# CONSTRUCTED WETLANDS TO TREAT HOUSE WASTEWATER. A SOLUTION FOR INDONESIA?

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## ABSTRACT

A pilot project of one constructed subsurface flow wetlands to treat sewage from family Subandi house has been built in Bandung Indonesian in February 1999. The water samples from both influent and effluent (COD, $BOD_5$, $NO_3$-N, $NO_2$-N, $NH_4$-N, $PO_4$-P, pH, and settleable solids, and $O_2$) were taken twice a month and analyzed. Fecal coliforms bacteria was determined by MPN method. The objective of this study was to install one constructed subsurface flow wetlands with vertical flow to treat sewage from private house. The treatment efficiency of this constructed wetlands was already relatively high, although this constructed wetlands was just only eleven months in operation. The results were very promising and give a possibility of constructed wetlands to be installed and developed in tropical countries, especially in Indonesia, as a viable alternative to conventional wastewater technology, because this system is and simple and cost effective.

**Keywords:** Constructed wetlands, wastewater treatment, conventional system, subsurface flow

# INSTALASI PENGOLAH LIMBAH UNTUK MENGOLAH AIR LIMBAH RUMAH TANGGA SEBAGAI SUATU SOLUSI UNTUK INDONESIA ?

## ABSTRAK

Sebuah instalasi pengolah air limbah rumah tangga telah dibuat di rumah keluarga Subandi, Bandung, Indonesia pada bulan Pebruari 1999. Instalasi ini merupakan pilot projek. Sampel air baik dari aliran masuk (inlet) maupun aliran keluar (outlet) dianalisa dua kali sebulan sekali terutama untuk COD, $BOD_5$, $NO_3$-N, $NO_2$-N, $NH_4$-N, $PO_4$-P, pH, settleable solids dan $O_2$ . Penentuan bacteri fecal dilakukan dengan metoda MPN. Tujuan dari penelitian ini adalah membuat suatu pilot projek instalasi pengolah limbah tipe vertikal untuk mengolah air limbah rumah tangga. Hasil penelitian ini menunjukkan bahwa efisiensi pembersih dari instalasi ini sudah relatif tinggi walaupun baru beroperasi selama 11 bulan. Instalasi pengolah limbah ini sangat menjanjikan dan cocok untuk dikembangkan di negara tropis terutama di Indonesia sebagai alternatif dari instalasi pengolah air limbah konvensional dikarenakan instalasi limbah ini murah dan mudah.

**Kata kunci**: Instalasi pengolah limbah, pengolah limbah, sistim konvensional, aliran subsurface

## INTRODUCTION

Environmental pollution in Indonesia especially at rivers, lakes and other public water sources has been increasing for the past few years. The main cause of water pollution in Indonesia is due to domestic wastewater (40%), industrial wastewater (30%) and the rest is contributed from agricultural wastewater, animal husbandry wastewater or other kinds of wastewater. In Indonesia only around 25% of the wastewater is being treated mostly at the primary level prior to disposal, and the remaining 75% of untreated wastewater is discharged into the rivers or other public waters. This has created severe environmental pollution problems such as eutrophication and transmission of waterborne diseases (cholera, typhoid, dysentery and hepatitis). Conventional systems of sewage treatment can be very effective. However, they do have limitations in Indonesia. Lack of local technical ability combined with repair and maintenance often requiring expensive foreign currency can cause system failures.

In recent years there has been increasingly interest in an alternative technology with the aims of developing low cost, low maintenance, high energy efficient methods of treating sewage. This system (***Constructed wetland for wastewater treatment***) originated in Germany through the work of Dr. Seidel and Prof. Kickuth in the 1960s. This system offers a simple and effective process design and perform well not only for municipal sewage treatment but also for agricultural and industrial wastewater (Reddy and Smith, 1987). It is highly appropriate for use in third world countries, due to their low capital and operational costs compared to the conventional system.

