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SCREENING OF CURRENT EXPERIENCES IN PHYTOTECHNOLOGIES FOR WASTEWATER TREATMENT IN EUROPE WITH A VIEW TO ADOPTING IT IN THE NIGER DELTA REGION, NIGERIA

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Abstract: In Europe, constructed wetlands are gaining importance as an effective and low-cost alternative for treatment of sewage effluents in small cities and/or food manufacturing companies. Such systems have certain advantages over the traditional wastewater treatment systems and inspite of its advantages and extended practice, its application in developing countries like Nigeria in general and the Niger Delta region, in particular, has not yet been reported anywhere. The corresponding author and other authors in the company of the Managing Consultant of these plants, visited in Northern Italy, two different constructed free water surface wetlands (FWS) located in Bologna and Ravenna cities. These facilities are used in treating municipal sewage wastewater and wastewater from a meat factory, respectively. In this article, the phytotechnologies involved in these projects are described. Each of these plants consists of a double artificial fresh water ecosystem with an integrated management: channel and reservoir with aerobic and anaerobic ponds for increased sedimentation and to reduce the retention time and some riffle or run stretches to enhance the mineralization of organic matter. Indigenous aquatic macrophytes (*Phragmites, Typha, Lemna, Potamogeton, Myriophyllum*) and riparian hydrophillic species like Populus and Salix were planted along the phytosystem. Prior to final disposal, the treated water goes for drainage through an engineered filter bed with biofilm. This stage guarantees that the water for disposal comply with statutory limits for drainage of public sewage systems into surface waters in Italy. Besides, the phytodepuration system of Ravenna town is a fertiirrigation plant, too, and it is used to irrigate water-demanding crops, saving a significant lot of inorganic nutrients and water. The authors, therefore, concluded that, because of the apparent simplicity of design and management, coupled with its efficiency and cost effectiveness and with the presence of abundant natural aquatic macrophytes, this phytotechnology can be adopted to treat municipal/sewage and industrial wastewater in the wetland ecosystems of the Niger Delta region of Nigeria.

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INTRODUCTION

Conventional mechanical wastewater treatment plants used in developed countries involve large capital investments and operating costs, and for that reason these systems are not a good solution for small communities and industrial establishments that cannot afford such expensive conventional treatment systems, particularly in a developing nation like Nigeria.

According to Solano *et al* [1], constructed wetlands are gaining importance as an effective and low-cost alternative for treatment of septic effluents in small villages. Such systems have certain advantages over the conventional treatment systems: they can be established in the same place as where the wastewater is produced; they can be maintained by relatively untrained personnel; they have relatively lower-energy requirements and are low-cost systems. They are usually utilized as secondary and even as tertiary treatment[2-5]. Alternatively, constructed wetlands can be used for primary treatment, where the wetland is the only type of treatment used and in this case, toxic effects on the aquatic plants due to the high organic loading of the influents have been reported [6, 7].

The use of constructed wetlands as phytodepuration systems has proved to be an effective and cheap method of treating wastewaters from municipal and specific industrial sources in developed countries [8]. However, the understanding of biological processes of constructed wetlands as phytodepuration systems is still modest and fragmentary. Most importantly, inspite of its cost-effectiveness and wide application elsewhere and despite the fact that research into the design and application of constructed wetland systems suitable for the African situation has been undertaken since the late 1970s [9]; its application in a developing country like Nigeria in general and the Niger Delta region in particular has not been reported any where.

There are three typical types of constructed wetlands which can be distinguished by structure and water flow direction: the free water surface wetland (FWSW), subsurface flow wetland (SFW) and vertical flow wetlands (VFW). Both FWSW and SFW generally flow horizontally; however, the water levels of these systems differ. VFW has a totally different structure such that water is distributed evenly at the surface of the wetland and then flows vertically to the bottom. Each of the three types of constructed wetlands has its own advantages and disadvantages with respect to construction, operation and management [8].

