

## Constructed wetlands for grey water treatment

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### Abstract

A vertical flow and horizontal sub-surface flow wetland were compared with a novel system (the GROW green roof water recycling system) for treatment of low-organic strength domestic grey water for reuse. The vertical and horizontal flow wetlands were planted with *Phragmites australis* in a sand:soil:compost medium. The GROW system was planted with a variety of marginal plants selected for treatment and aesthetic characteristics. BOD removal did not differ significantly between the three systems which all consistently met USEPA standards for grey water for reuse. However, the GROW system was most effective at removal of suspended solids and turbidity (mean removal 91.2% and 98.2% respectively) and both GROW and VF were more effective at removing pathogens (4.2 and 4.8 log reduction of total coliforms respectively) than the HF (2.7 log reduction).

**Keywords:** *E. coli*, green roof water recycling system, indicator microorganisms, recycling, reuse, water quality

**Pollutant transformation performance  
in a peri-urban African wetland system  
receiving point source effluent  
and diffuse source pollutant inputs**

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**Abstract**

Water quality investigations were undertaken in the Dionosoyiet wetland (Lake Victoria basin, Kenya) from June 2004 to April 2005 for nutrients and suspended solids. Hydrology and Water Quality modelling were performed based on the CRC FE POND model. The model was adapted to incorporate a rainfall runoff module based on the isochronal histogram technique and a partially stochastic prediction of water quality (TSS, TN and TP) based on incoming flow rates. Using the data gathered from June 2004 to April 2005 for calibration and earlier climatic data, modelling was performed to cover an 11 year period, from January 1994 to December 2004, and indicated that the wetland removed 43% TSS, 41% TP and 20% TN with average areal removal rates of 21.3 TSS, 0.038 TP and 1.03 TN ( $\text{kg ha}^{-1} \text{ day}^{-1}$ ).

The findings show that, in addition to being a central community activity feature of the town, the wetland performs significant functions of water quality improvement. The preservation of this wetland and other similar wetlands is important in ensuring sustainable utilisation of water resources in the Lake Victoria Basin.

**Key words:** Buffering; Lake Victoria; modelling; nutrients; runoff; surface-flow.

## **Efficiency of constructed reed bed and reed pond as tertiary wastewater treatment stages during their start-up period**

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### **Abstract**

A sand bed and a pond; both vegetated by reed (*Phragmites australis*), were monitored since their construction in summer 1997 till winter 1999/2000. The mean capacity during the study period equaled  $79 \pm 21 \text{ m}^3 \text{ d}^{-1}$ . The flow behind the secondary clarifier was divided equally between the reed bed and the reed pond, both of the same surface area about  $300 \text{ m}^2$ , giving the same hydraulic loads of  $132 \pm 35 \text{ mm d}^{-1}$ . The pH, TC, TOC, IC,  $\text{N-NO}_3^-$ ,  $\text{N-NH}_4^+$ ,  $\text{N}_{\text{Total}}$ ,  $\text{P-PO}_4^{3-}$  and  $\text{P}_{\text{Total}}$  have been analysed at the inlet and outlet of both systems. The performance of the secondary stage was sufficient except for nitrification ( $11.2\text{-}45.4 \text{ mg N-NH}_4^+ \text{ dm}^{-3}$  in the effluent from the secondary clarifier). No significant improvement in ammonia removal in the constructed wetlands has been observed. However, the nitrates quantities has been reduced by half. The investigations revealed better removal of suspended solids, total nitrogen and phosphorus by the reed bed than by the pond. The differences were greater during cold seasons.

**Key words:** wastewater treatment, constructed wetlands, reed bed, reed pond, nutrient removal.

## **Planted soil filters with activated pretreatment for compost-plant wastewater treatment**

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### **Abstract**

With the series of buffer tank, activated preclarifier and planted soil filters, it is possible to have a flexible operation by unsteady inflow and changing concentrations. An automatic control manages the storm-water runoff, and the water-recirculation provides a minimal feed, so the plant always runs effectively. Experiences with this plant since 1999 are given in the frame of the project "Planted Soil Filters as a Biotechnological Process", founded by the German Federal Environment Foundation (DBU). Today, after six years of running, the results are still satisfactory.

