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Initial efficiency of a bamboo grove–based treatment system for winery wastewater

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Abstract

The contamination of the water resource is a critical environmental issue. PHYTOREM®, a French company specialized in phytoremediation, has patented an innovative technology using temperate bamboos to treat wastewater. The latter is evenly spread over a bamboo grove and supplies water and nutrients for plant growth. The bamboo grove produces new culms each year and mature culms can be harvested and processed in wood or energy industries. The present experiment demonstrates the contaminant removal efficiency of a bamboo grove composed of three bamboo species. During 2 years winery wastewater was spread over a bamboo plot. Nutrient status of leachate was evaluated, and the results from the treatment plot did not show any difference compared to the control. This experiment showed that 99% of the organic matter and 98% of the nutrients were removed by the soil–bamboo system.

Keywords: Phytoremediation; *Phyllostachys viridis*; *Phyllostachys viridis* "sulfurea"; *Semiarundinaria fastuosa*; Wastewater treatment

1. Introduction

Surface water and groundwater pollution are critical environmental issues. Substances affecting water bodies include inorganic, organic and biological contaminants. In the last few years, natural treatment systems following phytoremediation principles [1,2] have been developed and provide an alternative to treat polluted water [3]. Most of them are constructed wetlands based upon symbiotic relationships found in natural marsh ecosystems at the soil–water interface. These relationships naturally contribute to the purification of fresh water and are efficient to

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treat organic and inorganic waste in the form of specially designed filter bed. Although constructed wetlands can treat high and constant water volumes, terrestrial treatment systems may be used to treat high load seasonal outflow (e.g., winery wastewater) or low load and continuous outflow (e.g., domestic waters).

Due to the seasonal character of wine production, winery wastewater volume and composition are much variable in time. The outflow volume and the concentration of organic materials increase during vintage between August and October. The Provence-Alpes-Côte-d'Azur (PACA) region (southeastern part of France) is among the biggest wine producers in France. In 2003, this region produced 4728 m^3 of wine representing 10% of the French production. In this context, treatment of winery wastewater is a major environmental issue in the PACA region. In 2002, the PHYTOREM company (Miramas, PACA Region, France) developed the BAMBOU-ASSAINISSEMENT® technology to give an alternative for the treatment of such wastewater.

This technology is a complete biological treatment system based on phytoremediation principles [2]. It uses the bamboo, a terrestrial plant that is known for its resistance to a wide range of stressors and for its high growth rate and biomass production. It has a large and extended root system which may exhibit high water and nutrient absorption abilities [4–6]. Temperate bamboos are "running bamboos" or leptomorphs and are characterized by an elongated rhizome. The bamboo is a pioneer plant and its rhizome supports its rapid colonization. New culms appear during spring while the rhizome and root system develop all around the year with a higher growth during summer and autumn. Each year new culms rise from the rhizome and their size (height and diameter) depends on the existing plant (older culms and root system). On average, culms' size increases by 30% to 50% each year until it reaches a maximum height after 4–6 years depending on the species and environmental conditions. Five-year-old culms can be harvested for a good-quality wood. With a good management of a temperate bamboo grove, new culms regenerate the stand while mature culms are harvested [6].

Briefly, the BAMBOU-ASSAINISSEMENT technology could be classified in between constructed wetlands and terrestrial treatment systems and consists in spreading wastewater evenly on a bamboo grove. The bamboo grove is composed of at least three different species of bamboos. Different species can be used for aesthetic purpose, for different light or soil conditions and for the prevention of the flowering of the whole bamboo grove. The colonization of the bamboo is restricted by an anti-rhizome barrier which defines the limits of the spreading area. The wastewater supply brings water and nutrients to the plant, which in turn absorbs contaminants and evapotranspires the water. As a result, organic materials enrich the soil and are transformed for biomass and wood production. In addition, the high evapotranspiration rates of a bamboo grove limit the loss of water from the bamboo–soil system and hence impede the transfer of contaminants to surface or underground water [4,5]. BAMBOU-ASSAINISSEMENT stations have no outlet since they are not sealed and they are sized to consume most of the water and elements brought to the system. As a result, this treatment system does not produce sludge but culms that can be processed in wood or energy industries. Moreover, the bamboo, having a high biomass production, is a recognized carbon sink and thus the use of such a wastewater treatment system contributes to the reduction of greenhouse gases. Hence, using bamboo grove to treat wastewater is totally in accordance with sustainable development principles.

