were determined at the start and end of the three phases of experiment Fig, 8(a) (b). Almost 50% removal of nitrates and phosphates was obtained Fig, 8(c).

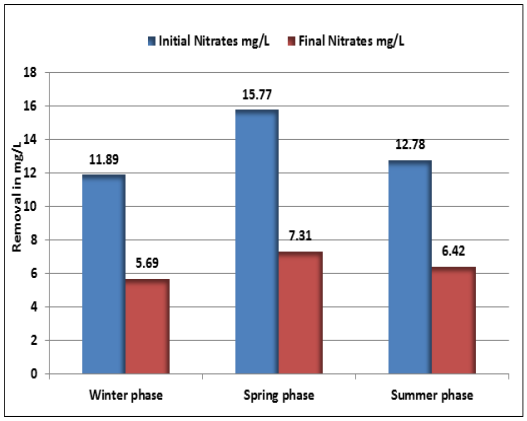


Figure 8(a): Nitrates observed in three phases

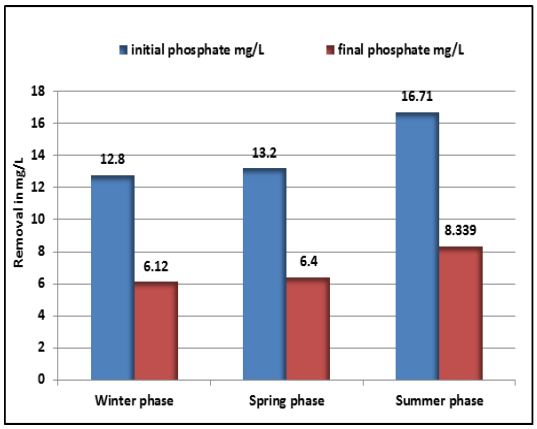


Figure 8(b): Phosphates observed in three phases

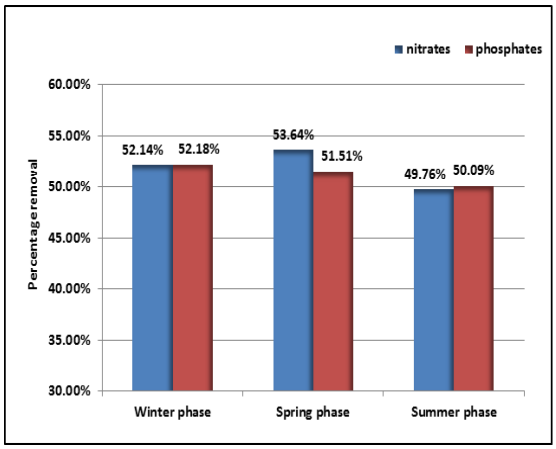


Figure 8(c): Percentage removal efficiency of nitrates and phosphates

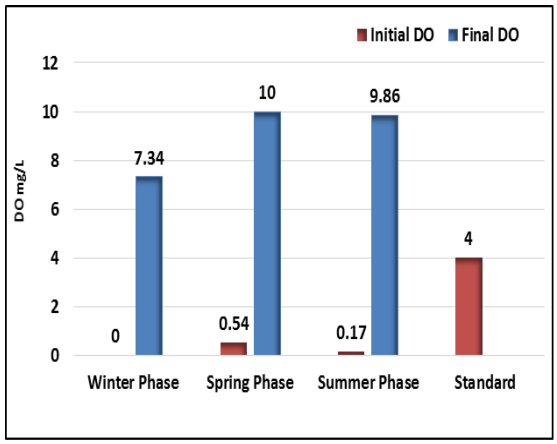


Figure 8(d): DO measured in three phases

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 (Azzuni, 2015). 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. 4mg/L of DO is normally required for fish in water. Dissolved oxygen detected in three phases is shown Fig, 8(d).

CONCLUSION AND RECOMMENDATIONS

Bio- Solar Reactor (SBR) was designed by PAKOSWISS 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.

REFERENCES

APHA. (2005). Standard Methods for the Examination of Water and Wastewater. 21st ed., American public Health Association, Washington D. C.

Azzuni, A. (2015). Design, implementation, and evaluation of an online water quality monitoring system in Lake Saimaa, Finland.

Corcoran, E. (Ed.). (2010). Sick water?: the central role of wastewater management in sustainable development: a rapid response assessment. UNEP/Earthprint.

Corwin, D. L., & Lesch, S. M. (2003). Application of soil electrical conductivity to precision agriculture. Agronomy Journal, 95(3), 455-471.

Florini, A., & Sovacool, B. K. (2011). Bridging the gaps in global energy governance. Global governance: a review of multilateralism and international organizations, 17(1), 57-74.

Häder, D. P. (1999). Aquatic ecosystems. In Global Aquatic and Atmospheric Environment (pp. 1-88). Springer Berlin Heidelberg.

Hartley, B., & Van Meter, H. J. (2011). The Human Right to Water: Proposal for A Human Rights-Based Prioritization Approach. Willamette J. Int'l L. & Dis. Res., 19, 66.

Johnstone, D. W. (2014). Regulation and reality: some reflections on 50 years of international experience in water and wastewater. International Journal of Water Resources Development, 30(2), 345-354.

Langergraber, G., & Muellegger, E. (2005). Ecological Sanitation—a way to solve global sanitation problems?. Environment international, 31(3), 433-444.

McLean, E. O. (1982). Soil pH and lime requirement. Methods of soil analysis. Part 2. Chemical and microbiological properties, (methodsofsoilan2), 199-224.

O'Connell, E. (2013). An in-situ optical fibre sensor for the monitoring of water quality using wireless motes.

Rolland, N. (2004). Was the emergence of home bases and domestic fire a punctuated event? A review of the Middle Pleistocene record in Eurasia. Asian perspectives, 43(2), 248-280.