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Fax: 1-323-984-7374, 323-908-0457
E-mail: environmental@davidpublishing.com; environmental@davidpublishing.org; info@davidpublishing.org

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Heavy Metal Determination in the Bottom Solid Waste Ash Produced from Sabah and Shuaiba Hospital Incinerators in Kuwait

Saleh Al-Muzaini

Earth Sciences and Environment Department, Kuwait University, Safat 23942, Kuwait

Abstract: In Kuwait, there is growing concern over the disposal of wastes produced by hospitals since hospital wastes contain hazardous and infected wastes. All hospitals in Kuwait have adopted incineration as an alternative method to dispose of their wastes. Due to inefficient combustion of hospital incinerators, the Kuwaiti government decided to shut down all hospital incinerators, while the Sabah Incinerator (SAHI) and Shuaiba Incinerator (SUHI) were kept running. This study was initiated to focus on the determination of heavy metals in the bottom ashes produced by the SAHI and SUHI incinerators. Bottom ash was collected over a period of one year and heavy metals were determined. They were shown variation in their concentrations due to the initial waste composition and the operational procedures of the hospital incinerators.

Key words: Hazard, hospital waste, incineration, toxic metals.

1. Introduction

In Kuwait, there is a major concern over the increasing amount of hospital wastes as shown in Fig. 1. The amount of hospital wastes generated have doubled in the past 40 years to reach 5 kg to 10 kg per patient, which corresponds to a total of 6×10^3 tons per year of hazardous hospital solid wastes. The expectation indicates that this figure will increase in the future due to the single disposable items used per patient [1].

Ninety-five percent of current hospital wastes were incinerated in nearly 25 facilities. However, inefficient combustion of hospital incinerators leads hospital incinerators to generate toxic emissions during their daily operations. As a result of epidemiological studies conducted by health authorities, it was revealed that there is a correlation between the proximity of a residence to a hospital incinerator and the incidence of various types of cancer. Thus, the health authorities decided to shut down hospital incinerators and retained the operation of the Sabah Hospital Incinerators (SAHI), which was modernized later on. At the same time, a new incinerator was installed at Shuiaba area called Shuaiba Hospital Incinerator (SUHI). Even though incinerations are good means to reduce the volume of hospital wastes and eliminating infectious components, the subject of hospital incineration is still under public debate. Recent studies showed that the impact of carcinogenic emissions from new hospital incinerators on human health was to be much low [2]. Comprehensive studies have been carried out on the impact of air pollutants in fly ash, while some general information is available from recent published studies on the determination of heavy metals in the bottom ash of hospital incinerators, which are yet to be understood. A preliminary study was conducted on the nature of bottom ash from hospital incinerators in Kuwait in 2001. The results revealed that bottom ash produced by hospital incinerators contained high levels of heavy metals such as Zn, Fe, Pb, Cr, Cu, Mn, Ni and Cd. The study suggested that further study should be conducted to understand the differences in the levels of heavy metals [3]. Lo, H. M., and Liao,

Corresponding author: Saleh Al-Muzaini, Ph.D., main research field: environment engineering.

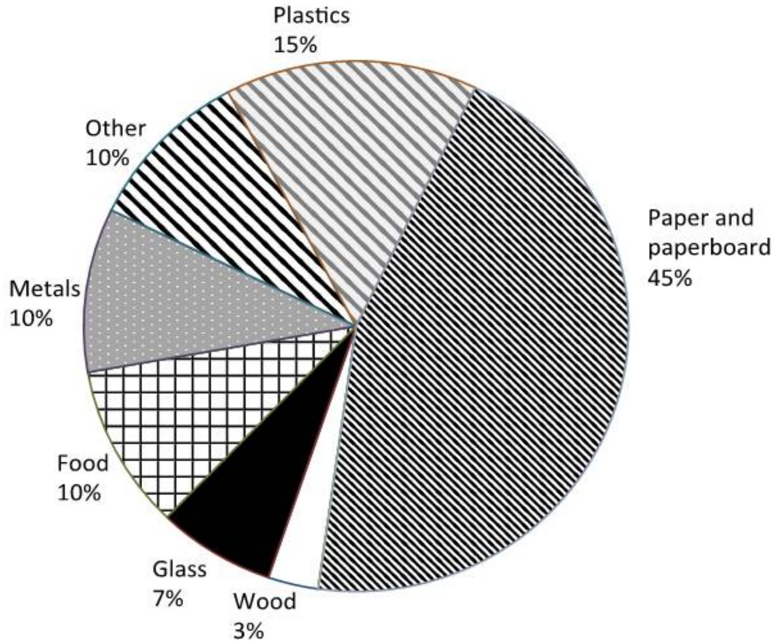

Fig. 1 Average hospital composition waste [33].

Y. L. [4] showed that incinerator bottom ash can create a significant risk to the environment. Recently, the European Union Council Declared that, hospital bottom ash as a dangerous waste material [5]. Unsafe disposal of hospital waste ash in a landfill can cause contamination to the soil and groundwater due to leaching of heavy metals [6]. For this reason, hospital waste ash requires special attention [7] during its disposal. Alba, N., et al. [8] reported that six hospital medical waste incinerator samples in northern Spain were collected and analyzed. Results showed high concentrations of chromium in hospital waste ash. However, Zhao, L., et al. [9] studied the chemical properties of heavy metals in hospital wastes incinerator ashes in China. They reported that heavy metals, such as Ca, Cr and Na were found in various quantities, where Cr had the highest concentration among other heavy metals. Kougemitrou, I., et al. [10] studied bottom ash samples from hospital waste incinerators in Athens, Greece. The results of their research showed that hospital waste ash contained a high content of heavy metals such as Cu and Cr. Zhao, L., et al. [11] studied hospital waste incinerator ash due to the outbreak of severe acute respiratory syndromes in China. The analyses showed that hospital bottom ashes contained a larger amount of heavy metals such as Ba, Cu, Cr, Mn, Ni, Pb, Sn, Ti and Zn. Heavy metals, such as Ba, Cr, Ni and Sn, were present in the residual fraction, while Mn, Pb and Zn were present in the Fe-Mn oxides fraction and Cu was present in the organic matter fraction. Zakaria, M., et al. [12] evaluated hospital waste incinerator performances based on their physical and chemical characteristics of bottom ashes. They concluded that incineration processes can easily destroy organic compounds and some heavy metals found in the hospital wastes. Furthermore, Levasseur, B., et al. [13] reported the hospital incinerators could produce large quantities of bottom ashes depend is on the amount of hospital wastes. Astar, M. [14] reported that incineration provides the ultimate means of disposal for toxic compounds. Tessitors, J., and Frankle, C. [15] pointed out that many hospital authorities decided to dispose of all hospital wastes through incineration for the following reasons: (1) landfill authorities are unwilling to accept any hospital wastes, and (2) liability consideration due to possible transmission of diseases such as AIDS and viral diseases. Doyle, B.W., et al. [16] and Timothy A., et al. [17] stated that pollutants in the bottom ashes from hospital waste incinerators may pose hazards to the environment if they are not properly disposed of. Rich, C., and Cherry, K. [18] pointed out that it is important to have a clear procedure to dispose of hospital wastes, as otherwise, these is a risk of severe acute respiratory diseases spreading later on. While Shen, T. [19] highlighted that the public are always concerned about hospital wastes, the potential risk always existed. Over 80% of many main elements, such as Fe, P, Al, Sr, Ca and some of the toxic elements, such as Cr, Co, Mg, Ni, Mo can remain in the bottom ash after incineration [20]. Also, 90% of Cd and 88% of Sb can be volatilized but they also remain in the bottom ash [20]. Based on recent research, low volatility heavy metals, such Ni, Cr, Cu and Zn always remain in the bottom ash [21]. The aim of this work was to identify heavy metals and their levels in hospital bottom ash and to compare the results of this study with published results. For this study, bottom ash samples were collected and analyzed over a period of one year.