This treatment process was patented by PHYTOREM and validated by the French water agency after a 2-year experiment on winery wastewater started in 2003. The objectives of this experiment were to evaluate the contaminant removal efficiency of a 5-month-old bamboo grove of 1080 m^2 on 162 m^3 of winery wastewater produced from a nearby winery. In addition, although the system is sized to consume most of the water and elements brought by wastewater, losses of water by infiltration can occur during strong rain events. This question was addressed in this experiment by analysing the eventual leachate to show that it satisfied the French standard of wastewater discharge in the environment. For this purpose, drains and ditches were set up all over the experimental field to evaluate leachate and surface run-off both quantitatively and qualitatively. The results obtained between September 2003 and May 2004 on soil and water analyses are discussed.

2. Materials and methods

2.1. Experimental set-Up

The experiment was done in an agricultural area near Miramas (Bouches-du-Rhône, south-eastern France) in the vicinity of Marseille. This location has a typical Mediterranean climate, characterized by hot-dry summers (from June to August, average temperature 23.5°C, rainfall <50 mm) and low annual rainfall (500 mm) mainly occurring during autumn (>50%) and spring (>25%).

The experiment was set up over a total area of 1520 m^2 with a slight slope (3%). It was divided into three plots: a treatment plot (1080 m^2), a recirculation plot (220 m^2) and a control plot (220 m^2) (Fig. 1). The treatment plot received raw winery wastewater, and the recirculation plot received water leaching from the treatment plot when available. As the system efficiency was unknown, the recirculation plot was necessary in case leachate from the treatment plot was above regulation standards and needed a complementary treatment. The control plot was not watered and was used to contrast the soil composition and eventual leachate of the treatment plot.

The treatment plot was dispatched into seven subplots (A, B, C, D, E, F and G) to distinguish leachate at different depth of drainage (20, 40, 60 or 75 cm deep or on the sandstone layer between 1.7 and 2 m deep). The experimental field included a sandy soil (80% of sand over 1 m deep) and a sandy loam soil (60 cm deep) lying over an impervious sandstone layer. The delimitation of the subplots took into account the different soils to distinguish leachate origin if necessary. Four subplots were delimited on the sandy soil (480 m^2, subplots A, B, C, D) situated in the upper part of the slope and three subplots were defined on the sandy loam soil (600 m^2, subplots E, F, G) in the lower part of the slope. In the lower part of the experimental field, ditches were dug down to the sandstone layer to collect surface and sub-surface run-off. Each ditch and drain was connected to distinct 1 m^3 tanks in the lowest point of the plots. Drain set-up was determined to collect 100% of the leachate.

The soil of the experimental plot was ploughed and harrowed in April 2003. In May 2003, the plots were planted with *Semiarundinaria fastuosa* and *Phyllostachys viridis* and *Phyllostachys viridis* "sulfurea". One-year-old bamboos were planted at a density of 1500 culms/ha and each planted bamboo corresponded in average to a culm of 1.5 m height. The bamboo culms were grown from transplanted rhizome in 7.5 L containers. *S. fastuosa* was the dominant species and represented 50% of the bamboo culms planted. To limit rhizome growth out of the experimental plots, an anti-rhizome barrier (made of HDPE) buried 1.2 m–1.5 m deep surrounded the whole plantation field. Furthermore, the treatment plot was separated from the control plot by an anti-rhizome barrier to avoid any influence of the