**Key words:** compost site, process-water treatment, constructed wetlands, sequencing batch reactor

## **Sludge treatment and drying reed bed systems**

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### **Abstract**

Sludge Reed beds have been used for dewatering (draining and evapotranspiration) and mineralisation of sludge in Denmark since 1988 when the first sludge processing system was introduced. Sludge from wastewater treatment plants (2500–125 000 PE) is treated in sludge reed bed systems with 1–18 basins with loading rates of 25–2200 tonnes dry solids/year for 10 years. In 2002, approximately 95 systems were in operation. Dimensioning and design of reed bed systems depends on the sludge production rate, sludge type, quality and regional climate. The maximum sludge loading rate is approximately 50–60 kg DS m<sup>-2</sup> year<sup>-1</sup>. Loading cycles are related to the sludge type and the age of the sludge reed systems. The sludge residue will, after approximately 10 years of operation, reach an approximate height of 1.2–1.5 metres with dry solids content of 30%. The concentration of LAS and NPE (total) in the sludge residue was reduced by a total of approximately 98% and 93%, respectively. Experience has shown that the quality of the final product with respect to heavy metals, hazardous organic compounds and pathogen removal after 10 years of treatment make it possible to recycle the biosolids to agriculture as an Enhanced treated product.

**Key words:** operations, dewatering, loading, emptying, quality of sludge residue.

## **Experiences of *Salix viminalis* application to water and sewage treatment**

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### **Abstract**

Willow (*Salix*), a pioneer plant in land reclamation process, was taken into account when a conception of plantations watered with sewage was developed. New application of *Salix* is an energy source. The experiences show that willow buffer zones can be used for removal of pollutants from diffuse sources. Laboratory and field experiments proved that *Salix viminalis* can be applied for treatment of sewage in individual household treatment plants. Application of willow gives increase of treatment efficiency in comparison to soil filters. Studies also show a successful application of willow plantations for sewage sludge utilization.

**Keywords:** willow, *Salix viminalis*, pollutants, sewage sludge

## **Application of used wetland filter media in agriculture – control of heavy metal contents and faecal contamination**

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### **Abstract**

Concentrations of heavy metals, bacteriophages and thermotolerant coliform bacteria (TCB) were investigated in light weight aggregate (LWA) filter media collected from four horizontal subsurface flow constructed wetlands in Norway. Comparison of heavy metal contents in these filters did not show any values exceeding the maximum allowable concentrations in organic materials, e.g. sewage sludge, used on cultivated areas (in accordance to Norwegian regulations). Also numbers of thermotolerant coliform bacteria did not exceed the number of 2500 TCB per gram of dry substance (TS), which is limited in such kinds of materials. Bacterial viruses were not detected in filter media.

**Key words:** Constructed wetland, bacteriophages, filter media, heavy metals, thermotolerant coliform bacteria, wastewater.

## **The role of willow roots in sub-surface oxygenation of vegetation filter beds – mass spectrometer investigations in Wales, U.K.**

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### **Abstract**

Membrane inlet mass spectrometry (MIMS) was used to monitor dissolved gas concentrations *in-situ* in laboratory microcosms and in a constructed willow vegetation filter bed used to treat leachate. Diurnal cycles in the concentrations of oxygen, carbon dioxide and methane were seen. O<sub>2</sub> is released from willow roots during daylight. CO<sub>2</sub> and CH<sub>4</sub> accumulate during the dark. Results also demonstrate sub-surface spatial heterogeneity in the willow bed, with locally high concentrations of O<sub>2</sub> within otherwise anoxic zones. This technique enables direct measurement of sub-surface environments in constructed wetlands, and provides evidence of the oxygenation capacity of willow vegetation filters.