2. Materials and Methods

2.1 Hospital Incinerator

This study was carried out in two hospital incinerators—SAHI and SUHI. They are located in urban areas. The nature of the incinerated waste is hospital waste and hospitals regularly incinerate without any preliminary sorting. SAHI was built in 1980 but since 2002 major technical modifications were made to update the current standards. SUHI, the second incinerator was built in 2010 and is located in the south of Kuwait city. Both incinerators are equipped with two combustion chambers with design capacities between 350 kg/h and 650 kg/h of hospital wastes. They are fitted with efficient electrostatic precipitators and liquid lime scrubbers. The combustion chamber temperature goes up to 1,500 °C. The decontaminated exhaust is released into the atmosphere by a 50 m high chimney. Bottom ash residues are transported by vibrating conveyors and stored in a bunker. All ash residues are subsequently transported to trucks for final disposal in a landfill.

2.2 Bottom Ash Sampling and Analysis

The bottom ash samples were collected from two incinerators. All samples were taken between January and December 2013. The bottom ash samples were collected at the end of operation day. A total number of 96 samples were collected in a period of one year from the combustion chamber. The samples were kept in a closed non-contaminating plastic bag. Each sample was about 1 kg to 2 kg. After all of the samples were collected, they were transported to the laboratory where they were analyzed. In the laboratory, each ash sample was crushed in a porcelain mortar and pestle, passed through a #40-mesh sieve, and stored in glass bottles. All ash samples were dried in the oven at 105 °C for 3 hour to remove any humidity. Approximately 1 gm + 2 gm of dry ash sample was placed in a digestion tube and then 15 mL of HNO_3 (100%) was added and mixed thoroughly for 1 hour at 70 °C. The sample was cooled to room temperature before filtration. After filtration, 50 mL of the sample was collected and sent directly for analyses. The Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Varian SPS3 analysis [22] was used for the analysis of heavy metals such as Cd, Co, Cr, Fe, Ni, Mn, Mo, Pb, Se, Sn, Sr, V and Zn. The ICP-OES instrument was already calibrated using reference standards and suitable blanks in order to produce high quality reading. Sampling and analysis were performed according to the Standard Methods [23].

3. Results and Discussion

3.1 Chemical Characteristics of Bottom Ash

The bottom ash samples were investigated for heavy metal concentration (Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sn, Sr, V and Zn). Table 1 shows the concentrations of heavy metals in the bottom ash of SAHI.

Table 1 Concentration of heavy metals in bottom ash SAHI.

Heavy Metals \ Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	Average
Cd	0.01	0.01	0.01	0.03	0.03	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02
Co	0.08	0.08	0.07	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.08	0.07	0.07
Cr	4.10	4.58	4.58	4.50	4.52	4.51	4.10	4.10	4.52	4.51	4.50	4.58	4.42
Cu	6.99	6.18	7.50	6.18	6.17	6.16	6.98	6.15	6.17	6.18	6.25	6.20	6.42
Fe	46.9	191	172	170	163	160	165	169	170	165	189	190	163
Mn	1.02	1.10	1.24	1.2	1.00	1.23	1.0	1.01	1.22	1.19	1.18	1.22	1.13
Mo	0.08	0.08	0.08	0.07	0.06	0.07	0.08	0.07	0.06	0.07	0.06	0.08	0.07
Ni	0.12	0.11	0.09	0.10	0.08	0.12	0.11	0.10	0.09	0.12	0.12	0.12	0.09
Pb	7.09	8.58	7.76	7.10	7.75	7.12	7.13	7.10	7.09	7.76	7.99	7.14	7.47
Se	< 0.01	0.01	0.01	< 0.01	0.01	0.01	< 0.01	0.01	< 0.01	< 0.01	0.01	0.01	0.01
Sn	0.27	0.26	0.27	0.26	0.26	0.26	0.27	0.27	0.26	0.26	0.26	0.26	0.26
Sr	3.58	3.55	4.23	4.20	3.60	3.60	3.75	3.59	3.60	3.62	3.67	4.20	3.77
V	0.10	0.11	0.12	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.11	0.12	0.12
Zn	194	120	192	180	130	190	192	191	193	130	194	193	175

* All reading in mg/L.