There has been little or no interest in applying the purifying potential of abundant indigenous aquatic macrophytes and testing their potentials/adequacy and viability as opposed to the more costly conventional mechanical systems of wastewater treatment adopted in many European countries. This research project was therefore designed to study two wastewater treatment systems using phytodepuration phenomenon, a phytotechnology in Ravena and Bologna, Italy. These wastewater treatment systems use various sequences of indigenous aquatic macrophytes/plant communities by virtue of their biological characteristics, in order to obtain a better physico-chemical and microbiological quality of effluent.

The aim of this work was to study the feasibility of the use of a phytotechnology system using constructed wetlands to treat raw wastewater from both municipal and industrial sources in two cities in Italy with a view to adopting same in small cities and industrial establishments in Nigeria in general and the Niger Delta region of Nigeria, in particular.

METHODS

Visit to the Phytodepuration System Sites in Ravenna and Bologna, Italy

The corresponding author and other co-authors of this article in the company of the Managing Consultant to these two (2) Phytodepuration systems (the last author) visited these systems in September 2008 (Figure 1), November 2008 (Figure 2) and March 2009 (Figure 3) in Italy.

Observation, Data Acquisition and Description of the Phytodepuration Systems visited

During each visit, the following aspects of each of the wastewater treatment/phytodepuration systems were studied.

i. The system design data for each of the phytodepuration systems:
ii. The indigenous aquatic macrophytes used, and
iii. Influent and effluent wastewater characteristics

Fig. 1: Visit to the Phytodepuration System at Ravenna in September 2008

Fig. 2: Visit to the Phytodepuration System at Bologna in November 2008

Fig. 3: Visit to the Phytodepuration System at Ravena in March 2009

RESULTS AND DISCUSSION

Description of the Phytodepuration Systems

The Phytodepuration System at Ravenna

The Phytodepuration system at Ravenna is built near the Ravenna Sewage Treatment Plant situated in the central part of Italy (Figure 4).

Fig. 4: The Phytodepuration system at Ravenna (red arrow shows the Ravenna Sewage Treatment Plant).

a. The system design data

This phytodepuration system is made up of two series of constructed wetland with different hydraulic application rates (HAR), 150 and 75mmday^{1} with retention times of 1.5 and 3 days, respectively and about 1km long but meandering channel (Figure 5).

Fig. 5: The 1km long meandering channel

b. The indigenous aquatic macrophytes used

Each series of the constructed wetland consist of beds both planted with Populus (*Populus* spp) and reed (*Phragmites* spp) (Figures 6a, b).

An impermeable geotextile liner is placed at the bottom of each bed to prevent groundwater contamination (Figure 7). An inlet and outlet zone, each 1m, consisting of large stones (510 cm), was used to eliminate the effects of the inlet and outlet. Each bed had a polyvinyl chloride (PVC) inlet pipe at its top, ending with horizontal drainage pipe of 1.5m long and 50mm diameter.