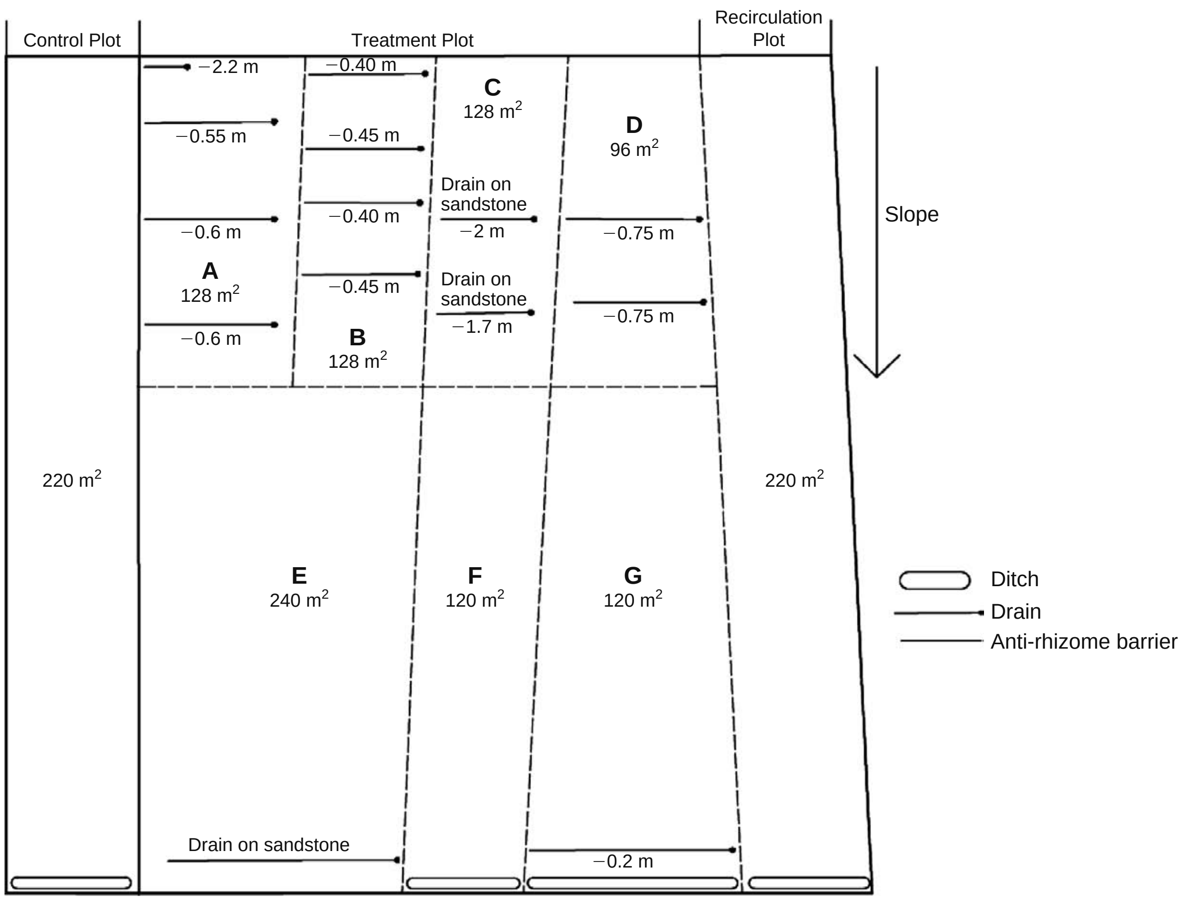

Fig. 1. Experimental set-up.

treatment (Fig. 1). The deepest part of the anti-rhizome barrier was attached to the sandstone layer to avoid any subsurface run-off originating from outside the experimental area. The upper part of the anti-rhizome barrier ended 15 cm above the ground to avoid surface run-off to enter experimental plots.