The concentration of Cd varied from 0.01 mg/L to 0.03 mg/L with an average of 0.02 mg/L, while Co concentration ranged from 0.06 mg/L to 0.08 mg/L with an average of 0.07 mg/L. However, concentration of Cr ranged from 4.10 mg/L to 4.58 mg/L with an average of 4.42 mg/L. The concentration of Cu ranged from 6.18 mg/L to 7.5 mg/L with an average of 6.42 mg/L, but Fe concentration ranged from 46.9 mg/L to 191 mg/L with an average of 163 mg/L. The concentration of Mn varied from 10 mg/L to 1.24 mg/L with an average of 1.13 mg/L, and Mo concentration ranged from 0.06 mg/L to 0.08 mg/L with an average of 0.07 mg/L. The concentration of Ni ranged from 0.08 mg/L to 0.12 mg/L with an average of 0.09 mg/L. Pb concentrations ranged from 7.08 mg/L to 8.58 mg/L with an average of 7.47 mg/L; however, Se concentrations ranged from < 0.1 mg/L to 0.1 mg/L with an average of 0.1 mg/L. Sn concentration varied from 0.26 mg/L to 0.27 mg/L with an average of 0.26 mg/L. Sr, V and Zn concentrations ranged from 3.58 mg/L to 4.30 mg/L, 0.10 mg/L to 0.11 mg/L, and 120 mg/L to 194 mg/L, respectively, while their average concentrations were 3.77 mg/L, 0.12 mg/L and 175 mg/L, respectively. The levels of heavy metals in bottom ash of the SAHI had an abundance of Zn > Fe > Pb > Cu > Cr >Sr> Mn > Sn > V > Ni > Mo > Co > Cd > Se in each sample. Table 2 shows the ash samples from SUHI.

Cd concentrations ranged from 0.01 mg/L to 0.02 mg/L with an average of 0.02 mg/L; however, Co concentrations ranged from < 0.01 mg/L to 0.03 mg/L with an average of 0.01 mg/L. Cr concentrations ranged from 0.91 mg/L to 1.07 mg/L with an average of 0.94 mg/L. Cu concentrations varied from 15.6 mg/L to 79.7 mg/L with an average of 52.3 mg/L; however, Fe concentrations ranged from 1.72 mg/L to 227 mg/L with an average of 197 mg/L. Mn concentrations ranged from 2.10 mg/L to 3.44 mg/L with an average of 2.65 mg/L, but Mo concentrations ranged from 0.01 mg/L to 0.05 mg/L with an average of 0.02 mg/L. Ni concentrations varied from 0.5 mg/L to 0.76 mg/L with an average of 0.63 mg/L, but Pb concentrations ranged from 27 mg/L to 35.3 mg/L with an average of 30.83 mg/L. Se concentrations ranged from < 0.01 mg/L to 0.01 mg/L with an average of 0.01 mg/L, but Sn concentrations varied from 0.60 mg/L to 0.72 mg/L with an average of 0.67 mg/L. Sr concentrations ranged from 2.17 mg/L to 3.20 mg/L with an average of 2.75 mg/L, but V concentrations ranged from 0.06 mg/L to 0.09 mg/L

Table 2 Concentration of heavy metals in bottom ash SUHI.

Heavy Metals \ Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	Average
Cd	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Co	0.03	< 0.01	0.01	0.01	0.01	0.01	0.01	< 0.01	0.01	0.01	0.01	<0.01	0.01
Cr	1.07	0.91	0.92	0.92	0.92	0.91	0.91	0.93	0.92	0.94	0.91	1.00	0.94
Cu	19.6	15.6	79.7	20.0	70.0	60.1	73.1	72.1	30.1	50.1	70.1	70.2	52.25
Fe	172	191	227	200	180	178	203	210	222	210	185	190	197
Mn	2.19	3.44	2.20	2.10	3.0	2.10	3.00	3.20	2.10	2.20	3.00	3.30	2.65
Mo	0.05	0.04	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.03	0.04	0.02
Ni	0.55	0.76	0.63	0.6	0.61	0.70	0.50	0.57	0.70	0.71	0.58	0.59	0.63
Pb	27.30	29.00	35.30	27.00	28.00	30.00	29	33.10	32.10	33.00	32.10	34.10	30.83
Se	< 0.01	0.01	< 0.01	< 0.01	< 0.01	0.01	0.01	0.01	0.01	0.01	0.01	< 0.01	0.01
Sn	0.63	0.72	0.69	0.60	0.70	0.70	0.71	0.64	0.63	0.65	0.70	0.64	0.67
Sr	3.18	2.17	2.31	3.20	2.80	2.30	2.30	2.31	2.80	3.00	3.00	3.10	2.75
V	0.08	0.09	0.06	0.06	0.06	0.08	0.09	0.06	0.06	0.07	0.06	0.07	0.07
Zn	120	185	111	130	125	120	130	140	130	135	140	145	134

* All reading in mg/L.

with an average of 0.07 mg/L. Zn concentrations ranged from 111 mg/L to 185 mg/L with an average of 134 mg/L. The levels of heavy metals in the bottom ash of SUHI had an abundance of Fe > Zn > Cu > Pb > Sr > Mn > Cr > Sn > Ni > V > Mo > Cd > Co > Se. In general, the levels of heavy metals in the bottom ash revealed a wide variation in the concentration of heavy metals due to the hospital wastes' contents.

This also means that incinerators were found to be inadequate in eliminating all of the metal contents. Furthermore, it appeared that the quantities of heavy metals in the hospital wastes may be high and cannot be eliminated easily by incineration. The concentration of Fe was the highest compared to other heavy metals, as shown in Fig 2. Also, metals, such as Zn, Cu and Pb, have high concentrations and can be compared to other elements. The variation in the concentration of heavy metals was probably due to two factors. The first factor was the variation in the hospital waste's composition, while the second factor was the improper operation of the two incinerators [24]. These levels were not unexpected since hospital wastes normally contain about 20% nonorganic materials and, occasionally, the levels increase as high as 30% [24]. Results show that some of the toxic elements (Cr, Co, Mg, Ni and Mo) always remained in the bottom ash due to their properties of metals [20, 21]. Table 1 shows that SAHI had the highest contents of Zn, Fe, Pb, Cu, Cr, while Zn and Fe had the highest concentrations, while Cd and Se had the lowest concentrations. Table 2 shows that the concentrations of Fe, Zn, Cu, Pb, Sr and Mn were the highest among other metals, while Se, Co, Cd, Mo had the lowest concentrations. Presence of Fe and Zn in the bottom ashes of two incinerators may due to the presence of cans, bottle capsules, pigments, and plastic materials [3, 25]. The results revealed that in comparing the total waste volume of two hospitals in the combustion chamber with the final ash residual collected after incineration process. Results indicated that the most of the waste loaded was burned properly and volume reduction has been achieved in all runs. The result also showed that the ashes collected from incineration process contained high concentrations of Fe, Zn, Cu and Pb. This is due to the fact that their small particles sizes were present and increased their availability surfaces to expose more to the adsorption process. The results revealed that the highest concentration of Fe in the ash might have been due to its highest melting point (1,493 °C), which makes it available in a larger