At present, there are thousands of constructed wetland for wastewater treatment systems in Germany (Kunst and Flasche, 1995). Although the use of constructed wetlands for wastewater treatment has received international attention, performance data of constructed wetlands operating under tropical conditions are limited. In addition, there is no information stating that constructed subsurface flow wetlands (rooted emergent systems) for wastewater treatment have already been constructed in Indonesia. The majority of constructed wetlands in Indonesia are free floating system (e.g. Duckweed systems and water hyacinth ponds). These systems in Indonesia have a lot of problems with low nitrification, mosquito, and odour. According to Reed *et al.* (1995) the advantages of subsurface flow wetlands in comparison to free floating systems are decreased risk of nuisance from flies and odour and a great efficiency in term of land usage. The tropical climatic conditions like in Indonesia are being conducive to the rapid establishment of aquatic macrophytes and all biological activities will be more efficient. Higher purification efficiency of nutrients and organic pollutants in vertical flow and also smaller land requirement offer a great potential of vertical flow system of constructed wetland for water pollution control to be installed in Indonesia.

The objective of this study was to install a pilot project of one constructed wetland with vertical flow system to treat sewage from private house.

## MATERIALS AND METHODS

One constructed wetlands (5m long, 3m wide and 1.1 m deep) to treat sewage from family Subandi house has been built in Bandung, Indonesia in February 1999. The constructed wetland is a subsurface flow constructed wetland (6 p.e., 2.50 $m^2$ surface/p.e., 15 $m^2$, vertical flow, discontinuous feeding by timing device and drainage system spread over the whole bed area), planted with *Phragmites karka*, with a density of seven plants per $m^2$. The wastewater is mechanically pre-treated in sedimentation tank (3 $m^3$) and pumped onto the sand filter via polyethylene pipe. The sewage is pumped onto the filter bed at one day interval. The bed is sealed with polyethylene membrane. The filter bed is a multi-layer beds with sand as the main media. The small size of gravel (8-16 mm) was used in the first top layer (10 cm), followed by 15 cm of bigger size of gravel (8-32 mm) and 5 cm of small size of gravel (8-16 mm). As the main layer (60 cm deep) was used sand with hydraulic conductivity ($K_f$ value) 6.2 x $10^{-4}$ m/s, $d_{10}$ (0.25 mm) and uniformity (U) 4.0, followed by 5 cm of small size of gravel (8-16 mm) and finally at the bottom filled by 15 cm larger sized of gravel (16-32 mm). The treated water is collected in a drain at the bottom of the filter bed and used again as irrigation water for gardening or directed to the nearest public water source.

## MEASUREMENTS

The water samples from both influent and effluent (COD, $BOD_5$, $NO_3$-N, $NO_2$-N, $NH_4$-N, total-N, $PO_4$-P, pH, temperature, $O_2$ and settleable solids) were taken twice a month and analyzed. Coliform bacteria was determined by MPN method.

## RESULTS AND DISCUSSION

The study demonstrated that constructed wetland Subandi (vertical flow system) in Bandung, Indonesia had a high treatment efficiency in term of Biochemical Oxygen Demand ($BOD_5$), and Chemical Oxygen Demand (COD). The average treatment efficiency for $BOD_5$ and COD during the period of March 1999-January 2000 was 85.58% and 81.08% respectively (Table 1 and Figure 1). These high removals of $BOD_5$ and COD were due to sufficient oxygen supply in an intermittently loaded vertical flow system of constructed wetland Subandi. Cooper and Green (1995) stated that constructed wetlands with vertical flow systems can achieve full $BOD_5$ and COD removal because of high amounts of oxygen transfer through the reed beds. The average concentration of oxygen in constructed wetland Subandi in Bandung, Indonesia rose from 1.10 mg $L^{-1}$ $O_2$ in the influent to 6.58 mg $L^{-1}$ $O_2$ in the effluent (Figure 1). A higher oxygen content in this wetland is required for bacteria to remove both organic and nutrient pollutants. Platzer and Mauch (1997) also reported that the removal efficiency of constructed wetlands with vertical flow systems is based on very efficient soil aeration and therefore, $BOD_5$, COD and $NH_4$-N removal are high, but total-N elimination was limited. The average concentrations of $BOD_5$ reduced from 229.54 mg $L^{-1}$ $BOD_5$ in the influent to low level of 28.86 mg $L^{-1}$ $BOD_5$ in the effluent, whereas the average concentration of COD reduced from 460.82 mg $L^{-1}$ COD in the influent to 68.50 mg $L^{-1}$ COD in the effluent.

Constructed wetland Subandi in Bandung, Indonesia had a relatively high average of treatment efficiency for $NH_4$-N and $PO_4$-P. The treatment efficiency for $NH_4$-N and $PO_4$-P during the period of March 1999-January 2000 was 90.54% for $NH_4$-N and 68.59% for $PO_4$-P (Table 1 and Figure 1). Vymazal (1996) reported that removal of nitrogen varied widely among constructed wetlands and in most cases did not exceed 60%. The average concentration of $NH_4$-N in the effluent was 6.59 mg $L^{-1}$ $NH_4$-N, $NO_3$-N was 22.55 mg $L^{-1}$ $NO_3$-N, while $NO_2$-N was 2.02 mg $L^{-1}$ $NO_2$-N. These results showed very good agreement between the influent and effluent concentrations, indicating that nitrification was the major mechanism for $NH_4$-N removal. The major processes responsible for nitrogen removal in constructed wetlands are nitrification and denitrification (Brix, 1994; Vymazal, 1996) and plant uptake (Koottatep and Polprasert, 1997). Filter material and retention time (the amount of time the wastewater remains within the system) were also important factors in eliminating nitrogen nutrients from wastewater (Geller, 1997). The average concentration of total-N in the effluent of constructed wetland Subandi was 65.60 mg $L^{-1}$ total-N. Higher rates of total-N concentrations in the effluent of constructed wetland Subandi in Indonesia was probably due to a short retention time, and absence of a denitrification zone. The retention time in constructed wetland Subandi was only 42 hours. The average concentrations of $NO_3$-N and $NO_2$-N in the effluent of constructed wetland Subandi were still relatively high. These results indicated that the denitrification process in this wetland was probably absence. Gersberg ***et al.*** (1983) stated that sufficient dissolved carbon in constructed wetlands are very efficient in promoting denitrification process with removal efficiencies greater than 95%. Furthermore, Geller (1997) stated that complete nitrogen removal requires a combination of horizontal and vertical flow systems.

The average concentration of $PO_4$-P of 18.70 mg $L^{-1}$ $PO_4$-P in the influent is reduced to 5.88 mg $L^{-1}$ $PO_4$-P in the effluent. Higher concentrations of $PO_4$-P in the effluent of constructed wetland Subandi were probably due to high consumption of washing and cleaning materials containing phosphor.

The treatment efficiency of fecal coliforms bacteria from constructed wetland Subandi during the period of March 1999 - January 2000 was higher than 99%, whereas the average amount of fecal coliforms bacteria of $6.2 \times 10^8$ in the influent is reduced to $9.3 \times 10^3$ in the effluent. According to Wood (1990) and Ottova ***et al***. (1997) there are three factors participated in reducing phatogenic bacteria in constructed wetlands, i.e.; (i) physical, (ii) chemical and (iii) biological factors. Physical factors include filtration, sedimentation and ultra violet radiation. Biological factors include antibiosis, ingestion by nematode, and natural death. Chemical factors include oxidation, adsorption and exposure to toxins released by other microorganisms and plants. Vincent *et al*. (1994) also reported that root excretions of certain aquatic plants (*Phragmites australis*) can kill fecal indicators (E. coli) and phatogenic (Salmonela) bacteria. High rates of ultra violet radiation in Indonesia would also contribute to high removal of bacterial count ($10^5$) in constructed wetland Subandi.

## CONCLUSIONS

The overall results show a great promise and possibility for constructed wetlands to be installed and developed in tropical countries, especially in Indonesia, as a viable alternative to conventional wastewater technology, because this system is cost effective and simple (appropriate technology). Other advantages of this constructed wetland in Indonesia include high temperature promote purification and high solar irradiation (ultra violet) increase pathogen destruction. This system is also suitable for small to medium sized communities, in sparsely populated areas and agricultural areas (e.g. transmigration areas).

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**Tabel.** Average concentrations of SS, $NH_4$-N, $NO_2$-N, $NO_3$-N, $BOD_5$, COD, $PO_4$-P, Total-N, pH, Temperature, $O_2$, electrical conductivity and fecal coliforms bacteria from influent and effluent of constructed wetland Subandi in the period from March 1999 to January 2000.

| Parameter | Influent | Effluent | Efficiency (%) |
|---|---|---|---|
| Settleable Solids (mL $L^{-1}$) | 0.19 | 0.0 | 100 |
| $NH_4$-N (mg $L^{-1}$) | 37.40 | 6.59 | 90.54 |
| $NO_2$-N (mg $L^{-1}$) | 0.67 | 2.02 | - |
| $NO_3$-N (mg $L^{-1}$) | 11.08 | 22.55 | - |
| $BOD_5$ (mg $L^{-1}$) | 229.54 | 28.86 | 85.58 |
| COD (mg $L^{-1}$) | 460.82 | 68.50 | 81.08 |
| $PO_4$-P (mg $L^{-1}$) | 18.70 | 5.88 | 68.59 |
| Total-N (mg $L^{-1}$) | 93.90 | 65.60 | 31.14 |
| PH | 7.64 | 6.59 | - |
| Temperature $^{o}$C | 22.58 | 22.55 | - |
| Oxygen ((mg $L^{-1}$)) | 1.10 | 6.58 | - |
| Elec. Conductivity (µS $cm^{-1}$) | 1750 | 1465 | 16.28 |
| Fecal Coliform (MPN/100 mL) | $6.2 \times 10^{8}$ | $9.3 \times 10^{3}$ | 99.61 |

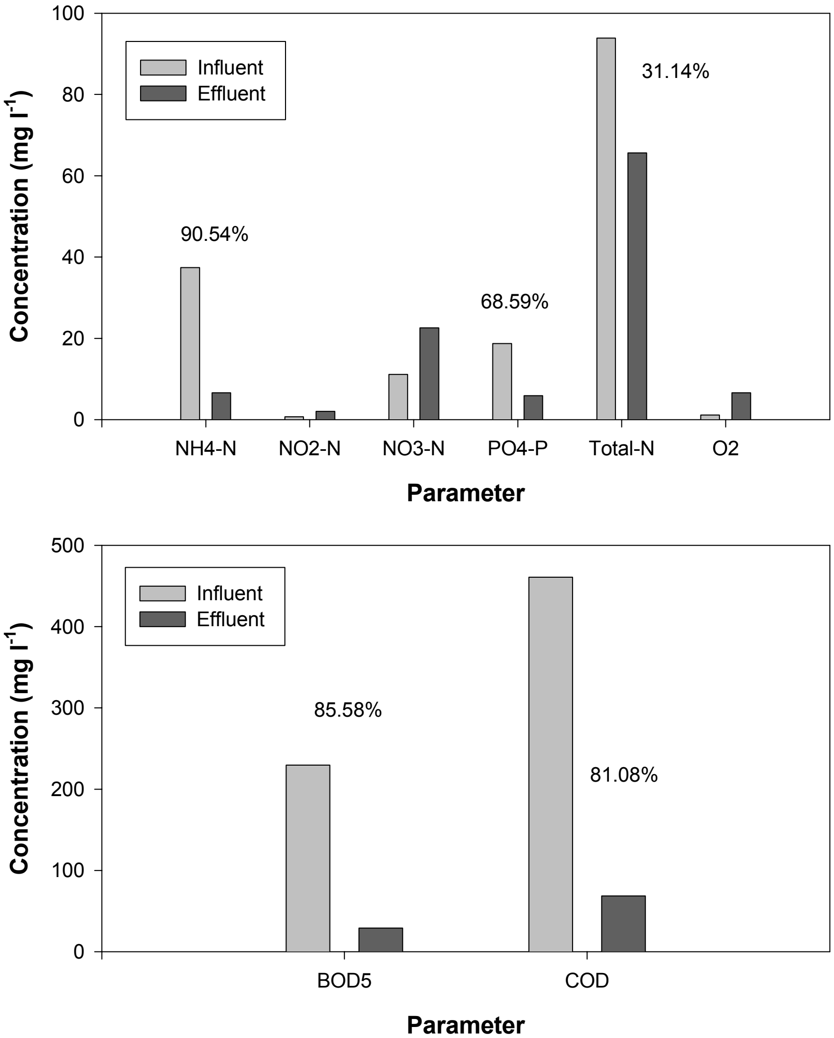


Fig. 1. Average concentration and treatment efficiency of $NH_4$-N, $NO_2$-N, $NO_3$-N, Total-N, $PO_4$-P, $O_2$, $BOD_5$ and COD (March 1999-January 2000).