2.2. Winery wastewater composition and applications

The winery wastewater came from a traditional winery in the neighbourhood of the experimental site (Domaine de Sulauze, Miramas, France). The winery wastewater originates mainly from the cleaning of wine tanks during vintage and clarifying. This occurs between September and December and accounts for 30% of the annual wastewater volume. The rest of the year, the wastewater volume and concentration are lower as the outflow originates from miscellaneous cleaning (e.g., floor, bottles). The winery wastewater was transported and stored in a 23-m^3 tank in the highest point of the experimental plot. The time of storage in the tank was 10 days, maximum, and we assumed that the effect on the raw wastewater composition was minimum. The wastewater was applied to the treatment plot using a simple gravity dispersal system as the experimental field had a natural 3% slope. For each spreading, a water pipe set at the top of the slope was filled in (by gravity) with wastewater from the 23-m^3 tank. Then, once the needed volume was reached in the pipe, the latter was emptied by opening the butterfly valves on its side. As a result, the wastewater could flow all over the treatment plot and was homogeneously applied, as much as possible. Each spreading was done when soil moisture reached 8%–12% except if a rain was forecasted for the next 2 days. The control plot was not treated and received only rain water. The recirculation plot received leachate and surface run-off water collected from the treatment plot. These water losses were pumped and stored in a buffer tank of 7.5 m^3 located next to the raw wastewater tank. When a sufficient volume of leachate was available in the buffer tank, the spreading on the recirculation plot was done using the gravity dispersal system described above.

The soil–bamboo system was considered as a black box, and the difference between inlet (spreading and rain) and the water losses (leachate and run-off) was attributed to the evapotranspiration (ET) and to the variation of the soil water reserve (not determined). The water height of leachate and run-off was calculated from the volumes collected in each tank at the bottom of the slope. The water height of rain and reference evapotranspiration (ET_0) over the time of the experiment were obtained from a nearby meteorological station of METEO France (French meteorological agency). The ET_0 and empirically determined crop coefficient (data not shown) of bamboo grove were used to determine the maximum evapotranspiration (ET_m) of each plot [7]. The latter was only used as an indication of the bamboo growth impact on the water balance. The raw wastewater, leachate and run-off were all analysed by the CETE APAVE sud laboratory (Martigues, France). Eight samples of raw wastewater were collected evenly between September and May for the analyses and this sampling corresponded to the loading of the 23 m^3 tank. The time of storage in the tank was 10 days, maximum, and we assumed that the effect on the raw wastewater composition was minimum. The surface run-off and water leaching from the three plots were collected and analysed when available after each spreading or rain events (seven samplings) and once in the buffer tank in December 2003 (mix of leachate and run-off). pH, total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD_5), total Kjedahl nitrogen (TKN), and P, K and Cu concentrations of the raw wastewater and water losses were determined following French standards of laboratory analyses, respectively, NF T 90-008, NF T 90 105.2, NF T 90-101, NF EN 1899-1, NF EN 25663, and NF EN ISO 11885. Soil texture and soil chemical characteristics were evaluated in the initial state before the first wastewater application in September 2003 and after the last application in July 2004 of treatment. For each plot, chemical analyses (pH, C/N ratio, N, P, K, Ca and Mg) were done on 12 randomly collected topsoil (0–20 cm) samples. Texture, pH, organic carbon and total N of soil samples were determined using the method defined by the French standard, respectively, NF X 31-107, NF ISO 10390, NF ISO 10694 and NF ISO13878. Available P (P_2O_5) was extracted with a sodium bicarbonate solution (w/v: 10 g/200 ml), then determined by spectrophotometry (NF X 31-161). Exchangeable ion (K^+, Mg^{2+} and Ca^{2+}) concentrations were determined after percolation of soil samples with ammonium acetate solution (w/v: 10 g/250 ml; ISO NF X 31-108) by a flame atomic emission spectrometer (K^+), and by a flame atomic absorption spectrometer (Mg^{2+} and Ca^{2+}) [8].