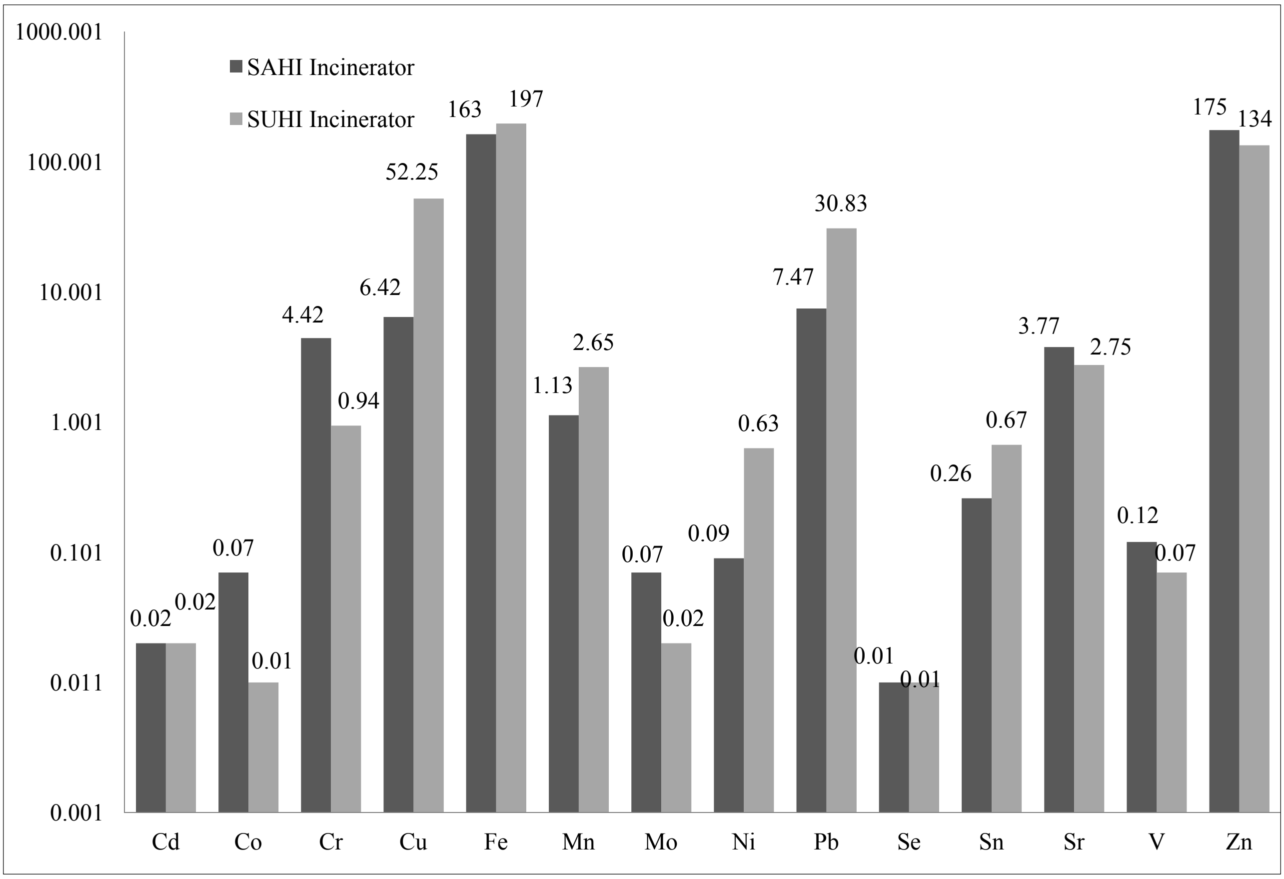

Fig. 2 Average concentration of heavy metals in bottom ash of incinerators.

Table 3 Comparison of parameters of bottom ash of hospital incinerators with published results and EPA TCLP levels.

Heavy metals	SAHI (a)	SUHI (a)	Sabah (b)	Ben-Sina (b)	Psychological (b)	Regulated levels for toxicity of heavy metals (c)
Cd	0.01-0.03	0.01-0.02	2.0-10.0	1.0-56.0	2-16.	1.0
Co	0.06-0.08	< 0.01-0.03	NR	NR	NR	NR
Cr	4.58-4.10	0.91-1.07	200-667	100-2,000	183-633	5.0
Cu	6.15-7.50	15.6-79.7	150-687	138-1,998	208-2,034	NR
Fe	46.9-191	127-227	727-8,867	1,167-5,700	4,233-1,233	
Mn	1.10-1.24	2.10-3.44	127-597	31-328	99-389	NR
Mo	0.06-0.08	0.01-0.05	NR	NR	NR	NR
Ni	0.08-0.12	0.55-0.76	24-41	25-141	21-52	NR
Pb	7.09-8.58	27.0-35.3	601-2,940	192-5,866	815-2,305	5.0
Se	< 0.01-0.01	<0.01-0.01	NR	NR	NR	1.0
Sn	0.26-0.27	0.60-0.72	NR	NR	NR	NR
Sr	3.55-4.20	2.30-3.18	NR	NR	NR	NR
V	0.10-012	0.06-0.09	NR	NR	NR	NR
Zn	120-194	111-185	730-6,800	827-27,800	-16,067	NR

* Note: (a) This study; (b) [3]; and (c) [26].

amount in the bottom ashes. When the levels of heavy metal of this study were compared with published data, it was found that the existing incinerators' performances were much better than previously, as shown in Table 3.

It seemed likely that both SAHI and SUHI incinerators had high efficiency to reduce the heavy metals. This means that the incinerator performance depends entirely on the combustion degrees. To classify the produced bottom ash from the two incinerators as hazardous or not, toxicity characteristic leaching procedure and characteristic waste Toxicity Characteristic Leaching Procedure (TCLP) list was applied [26]. According to the TCLP guidelines, results showed that Cd, Cr and Se had a lower concentration than TCLP. But Pb concentration was found to have exceeded the permissible limits. Due to Pb toxicity, the bottom ash is considered hazardous waste, as shown in Table 3. Therefore, the produced bottom ash from the two incinerators may be classified as hazardous wastes, and care should be taken during dumping [25, 27, 28]. Otherwise, it can cause problems to the surrounding environment [29, 30]. Therefore, utilization of bottom ash is much safer than dumping it in landfill sites [31-33].

4. Conclusions

The results of this study demonstrated that incineration is the best technology to destroy the increasing volume of hospital wastes. Hospital incinerators do not completely destroy heavy metals, but simply concentrate them into bottom ash. Bottom ash residues arising from both incinerators were found to contain high concentrations of hazardous elements, such as Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sn, Sr, V and Zn. However, the performances of both incinerators were much better than previously. Fe, Zn, Pb and Cu were found in the bottom ashes of two hospital incinerators. They were in high concentrations compared to other heavy metals found in the bottom ashes. Moreover, the highest melting points of some heavy metals mean a larger amount of their residues. The average concentrations of Pb were found to be higher than TCLP; therefore, bottom ashes could be classified as hazardous waste on most sampling days. It is likely to have highly mobile constituents of heavy metals. If they were improperly managed, they could contaminate the groundwater. Therefore, it is recommended that more efforts are needed to identify why bottom ashes contain high concentrations of Fe, Zn, Pb and Cu. Hospital bottom ashes should be disposed by properly designed engineered treatment methods.

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Green House in Semi-arid Regions of Mexico

Maria de los Angeles Rechy Carvajal[1], Emil von Roth[2] and Jose Alberto Murillo Rodriguez[3]

1. Faculty of Forestry, Universidad Autónoma de Nuevo León, Linares, Nuevo León 67700, Mexico

2. Aegis Structural Engineers, Studio City, California 91604, USA

3. Universidad Autónoma de Nuevo León, Linares, Nuevo León 67700, Mexico

Abstract: The subject structure was consisted of a proto-type house with plan dimensions of 8 m × 4 m. A variety of materials was used to the construction, with special emphasis on using environmentally friendly non-toxic materials. The structure's core consisted of reinforced concrete frames with masonry infill walls. Inside faces of the walls and the roof's outside face were covered with proprietary composite panels, which are manufactured with a mixture of cement, volcanic ash, and local sawmill waste. These panels were analyzed for their physical and chemical properties, as well as for their resistance to decay and insects when subjected to extreme conditions for 15 years. The panels have also shown to provide thermal insulation and nonflammable when in direct contact with fire. The roof surface was further covered with a blend of local drought-resistant succulents and cacti. This study provides a detailed review of the construction process and materials employed.

Key words: Prototype house, thermal insulation, non-combustible, resistant to decay.

1. Introduction

The objective of this research was to develop a low-cost method to improve thermal insulation for houses located in the semi-arid Northeast of Mexico. This research was carried out in the city of Linares, in the state of Nuevo León, having the geographic coordinates: 20°50′16″ N and 99°32′41″ W (Fig. 1).

According to the Köppen-Geiger climate classification, the climate in this area is considered semi-arid (BS_h). The average annual precipitation is 600 mm/m², dropping to an average of 400 mm/m² during dry years. Most of the precipitation takes place during the months of May and September. This climate has led to the formation of thorn savannahs (known as Matorral in the Spanish language).

The region where the study was performed is rural, which leads to the restriction of being limited to use locally available raw material. Automated production of lightweight pumice or wood concrete block stones is therefore not practically feasible.

A research project carried out at the Faculty of Forestry of the Universidad Autónoma de Nuevo León (Linares, Mexico) studied various locally available materials with the intent of identifying their suitability for thermal insulation purposes. Local availability and material cost led to the choice of wood concrete. This material is characterized by being nonflammable and highly resistant to biologically induced degradation.

2. Materials

2.1 Traditional Clay Masonry Construction

The traditional construction is clay masonry based with thatch or palm-leaf roofs. The clay masonry bricks employed have a density of 2 g/cm³ and a thermal conductivity of 1.20 W/(m·K). Lighter straw clay bricks have a density of 1.6 g/cm and a thermal conductivity of 0.80 W/(m·K). Such values do not allow for energy-saving construction. Additionally, clay construction requires constant maintenance to achieve good durability.

2.2 Current Concrete Masonry Construction

Hollow concrete masonry construction with reinforced concrete roofs has displaced the traditional building

Corresponding author: Maria de los Angeles Rechy Carvajal, professor, research field: forestry.

Fig. 1 Geographical location of the studied area.

method over the last few decades. This foster by the ease of construction, durability, and speed of construction. Concrete's thermal conductivity λ is 2.1 W/(m·K). This results for 15 cm thick hollow concrete masonry blocks in a thermal conductivity λ is 0.80 W/(m·K). As a result, the thermal isolation of today's homes in the region is not good. Thermal conductivity values are determined experimentally through hot plate tests (Fig. 2).

Without considering thermal boundary layers, the thermal resistance $R_w/(R_{wall})$ for these walls is 0.15/0.80 = 0.19 m²·K/W. A 12 cm thick roof has a thermal resistance of $R_r/(R_{rof})$ = 0.12/2.1 = 0.06 m²·K/W. These values are too low for habitable spaces in semi-arid regions given that minimum recommended R-values are R_w = 0.50 m²·K/W and R_r 1.0 m²·K/W for walls and roofs respectively. Lack of thermal insulation makes these houses barely habitable, This leads to high costs related to cooling and heating.

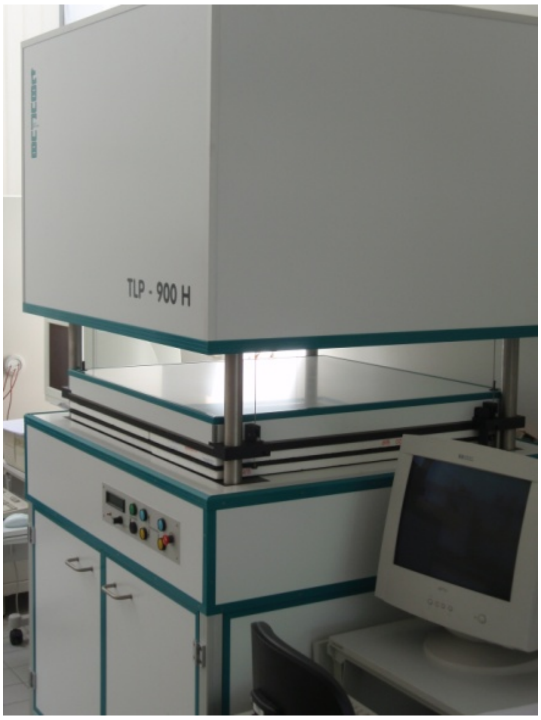

Fig. 2 Equipment for determination of heat transfer.

Although high-density building materials typically exhibit high load capacities, they are also typical characterized by low thermal insulation properties.

3. Construction Method Used

3.1 Wood Concrete as Insulating Material

The previously mentioned research led to the selection of wood concrete as insulation material due to local availability and low-income wages. Wood chips needed for manufacture of this insulation material can be procured easily at low cost. A common concrete mixer (Fig. 3) can be used to mix the wood chips and cement. Manufacture of insulating wall panels is benefitted by the use of a hydraulic press or jack. Poured-in-place roof insulation can be compacted with a manual compactor.

3.2 Installation of Thermal Insulation

Installation of the insulation is relatively simple. Wall panels are adhered to the interior faces of the walls. At the roof, the insulating wood concrete layer is placed below and prior to pouring the load-carrying reinforced concrete plate.

Fig. 3 Small concrete mixer.

Fig. 4 Outside view of the prototype house.

A prototype house with an area of 4 × 8 m was built to test the effectiveness of the wood concrete insulation material (Fig. 4). The walls were provided with 5 cm thick insulation panels adhered to the inside faces. The poured-inplace roof insulation thickness was 8 cm. (Fig. 5). Average grade wood concrete (density ρ = 0.6 g/cm³) was used to allow for installation of normal household items (lamps, pictures, etc.).

4. Results and Discussion

The research results for wood concrete was performed following DIN 4108 and DIN EN 832 (2011), being shown in Table 1.

Thermal insulation for cooled and heated houses should provide at the exterior of the building in order to allow for thermal inertia of the heavy concrete construction to contribute to a balance of interior temperatures. In buildings that are not cooled and only heated when required, the thermal insulation should be provided at the interior in order to take advantage of the nocturnal fall of temperature during the Summer and of quick heating with minimized temperature loss during the Winter.

The thermal conductivity λ of wood concrete is 0.16 [W/(m·K)], thus resulting in a thermal resistance for the walls of R_{wall} = 0.15/0.80 + 0.05/0.16 = 0.50 [m²·K/W] and for the roof of R_{roof} = 0.12/2.1 + 0.08/0.16 = 0.56 [m²·K/W].

The insulation provided at the walls met the minimum requirement for habitable spaces. In contrast, the insulation at the roof required improvement. This roof insulation improvement was achieved through a green roof insulation layer. Detailed quantitative information on the level of thermal insulation provided by the green roof was not available at time of this publication because of the large variability of green roof assemblies and the complexity of determining the thermal insulation achieved.

Permanent temperature controls at the interior and exterior surfaces showed an average temperature delta of close to 10 °C during summer months.

Table 1 Research results for wood concrete.

Density	Compression strength	Thermal conductivity
[g/cm³]	MPa	w/(m·K)
0.45-0.80	1.50-2.10	0.10-0.25

Fig. 5 Interior corner showing wall and roof interface.

Fig. 6 Green roof with drought-resistant plants.

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Factors Affecting the Ovilarval Density of *Aedes* Spp. Mosquitoes in Selected Rice Fields of Muňoz, Nueva Ecija

Jerome Cadiente Soriano and Clarissa Yvonne Jueco-Domingo

College of Veterinary Science & Medicine, Central Luzon State University, Nueva Ecija 3120, Philippines

Abstract: Variables among the macroclimate, microclimate and rice canopy categories and three other different farming systems were evaluated on their effects to the egg and larval density of Aedes spp. mosquitoes known as transmitters of animal and human diseases. No statistical difference in egg density (#eggs/mL) among farming systems ($P = 0.345$) were observed. However, there was significant difference in larval density (#larvae/mL) among farming systems ($P < 0.001$) particularly between organic and conventional farms and between organic and mixed farms at ($P < 0.05$). Among the variables in the macroclimate category, wind velocity and ambient temperature significantly influenced larval density in conventional farms. Among the variables in the microclimate category, water temperature significantly contributed to larval density in both the mixed and conventional farms whereas water turbidity, in conventional farms. Among the variables in the rice canopy category, the number of tillers per plant was a significant contributor to larval density in all farm types. No variable among the environmental exposure categories affected the larval density in organic farms.

Key words: Mosquito larval control, farming system, ovilarval density, organic farming, Aedes Spp. Mosquito.

1. Introduction

Mosquitoes serve as transmitters of human and animal diseases. The increasing trend of mosquito borne diseases remains a challenge to national and international health agencies to implement strategies to control it. Some of the known diseases are yellow fever, encephalitis, dengue, and dirofilariasis, fowl pox [1].

Vector control is an important strategy known to enhance the sustainability of high drug coverage. It helps interrupt transmission in combination with mass drug administration particularly in high risk, peri-urban areas and prevent-re-establishment of transmission in vulnerable areas [2].

From the global standpoint, approximately 140 million hectares of land are annually devoted to rice cultivation. Because the rice fields are flood on a semi-permanent basis during each growing season, they provide ideal breeding habitat for a number of potential vectors of vector borne diseases [3].

Natural environment such as the interaction between temperature, rainfall or variations in daily microclimates may be important determinants in density of eggs and larvae of mosquitoes in breeding sites. These are very important factors in the identification of key vector-breeding sites and the reason is they are mosquito productive.

By determining environmental factors that influence density of eggs and larvae of *Aedes* spp. mosquitoes in three different rice farm systems in the Science City of Muñoz Nueva Ecija namely, pure organic, mixed and conventional farming, farmers could be advised to be on the look out for the density of mosquito eggs and larvae in order to make them responsible for adopting modified human behaviors that would protect them, their family and even their livestock reared around their farms against the bites of mosquitoes.

Corresponding author: Clarissa Yvonne Jueco-Domingo, Ph.D., main research field: parasitology.

Hence, the study determined the presence of association between environmental factors together with the different rice farm systems being adopted by rice farmers in the Science City of Muñoz, Nueva Ecija and the egg and larval density of *Aedes* spp. of mosquitoes. Specifically, the study determined whether the following environmental factors affected the egg and larval density of *Aedes* spp. mosquito: (1) types of farming systems namely organic, mixed and conventional farms; (2) macroclimate factors such as rainfall, humidity, ambient temperature and wind velocity; (3) microclimate factors such as water temperature, water pH and water turbidity; and (4) rice canopy factors such as rice height (cm), number of tillers per rice plant and number of panicles per rice plant. Likewise, the study predicted egg and larval densities of *Aedes* spp. mosquitoes using multiple logistic regression models computed from environmental factors found to be effect modifiers at ($p < 0.05$).

2. Material and Methods

2.1 Identification and Collection of Samples

Three organic, three mixed and three conventional rice farms were identified within the Science City of Munoz, Nueva Ecija for sampling collection through the assistance of the Philippine Rural Reconstruction Movement farmers' cooperative. External in puts such as herbicides, fertilizers and pesticides applied on the rice fields by farmers were noted.

Evaluation of rice plants and collection of water samples with mosquito eggs and larvae were done from three different sites of each rice field as replicates. Duration of collection period for the entire study was two months with weekly collections for a total of eight (8) collections.

2.2 Gathering of Macroclimate Variables

Macroclimate variables include meteorological factors such as ambient temperature (^{o}C), humidity (%), wind velocity (mps) and rainfall (mm). They were taken from the Agrometeorological office of the Dept. of Agronomy, Philippine Rice Research Institute in Maligaya, Science City of Munoz and Nueva Ecija.

2.3 Gathering of Characteristics of Rice Paddy Water

Around fifty (50) milliliters (mL) of water from the rice paddies were collected and placed in clean properly labeled plastic bottles. Samples from the water were submitted for pH and water turbidity analysis at the Philippine Rice Institute Department of Agronomy. The pH was measured using a pH meter while the water turbidity was analyzed using spectrophotometric measurement for light absorbance (nanometer). Water temperature was measured from all sample sites using the Field Environmental Thermometer.

2.4 Evaluation of Rice Canopy Development

All rice plants within the area of one by one square meter, also designated for collection site of water sample, which was evaluated for rice canopy factors:

1. Plant height in centimeters (cm)-taken from the base of the plant which was submerged in water until the highest tip of the plant. A meter stick was used for measuring;
2. Number of tillers per plant-number of culmns or tillers was counted per plant and the mean per sampling site was recorded;
3. Number of panicles per plant-number of panicles was counted per plant and the mean per sampling site was recorded.

2.5 Identification & Counting of Eggs and Larvae of Aedes spp. Mosquitoes

Three (3) different collection sites for each type of rice farm were sampled for water to determine the number of eggs and larvae. Each site was marked with a flag to identify the area for collection throughout the study period.

Around 240 mL of water with eggs and larvae was collected from each replicate site and placed in chemically clean bottles. An aliquot of ten 10 mL was transferred to a vial and a thin layer of mineral oil was placed over the surface of the water sample to suffocate the larvae. After the larvae have been killed, the entire contents of the vial were poured into a Petri dish and the eggs and larvae were counted using magnifying lens.

Only *Aedes* spp. mosquito eggs that were laid singly and did not have lateral floats were counted. The larvae that hanged diagonally from the water surface were assumed to be *Aedes* spp. Although *Culex* spp. also has larvae that hang diagonally from the water surface, the females prefer to lay eggs in stagnant, dirty water as compared to *Aedes* spp. that lay eggs in rice paddies.

Egg density per milliliter was computed by number of eggs counted divided by 10 mL while larval density per mL was measured by the number of larvae counted divided by 10 mL. Values of the egg and larval densities were transmuted according to the area of the entire rice field.

2.6 Data Analysis

Mean scores of the replicates of each rice farm were computed. One-way analysis of variance was used to evaluate the significant difference of the different environmental exposure variables by farm and the significant difference of mean egg and larval densities by farm.

Multivariate analysis was done to assess the association of exposure variables grouped in categories or as individual entity to the mean egg density or mean larval density. Each category, for instance, macroclimate, microclimate and plant canopy was forced into a multiple logistic regression model. A regression model per category was created which served as the main effects model. Each exposure variable under that category was assessed on how it interacted to the main effects model. The category which had a log likelihood ratio p-value of less than 0.05 was considered an effect measure modifier. Hence, it could significantly modify either the mean egg density or the mean larval density.

Similarly, individual exposure variables were subjected to multivariate analysis to assess their association to the mean egg density or mean larval density. Each exposure variable was forced into a multiple logistic regression model. An exposure variable which had a log likelihood ratio p-value of less than 0.05 was considered an effect measure modifier, hence, it could significantly modify either the mean egg density or the mean larval density.

3. Results and Discussion

Comparing the summation of the mean egg density (#eggs/mL) and larval density in organic, mixed and conventional farms, ANOVA showed no significant difference at ($p = 0.345$) in the egg density while larval density was significantly different among the farming systems at ($p < 0.001$) (Table 1). This implies that the water paddies in mixed and conventional farms are better culture grounds for sustaining larval development. On the other hand, water paddies of organic farms are least attractive for sustaining larval density.

Likewise, results imply that egg density is not a good monitoring index for mosquito density in evaluating strategies for integrated vector control management program since there is no difference in the density among farms despite of a significant difference in the larval density. Hence, between egg and larval density, the latter is more sensitive as environmental index for monitoring mosquito density.

Table 1 Analysis of variance of the summation of the mean egg and larval density by farming system.

	Egg density (No.eggs/mL)	Larval density (No.larva/mL)
Organic	1,730 ^{a}	2,711 ^{a}
Mixed	2,093 ^{a}	5,229 ^{b}
Conventional	2,651 ^{a}	7,590 ^{c}
P value	0.345 ^{ns}	0.000 **

* ns-not significant (similar superscripts are not significantly different);

** highly significant.

Table 2 shows the crude analysis of environmental exposure categories by farm type to identify which one would be an effect modifier ($p < 0.05$) to egg density of *Aedes* spp. Macroclimate variables include the ambient temperature (°C), humidity (%), wind velocity (mps) and rainfall (mm). Results showed that only the macroclimate had a moderate modifying effect at p = 0.05 to egg density in organic farms. In the case of mixed farms, no environmental exposure category had any association with egg density while the microclimate category had a modifying effect at p = 0.002 to egg density in conventional farms. Microclimate variables include those which characterize the water quality of the rice paddies such as water pH, water temperature and water turbidity.

When taken individually (Table 3), the wind was a significant contributor under the macroclimate category at p = 0.031 in organic farms while it was the ambient temperature at p = 0.008 in conventional farms. The water temperature under the microclimate category was a significant contributor to egg density at p = 0.019 in mixed farms and p = 0.000 in conventional farms.

Table 4 shows the crude analysis of environmental exposure categories by farm type to identify which one would be an effect modifier ($p < 0.05$) to larval density of *Aedes* spp. Results showed that no environmental exposure category had a modifying effect to larval density in organic farms. However, the microclimate category was an effect modifier at p = 0.031 in mixed farms whereas all environmental exposure categories were effect modifiers to larval density in conventional farms.

Table 2 Multivariate analysis of environmental exposure categories by farm type against egg density of *Aedes* spp.

	Organic farm	Mixed farm	Conventional farm
Macroclimate	0.05*	0.123	0.057
Microclimate	0.561	0.109	0.002**
Plant canopy	0.679	0.116	0.488

*significant;

**highly significant.

Table 3 Significant exposure variables to mean Egg Density (ED).

	p-Value < 0.05 (effect modifier)		
	Organic farms	Mixed farms	Conventio-nal farms
Macroclimate category	0.05	0.123	0.057
Wind (mps)	0.031*	0.134	0.782
Rainfall (mm)	0.730	0.096	0.600
Humidity (%)	0.203	0.060	0.633
Ambient temp. (°C)	0.561	0.850	0.008*
Microclimate category	0.561	0.109	0.002*
Water pH	0.953	0.293	0.760
Water temp. (°C)	0.304	0.019*	0.000*
Water turbidity (nm)	0.447	0.604	0.251
Rice canopy category	0.679	0.116	0.488
Plant height (cm)	0.414	0.678	0.442
No. of tillers/plant	0.401	0.442	0.406
No. of panicles/plant	0.418	n.a.	0.395

* na-not applicable;

*statistically significant.

Table 4 Multivariate analysis of environmental exposure variables by farm type against larval density of *Aedes* spp.

	Organic farm	Mixed farm	Conventional farm
Macroclimate	0.342	0.511	0.000**
Microclimate	0.302	0.031**	0.000**
Plant canopy	0.059	0.054	0.000**

*significant;

**highly significant.

When taken individually (Table 5), the wind velocity and ambient temperature strongly contributed to the macroclimate category in affecting the larval density in conventional farms at p = 0.030 and p = 0.004 respectively. Water temperature and water turbidity strongly contributed to the microclimate category in affecting the larval density in conventional farms at p = 0.000 and p = 0.019 respectively. Finally, the number of tillers per plant strongly contributed to rice canopy category in affecting the larval density in conventional farms at p = 0.04. Rice canopy indicators include plant height (cm), the number of tillers per plant and number of panicles per plant.

Table 6 shows the analysis of variance of the mean values of individual exposure variables by farm type. Water temperature, water pH, number of tillers and panicles per rice plant significantly differed by farm system whereas, water turbidity and plant height were not significantly different at p = 0.115 and p = 0.766 respectively, significantly by farm type.

Table 5 Significant exposure variables to mean Larval Density (LD).

	p-value < 0.05 (effect modifier)		
	Organic farms	Mixed farms	Conven-tional farms
Macroclimate category	0.342	0.511	0.000*
Wind (mps)	0.249	0.111	0.030*
Rainfall (mm)	0.164	0.293	0.078
Humidity (%)	0.426	0.233	0.126
Ambient temp. (^oC)	0.376	0.939	0.004*
Microclimate category	0.302	0.031*	0.000*
Water pH	0.065	0.228	0.997
Water temp. (^oC)	0.477	0.057	0.000*
Water turbidity (nm)	0.878	0.211	0.019*
Rice canopy category	0.059	0.054	0.000*
Rice plant height	0.374	0.953	0.565
No. of tillers/plant	0.158	0.646	0.04*
No.of panicles/plant	0.064	n.a.	n.a.

* na-not applicable;

*statistically significant

Table 6 Comparison of mean values of environmental exposure variables by farm systems.

	Organic farms	Mixed farms	Conventio-nal farms	p-value
Mean H_2O temp. (T^o)	33.87	34.46	34.83	0.002**
Mean H_2O pH	7.790	7.754	7.521	0.002**
Mean H_2O turbidity	88.58	90.514	91.162	0.115^{ns}
Mean rice ht. (cm)	34.26	35.37	35.65	0.766^{ns}
Mean no. of tillers/plant	33.00	27.97	29.45	0.002**
Mean no. of panicles/plant	296	293	341	0.04**

* ns-not significant;

** means highly significant.

Multiple logistic regression models were created to predict larval density using all the environmental exposure variables that were identified as effect modifiers at $p < 0.05$. Since majority of the environmental exposure variables strongly modified larval density than egg density (Tables 3 and 5), only prediction equations for larval density were computed.

Mixed Farms

Estimated equation for larval density =-41,881 + 525(H_2O (Temp.)) + 2,161(H_2O (pH)) + 129 H_2O (Turbid.)

Estimated equation for larval density =10,771 - 20 (Rice Ht) - 231(Rice Tillers)

Conventional Farms

Estimated equation for larval density =-2,805－580(Rainfall) － 449(Humidity) + 1,983(Wind) + 1,467(Temp.)

Estimated equation for larval density = -134,062 + 3426 (H_2O (Temp.)) + 8 (H_2O (pH)) + 240 (H_2O(Turbid.))

Estimated equation for larval density = 21,824－98 (Rice ht.)－479 (Rice tillers)

From results of the study, the implications are herein presented.

3.1 Macroclimate Category

In general, the macroclimate category was not significantly associated with egg density in all farm systems since the collection period was made during rainy season with no significant differences in macroclimate variables across the different farms based on location and replication site ($p > 0.05$). Thus, the macroclimate category did not produce a significant difference in its effect on the egg density among the different farm systems. On the other hand, it was significantly modified the larval density in conventional farms.

Wind velocity was found to be a significant contributor to this category. Wind affects the survival of mosquitoes which sustains disease transmission. A gentle breeze facilitates a flight range of 10 meters. The flight range for females is usually longer than males and some have been recorded as far as 75 miles from their breeding source [4]. *Aedes* spp. mosquitoes vary with species and some are reported to migrate many miles from their aquatic larval habitat.

Similarly, ambient temperature was also seen as a contributor. Environmental temperature is essential in hastening the maturity of female mosquitoes to breed and lay eggs and in hastening the hatching of eggs to larvae [5].

3.2 Microclimate Category

In general, the microclimate category was significantly associated and effectively modified the egg density in conventional farms and larval density in mixed and conventional farms. Variables under the microclimate category are those which characterize the water quality of the rice paddies. External inputs in mixed and conventional farms could have affected the water quality that significantly influenced egg and larval densities in these farm systems [6].

Water temperature in mixed and conventional farms was found to be significantly warmer (34.46 ^{o}C and 34.83 ^{o}C, respectively) than in organic farms. Studies have observed that female mosquitoes are more attracted to warm temperatures. Since water is the preferred breeding and egg laying site of mosquitoes these could be the reason why more eggs were oviposited in conventional farms. Similarly, mosquito larvae must live in water from 7 days to 14 days depending on water temperature. