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A day – night solar dryer with the temperature and the flow control: numerical simulation

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Abstract

A solar dryer working continuously during day and night had been experimented in Guadeloupe (FWI) and in French Guyana. To improve the prototype components size, a dynamic numerical simulation has been done in the electrical analogy scheme. Electrical tools, PSPICE / MATLAB and the thermal transient code TRNSYS has been used. The numerical results has been compared with the experimental data when the air temperature and (or) the air flow was controlled. A good agreement has been obtained.

Nomenclature

P_i	Solar Power, (W)
T_i	Temperature, (°C)
C_i	Thermal capacity, (J.kg ⁻¹ .K ⁻¹)
R_i	Thermal resistance, (° K.W ⁻¹)
C_{air}	Air thermal capacity, (J.kg ⁻¹ .K ⁻¹)
I	Electrical current, (A)
V	Electrical potential, (V)
C	Electrical capacity, (F)
R	Electrical resistance, (Ω)
η	Optical efficiency of the solar panel

Introduction

Fruits production follows saisonnal cycle. In rural regions the overabundance followed with blackout periods is prevented by drying fruits exposed under the sun radiation [1]. Others more performant methods have been developed but they use energy sources such as gaz and electricity which are not disponible in isolated sites.

In regions where solar energy is abundant, the solar dryer is an adequate solution [2]. However the lack of sun during the night stop the drying process and could be responsible of the degradation of the product. To prevent this damage, a solar dryer has been completed with a solar hot water storage which is used during the night. A patent has been filed [3] in which a solar open cycle air dryer was included using a solid desiccant. When the air temperature is controlled, the drying process is more reproducible.

With the electrical analogy, complex systems can be represented with electrical circuits in place of differential equations.

In the following sections we will use this electrical analogy to modelize and to simulate our solar dryer and we propose to use the common electronics software (Orcad PSPICE) in order to make quantitative investigations of the solar dryer.

Both results from the well known TRNSYS software and the code used in the electrical engineering processes (Matlab-Simulink) has been compared with the experimental results.

Description of the solar dryer

On the figure 1 is given a synoptic diagram of the machine. The principal components of the dryer has been reported: the air solar collector and the drying room, the air water exchanger, the hot water storage. The electrical elements such as pump and fans could be supplied with photovoltaic panels. An automaton gave order to shut or open the valves introducing ambient air to be mixed with the hot air. A constant air flow is maintained in the drying room. Moreover, to manage a more reproducible drying process, a constant temperature with a constant air flow was necessary in the drying room. A PID controller was used for the regulation.

But, during the day, the air temperature depends of the solar collector temperature. During the night, a better temperature regulation could be obtained from the hot water storage temperature through the water-air heat exchanger

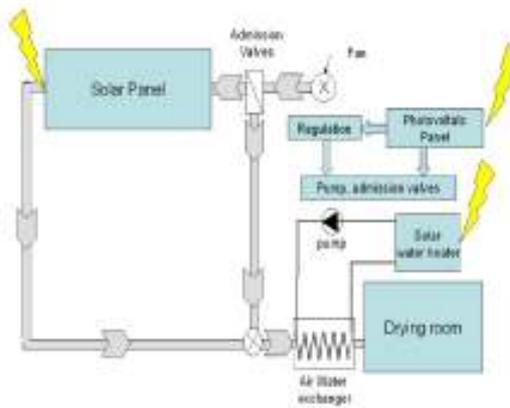


Figure 1. Synoptic diagram of the dryer

Modelisation

Solar collector :

On the table 1 has been given the analogy between electrical and thermal parameters and the relations between these parameters, the subscript i is a generic letter corresponding to a component of our solar dryer.

Thermal parameters	P_i	T_i	R_i	C_i	$T = R_i P_i$	$P = C_i \frac{dT}{dt}$
Electrical parameters	I	V	R	C	$V = R_i I$	$I = C_i \frac{dV}{dt}$

Table 1: Electrical and thermal parameters

The thermal power P_i is associated to the electrical current I as respectively the temperature T_i , the thermal capacity C_i , the thermal resistance R_i to the potential V , the electrical capacity C and the electrical resistance R .

In the model, T_e is the inlet and T_s is the outlet collector temperatures. T_a is the ambient air temperature. With a constant efficiency η the absorbed power by the collector P_R , the collector lost P_L and the power flow rate to the air P_s could be expressed with the followed equations:

$$P_R = \eta \cdot P_S \tag{1}$$

$$P_L = (T_s - T_e) / R_L \tag{2}$$

$$P_s = (T_s - T_e) / R_D \tag{3}$$

where R_L is the collector thermal resistance and $R_D = 1 / (C_{air} \cdot D)$ the thermal resistance of air through the collector. D was the mass flow rate and C_{air} the air thermal capacity.

The power balance gave the differential equation of the outlet air temperature where C_p is the thermal capacity of the collector:

$$C_p \cdot dT/dt = P_R - (T_s - T_e) / R_D - (T_s - T_a) / R_L \tag{4}$$

The equation (4) gave the electric diagram of the solar collector reported in the figure 2.

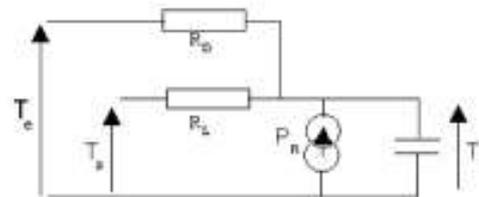


Figure 2. Equivalent circuit of the solar collector

The transfer function in Laplace space is :

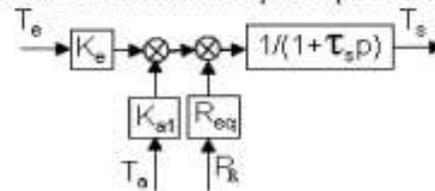


Figure 3: Transfer function of the solar collector.

$$K_{a1} = R_{eq} / R_L, K_e = R_{eq} / R_D, \tau_c = R_{eq} \cdot C_p$$

Air temperature and flow rate regulation :

Control of the air mass flow rate and of the air temperature has been obtained with two valves. Their openings was ordered depending of the outlet air collector temperature and of the air flow rate D . The ratio x of new ambient air was mixed with $(1-x)$ ratio from the solar collector. In final regulation was controlled by the balance equation: $T_{mix} - T_e = x(T_s - T_e)$ with $0 \leq x \leq 1$. T_{mix} is the inlet temperature of the drying room.

Drying room:

The balance of the thermal flow rate entering and leaving the drying room leads to an equivalent circuit.

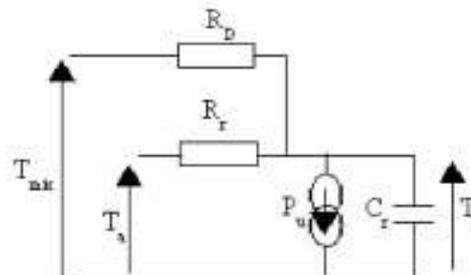


Figure 4: Equivalent circuit for the drying room.



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R_r is the thermal resistance between the drying room and the ambient air, T_r is the room temperature. P_u is the thermal power needed for the dehydration process.

The whole transfer function is given on the figure 5. Both, the electric circuit (with Orcad PSPICE for example) and the transfer function (with Matlab Simulink) allowed to simulate the heat transfer in dynamic regime.

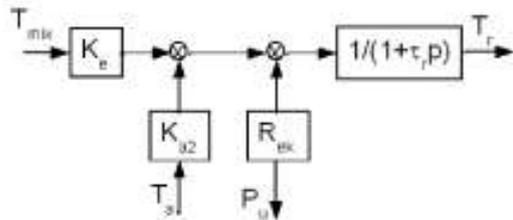


Figure 5 : Transfer function of the drying process.

$$1/R_{ek} = 1/R_D + 1/R_r, K_{02} = R_{ek}/R_c, K_e = R_{ek}/R_D, \tau_r = R_{ek} \cdot C_r$$

Simulation

The thermal resistances and the thermal capacities are reported on the table 2. The values has been determined from the thermophysical parameters the masses, the thickness of the different pieces of the prototype built in our laboratory [3,4].

Solar collector	$C_D = 41.10^3 \text{ J}^\circ\text{C}^{-1}$	$R_D = 29.10^{-1} \text{ }^\circ\text{C}^\circ\text{W}^{-1}$
Drying room	$C_r = 20.10^3 \text{ J}^\circ\text{C}^{-1}$	$R_r = 0.50 \text{ }^\circ\text{C}^\circ\text{W}^{-1}$

Table 2 : Values of the parameters used in the simulation

The figure 6 gives a Simulink diagram of the whole solar dryer using all the transfer functions. The regulation of the temperature used a PID controller coupled with the control flow rate.

Test of the solar dryer model

The simulation has been tested in comparing the calculation results with the experimental data. The outlet temperatures from the solar collector and the drying room compared on the figure 7 and 8 allowed a fitting of the thermal resistances of the collector and the drying room. No more then a 10% adjustment has been necessary.

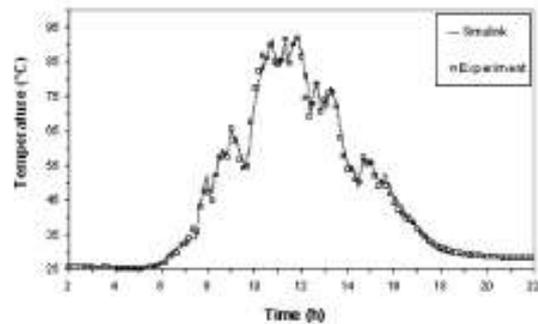


Figure 7. Outlet solar collector temperature.

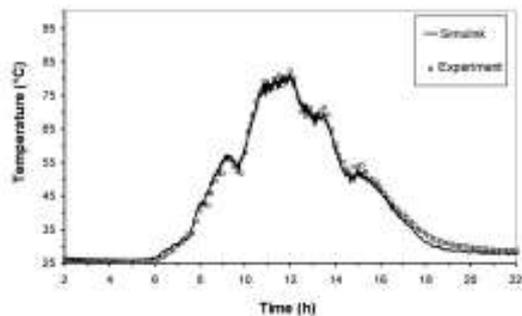


Figure 8 : Drying room temperature.

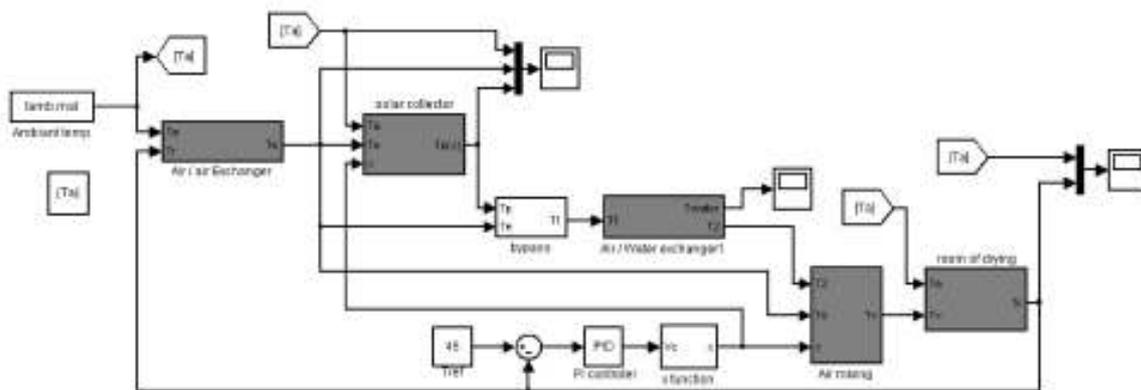


Figure 6: Simulink diagram of the regulated solar dryer



Comparison between Matlab-Simulink and TRNSYS simulations.

TRNSYS and Simulink simulations are compared on the figure 9 where the temperature of the drying room has been calculated for 25 m³.h⁻¹ and 55 m³.h⁻¹ flow rates:

These results show that the both approaches seemed equivalent. They give the same qualitative evolution of temperature as a function of the time in spite of some difference near the maximum.

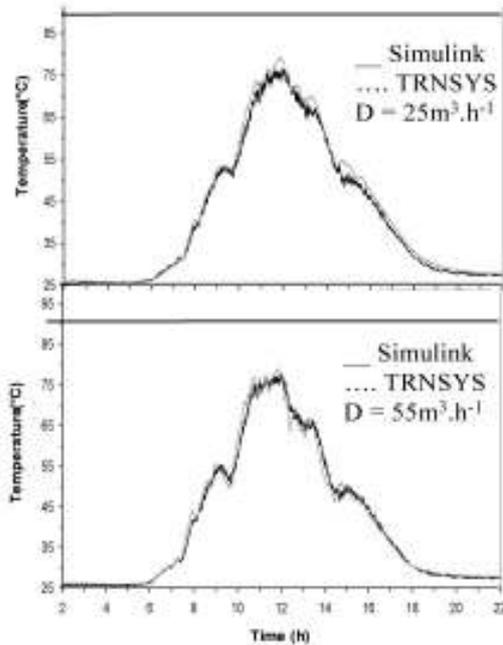


Figure 9 :Comparison of the TRNSYS and the Simulink calculated air temperatures in the drying room.

We concluded that it was possible to model a thermal system with electrical engineering software (Matlab/Simulink, Orcad Pspice). Indeed, these softwares allowed to model the behaviours of electrical devices (for example the control system) and to model the heat flow

Regulation of the drying room temperature.

The temperature of the drying room has been regulated with a constant flow rate

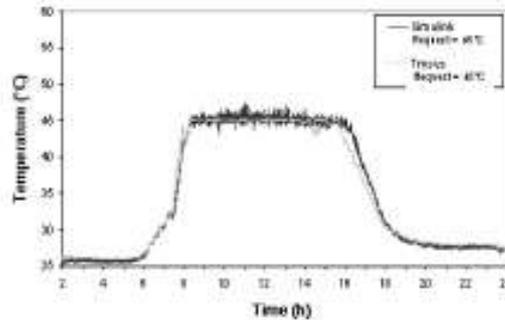


Figure 10 : Regulation of the drying temperature at 45°C.

During the night process with two intake valves and a PID control. The results from Matlab Simulink and TRNSYS are compared on the figure 10 when the drying temperature has been fixed at 45°C, the air flow rate at 55 m³.h⁻¹. The temperature of the drying room has been regulated with a constant flow rate. Simulink and TRNSYS approaches gave the same evolution of the drying room: the beginning of the regulation near 8 am, low temperature variations near the requested value (45°C), decreasing of the temperature after 16 pm when the sun went down.

Conclusion

In this paper a simulation method of a thermal system like a solar dryer has been proposed using the electric analogy. The Matlab Simulink software has been used. The model has been validated with experimental data.

Such approach of the heat transfer simulation using the Matlab Simulink graphic tools, has been compared with TRNSYS code commonly used to describe thermal systems in dynamic regime. The two simulations are in good agreement and the electrical approach will make easier a rapid description of heat transfer from an electrical scheme. The model will be completed to describe the whole system continuously during day and night.