3. Results and discussion

The composition of the raw wastewater was considered typical of winery wastewater and exhibited an acidic pH, ranging from 4 to 5, and a high load of organic matter (Table 3, see inlet total load). As expected, the concentration of organic matter increased at the wine production peaks and especially during vintage and clarifying. During vintage, wastewater was loaded with biodegradable organic matter with a COD/BOD_5 ratio lower than two, while during clarifying, the COD/BOD_5 ratio was higher than two (data not shown). Suspended solids are also much higher during clarifying. Copper was only present in wastewater during vintage due to deposits on grape skin (anti-fungal treatment).

As the soil–bamboo treatment system is considered as a black box, the leachate and run-off are the most relevant results presented in Table 1 while the calculated ET_m is only given to indicate the influence of the bamboo plantation in the water balance. Between September 2003 and May 2004, 162 m^3 of wastewater was collected and spread over the experimental plot in 22 applications. With a maximum height of 20 mm of wastewater applied in May 2004, 10–20 m^3 was spread every month with approximately 10 days between each application depending on wastewater production and rain amount and frequency. During this period, seven rain events were recorded including one extreme of 110 mm on 2 December. The recirculation plot did not receive all of the water losses collected as the buffer tank was not sufficient for intense rain events. The excess water losses were discharged in a nearby draining ditch as their composition was below regulation standards.

The sizing of the treatment plot aimed at minimizing leachate and this was confirmed in Table 1 as the water balance was generally negative at the scale of a month with water collected in tanks inferior to 1% of the inlet flux. Moreover, the water losses (Table 1) collected in tanks between September and May were due to run-off. The total water height of leachate was very low with 7 mm collected mostly on subplot B (0.9 $m^3 \times 128\ m^2$). The latter leachate was collected at 45 cm depth and thus was not included in the results shown in Table 1 as the water

Table 1
Water height (mm) of the inlet (spreading and rain) and outlet (water losses collected in tanks) fluxes of the bamboo grove treatment system over the 9 months of spreading. Values should be related to the surface of the plot concerned

	Spreading			Water Losses Collected in Tanks			
Month	Treatment	Recirculation	Rain	Treatment	Recirculation	Control	ETm[a]
SEPT	37.2	9.1	150.0	6.1	6.7	9.1	248.0
OCT	16.9	0.0	80.0	1.7	0.0	4.8	161.3
NOV	10.7	11.5	65.0	3.2	0.0	6.3	41.7
DEC	8.1	13.8	45.0	6.6	5.0	5.9	35.0
JAN	18.7	20.5	90.0	0.0	0.0	0.0	35.4
FEB	5.6	0.0	40.0	0.0	0.0	0.0	31.0
MAR	13.5	0.0	25.0	0.0	0.0	0.0	127.8
APR	19.5	0.0	75.0	0.3	0.1	0.0	237.5
MAY	19.4	0.0	45.0	0.0	0.0	0.0	454.3
Total	**149.7**	**54.9**	**615.0**	**17.9**	**11.7**	**26.1**	**1372.1**

[a]Maximum evapotranspiration of the bamboo if all the water needed is available.

infiltration can be considered lost by the bamboo–soil system only if reaching drains lying on the sandstone layer (subplot C and E). Most of the leachate and run-off occurred between September and December after strong rain events. Between November and February, the water balance was positive as the ET_m was the lowest and the soil water reserve was possibly high (data not shown) and favoured run-off. By contrast, from September to October and from March to May, the ET_m of the bamboo grove was higher by an order of magnitude than rain and spreading volume what possibly favoured soil penetration.

The leachate composition was similar for the three plots (data not shown). Based on the analyses of the mixture of the leachate and the run-off water in the buffer tank, the water losses exhibited a neutral pH (7.5) and a weak contaminant load (COD < 30 mg/l and BOD_5 < 5 mg/l) (Table 2). These water losses from the soil–plant system showed a composition respecting regulations for a release in the environment (Table 2) [9]. Due to the limited leachate volumes, the contact time (determined using the soil water holding capacity, data not shown) with the bamboo root system was maximized and thus favoured biodegradation and absorption of elements by the plants. The removal efficiency of the system was evaluated by comparing inlet (wastewater load) and outlet (water losses). The results presented in Table 3 show removal efficiency higher than 99% for the TSS, COD, BOD_5, and N, P, K and Cu. As a result, the recirculation plot was unnecessary to refine the first treatment (treatment plot). In addition, as the subplots E and G did not have any leachate collected, there was no significant difference between the two types of soil (data not shown). However, such a result on a sandy soil (highly permeable) showed that the system in its initial state was efficient even with a low soil water storage capacity [10].

