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# Removal of Nutrients from Urban water by Engineered Constructed Wetland with Bio-Geo Filter and Biotope

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***Abstract -*** *The aim of this research was to introduce Bio Geo Filter – an engineered constructed wetland, on removal of nutrients of polluted urban stream water by using plants and geo materials which can be affordable in low income countries. Selected physical and chemical parameters of urban water were investigated during dry and wet seasons while monitoring the stream discharges with rainfall to obtain the concentrations of pollutants. According to topography and geotechnical properties of soil layers, and pollutant loads of the urban stream an ecofriendly, economical, engineered solution namely Bio Geo Filter (BGF) and Biotope was proposed. The entire treatment system was designed to withstand during possible flash flood flows during storm events. Biotope was established with tropical and terrestrial plants while the aquatic plants with high economic value were recommended for the BGF. A polishing pond at the downstream of the BGF was employed to visualize treatment efficiency before water enters to the Urban Canal. Biotope with uniform environmental conditions provides a living place for a specific assemblage of plants and animals was established on the stream embankments.*

***Keywords***: *engineered constructed wetland, Bio-Geo Filter, Biotope, pollutant load, nutrient removal, urban water*

## Nomenclature

As - Surface area of wetland ($m^2$)
L - Length of the wetland cell (m)
W - Width of the wetland cell (m)
Q - Average flow through wetland ($m^3/d$)
$C_e$ - Effluent pollutant concentration (mg/l)
$C_o$-Influent pollutant concentration (mg/l)
$K_T$ - Temperature-dependent first-order reaction rate Constant ($d^{-1}$)
y - Depth of water in the wetland cell (m)
n - Porosity

*Greek Letters*

$\sigma$ -Stefan Boltzmann Constant
$\varepsilon_{app}$ - Apparent thermal emittance

*Subscripts*

*e* - Effluent
*o* - Influent
*s* - Surface
$_T$ - Temperature

## 1 INTRODUCTION

The growing population and an increase of industrialization and agricultural production in numerous countries such as Sri Lanka require more and more water of adequate quality. In many regions there is a lack of surface water and severe water contamination is to be found (Ileperuma, 2000). Therefore, it is of high priority to take into consideration all the proved water techniques that could help to reduce the existing disaster of water pollution.

Nutrient enrichment of natural water system due to wastewater disposal is a critical issue in Sri Lanka. The Diyawanna Oya water system which consists of Kirulapone Canal is an important surface water source in Colombo metropolitan region is currently getting polluted due to haphazard wastewater disposal practices of surrounding communities. One of the streams, which connect to Kirulapone Canal, flows across the Open University of Sri Lanka (OUSL) premises, gives unpleasant image to the OUSL, as it carries greywater of nearby community as shown in Fig 1 and Fig 2. The government of Sri Lanka has been proposed to use the Diyawanna Oya for transportation (Times online, 2011). However with the present condition it is rather questionable and therefore, the water has to be clean and free from significant pollutants as well as undesirable colour or odour.

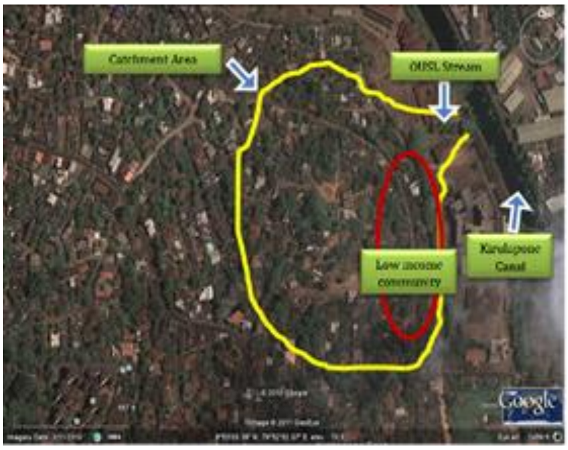


**Figure 1 Location map and the catchment of the OUSL stream**

The objective of this research is to establish a Bio Geo Filter (BGF) and Biotope on the stream bed and at the embankments of the stream in order to purify the stream water by removing nutrients before flowing into the Diyawanna water system. In addition this research study would play an important role in the development of the city and an educational model to enhance public attention on clean and pleasant environment.

### 1.1 Study Area

The stream involved in this research is located in between the Media House and Exam Hall-03 at the main campus of The Open University of Sri Lanka at Nawala, Nugegoda in Colombo District. The approximate length of the stream is 82 meters and the streamwater originated from a low income community about 150 population in adjacent lands of the OUSL premises. It is recorded that the influent contains the grey water such as wastes from bathrooms, kitchens and black water from toilets.

(a)

(b)

**Figure 2 The view of the urban stream (a) Stream covered with aquatic plants (b) Stream and Culvert at the OUSL premises**

## 2 RATIONALE

BGF represents the combination of Bio and Geo materials for the filtration (Jayasekara, 2008). The BGF design is based on **Free Water Surface (FWS) Constructed Wetland.** The said technology of wastewater purification has many advantageous over the other methods used in Sri Lanka. Biotope is a distinct set of environmental conditions that supports a particular ecological community of flora and fauna provides an aesthetically pleasant environment. This research is twofold focusing to propose water purification system for Kirulapone Canal flowing across the OUSL to Diyawanna water body using Bio Geo Filter Ditches and to develop a Biotope at the embankments.

### 2.1 Stream pollution and related impacts

The stream pollution can be occurred due to disposal of wastes into streams or any water body. Eutrophication and biomagnification are the most critical issues that may occur due to stream pollution. Hence, a special care should be taken to avoid or minimize these to save the nature and to provide a healthy life of nation and endorse the importance of avoiding pollution of streams is very obvious.

There are various methods available to treat wastewater. Most of those require separate units such as treatment plants for the treatment process. Those units require continuous maintenance and involve high initial and operational costs (Reed *et al*, 1995; Jayasekara, 2008). Therefore, such methods are inappropriate to treat polluted streams. **Constructed wetland is one of the low cost most appropriate solutions used all over the world which can be applied for polluted streams (Reed *et al*, 1995) having continuous flow with nondestructive surrounding.**

Constructed wetlands purify wastewater for improving water quality (Moshiri, 1993) and support wildlife habitat. It can also be a cost-effective and technically feasible approach to treat wastewater. Construction wetlands are often less expensive to build than traditional wastewater treatment options, having low operating and maintenance expenses and can handle fluctuating water flows. Additionally, it provides aesthetically pleasing environment and reduces or eliminates odors associated with wastewater (Kadlec & Knight, 2004).

Aquatic plants in the constructed wetland systems play the key role of purifying wastewater, entered to the system (Campbell & Ogden, 1999). A complex variety of physical, chemical and biological processes, including sedimentation, filtration, aerobic degradation, anaerobic degradation, nitrification, de-nitrification, adsorption and precipitation reactions are contributed to this purification process with microorganisms living on and around the plants.

## 2.2 Bio–Geo Filter (BGF)

The Bio–Geo Filter (BGF) is based on **Subsurface Flow (SF) Constructed Wetlands** and introduced as an ideal treatment system that suits for small waste capacities and for domestic installation with a combination of bio and geo materials namely Bio -Geo Filter (BGF) ditches. Cattail, duck weed, reed and bulrush are prominent aquatic plants, which are widely used for wetland cells in European countries, (Reed *et al*, 1995). Abe (2001) showed that papyrus, kenaf, crysanthemum, salvia and tomato can also be used as Bio-Geo filter vegetation.

A pilot scale Bio-Geo Filter ditches has been established at the Open University premises to demonstrate the potential for treatment of domestic wastewater using geo materials and plants. Selected bed filter materials and useful terrestrial plant species such as African merigold, canas, papyrus and reeds were employed for nutrient removal. This pilot-scale BGF containing laterite (kabook) stones with its rich composition of iron and aluminium, has been achieved nearly 100% removal of phosphorus (Jayasekara, 2008).

The pilot scale BGF shows the excellent pollutant removal efficiencies for $NH_4^+$, $NO_3^-$, and $NO_2^-$. It was recorded that pollutant removal efficiencies are generally high in the BGF showing 90% removal efficiency for $NH_4^+$ while the removal of $NO_3^-$ and $NO_2^-$ is around 100%. The BGF significantly removes TDS, conductivity and salinity and further the COD and turbidity reduction was above 90%. Ditches with papyrus and reed help to control pH before discharge. The plant species, which provide economic and aesthetically appealing aspects, are engaged to produce renewable energy in further step of this study (Liyanage *et al,* 2010).

## 2.3 Biotope

Biotope is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. Biotope is almost synonymous with the term habitat, while the subject of a habitat is a species or a population, the subject of a biotope is a biological community. Although the term "biotope" is considered to be a technical word with respect to ecology, in recent years the term is more generally used in administrative and civic activities.

# 3 METHODOLOGY

Water quality parameters such as Phosphate, Nitrate, Ammonia, COD, pH, Total Dissolved Solids (TDS), Salinity and Conductivity of the wastewater were tested. Phosphate, Nitrate and Ammonia are tested using Spectrophotometer (Hatch potable type) while pH, Total Dissolved Solids (TDS), Salinity and Conductivity were obtained using pH meter. The COD test was carried out by Open Reflux Method. The maximum and minimum discharge of wastewater in the stream was measured in wet and dry seasons respectively using a current meter of model Electromagnetic Flow Meter 801. Using the flow velocity readings given by the current meter relevant discharge was calculated. The rainfall of the project area was measured for each 10 minutes interval through the months October, November and December of the year 2010 with "Watch Dog-Spec 8 Pro" Rainfall Gauge. The rainfall gauge was placed at the roof top of a building nearby place to the stream.

The leveling survey was carried out to find the gradient of the stream and the topographical features of the area where the treatment unit is to be constructed. Longitudinal sections of stream and the cross section at 4m chainage where the dam is to be constructed are drawn. The geotechnical Investigation was carried out to identify soil condition of the area using borehole records such as soil types, thickness, SPTN values, of soil layers.

The collection pond was designed to control the flow of wastewater prior to enter to the BGF minimizing fluctuation of the stream velocity. The dam was designed by considering the hydraulic, geotechnical and structural design procedures. The hydraulic design of the collection pond was done based on the required retention period to be fulfilled the effluent quality according to the regulations stipulated by the Central Environmental Authority, Sri Lanka. The depth of the dam to be driven from the dredge level was calculated following cantilevered sheet pile design while the dam was designed by using cantilevered retaining wall design. The reinforcement calculation was done with respect to the critical bending moments at the base and wall of the dam. The design was completed by checking the satisfaction for the required conditions. The cost estimation was done based on the current rates of materials.

## 3.1 Design and Establishment of BGF & Biotope

The system was worked out to suit the topographical condition and flow rate and pollutant concentrations of wastewater. The BGF design was done by using the design concepts of **Free Water Surface (FWS) Constructed Wetlands. The surface area, number of cells and the depth of water were considered as the most important facts which were focused in the design.**

The design procedure for BOD removal of FWS constructed wetland is given by equations 1, 2 and 3.

*Surface area*

The surface area of the wetland can be determined by using Eqn-1 (Reed et al, 1995). Since the BGF design is based on FWS Constructed Wetland, the same equation is used in BGF design.

$$A_s = LW = \frac{Q(lnC_o - lnC_e)}{K_{Tyn}} \qquad (1)$$

*Reaction rate constant*

Temperature dependent first order reaction rate constant, $K_T$ was found by the Equation 2.

$$K_T = K_{20}(1.1)^{(T-20)} \qquad (2)$$

$$K_{20} = 1.104d^{-1}$$

*Hydraulic retention time*

The hydraulic residence time in BGF was calculated by the Equation 3,

$$t = \frac{LWyn}{Q} \qquad (3)$$

The suitable plants for the BGF and Biotope were identified according to the condition of the stream and the efficiency of pollutant removal of the plant species. Planting for Biotope was undergone with selected plant species on the embankments of the stream to improve the aesthetic view at the stream embankments.

## 3.2 Plants for BGF

Generally, emergent plants, those rooted in the soil or granular support medium that emerge or penetrate the water surface are used in wetland systems. The plants species used most frequently in constructed wetlands include Cattails, Reeds, Carex, Bulrushes and Papyrus. Therefore these species and some more locally available plants with Habarala which is readily available at the stream was used in BGF in the stream. Suitable plants for Biotope were identified and the appropriate plant species for stream embankment for Biotope were listed. First stage of planting on the embankment of the stream for Biotope was done with the plants given in Table 1. These plants were selected by considering the condition of the stream area and to provide an aesthetically pleasant view.

**Table 1 The list of plant species for Biotope**

| **Common Name** | **Botanical Name** |
|---|---|
| Murutha | Lagerstroemia speciosa |
| Kumbuk | Terminalia Arjuna |
| Bamboo varieties | Bambusa vulgaris<br>Ochlandra stridula<br>Bambusa multiplex |
| Wel kaduru | Cerbera manghas |
| Thimbiri | Diospyras malabarica |
| Girithilla | Argyreia populifolia |
| Wild Lilies<br>(White and green) | Anthurium sp. |
| Sooriya | Thespesia populnea |
| Walbeli | Hibiscus tiliaceus |
| Watakeiya | Pandanus latifolius |
| Diya Hawariya | Blyxa aubereei |
| Diya Koodalu | Impatiens sp. |
| Diya Meneriya | Commelina  benghalensis |
| Diya Mudilla | Barringtonia asiatica |
| Kekatiya | Aponogeton crispus |
| Diya Kaduru | Cerbera manghas |
| Kelani Tissa | Tecoma stans |
| Koboleela | Bauhinia variegata |
| Batakirilla | Erythroxylum moonii |
| Kahapethan | Bauhinia tomentosa |
| Goda Kaduru | Strychnos nux-vomica |
| Thun Iriya | Horsfieldia iriya |
| Thebu | Costus speciosus |
| Nelun | Nelumbo nucifera |
| Ma-Nelum | Nymphaea lotus |
| Olu | Nymphaea pubescens |
| Nil Manel | Nymphaea Stelleta |
| Kumudu | Nymphoides indica |

**Since the Phosphorous concentration of the stream is higher than the stipulated values, the possibility of phosphorous removal also considered in BGF design. It is found that "Kabook" (a form of Laterite) is capable of removing phosphorous (Jayasekara, 2008; Liyanage *et al*, 2009). Therefore, "**Kabook" was selected as the bed material for BGF with the experimental proof on phosphate removal efficiency of "Kabook".

### 3.3 Polishing Pond

The polishing pond was proposed to establish at the downstream of the BGF with a pleasant view to visualize the condition of treated water before it enters to the Kirulapone Canal. Flora and Fauna are supposed to introduce into the pond as performance indicators to evaluate the success of the treatment process.

### 3.4 The Catchment Area

The catchment area was identified by field observation at the rain due to unavailability of micro catchment contour maps. Fig 1 shows the micro catchment of OUSL stream, which carries the grey water of the adjacent low-income community.

### 3.5 Phosphate removal

Several tests were performed to investigate the applicability of "*kabook*" as the bed material in the BGF. Retention time of the BGF cells was taking in to consideration when designing the experiments for phosphate removal efficiency of *kabook*. Kabook was kept in the water samples with different phosphate concentrations and sampling was done at 10 minutes intervals. Since the retention time of one BGF cell is 20 minutes, tests were carried out to check the efficiency of *kabook* for 20 minutes of retention as well.

## 4 RESULTS

Selected water quality parameters of the stream in dry and wet season were measured and are given in Table 2. COD was measured only in dry season and recorded as 58 mg/l. This is extremely lower than the stipulated values by the CEA and therefore no specific treatment was designed for COD.

**Table 2 Water quality parameters of the stream**

| Water quality parameter | Date | | | |
|---|---|---|---|---|
| | Dry season | | | Wet season |
| | 8/2/2010 | 17/2/2010 | 23/2/2010 | 5/5/2010 |
| Conductivity (µs/cm) | 628 | 528 | 687 | 467 |
| Salinity (g/l) | 0.5 | 0.5 | 0.5 | 0.5 |
| TDS (mg/l) | 374 | 319 | 413 | 280 |
| Ammonia-N (mg/l) | 9.6 | 7.3 | 17.1 | 2 |
| Phosphate (mg/l) | 5.7 | 4 | 8.9 | 0.9 |
| pH | 6.73 | 6.93 | 7.17 | 6.6 |

The rainfall of the study area was measured for each 10 minutes interval through the year 2010.. The maximum rainfall recorded was 432.2 mm on 10th of November 2010 (not shown) when the whole area has flooded. This is the highest rainfall occurred for a day in the year. According to the records from Met Department, a closer value to this rainfall was recorded in 1992 that is about 18 years ago. Fig. 3 shows the daily rainfall records during January to July in 2010 in study area. It also indicates the sampling time during dry and wet seasons.

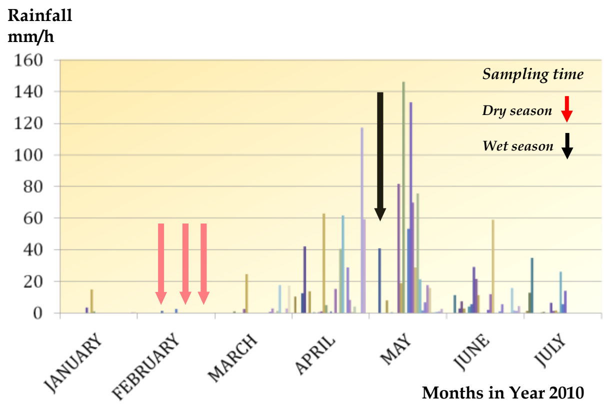


**Figure 3 Daily rainfall variations of the study area from January to July in 2010**

**Table 3 Phosphate removal efficiency of Kabook with time**

| **Retention time (Minutes)** | **Phosphate (mg/L)** | **Removal efficiency (%) *(Cumulative)*** |
|---|---|---|
| 0 | 4.5 | 0 |
| 10 | 3.05 | 67.7 |
| 20 | 2.15 | 47.7 |
| 30 | 1.4 | 31.1 |
| 50 | 1 | 22.2 |
| 60 | 0.82 | 18 |

## 4.3 Purification System

The purification system was proposed for dry flow with high pollution concentrations. Hydraulic design was done using Equations 1-3 and obtained the capacity of the collection pond which was 15.4 $m^3$. It is assumed that wet season treatment does not require as wastewater dilutes by rainwater. Further system allows overflowing during flash flows without damaging the treatment system. The average flow rate in dry season is 5.5 l/s. Hence the retention time of the collection pond is limited for 47 minutes. Lay out of the proposed system is shown in the Figure 4.

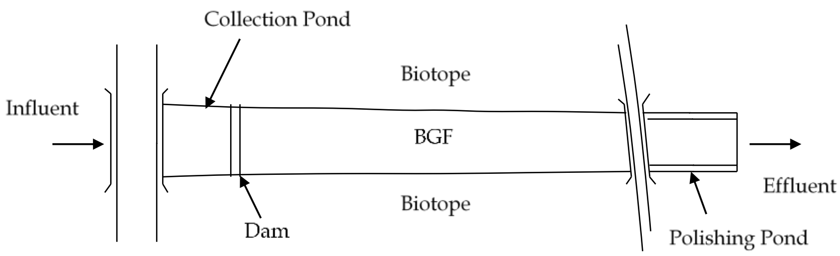


**Figure 4 Schematic diagram of the proposed purification system**

The waste stream enters to the OUSL premises and flow through culvert across the road. The proposed treatment system inlet is located at the culvert exit. Since the area is narrow stripe with peat soil, the design of collection pond involves hydraulic design, geotechnical design and structural design.

### *4.3.1 Hydraulic Design*

The average flow of the stream in dry season i.e. 475 $m^3/d$ was considered for hydraulic design. Based on the equations given, the dimensions of the collection pond for treating wastewater was estimated as length, width, and depth was estimated as 4m, 3.85m and 1m respectively. The capacity of the collection pond is 15.4 $m^3$ while the retention time provided is 47 minutes. The BGF was designed with three cells of each with 3m x 21m x 0.2m in dimensions and 189$m^2$ of total surface area. The details of the hydraulic design is given in Fig.5.

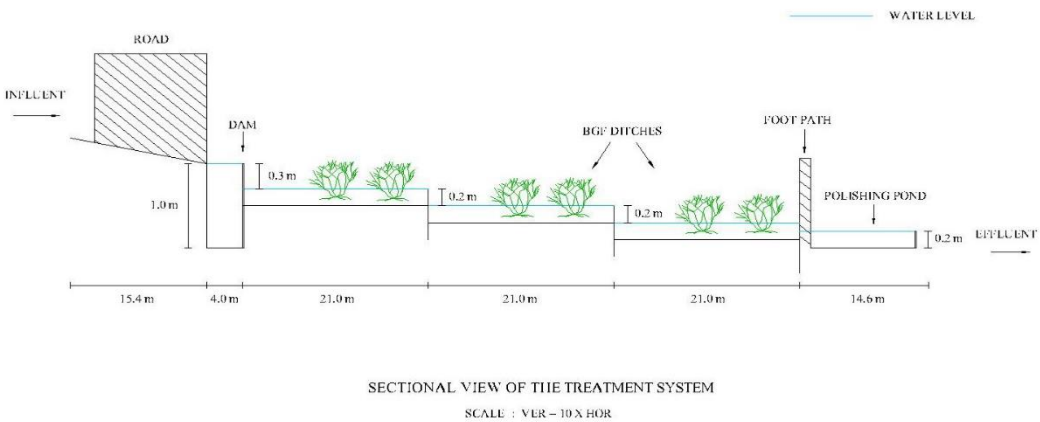


**Figure 5 The sectional view of the BGF cells and polishing pond**

### *4.3.2 Geotechnical Design*

According to the borehole details, the surface soil goes up to -2.5 m from the ground level and then the peat soil exists from -2.5 m to -4.75 m. The groundwater table exists at -0.8 m from the surface level at the study area. Considering the soils conditions, for the stability of the proposed water retaining structure, geotechnical design was carried out to make sure the dam is stable in the existing soil condition. The depth of the dam to be driven below the dredge level is found by using the concept of Cantilevered Sheet Pile design. The calculations are given below. Fig. 6 shows the levels of proposed dam and existing soil layers. For safety measures it was assumed that the stream bed level and the bottom level of collection pond are same. Determination of extended length is done by Descans Formula, and the depth of the dam from the bottom level of the collection pond was taken as 1.3 m.

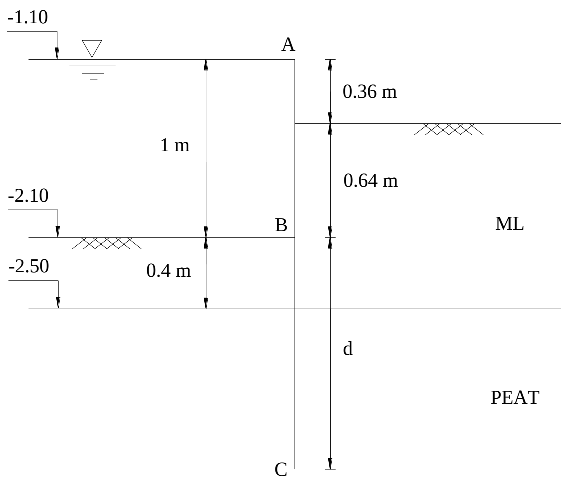


**Figure 6 The levels of proposed dam and existing soil layers**

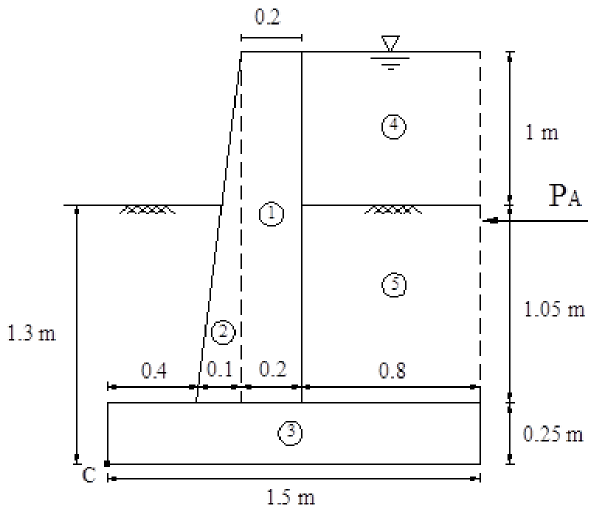


**Figure 7 Diagram of dam for designing**

### *4.3.3 Structural Design*

The design of dam was done by using the concept of Cantilever Retaining Wall. The finalized dimensions of dam for structural design are given in the Fig.7 while reinforcement details are given in Fig.8.

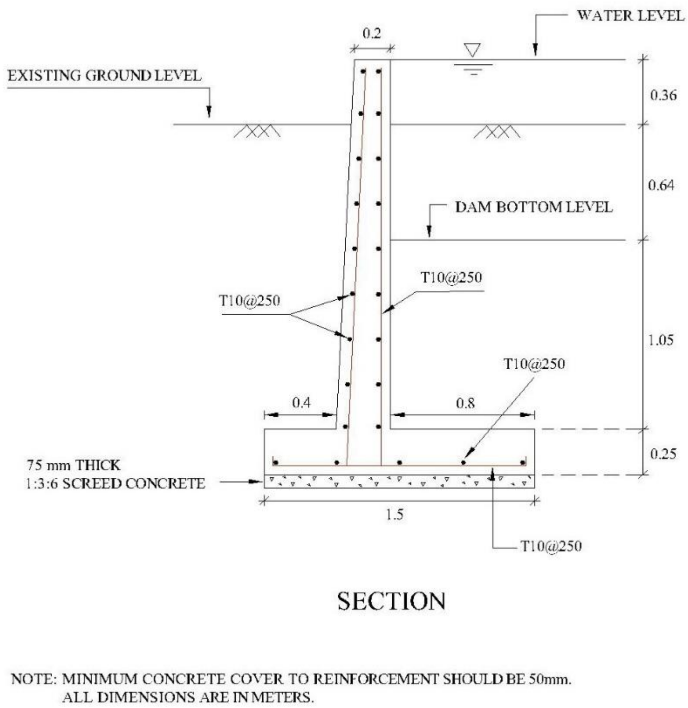


**Figure 8 Reinforcement details of the proposed dam**

## 4.4 Cost estimation

The peat layer of 2.35m thick was found just 0.4m below the bottom level of the proposed collection pond. Therefore, to carry out the construction, the peat layer supposed to be removed and that should be replaced by quarry dust. Nevertheless that method is costly and to reduce the project cost, two adjustments were carried out: (1) Instead of removing entire peat layer, only 150mm thick peat below the footing to be removed and replaced by quarry dust. (2) Width of the footing to be increased from 1.5m to 2m to reduce the bearing pressure.

## 5 DISCUSSION

The test results show that some of the pollutants of the wastewater exceed permissible levels mostly during dry season. The levels of phosphate and BOD in dry season were drawn special attention as they lie over the permissible level stipulated by the CEA that is 5mg/l and 30 mg/l respectively. Since phosphate is one of the causes of eutrophication, it may effects the ecosystem of the Kirulapone Canal and also may cause adverse effects even in the marine ecosystem of sea. The maximum BOD observed was 36 mg/l where the permissible level is <30 mg/l.

Generally stream water purification systems are hardly ever practiced in the word due to impracticality. Instead source protection applies through conventional wastewater treatment methods that involves three stages treatment such as primary, secondary and the disinfection which involves high initial and maintenance cost, more frequent maintenance; artificial chemicals etc. The greywater generated due to the malfunction of the existing treatment system and also due to wastewater generation through small commercial spots such as cycle repairing shops, boutiques. Focusing on above factors an engineered constructed wetland was proposed as the ideal solution to purify urban stream water.

The proposed purification system is with BGF which based on FWS constructed wetland. From the literature survey, it is evident that FWS constructed wetland is an efficient natural wastewater treatment method mostly used in United States, Europe (Arceilvala & Asolekar, 2007; Reed *et al*, 1995) and Australia (Vymazal & Kropfelova, 2008). It is capable of removing most of the similar pollutant found in the wastewater of the stream as well (Reed *et al*, 1995). Though this method requires large area for high performance, the BGF design was successfully done to achieve the required removal efficiency according to the pollutant concentrations and flow of the stream. Therefore, this treatment system was designed with adequate performance, low cost and environmental friendly manner which extremely suit even as educational model at the University.

### 5.1 The Collection Pond

This unit was designed to control the varying flow and to reduce the pollutant level to some extent prior to enter the BGF. According to the space available, the unit was designed to have 45 minute of retention time for dry season flow. Rao & Datta, (1987) recorded that since the water retain in this pond is in aerobic condition, the water look reasonably clean and are free from odour. Therefore, it is expected to remove odour as the pond is aerated by allowing water falls into the pond continuously.

### 5.2 The BGF

The aquatic plants and the bed material are the two of main components of BGF. The most appropriate aquatic plants and bed material were selected for the better performance of BGF.

The plants species used most frequently in constructed wetlands include Cattails, Reeds, Carex, Bulrushes and Papyrus (Jayasekara, 2008). Therefore, these species and some more locally available plants such as Gal ehi pan, Thunhiriya pan, Havan pan, Thela hiriya and Welhiriya with Habarala which is already available on the stream are selected as aquatic plants in BGF. Nevertheless detailed analyses of the performances of locally available aquatic plants are under experiment and are not readily available.

Most commonly used bed materials in constructed wetlands are gravel, coarse aggregates and sand (Arceilvala & Asolekar, 2007; Reed *et al*, 1995; Moshiri, 1993). In addition several locally available materials have been used in Japan (Abe, 2001). The expected outcome from the bed material is to reduce the pollutant level and to support the vegetation growth. By considering these two factors and the availability "Kabook" **(a form of Laterite) was selected as bed material for the BGF. From the literature studies and the test results done, it is proven that Kabook is an efficient Phosphorous removing media (Wood & McAtamney, 1996;** Zhang *et al*, 2011; **Liyanage, 2001). The high composition of Fe and Al of Kabook soil ($Fe_2O_3$-32.58% and $Al_2O_3$-34.31%) increase the Phosphorous removal process through its adsorption characteristics (**Zhang *et al*, 2011**).**

**The purification system contains three BGF cells of each with 20 minutes retention time. The depth of bed material in each cell is 75 mm which is 37.5% of the depth of a cell where the depth of a cell is 200 mm. The tests were performed to check the efficiency of *Kabook* and the results shows that the phosphorous** removal efficiency of *kabook* is about 50% for the retention time of 20 minutes and about 80% for the retention time of 1 hour. Variation of phosphate removal efficiency of *kabook* at different time intervals is shown in Fig.8.

The maximum level of phosphate obtained from the laboratory tests was 8.9 mg/l. Since the total retention time of BGF is 1 hour, the expected Phosphorous removal efficiency can be estimated as 80% which is satisfactory to reduce the Phosphorous to meet the permissible level. Zhang *et al*, (2011) have reported higher temperature is suitable for the adsorption reaction of phosphorus onto Laterite. Therefore using Kabook in a tropical country like Sri Lanka it can be expected more positive results.

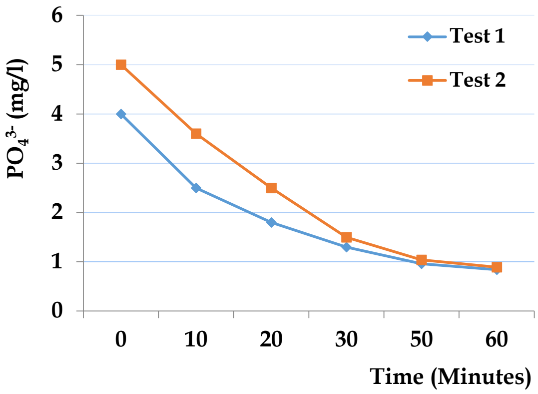


**Figure 8 Variation of Phosphate removal efficiency of Kabook at different time intervals**

## 5.3 The Polishing Pond

The treated wastewater is visualized in the polishing pond before discharging into the Kirulapone Canal. This study not only focuses on wastewater treatment but also provides aesthetically pleasant view to the study area. Therefore, a polishing pond also takes part on later stage of the treatment. The polishing pond is the final segment of the treatment system which contains the treated water. This pond will contain some bio- indicators to prove the quality of treated wastewater. Flora and Fauna will be introduced in the pond as the indicators which also provide aesthetically pleasant view at the downstream of BGF. The quality of treated wastewater is ensured by the lasting of these bio-indicators.

### 5.4 Performance of the Treatment System

The treatment system was designed to reduce the pollutants level of the wastewater under the permissible level stipulated by the Central Environmental Authority. The concentration of $BOD_5$ and phosphate are above the permissible level in dry season. Therefore, special attention was given to these two parameters in the design of treatment system. The maximum $BOD_5$ value obtained from the test results is 36 mg/l. since the permissible level of $BOD_5$ to be discharged is 30 mg/l, the BGF design was done to accomplish the discharge requirements. The maximum phosphate level obtained was 8.9 mg/l and the permissible level was 5 mg/l. According to the design, the phosphate removal of the BGF is 80% which reduces the concentration level far below the permissible level. Moshiri, (1993) obtained removal efficiencies of TSS and COD about 78% and 80-85% respectively by using constructed wetlands. From the similar studies, N removal efficiency in the forms of $NH_4^+$ -N, $NO_3^-$-N and $NO_2^-$-N is also expected more than 90% (Liyanage *et al*, 2010). Hence the proposed system would be expected high performance similar to those studies.


**Figure 10 The pictorial view of proposed BGF and Biotope at OUSL premises**

Biotope is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. The planting area for biotope is restricted up to 2 m from the embankment of each side of the BGF. The completion of establishment of biotope creates beautiful, pleasant and nature friendly view which will be a useful creation and educational model for the University. A pictorial view of proposed BGF and Biotope at OUSL premises is shown in Fig 10.

### 5.5 Cost effectiveness

As per the cost estimation, the total cost incurred for the treatment system is Rs 191,000 (U$1470) including the labour cost. With in-house labour, the cost can be reduced to Rs 135,000. Both of these amounts are comparatively very low than the cost incurred for construction of typical wastewater treatment systems.

### 5.6 Mosquito control

The objective of mosquito control is to suppress the mosquito population below the threshold level required for disease transmission. The following steps will be considered after the implementation of the project. It can be done by introducing of fish which provide effective control as used in FWS constructed wetland in United States (Moshiri, 1993) in the collection pond BGF and polishing pond. Further, removal of unnecessary plants or overgrown plants tightly together which may block the movement of water and by removing any part of plants or any obstacles that block the sunlight on to the water in the treatment system is recommended.

### 5.7 Stability of the Purification System for flash floods

Although the design for the wastewater purification was done by focusing the dry season, the design for stability of the whole system was done to withstand in wet season when the high flow of water in the stream is occurred. The dam was designed to stable structurally when the high flow in the stream is expected at rainy season. The BGF ditches were designed to withstand without washout in the high flow. Further, the types of plant species selected for BGF and Biotope are capable to exist in high flow of wastewater without any harm.

## 6 CONCLUSIONS AND RECOMMENDATIONS

The proposed treatment system with collection pond, BGF, polishing pond and biotope which provide aesthetically pleasant environment, is an appropriate and economical solution for a polluted stream. This study further reveals that the $PO_4^-$-P removal efficiency of "*Kabook*" **is about 80% and therefore can be used as the geo material for the BGF.** Cantilever retaining wall type of dam design was satisfactory for the soil and geotechnical conditions by increasing the width of footing from 1.5m to 2m in the design. The entire treatment system was designed to withstand during possible flash flood flows during storms.

Further experiments can be carried out with some other locally available geological materials to examine whether those are efficient enough and low cost to employ as bed materials for BGF. It is recommend to verify the applicability of other locally available aquatic plants for suitability according to the condition of the stream such as water level of BGF, depth of root zone, nature of bed material that provides nutrients for root zone. Continuous monitoring is needed to identify the time of replacement of geo material. However, the low-income community to be educated on proper waste disposal methods for preventing further pollutions of water system.

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