**Key words:** Willow vegetation filters, constructed wetlands, leachate treatment, membrane inlet mass spectrometry, mini-rhizotron camera, oxygenation, microbial processes.

## **The legal regulations of sewage sludge management**

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### **Abstract**

Both preliminary and excessive sludge can contain microorganisms and toxic compounds (heavy metals and organic compounds) which may be potentially hazardous for the biota and environment. The objective of the paper is to present the technological possibilities of sludge utilization in terms of continuously changing regulations. Among the presented methods of sewage sludge utilization, a thermal one seems to be the most developed and long-term way. The landfilling of sludge will be not economical reasonable and also become illegal in the nearest future. Agricultural application (as a fertilizer or recultivation), although consistent with the idea of organic matter circulation in the environment, will be more and more difficult due to restrictive requirements.

**Key words:** sludge processing, decree, incineration, composting, landfilling

## **Conducting hydraulic tracer studies of constructed wetlands: a practical guide**

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### **Abstract**

This paper reviews and summarises the theory and techniques used when conducting hydraulic tracer tests in treatment wetlands, with particular attention paid to the practical issues to be considered during the planning and implementation phases. Typically, a single-shot impulse of tracer is introduced at the inlet and the concentration tracked at the outlet or other internal point in order to uncover information about the hydraulic characteristics of the wetland. The following aspects are discussed: the range of commonly used tracer substances, the mass of tracer to be added, and planning of the sampling regime. A range of graphical and statistical tools are described for interpreting the data from a tracer study, with example data from an impulse tracer study used to demonstrate the required computational procedures. It is recommended that a standardised approach be adopted for presenting tracer study data in order to allow the direct comparison of data from different wetland systems.

**Key words:** impulse tracer study, mixing, plug flow, residence time distribution, tracers.

## Tracer and spike tests of constructed wetlands

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### Abstract

This paper reviews the types of tracer testing that have been used in treatment wetlands, and summarizes example studies and collections of results. Impulse tests typically produce outlet gamma distributions, characterized by  $N$  tanks in series (*TIS*) and a volumetric efficiency ( $e_v$ ) calculated from the mean tracer detention time. *TIS* values center on  $N = 4$  for *FWS* and  $N = 6$  for *SSF* wetlands; while median  $e_v$  values are 77% for *FWS* and 89% for *SSF* systems. When used in conjunction with inert tracers, reactive material behavior may be better understood via spike additions. Thus dual additions of an inert, such as bromide, accompanied by a spike of a target substance, such as a pathogen, can provide easy interpretation of the removal rate. Sample results from  $^{32}\text{P}$  and  $^{15}\text{N}$  studies are shown to yield valuable insights into internal processes and their speeds. Wetland sediment storages build slowly, but the progress of accretion can sometimes be followed via radioisotopes such as  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$ .

**Keywords:** constructed wetlands, tracers, hydraulics, detention time, accretion

## **Performance dynamics of a LWA-filled hybrid constructed wetland in Estonia**

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### **Abstract**

Purification efficiency and mass removal of organic matter, suspended solids, nitrogen and phosphorus was analysed in a hybrid constructed wetland (CW) system with two subsurface flow filter beds, using Light Weight Aggregates (LWA), a two-chamber vertical subsurface flow filter (VSSF) followed by a horizontal subsurface flow filter (HSSF) with a total area of 432 m<sup>2</sup>. The analyses show purification effect: for BOD<sub>7</sub> the average purification efficiency is 86%, for suspended solids (SS) 84%, for total P 89%, for total N 53%, and for NH<sub>4</sub>-N 73%. The average outlet values for the above-listed parameters were 7.2, 6.0, 0.46, 20.4 and 9.0 mg dm<sup>-3</sup> respectively. The purification parameters meet the standards set by the Water Act of Estonia for wastewater treatment plants. The results show that hybrid CW systems consisting of subsurface flow filters can work efficiently in Estonia's cold climate. Using locally produced LWA as a filter material in CWs has shown good hydraulic conductivity and phosphorus sorption capacity. The Paistu CW, with its proper design and outstanding purification results, can be considered one of the best systems in Estonia.

**Key words:** BOD, mass removal, nitrogen, phosphorus, school house, treatment efficiency

## **Application, design and operation of constructed wetland systems: case studies of systems in the Gdańsk region, Poland.**

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### **Abstract**

Constructed wetland systems in Poland are applied to provide secondary treatment of domestic wastewater, protection of surface water and treatment of landfill leachate. Due to climatic conditions vegetated submerged beds (VSB) are most commonly applied for sewage and leachate treatment. For water protection systems with FWS or with mixed flow are more commonly used. The objective of the study was to recognize the efficiency and operation conditions of existing constructed wetland in Poland. It was concluded that discharging of too high loads of contaminations as well as too high hydraulic loadings leads to beds clogging and to the decrease of treatment efficiency in consequence. The average rates of organic matter and total nitrogen decomposition rates at the CW Wiklino were twice higher for the HF-CW II in comparison to corresponding rates for HF-CW I. The constants were dependent not only on temperature of sewage but on loads of contamination in the sewage as well.

**Key words:** water and wastewater treatment, constructed wetland, design, clogging

## **Influence of COD-fractions on removal effectiveness and accumulation of organic matter in constructed wetlands**

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### **Abstract**

The effect of the different type of organic substance present in sewage on the organic matter accumulation and removal effectiveness in the hybrid constructed wetlands has been analysed.

Effectiveness of organic matter removal from domestic sewage in hydrophyte beds depends on the type of organic matter fractions and their concentrations. Basing on analysis of COD fractions (soluble and suspended easy-to-decompose and hard-to-decompose fractions) it was proven that accumulation of organic matter in hydrophyte beds is determined by hard-to-decompose suspended fraction. Colmatation in the HF-CW beds was observed for the loads over  $10.0 \text{ COD}_{\text{xs}} \text{ g m}^{-2} \text{ d}^{-1}$ , while in the VF-CW beds – for the loads over  $12.5 \text{ COD}_{\text{xs}} \text{ g m}^{-2} \text{ d}^{-1}$ .

**Key words:** COD-fractions, organic matter accumulation, horizontal flow constructed wetland, vertical flow constructed wetland, efficiency

## **Pollutants removal effectiveness in hydrophyte filters with sequential vertical and horizontal flow**

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### **Abstract**

The performance of constructed wetland composed of sequential reed beds with vertical and horizontal flow of sewage was evaluated, basing on results of concentrations of organic matter, suspended solids and nutrients in inflow and in outflow as well as after subsequent stages of treatment in period 2001–2003. It was proved that dominant role in organic substances removal reaching 98.0% plays vertical flow filter. The removal of phosphorus took place in horizontal flow constructed wetland with efficiency of 36.5%, in vertical flow bed with efficiency 32.9%. Additionally applied adsorption filter removed the rest of phosphorus compounds to the value below 1 mg d<sup>-1</sup>.

Horizontal flow bed secured efficient nitrification of ammonia nitrogen average equal to 81.1% during vegetation season and 93.9% in outside vegetation season. The efficient the denitrification process took place only in 2001 year in horizontal flow constructed wetland with efficiency equal to 0.5 g N day<sup>-1</sup> (below project assumptions). In the further time of exploitation colmotation of filling material occurred due to excess load of contaminants from illegal discharge of sewage from individual farms.

**Key words:** hybrid constructed wetlands, horizontal flow constructed wetland, vertical flow constructed wetland, efficiency

## **The efficiency of landfill leachate evapotranspiration in soil-plant system with reed *Phragmites australis***

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### **Abstract**

The effectiveness of leachate evapotranspiration from soil-plant systems with reed *Phragmites australis* was investigated within two years period.