In this experiment, as in all plant–based treatment systems, the bamboo–soil system was considered as a black box. The topsoil composition was similar for the treatment and control plots indicating that the spreading of wastewater did not influence any soil parameter in the short term [9]. This suggests that there was no accumulation in the substrate and thus the system should keep its initial efficiency in the future. Elements brought by wastewater to the bamboo grove were dispatched in the soil–plant system between the soil, the soil microflora and fauna, and the bamboos. The degradation of the

Table 2
Average physico-chemical characteristics of winery wastewater (n = 8), leachate (n = 1, from the buffer tank) and the French standard for wastewater discharge in the environment

Parameters[a]	Winery wastewater	Leachate	French standard[b]
pH	4.95	7.50	5.5–8.5
TSS (mg/l)	1746.00	40.00	<100
COD (mg/l)	8735.00	<30.00	<300
BOD_5 (mg/l)	6447.00	<3.00	<100
NO_3- (mg/l)	86.00	33.00	n.d.
Total P (mg/l)	12.00	0.30	n.d.
Total K (mg/l)	165.00	7.90	n.d.

[a]PE: Population equivalent; TSS: total suspended solids; COD: chemical oxygen demand; BOD: biological oxygen demand.
[b]French standard for wastewater discharge (decree 2 February 1998).
n.d.: not determined.

Table 3
Removal efficiency of contaminants from winery wastewater by the Soil–bamboo system.

	TSS	COD	BOD_5	N	P	K	Cu
Inlet (kg)							
Sept	40.76	375.20	294.86	1.64	0.26	4.44	0.69
Oct	58.30	135.65	83.76	3.22	0.40	4.99	0.02
Nov	158.37	249.97	109.17	7.18	0.73	7.71	0.02
Dec	121.11	191.16	83.48	5.49	0.56	5.90	0.02
Jan	120.60	302.91	171.11	3.42	0.66	3.52	0.03
Feb	123.60	228.42	112.05	4.16	0.66	5.60	0.01
Mar	526.04	751.85	307.74	20.35	2.77	12.80	0.09
Apr	151.92	215.22	71.32	7.95	0.76	4.85	0.03
May	75.60	78.41	30.16	2.67	0.36	2.02	0.02
Total	**1376.30**	**2528.79**	**1263.65**	**56.08**	**7.15**	**51.83**	**0.93**
Outlet (kg)							
Sept	0.60	5.07	3.64	0.02	0.00	0.18	0.00
Oct	1.14	0.54	0.15	0.01	0.00	0.04	0.00
Nov	0.64	0.60	0.24	0.02	0.00	0.10	0.00
Dec	0.57	0.36	0.05	0.02	0.03	0.01	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**2.95**	**6.56**	**4.08**	**0.06**	**0.04**	**0.32**	**0.00**
Removal efficiency by the bamboo*soil*climate system							
	99.8%	**99.7%**	**99.7%**	**99.9%**	**99.4%**	**99.4%**	**99.9%**

organic matter brought about by the spreading of wastewater was possibly achieved through physico-chemical reactions and the activities of micro-organisms and plants (e.g., exudates) in the soil [2, 11–13]. Bamboo growth (data not shown) was not different between the three different plots at the time of the first winery wastewater application [14] and it is quite possible that most of the growth and biomass accumulation occurred belowground during 2004 [6]. During the following year, aerial growth of the bamboos increased significantly (higher, larger basal diameter and higher number of culms) on the treatment plot compared to the other plots [15].

4. Conclusion

Bamboo grove stations can be considered as an infiltration area designed for phytohydraulic control, phytoextraction and/or phytodegradation of contaminants from wastewater [2]. The results observed for a 2-year experiment suggest that the soil–bamboo system can treat winery wastewater and that the bamboo grove treatment system has high contaminant removal efficiency. Overall, 99% of the organic matter and 98% of the nutrients spread over the bamboo grove were treated. In addition, water losses by infiltration were extremely low and confirm the necessity of carefully sizing stations to meet the needs of the bamboo grove and the needs of treatment (discharge standards) in given soil-climate conditions.

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References

[1] N. Adams, D. Carroll, K. Madalinski, S. Rock, T. Wilson and B. Pivetz, *Introduction to Phytoremediation*, National Risk Management Research Laboratory, Cicinnati, Ohio, USA, 2000, 72 p.

[2] S.C. McCutcheon and J.L. Schnoor, *Phytoremediation – Transformation and Control of Contaminants*, Wiley Inter-Science, USA, 2003, 987 p.

[3] L.A. Licht and J.G. Isebrands, Linking phytoremediated polluant removal to biomass economic Opportunities, *Biomass Bioenerg.*, 28(2005), 203–218.

[4] D. Mailly, L. Christanty and J.P. Kinunins, 'Without bamboo, the land dies': nutrient cycling and biogeochemistry of a Javanese bamboo *talun-kebun* system, *Forest Ecol. Manag.*, 91(1997), 155–173.

[5] P.S. Ramakrishnan and O.P. Toky, Run-off and infiltration losses related to shifting agriculture (jhum) in north-eastern India, *Environ. Conserv.*, 8(1981), 313–321.

[6] V. Kleinhenz and D.J. Midmore, Aspects of bamboo agronomy, *Adv. Agron.*, 74(2001), 99–145.

[7] R.G. Allen, L.S. Pereira, D. Raes and M. Smith, Crop evapotranspiration. Irrig. and Drain. Paper 56, Food and Agric. Organization of the United Nations, Rome, Italy, 1998, 300 p.

[8] G. Aubert, *Méthodes d'analyses des sols*, CNDP edn, Marseille, 1978, 191 p.

[9] R. Wang, *Phytoépuration d'effluents vinicoles par une plantation de bambous, UMR CNRS 6116*, Institut Méditerranéen d'Ecologie et de Paléoécologie, Aix-Marseille university, France, 2005.

[10] G. Bourrié and F. Trolard, *Interprétation des analyses de sols de l'expérimentation de la technologie BAMBOU-ASSAINISSEMENT® pour le traitement des effluents vinicoles*, INRA, Aix en Provence, France, 2004.

[11] J.L. Jordahl, L. Foster, J.L. Schnoor and P.J.J. Alvarez, Effect of hybrid poplar trees on microbial populations important to hazardous waste bioremediation, *Environ. Toxicol. Chem.*, 16(1997), 1318–1321.

[12] Y. Isagi, T. Kawahara, K. Kamo and M. Ito, Net production and carbon cycling in a bamboo *Phyllostachys pubescens* stand, *Plant Ecol.*, 130(1997), 41–52.

[13] A. Arunachalam and K. Arunachalam, Evaluation of bamboos in eco-restoration of 'jhum' fallows in Arunachal Pradesh: Ground vegetation, soil and microbial biomass, *Forest Ecol. Manag.*, 159(2002), 231–239.

[14] N. Korboulewsky and S. Dupouyet, *Bioassainissement d'effluents de cave par une plantation de bambous (rapport intermédiaire)*, Aix-Marseille university, Institut Méditerranéen d'Ecologie et de Paléoécologie, UMR CNRS 6116, 2004.

[15] N. Korboulewsky, S. Dupouyet, C. Rolando and R. Wang, *Bioassainissement d'effluents de cave par une plantation de bambous: Comportement du sol et des végétaux (rapport final)*, Aix-Marseille university, Institut Méditerranéen d'Ecologie et de Paléoécologie, UMR CNRS 6116, 2005.