Fig. 6a: *Populus spp*

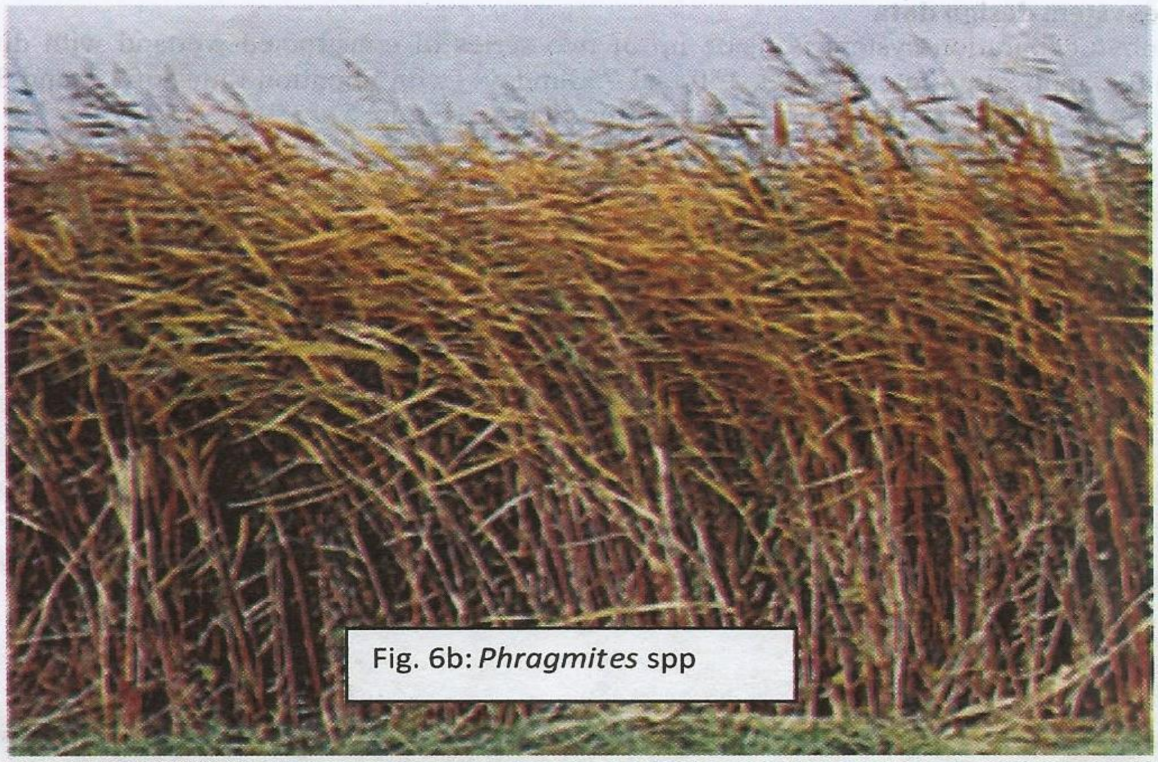

Fig. 6b: *Phragmites* spp

Fig. 7: An impermeable geotextile liner at the bottom of each bed to prevent groundwater contamination

c. Influent and effluent wastewater characteristics at Ravenna Plant

Influents into the plant are from urban sources: sewage and domestic wastewater, urban runoffs and a small percentage (1.53%) is industrial wastewater. The influent into each bed is controlled to maintain the designed daily flow rate. The characteristics of influent into this plant are shown in Table 1.

Table 1: Mean physicochemical and microbiological parameters in influents and effluents at Ravenna System.

Parameters	Values		Mean % Removal
	Influent	Effluent	
pH	8.0	7.2	10
BOD, mg l^{-1}	607	146	76
COD, mg l^{-1}	875	280	68
TSS, mg l^{-1}	430	47.5	85
Ammonia – N, mg l^{-1}	40	8	80
Nitrate – N, mg l^{-1}	26	2.6	90
Nitrite – N, mg l^{1}	0.7	0.13	82
Phosphate – P, mg l^{-1}	8.1	1.0	88
Total Coliforms, MPN / 100 ml	3.2×10^6	5.0×10^5	85
Faecal coliforms, MPN / 100 ml	4.0×10^5	2.0×10^4	95
Faecal Streptococci, MPN/100 ml	1.0×10^4	2.3×10^3	87

The Phytodepuration System at the Meat Factory at Bologna, Italy

a. The system design data

The phytodepuration system here consist of two aerobic ponds and one anaerobic pond linked by about 0.8 km long but meandering channel and a terminal wetland biofilm bed (Figure 8). The ponds, channel and the wetland bed are lined by an impermeable geotextile layer to prevent groundwater contamination.

b. The indigenous aquatic macrophytes used

The 0.8km-long but meandering channel is planted with cattail (*Typha latifolia*) (Figure 8) and reeds (*Phragmites spp*) while *Lemna* spp (Figure 9) grow on the aerobic ponds.

The Plant capacity, hydraulic flow, retention times as well as other design data/information considered in the design of the Bologna meat factory wastewater treatment system are as presented below.

Fig. 8: The 0.8 Km channel planted with Cattail (*Typha latifolia*)

Fig. 9: One of the two aerobic ponds with *Lemna* spp. growing in it

c. Influent and effluent wastewater characteristics at Bologna System

Influent into the Bologna wastewater treatment system was from a meat factory. The influent into the 0.8 km channel was controlled at about 8°C and to maintain the designed daily flow rate. Table 2 presents the characteristics of influent into this system.

Table 2: Mean physicochemical and microbiological parameters in influents and effluents at Bologna System

Parameters	Values		Mean % Removal
	Influent	Effluent	
pH	8.5	7.4	13
BOD, mg l^{-1}	732	146.6	80
COD, mg l^{-1}	855	213.7	75
TSS, mg l^{-1}	438	57	87
Ammonia – N, mg l^{-1}	38	6	85
Nitrate – N, mg l^{-1}	30	2.1	93
Nitrite – N, mg l^{-1}	0.5	0.1	85
Phosphate – P, mg l^{-1}	8.5	1.3	85
Total Coliforms, MPN / 100 ml	5.3×10^6	6.4×10^5	88
Faecal coliforms, MPN / 100 ml	2.5×10^6	2.0×10^5	93
Faecal Streptococci, MPN/100 ml	3.6×10^5	3.6×10^4	90

Treatment Systems Efficiency

The efficiency of the two treatment systems were different, probably due to the systems designs that were different and the different aquatic macrophytes in each treatment plant (Tables 1 & 2). Apart from pH, the percentage removal of pollutants from the Ravenna Plant influent wastewater ranged from 68% to 95% (Table 1) while the percentage removal of pollutants from the Bologna System influent wastewater ranged from 75% to 93% (Table 2). This percentage removal of pollutants from the two systems was with the treatment systems with HAR of

75mmday^{-1}. This finding is in agreement with results reported by Mandi et al.[10] for *Phragmites australis*.

Concerning the bacteriological analysis, the removal efficiency of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) were found to be very high (ranging from 85% - 95%) for the two plants. Generally, pollutant removal from 60% - 70% range are attributed to microbial breakdown of carbonaceous compounds being limited by low oxygen availability.

Prior to disposal into public sewer, the treated effluent from each of the plants are sprayed onto an engineered bed with biofilm (Figure 10) and confirmed that this water meets statutory limits for disposal into public sewers in Italy.

Fig. 10: The last stage of the Phytodepuration system at Bologna showing treated water being sprayed onto an engineered filter bed with biofilm

CONCLUSION

In conclusion, no significant difference between cattails and reeds in their ability to remove the studied parameters was observed as the differences in the percentage removal of pollutants were insignificant. Similar findings have been reported by Neralla *et al*[5] when comparing four different plants (*Canna* sp., *Typha latifolia*, *Typha angustifolia* and *Iris* sp.), and Burgoon et al[11] who also found no significant differences in BOD removal from settled domestic wastewater in 22 litre gravel-bed wetland, planted with four different species. This emphasizes the relative importance of physicochemical and microbial processes operating within the gravel matrix and associated biofilms[12].

Summarily, the high percentages of removal for both physicochemical and microbiological parameters have been attained by the two treatment plants without any significant relationship to plant species. This emphasizes the relative importance of physicochemical phenomena (i.e., flocculation and settling of suspended solids) and microbial processes (i.e., aerobic and anaerobic decomposition) operating within the treatment plants.

No seasonal differences were found in the performance of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and pathogens. During the winter (March - May), the removal of those pollutants was lesser, although the removal percentages have never been below 60%. Results obtained are promising for the studied system to be used as an efficient treatment in small cities in a developing economy like Nigeria.

The authors, therefore, concluded that, because of the apparent simplicity of design and management, coupled with its efficiency and cost effectiveness and with the presence of abundant natural aquatic macrophytes, this phytotechnology can be adopted to treat municipal/sewage and industrial wastewater in the wetland ecosystems of the Niger Delta region of Nigeria.

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