Significant linear dependence between reed biomass growth and transpiration was observed. It was revealed that cumulative curves of evaporation and evapotranspiration were linear and estimated models were well fitted to the experimental dates. Daily evapotranspiration was in the range from 1.01 to 3.15 mm d<sup>-1</sup> in the first year of research and from 2.68 to 4.94 mm d<sup>-1</sup> in the second year. It indicates the usefulness of soil-plant systems with reed in landfill leachate treatment by vaporization. Additionally, the research showed that the application of sewage sludge into the soil caused the increase in the vaporization efficiency.

**Key words:** phytoremediation, *Phragmites australis*, transpiration, landfill leachate.

## **Treatment of wastewater from small slaughterhouse in hybrid constructed wetlands systems**

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### **Abstract**

Suitability of CW systems for treatment of wastewater from small slaughterhouse of pigs was tested. In the first part of the experiment, a system comprising two VF (vertical flow constructed wetlands) and an HF (horizontal flow constructed wetlands) was used. In the second part, VF + HF system was used with recirculation of outflow from VF to sedimentation tank in the range 100 to 200%.

The experiment showed that sand and gravel beds of VF can be very effective in removal of organic substances, TSS and  $\text{NH}_4\text{-N}$  from strong wastewater,  $\text{BOD}_5$  reaching an average of  $2500 \text{ gO}_2\cdot\text{m}^{-3}$ , TSS –  $560 \text{ g}\cdot\text{m}^{-3}$ ,  $\text{NH}_4\text{-N}$  –  $400 \text{ gN}\cdot\text{m}^{-3}$ , and  $\text{N}_{\text{tot}}$  –  $500 \text{ gN}\cdot\text{m}^{-3}$ . The hybrid system of 2VF + HF removed only 78.2 %  $\text{N}_{\text{tot}}$ . Application of recirculation, depending on the extent, raised this index to as high as 85.7 – 96.6 %. Unexpectedly low was the effectiveness of denitrification in gravel bed of HF.

**Key words:** abattoir, effluent, reed beds, organic substances, suspended solids, nitrogen, denitrification, recirculation.

## **Management of sugar effluent in the Lake Victoria region**

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### **Abstract**

This paper presents an investigation of means to improve the existing effluent treatment system in a Kenyan sugar industry. Data presented include an investigation of the treatment efficiency of the existing stabilisation pond system, preliminary results from a pilot scale constructed wetland (CW) system and cost estimates of different options for improving the treatment system.

The existing stabilisation ponds seem to function well for COD and TSS but little P is removed. Constructed wetlands may provide cost-effective nutrient removal, based on preliminary results and literature data. An even more interesting system is the use of treated effluent for sugar cane irrigation.

**Key words** Constructed wetland, costs, Kenya, stabilisation ponds, sugar industry, water quality

## **Treatment of aged landfill leachate by cascade constructed wetland systems**

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### **Abstract**

Advanced treatments of landfill leachate are usually costly and energy-consuming. The ecotechnology of constructed wetland treatment systems may reduce the cost and energy required to treat leachate. In this study, the leachate from a ten-year-old landfill site was treated by five microcosm cascade constructed wetland (CCW) systems. Each system consisted of two types of basins in series, free water surface (FWS) and subsurface flow (SSF) microcosm, vegetated with three plant species, reeds, cattails and virens. The experimental results showed that the cascade constructed wetland system with reed in FWS and virens in SSF presented the highest removal efficiencies of COD, TSS, and TN. It was also found that all systems presented high  $\text{NH}_3\text{-N}$  but low TN removal efficiencies indicating less denitrification occurring in the systems. It was verified in this study that rising BOD values in influent could be helpful to denitrify aged leachate by CCW.

**Key words:** Denitrification, ecotechnology, microcosms, nitrification.