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Lack of significance of usual ecological indicators in predicting pesticides contamination: specificities of tropical islands freshwaters

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Abstract

Residues of pesticides were measured in the freshwater fauna of five rivers situated in Basse-Terre, Guadeloupe (French West Indies). The results confirm the presence of pesticides at high levels in fish and crustaceans with four recurrent molecules : organochlorinated insecticides (chlordecone, β -HCH, dieldrin) and fungicides (dithiocarbamates). In the same locations, common ecological indicators were calculated but no link was detected between the biocontamination levels and these indicators usually used to express the environmental quality. This lack of significance is interpreted as the result of the strong originalities of tropical freshwater ecosystems that are pointed out.

Introduction

Most of the freshwaters ecosystems of Guadeloupe are affected by varying pollutions. Intensive agriculture led to the use of considerable amounts of pesticides which could contribute to the degradation of water quality and ecosystems. Organochlorinated insecticides (chlordecone/kepone, β -HCH and dieldrin) and fungicides (dithiocarbamates) were detected at high levels in some river mouths of the south of Basse-Terre (up to 3.2 $\mu\text{g/L}$ of chlordecone (DIREN, 2004)). These chemicals, toxic and persistent, are usually considered as a threat for freshwater fauna.

This study was aimed at *i*) assessing the level of biocontamination of fish and crustacean species from the most contaminated area and *ii*) confronting these results with common ecological indicators used to evaluate quality in ecological surveys.

Materials and methods

Sampling : stratified sampling was performed in five rivers with various levels of pesticide contamination (Figure 1). Organisms collected by electrofishing were numbered, measured, weighed and returned alive to the river, except for a sample which was subjected to analyses of its pesticide content. Collected species belong to the three major groups of tropical freshwater organisms : the Fishes, the *Palaemonidae* shrimps (Ouassous) and the *Atyidae* shrimps (Cacadors).



Figure 1 : Sampling stations in Basse-Terre island, Guadeloupe (Source: DIREN, 2001).

Chemical analysis : sample processing (extraction and purification) and measurement of pesticide concentrations were carried out at the Laboratoire Départemental d'Analyses de la Drôme (Valence, France). We checked for 126 pesticides in various tissues (muscle, liver, hepatopancreas or gonad).

Ecological indicators (species richness, total abundance, total biomass, diversities) were calculated for each river studied.

Results and Discussion

Whatever the species and the tissue analysed, all organisms collected were contaminated by various and high levels of pesticides (Table 1). Four recurrent molecules were identified: three of them belonging to the organochlorinated



pesticides (chlordecone, β HCH, dieldrin) and the other pooled as a group, the dithiocarbamates. Chlordecone, an insecticide used during forty years and prohibited in 1993 in Guadeloupe, showed the highest concentrations in organisms, up to 39400 $\mu\text{g}/\text{kg}$ wet weight in the liver of the fish *Gobiomorus Dormitor* at the Rivière Grande Anse (RGA).

Table 1 : Higher levels of pesticides detected in aquatic fauna of the freshwater contaminated area

Rivers	Pesticides detected in organisms	Bioconcentrations ($\mu\text{g}/\text{kg}$ wet weight) in the most contaminated species
GRG	-chlordecone -dithiocarbamates	290 $\mu\text{g}/\text{kg}$ chlordecone in liver of <i>Eleotris sp.</i>
RdP	-chlordecone - β HCH -dithiocarbamates	1 300 $\mu\text{g}/\text{kg}$ chlordecone in gonad and hepatopancreas of <i>Macrobrachium carcinus</i>
RGC	-chlordecone - β HCH -dithiocarbamates	2 100 $\mu\text{g}/\text{kg}$ chlordecone in muscle of <i>Macrobrachium faustinum</i>
GRC	-chlordecone - β HCH -dithiocarbamates	8 700 $\mu\text{g}/\text{kg}$ chlordecone in gonad and hepatopancreas of <i>Macrobrachium faustinum</i>
RGA	-chlordecone - β HCH -dithiocarbamates -dieldrin	39 400 $\mu\text{g}/\text{kg}$ chlordecone in liver of <i>Gobiomorus dormitor</i>

Ecological indicators, reported in Table 2, are calculated for the same surface unit (80 m²) sampled in each river .

Table 2: Ecological indicators

Rivers	Species richness	Abundance	Biomass	Diversity index H'
GRG	10	869	1701 g	1.26
RdP	11	904	736 g	1.52
RGC	8	232	439 g	1.48
GRC	8	372	557 g	1.44
RGA	11	822	1715 g	1.66

Three of the best values for these synthetic indicators were found in the Rivière Grande Anse (RGA), where we detected the most contaminated organisms.

Conclusion

The incidence between pesticides contamination and perturbation of aquatic species equilibriums is well documented in the literature. However, our results do not reveals any link between the biocontamination levels and the ecological indicators usually used to express changes in environmental quality. This lack of significance is the result of the strong originalities of 90 % of the species living in our tropical freshwater ecosystems :

1. they are amphidromous species that spend their larval and juvenile stages elsewhere in saline waters or open sea,
2. every year, juveniles migrate upstream and colonize new biotopes,
3. at adult stage, individuals move regularly through altitude gradients.

These species finally never spend their entire life cycle in the same place and are poorly integrative of the ecosystem quality. These results emphasize the need of more accurate studies in order to set up physiological or ecological indicators of tropical freshwater ecosystems characteristics.

Acknowledgements

Financial support from the Direction Régionale de l'Environnement de Guadeloupe (DIREN) is gratefully acknowledged.

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A Reactor for the Decontamination of Water using Titanium Dioxide Nanoparticles and Solar Energy.

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Abstract

In previous work using the solar disinfection (SODIS) method we have shown that a 99.9% deactivation of *E. coli* bacteria is achieved after four (4) hours of insulation and that with simple solar concentration techniques the decontamination time was reduced to one (1) hour. We have now built and successfully tested a photocatalytic reactor using TiO_2 nanoparticles immobilized on a glass plate. This reactor is capable of decontaminating water on a larger scale and in a shorter time than is possible with SODIS. A 1 m^2 glass plate on which TiO_2 is deposited forms the lower plate of a sealed double plate reactor. The top plate consists of glass which is not only protective but also serves as the window for infrared and ultra-violet light either from the sun or an artificial source (two 500 watt halogen lamps). The reactor can be tilted at angles in the range 0-30 degrees and can be rotated to track the sun if necessary. Initially it was oriented in a north-south direction on the roof of the Natural Science building at an inclination of 11 degrees to the horizontal consistent with the latitude of Trinidad and exposed to sunlight. Contaminated water is pumped from a reservoir to the top of the reactor and flows by gravity over the active surface back to the reservoir. Bacterial counts were carried out on samples of water from the reservoir at various intervals. Experiments were also carried out during nighttime as a control. While, under sunny conditions (1058 Wh/m^2) complete disinfection occurred after thirty (30) minutes, under cloudy conditions (750.5 Wh/m^2) the time required was sixty (60) minutes. There was no effect for runs carried out at night-times. This rapid sterilization of contaminated water is attributed to the production of highly reactive species of hydroxyl radicals produced by titanium dioxide in the presence of the UV component of sunlight.

Introduction

The availability of potable water is an important issue in the modern world. In the developed countries the purification and recycling of wastewater by modern technologies such as reverse osmosis have contributed significantly to improving the availability of potable water. Today, about two billion people in mainly in the developing world do not have a safe supply of drinking water (WHO Report, 1993). Diarrhea and the resulting body dehydration are responsible for about 2.5 million deaths annually in the third world. Additionally, fresh water availability can become a life threatening issue as a result of natural disasters. The aftermath of the tsunami in South East Asia on December 26th 2004, and the effects of hurricane Katrina in the United States in August of 2005 are clear examples of the effect of disasters on the fresh water supplies. It is therefore important that

simple technological methods be developed not only to satisfy the needs of poor communities in areas of the developing world such as Latin America and the Caribbean but also to address the immediate needs of people following natural disasters. In earlier publications we have shown that the solar disinfection (SODIS) method can be applied under the environmental conditions of Trinidad and Tobago. Water contaminated with *E. coli* bacteria can be purified in four hours by the SODIS method using PET bottles and in two hours using simple solar concentration techniques. In this paper we report on the disinfection of artificially contaminated water using solar energy together with a reactor with an active surface containing titanium dioxide nanoparticles.

Materials & Method

Figure (1) is a schematic view of the Titanium dioxide (TiO₂) reactor system.

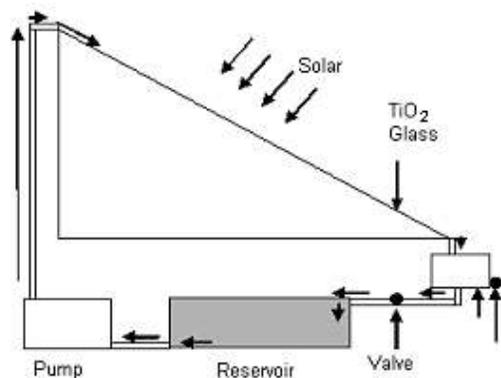


Figure (1) Schematic view of the Reactor

The reactor consists of two glass plates mounted in an aluminum frame. They are separated by about 8.0cm. TiO₂ is deposited on the lower plate, which is made of frosted glass. This is the “active” surface of the reactor. The upper plate is protective and consists of normal transparent clear glass. Both plates are supported by “channelings” on the inner perimeter of the aluminum frame. The supporting base consists of three sections, which can be easily dismantled making it very portable. The upper section has a deep recessed area to accommodate the reactor and built in locks to firmly secure it. The middle section has adjustable stability pins at the corners to ensure stability of the entire structure. It has, in addition, two pivots at one end for attachment to the upper section and a centrally mounted car jack to permit elevation of the upper section, which carries the reactor. The lower section is the “foot” of the entire system. It contains a centrally mounted bearing to which the middle section is connected. This section permits rotation of the middle section about its axis for solar tracking. In operation the upper section forms a sealed chamber, which can be inclined at an appropriate angle. The peristaltic pump ensures a fixed flow rate of contaminated water to the top of the active reactor plate, which then flows under the influence of gravity to the collection point at the lower end of the plate.

The flow rate can be varied to determine the optimum rate for photo-degradation. The stainless steel reservoir can be isolated from the main reservoir by a valve, which therefore permits single runs or multiple runs. The inlet port and both outlet ports are made of polyvinyl chloride (PVC). All areas with which the contaminated water will be in contact are constructed with either stainless steel, glass, PVC or non-reacting Tygon hoses. To coat the active reactor plate with TiO₂, the protective plate of the upper section was removed to expose the active reactor plate and the “sedimentation” method used. With this plate in a horizontal position, a suspension of 8gm of TiO₂ in two (2) litres of water was poured onto it. The TiO₂ in the suspension was deposited on the frosted glass plate in about twelve (12) hours and excess water removed by evaporation.

Contaminated water from a reservoir is pumped at a rate of 50 litres per hour into the reactor and allowed to flow by gravity over the active surface while being exposed to sunlight. Water collected from the reactor flows into the reservoir and is recycled. It is also tested for fecal coliform bacteria at intervals using the COLILERT 18 method.

This experiment was performed on four separate occasions as indicated in the results.

Results & Discussion

Sunday 12th June 2005, 11:10 am — 1:40 pm

This was a sunny day with mild cloud cover. The weather pattern changed however after forty minutes into the experiment. Increasing cloud cover caused the insolation to drop to values as low as 316Wh/m² for a short time duration. Subsequently the insolation values increased rapidly to yield a maximum value of 1.1kWh/m² for the latter part of the testing. The average insolation was 1058 Wh/m².

A maximum air temperature of 36^o C was attained about thirty minutes (30) into the run. This fell with the increase in cloud cover to 30^oC but then increased to 32^oC. The inner layer (area between the both plates) temperature at the start was 42^oC and it remained at this temperature for 40 minutes. With the drop in insolation values,



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the temperature also decreased. The reservoir temperature rose from 27.4°C to 43.5°C in 40 minutes. Again with the drop in insulation its characteristics were similar to that of the other parameters. Both the reservoir temperature and the inner layer temperature rose to a maximum of 48°C after 150 minutes. Bacterial counts were down to measurable values within 10 minutes and all bacteria were totally destroyed after a further 15 minutes.

Thursday 23rd June 2005, 12:30 pm — 1:30 pm

There was more cloud cover than what was experienced on June 12th. A marked reduction in the insulation with an average value of 733 Wh/m² was observed.

A maximum air temperature of 34°C was observed at the start but there was a gradual drop in value throughout the experiment with a minimum value of 27°C being recorded. The reservoir temperature increased from 24.5°C to a maximum of 41.7°C. The inner layer however maintained an average temperature of 41°C. Bacterial decrease was rapid. After 15 minutes the bacterial count per 100 ml was down to a measurable level and it fell to zero in a further 15 minutes.

Thursday 30th June, 2005, 2:10 pm – 3:10 pm

This day in comparison with the other days was overcast. There was a decrease in insulation from a maximum value of 820 Wh/m² to a minimum value of 645 Wh/m². The average insulation for the duration of the experiment was 750.5 Wh/m².

The air temperature was constant throughout the experiment with an average value of 34°C being observed. The reservoir temperature increased from 28.9°C to 42.4°C in just one hour.

Bacterial decrease was not as rapid as with the previous two days, however, after 45 minutes, the counts per 100 ml were down to a measurable level. Total degradation was achieved in a further 15 minutes.

Wednesday 6th July, 2005, 8:45 pm – 10:45 pm

The same procedure was followed as with the other days with one exception. This experiment was performed in the night. The insulation was zero throughout the experiment. The air tempe-

perature was at 28°C at the start and it dropped to 27°C for the balance of the experiment. At the start, the reservoir temperature was 25.4°C and it decreased by 0.4°C over the 2-hour duration of the testing. Bacterial counts were unaltered for the experiment.

For comparison purposes the insulation values are shown in Fig (2). As previously mentioned the average value of 1058 Wh/m² for June 12th was the highest.

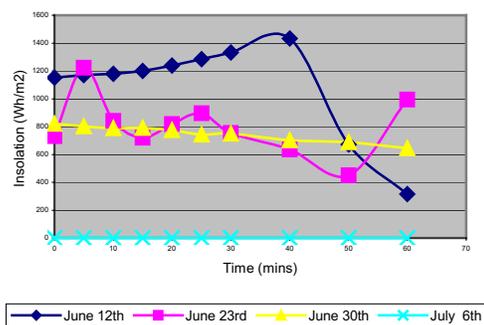


Figure (2) Insulation graphs for the 12th, 23rd and 30th of June and the 6th of July.

Except for the night run there was generally an increase in the temperature of the reservoir as well as the reactor with time. The final temperature of the reservoir after one hour in each case was 42 degrees Celsius as shown in figure (3). This increase in temperature will contribute to a reduction in the bacterial concentration (see Clarke et. al, 2005). However temperature increase cannot fully account for the data since SODIS must operate for about four hours for complete removal of E coli.

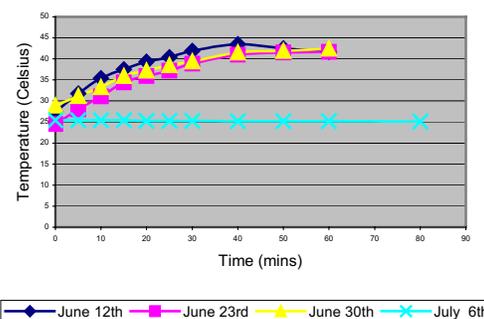


Figure (3) Reservoir temperatures for the 12th, 23rd and 30th of June and the 6th of July.



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No heating effect was observed on the night of July 6th. The temperature recorded was the ambient temperature and this decreased by less than 1^oC as the night became cooler. There was no insulation also as expected. In our experiments complete disinfection was obtained after 30 minutes on two occasions and 60 minutes on another occasion as shown in figure (4).

We believe that the photo-catalytic effect of Titanium dioxide is the main contributor to the observed decrease in bacterial concentration with the assistance of ultraviolet light. TiO₂ is a photocatalyst, which absorbs ultraviolet light from short wavelengths up to 385nm and is known to be effective in solar detoxification (Pelizzetti et al, 1990; Linsebigler et al 1995).

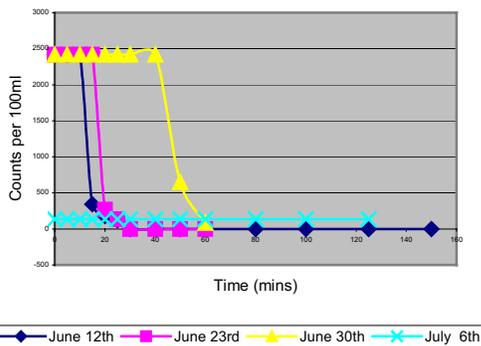


Figure (4) Bacterial decrease with time for the 12th, 23rd and 30th of June and the 6th of July.

Upon near UV irradiation, TiO₂ generates electron/hole (e⁻/ h⁺) pairs, according to equation (1).



The latter can react with surface bound hydroxyl groups to generate hydroxyl radicals as shown in Equation (2).



The hydroxyl radicals then attack the bacteria thereby disinfecting the water. It is perhaps significant to note that while the solar insolation on June 30th was about the same average value as on June 23rd, bacteria were totally eliminated in 60 minutes on June 30th but in 30 minutes on June 23rd. June 30th was however a cloudier day which suggests a reduced UV effect and consequently an increased time duration for complete disinfection. This also explains why no effect was obtained for the night run.

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Metallic contaminations in two bays of Guadeloupe - Set up of a biomonitoring survey by using a biomarker of genotoxicity on the mangrove oyster (*Crassostrea rhizophorae*).

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Abstract

The pollution of coastal marine ecosystems has become an important concern for the Caribbean islands and especially in Guadeloupe (Lesser Antilles). In this island, many human activities are concentrated around two bays: the Grand Cul-de-Sac Marin and the Petit Cul-de-Sac Marin, and contribute to the contamination of the whole coastal ecosystems by polluting substances such as heavy metals. The present study aimed at assessing the metallic contamination of these two bays. Effects induced by the pollution in oysters were assessed by using a biomarker of genotoxicity in a "comet assay". Concentrations of three non-essential trace metals with toxicity (cadmium: Cd, mercury: Hg and Lead: Pb) were measured in fine sediment fraction (<63µm) and soft tissues of mangrove oysters (*Crassostrea rhizophorae*). Heavy metal concentrations recorded in Guadeloupe were generally lower than concentrations recorded in other Caribbean and South American countries. Nevertheless, stations localised within the Grand Cul-de-Sac Marin marine reserve, near the dump of Grand-Camp (Rivière Salée), exhibited high metallic concentrations. The comet assay underlined important induced effects on oysters coming from contaminated stations. Further investigations involving a wider range of indicators should be conducted to properly quantify the metallic contamination detected in these areas.

Introduction

The pollution of coastal marine ecosystems has become an important concern in a worldwide scale. In the Caribbean Islands, Guadeloupe (F.W.I.) is concerned by this problem as well. Indeed, many human activities are expanding on Guadeloupe's coastline. The main goals of the study are to establish an assessment of metallic contamination in two bays of Guadeloupe: the Grand Cul-de-Sac Marin and the Petit Cul-de-Sac Marin, and to evaluate the effects induced by pollution on the organisms.

Materials & Methods

Samples were taken in 22 stations around the Grand Cul-de-Sac Marin, the Rivière Salée and the Petit Cul-de-Sac Marin (Figure 1) from January to February 2005.

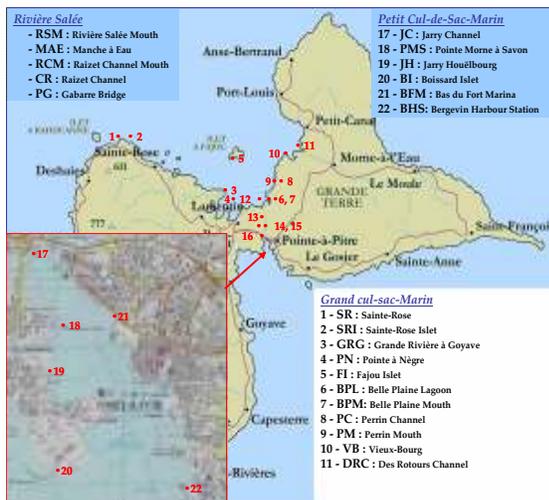


Figure 1: Location of the different stations in the study area

Samples of sediment and mangrove oysters were collected. Surface sediment samples were collected by core sampling and dried at 50 °C. The fine fraction

(<63 µm) separated by nylon sieves was conserved to be analyzed. After 24 hours of depuration, mangrove oysters tissues were collected, pooled (10 individuals per lots) before homogenization and drying at 50 °C.

For heavy metals analysis, sediment and oyster soft tissues were dissolved in concentrated nitric acid. Reagent blanks and standard reference materials were submitted to the same protocol as the samples. Atomic absorption spectrophotometry by flame or graphite furnace was used to analyze cadmium and lead. Total mercury was analyzed with an Automated Mercury Analysis system fit for solid sample.

For genotoxicity analysis, the Comet assay/Single Cell Gel (SCG) was used. It is a recent technique developed to detect DNA strand breaks (1). A suspension of oyster's gills single cells was included in agarose gel. Cells were lysed in an alkaline solution to liberate DNA, prior to be submitted to an electrophoresis. DNA was stained with ethidium bromide and then visualized by microscopy. Comets were classified into four categories based on the length of migration and/or the perceived relative proportion of DNA in the tail. By assigning a numerical value to each category, an average could be calculated. This test was realized on 11 individuals sampled in five stations.

Results

Concentrations of Cd, Hg and Pb in the sediment and mangrove oyster's soft tissues (*Crassostrea rhizophorae*)

The concentrations range from 0.059 to 0.764 mg/kg, dw for Cd; from 0.03 to 0.75 mg/kg, dw for Hg and from 4.88 to 465.9 mg/kg, dw for Pb (Figures 2a, 2b).

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In the fine surface sediment, the highest concentrations of Cd, Hg and Pb are found in the site of Rivière Salée.

In oysters soft tissues, the concentrations range from 0.11 to 0.92 mg/kg, dw for Cd ; from 0.04 to 0.205 mg/kg, dw for Hg and from 0.072 to 1.47 mg/kg, dw for Pb (Figure 3).

In the soft tissues of oysters, the highest concentrations of Cd, Hg and Pb are found in the site of the Rivière Salée.

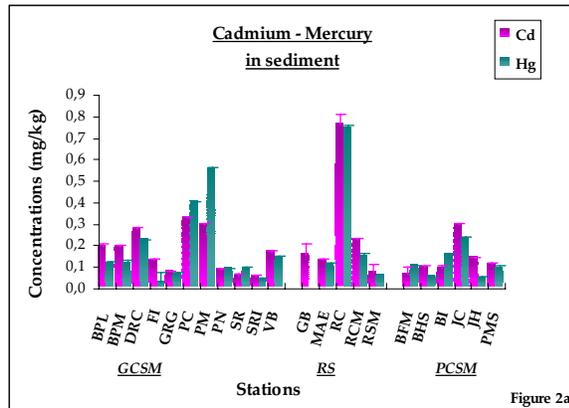


Figure 2a

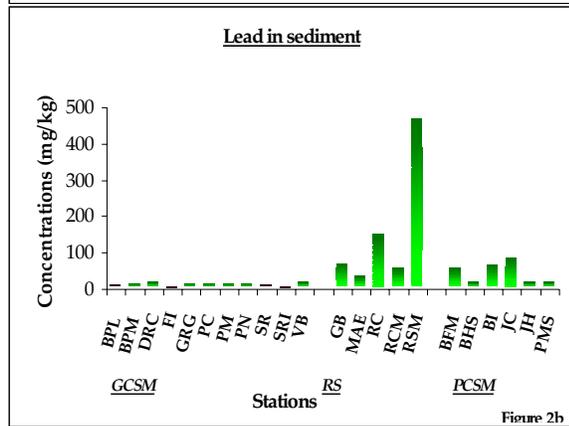


Figure 2b

Figures 2: Average values of metallic concentrations (mg/kg, dry weight) into the sediments coming from the three sites of the study zone. GCSM: Grand Cul-de-Sac Marin; RS: Rivière Salée; PCSM: Petit cul-de-sac Marin.

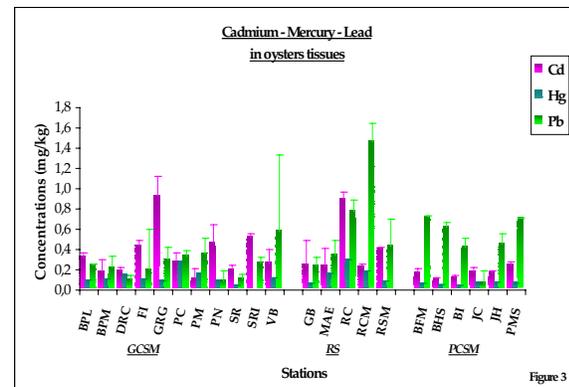


Figure 3

Figure 3: Concentration of Cd, Hg and Pb (mg/kg, dry weight) in the total soft tissues of mangrove oysters (*Crassostrea rhizophorae*) coming from the three sites in the study zone (value are expressed as means \pm S.D). GCSM: Grand Cul-de-Sac Marin; RS: Rivière Salée; PCSM: Petit Cul-de-Sac Marin.

Genotoxicity analysis: results of the Comet assay
Stations GB, GRG and RC are not significantly different and show important mean scores, while RSM and FI mean scores are less important.

Discussion and Conclusion

In Guadeloupe, the concentrations recorded are generally lower than those recorded in other Caribbean and South American countries (2, 3).

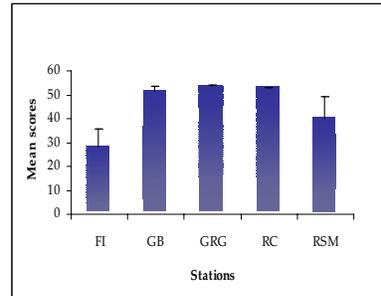


Figure 4: Mean scores (n = 11) for the five stations studied. FI: Fajou Islet; GB: Gabarre Bridge; GRG: Grande Rivière à Goyave; RC: Raizet Channel; RSM: Rivière Salée Mouth.

In the Rivière Salée site, the concentrations recorded into the sediment and the oyster' soft tissues are higher than the other sites. Into Rivière Salée site, the highest concentrations of cadmium, lead and mercury, three non-essential trace metals with high toxicity (4, 5) were recorded in Raizet Channel which receives all the lixiviation products of the intercommunal Grand-Camp dump (6).

These data suggest that Cd and Hg have a high bioavailability coupled with an eventual partial or non-existent regulation, contrary to Pb (Figures 2, 3). The comet assay underlines important induced effects into contaminated stations. Nevertheless it only permits to evaluate the health level of oysters analyzed because this test is not specific to metals.

It would be advisable to continue these investigations in regular studies by using a wide range of bio-indicators, and metallic specific biomarkers like métalloamthionéines (7). Moreover, it would be interesting to keep Fajou Islet as a reference station for forthcoming studies.

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Short - Time Scales Variability of the Global Solar Radiation in Guadeloupe

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Abstract

The amount of solar radiation arriving at a particular location varies greatly with time. A part from the astronomical and geographic factor, such as the day of the year, the time, latitude and surface geometry that constitute its deterministic component, the solar radiation also depends on the size, velocity and type of clouds, which is responsible of rapid stochastic irradiance variations. Thereby, as shown by a preliminary measurement campaign, these rapid stochastic variations at a given time can reach a significant amount (nearly 60%) of the expected clear sky irradiance. Moreover, these variations can occur on very short time scales (down to few seconds), a situation frequently observed in tropical climate.

The global solar irradiance variability at surface level is an important parameter in designing solar energy applications such as photovoltaic cells or energy efficient building design. For instance, this volatility of the solar radiation demands a specific adaptation of the electronics (regulator, UPS, ...) for grid connected photovoltaic systems, as it can initiate instabilities on the electrical utility network. Thus, managing the electrical network could benefit from short time scales probabilistic forecasting models.

This emphasizes the need for statistical and dynamical characterization of the short time scales solar radiation variability.

Following this goal, we are carrying out solar radiation measurements at two locations in Guadeloupe (FWI) with a 1 Hertz sampling frequency. The collected data are processed to identify and to classify the different time sequences not only from their mean irradiance but also from their stochastic variations characteristics.

The results will be conditioned so as to provide the tools necessary to build a synthetic solar radiation signal to test the effect of solar radiation variability on the overall solar energy system performance.

Acceptance, Applicability and Efficiency of Batch Disinfection of Rainwater for Human Consumption in Rural Communities of Trinidad Using Solar Radiation

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Keywords: Trinidad, BOD, batch solar disinfection (SODIS), solar concentrators, natural ultraviolet radiation.

Abstract

This project sought to investigate probable solutions to the current problem of the lack of potable water in several rural villages throughout Trinidad. Attempts to attain this ultimate goal initiated the objectives of this study. This paper gives results of an investigation into the applicability of batch solar disinfection (SODIS) for the treatment rain and river water within five (5) rural areas in Trinidad: Caura, Cedros, Guayaguayare, Matura and Quinam. The assessment of SODIS' applicability incorporated a social survey of the ability of residents in the above-mentioned rural areas to conduct batch SODIS successfully after learning the method by demonstration.

SODIS was investigated by the use of plastic (i.e. polyethylene terephthalate) bottles - in both the half blackened (i.e. 1/2BB) and transparent (i.e. TB) states - that are typically discarded by most



Trinidadian households and natural ultraviolet radiation (i.e. from the sun). Bottle volumes of 650mL, 1L and 2L, in both 1/2BB and TB, were subjected to rainwater, river water and RBC effluent. Each filled bottle size was also subjected to four (4) solar concentrators: double parabola, galvanised sheet, square and rectangular. Faecal coliform and heterotrophic bacteria were used as the indicator organisms as to determine when SODIS was successful. As a result, water samples were taken from each test bottle every ten (10) minutes for indicator analyses to be done.

The use of all four (4) concentrators effected total inactivation of both faecal coliform and heterotrophic bacteria under sunny conditions. When effectiveness of reduction of faecal coliform and heterotrophic bacteria was based on the time for inactivation, for all sample types, the double parabola was found to be the best concentrator. Further, bottles in the 1/2BB state were found to give superior results than their volume-respective TB. In terms of container size, whether 1/2BB or not, it was determined that the smaller the container volume the quicker that SODIS is effected. When the effect of turbidity on SODIS was investigated it was found that only waters with turbidity less than 30 NTU could be successfully subjected to SODIS. Overall, it can be said that SODIS, by use of any concentrator, bottle state and bottle size investigated, can be effective in Trinidad for achieving potable water standards in terms of microbial count provided the water needing solar disinfection has a turbidity below 30 NTU.

Retrieval of Aerosol Optical Thickness from Solar Radiation Data: Study of a Saharan Dust Event In Guadeloupe

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Abstract

Saharan dust outbreaks are often reported over Caribbean islands during the wet season, due to the long-range transport of air masses from African natural sources. From May to August 2005, several notable dust events were observed in Guadeloupe (French West Indies, 16.2°N, 61.5°W).

During this period, global and diffuse solar irradiance and downward infrared irradiance measurements respectively by two ground-based pyranometers and a pyrgeometer were collected at Petit Canal, at the same place as Aerosol Optical Thickness (AOT) measurements by a sun photometer, part of AERONET network. On this site, rainfall depth, relative humidity, ground temperature in the shade and horizontal velocity data from a meteorological station were also available during the experiment. About 30 kilometers far from that, horizontal visibility from Meteo France, and PM₁₀ mean concentrations from Guadeloupe air quality network Gwad'air, allowed to attest high concentrations of dust in the air masses flying over the archipelago during the studied period.

In this paper, direct solar irradiance is calculated from global and diffuse irradiance and is compared to AOT data. A good correlation is found between these two quantities. The main difficulty of this study was to detect the fluctuations of irradiance signals due to the presence of clouds over the area of measurements and to eliminate the corresponding data from the study.

The observed agreement between AOT and direct irradiance allows to conclude that the climatology of Saharan dust incomings in Guadeloupe should be established from irradiance data, even in the absence of photometric measurements. AOT measurements began in Guadeloupe in 1993 whereas irradiance data are registered since several decades. Then, it will be possible to verify the assumption according to a greater and greater amount of dust is travelling between African and American continents in relation to global warming.



High Particles Concentration Levels and Relationship with Air Conditioning: Study of Three Cases of Intoxication in Public Offices

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Abstract

In recent years, scientists have noted a tremendous increase of problems in the working environment, due to limited natural ventilation in closed buildings.

In Guadeloupe, some cases of indoor pollution have been reported. During the last year, three public offices had to be cleared out because of respiratory and allergic troubles dramatically experimented by the employees.

Following these incidents, the LPAT (Laboratoire de Physique de l'Atmosphère Tropicale) was asked for analyses of the indoor air composition. Particles were collected on filters with a 10 liters per minute airflow and analysed by gravimetric method. Parts of the filters were observed by electronic microscopy to investigate the sizes and composition of particles.

Results have put into evidence the presence of highly numerous very fine particles of respirable size (particles diameter lower than 2,5 µm). Previous studies have showed that these particles are the most hazardous for health. They were mainly composed of carbon coming from combustion of petrol derived released in the neighbouring outdoor air. Indoor air quality should be corrected by air filtration. This solution has an inconvenient since it could be incompatible with energy savings. The balance between health protection, energy savings and human comfort is an essential question to solve in our inter tropical countries.

Measurement and Analysis of Wind Velocity and short Time Scale Wind Speed Forecast

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Abstract

Increasing the part of wind energy sources in a given electrical network needs the knowledge of not only the expected mean power but also of the variability of such a stochastic source. More precisely the choice of storage systems and/or of alternative conventional generators, as well as the development of forecasting tools devoted to the network management, require the determination of the statistical and dynamical properties of this variability. For instance, using thermal power stations, where combustion acts as the energy source, to palliate the shortcoming of wind energy could lead to starting times ranging from 10 to 60 minutes. Therefore as soon as wind power becomes a significant part of the electricity sources, as it could be in island network, efficient forecast tools for time scales smaller than one hour are needed. If meteorological offices provide forecast information and wind variability characteristics for times scales larger than one or a few hours, this is no longer the case when time scales smaller than one hour are considered.

The results of a six month campaign of 1hz velocity measurements, that we performed during the trade wind season in a Guadeloupe wind farm, are used to develop a statistical and dynamical analysis of the wind velocity. More precisely, we first proceed to a time scale separation of the wind speed signal to provide the main statistical characteristics of the wind fluctuations (probability density functions, first to fourth momentum, autocorrelation time, power density spectra...) on time scales ranging from ten minutes to one hour. The corresponding time series are then compared in order to proceed to a classification of the different possible time series. The results are then discussed from the point of view of wind speed forecast, for time scale smaller than one hour. Different strategies are envisaged to achieve such short time scales wind speed forecast.



Simulation of Rainfall Interception Processes for Pollution Hazards Estimation Under Banana Plants

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Abstract

Rainfall interception by plant canopies varies according to the plant structure and raindrop physical properties. Banana plant architecture provides important rainfall redistribution as stemflow (water flux on the stem) and throughfall (water fluxes through the foliage). Experimental measurements of drop diameters under banana plants showed the plant structure affected the drop size distribution by generating large drip diameters. Large kinetic energies and dripping rates may affect soil erosion as well as location of fertilizers and pesticides spread to the soil near the plant collars and sprayed on the leaves. These agrochemicals can be leached and carried to surface or ground waters, threatening environment and human health.

In order to locate these hazard zones, we used the DROP (Distribution of Rainfall On Plants) model combining first 3-D representation of the plant architecture given by digitising and triangulation, second rainfall distribution simulation according to the plant physical properties. Firstly, thanks to experimental measurements we developed empirical laws describing splash and storage losses at the leaf surfaces. Secondly, we introduced these laws into the model to improve the simulation of rainfall distribution under the foliage. Thus, splash and storage amounts resulting from incident rainfall interception were evaluated according to leaf inclination, drop diameter and drop fall height.

Experimental results showed splash increased with fall height and decreased with leaf inclination. Storage was not affected by fall height, increased with drop diameter and decreased exponentially with leaf inclination. Interception laws inferred from these results improved significantly DROP water flux simulation which provided in agreement with measurements 1 mm interception losses on average per rainfall event. Moreover, high kinetic energies and rainfall rates were simulated in a ring comprised between $\frac{1}{2}$ and $\frac{3}{4}$ of the maximum crown radius. In addition to stemflow area, this ring could be considered as a zone favouring agrochemicals leaching or run-off.

Molasse Spentwash Treatment by Two Processes: Adsorption on AC and Biodegradation

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Abstract

Fermented molasses are used in order to produce ethanol in distilleries. After distillation of the fermented product, huge amount of wastewater (molasse spentwash) are generated. They have a dark brown color due to melanoidin and phenolics compounds. This colored effluent is a major pollutant when it is discharged into natural waters because of its high organic content, it has approximately a Chemical Oxygen Demand (COD) ranging between 60 and 120 g/L. Anaerobic digestion is an



efficient process in order to treat them but only partially. The aim of this work is to set up a remediation procedure of digested molasse spentwash (DMS) from sugar cane industries.

First, the adsorption potential of different activated carbons for this effluent and its recalcitrant compounds has been studied. Adsorption kinetics and adsorption isotherms of (DMS) and its recalcitrant compounds (gallic acid, tannic acid, melanoidin and phenol) have been measured using three commercial carbons: PICTACTIF TA50, PICTACTIF TE60 and vegetal activated carbon (VAC). The adsorption kinetic of these compounds was determined at three different pH (3, 7 and 10) and temperatures (20, 25 and 35 °C). Kinetic data were fitted using the pseudo- first order equation of Lagergren ($\log(q_e - qt) = \log q_e - k_1 t$) or a pseudo- second order model ($t/qt = 1/k_2 + t/qe$). Isotherm adsorption data were fitted using the Freundlich model or a modified Freundlich model. Thermogravimetric study of the different activated carbons loaded with these compounds were performed in order to quantify the mass loss and to determine the adsorption energy.

Secondly, biodegradation of DMS and its recalcitrant compounds has been studied. In a first step, using Poly Chain Reaction (PCR) and sequencing techniques, *Citrobacter amanolaticus*, a pure bacterial culture which may be able to use DMS as sole carbon source, has been identified. In a second step, aerobic degradation of these compounds by another pure bacterial culture of *Burkholderia caribensis* isolated in martinique's vertisols has been studied. Degradation study of DMS by *Citrobacter amanolaticus* will be studied in the near future.

Measurement and Computer Representation of Banana Plants for Environmental Studies

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Abstract

Plant computer models are increasingly used for entertainment and environmental studies. For example, energy and mass transfers between plants and the aerial environment can be simulated on 3D computerized plant mock-ups. The design of these mock-ups needed both detailed data acquisition and mathematical development for the geometrical representation of plants.

In order to evaluate environmental hazards due to rainfall interception in banana plantation, we had to examine water fluxes for several possible plant patterns. We then had to design a database of the 3D coordinates of several plants collected in the fields. For that purpose we developed data acquisition and plant rendering software.

Firstly, we evaluated and specified the use in the field of a long-range electromagnetic digitizer. We developed a computer software that drive the digitizing process and allow simultaneously data visualization and correction in order to ensure fast and accurate data collection. The digitalization process consisted in describing each leaf by series of ordered points on the leaf edges and on the midrib.

Secondly we developed a new method to represent complex plant leaves by meshes of triangles in the 3D space. Banana leaves are complex because they are large and occasionally torn by wind and rain. Usually, leaf triangulation algorithms were based on "Constrained Delaunay Triangulation" and were not adapted to these complex shapes.

Digitized banana leaves formed three dimensional polygons for which triangulation is a NP-complete problem. As surface meshing methods need 3D data projection on a plane, the problem led to the triangulation of non simple and self-intersecting polygons. We adapted existing robust methods (i. e. ear clipping and edge flipping methods) in order to obtain a sub-optimal but generic and satisfying triangulation of torn leaves. This algorithm could be used to process other complex leaf shapes. We used these data acquisition and triangulation algorithm to design a convivial graphical tool, using the DROP model to visualize rainfall interception and water transfers in heterogeneous plant patterns.



Energy / Environment / Pollution

Energy Production and Pollutant Mitigation from Broiler Houses on Poultry Farms in Pennsylvania and Jamaica

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Abstract

This proposal forms part of the development of a collaborative research and design program in the area of energy production for use in the agricultural sectors of both Jamaica and the United States, while addressing environmental concerns in each country.

While the underlying technology of bio-digestion is not new to Jamaica (introduced by the then Ministry of Mining and Energy in the late 1970s), the use of chicken litter as a feed material for digestion was viewed with scepticism. This is due to the fact that in Jamaica, poultry are fed with antibiotics to treat some of the common illnesses. These antibiotics are known to have adverse effect on the microorganisms required to carryout the digestion process, and ultimately negatively affect the gas generated by the process.

The project explores the economic viability of this technology by constructing and testing simple, inexpensive anaerobic biodigesters capable of producing methane gas from a variety of feed materials. The digesters were fed with pure chicken litter, a mixture of chicken and cow litter, a mixture of chicken and swine litter and a mixture of chicken litter and vegetable material. The quality and quantity of gas produced will be measured to determine the concentration of chicken litter required for optimum gas production.

Jamaica produces 6.1 million birds annually for broiler meat processing; these birds with an average life span of six weeks will produce 206.64 Giga-grams (206,640 tonnes) of litter annually. This waste can be digested to produce 57 million cubic meters of biogas, with the potential of producing 1200 Tera-Joules of energy, which is equivalent to 333.3 Gigawatt hours annually.

Focusing primarily on contract poultry operations the project will present a technological option, which will ultimately have two impacts. Firstly, the mitigation of environmental degradation caused by the release of high load of untreated phosphorus and nitrogen and secondly, a renewable energy source which will enhance the competitiveness of the industry.



Root Growth Responses of a wheat Cropland Weed, *Melilotus indicus*(L.) All., Papilionaceae to Air Pollution

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Abstract

The root length, root biomass and net primary productivity were studied at the monthly intervals on a wheat crop land weed, *Melilotus indicus* growing under the stress of air pollution caused by coal burning of a thermal power plant of Kasimpur (U.P, India). The daily average of sulphur rich bituminous type of coal consumption in the whole power plant complex during the winter season is about 3483 Metric tonnes. The rate of coal consumption and the amount of three major gases viz. oxides of Sulphur, Nitrogen and Carbon and particulate matters released from the power plant complex are 0.14Kg./hr, 2.58 Kg. /hr, 23.38Kg./hr and 32.2x 10³ Kg. /hr respectively. Ten Plants of *Melilotus indicus* growing in a wheat crop land under almost similar edaphic factor as well as ecological and agricultural practices were collected randomly on monthly interval basis at the four selected sites situated at 0.5km, 2 Km, 4Km and 20 Km leeward from the source of pollution. The data indicates that the degree of response increased with decreasing distance from the source of pollution. The trend of loss in the root length and root biomass is similar in all the stages. The root length and root biomass affected significantly at the 0.5 Km. in the seedling stage while, in the middle stage and old stage the loss is significantly increased up to 4 Km. in comparison to the reference site situated at 20 Km. away from the source of pollution. However, the severity of loss was found to be higher at the vicinity that 0.5 Km. in comparison to the reference site. The root length, root biomass and net primary productivity were more affected by pollutants at the middle stage (60%, 87.2% and 95.6% respectively) followed by old stage (52.4%, 85.6% and 66.7% respectively) and seedling stage (27.7%, 70.4% and 71% respectively). The root length and root biomass showed a significant and positive relationship with the distance from the source. The degree of relationship, however, increased from seedling stage to middle stage and decline at the old stage. Root length showed 19.4 to 66% dependence on the distance from the source while, the root biomass exhibited a relatively greater degree of dependence and varied from 46.3% to 67.3%. The consumption rate at the power plant, relative humidity, wind direction and other environmental factor were found to influence the degree of growth response to air pollution. Losses in the root growth are also possible in the Caribbean countries that are emitting air pollutants from diesel generating power plant and other industries.

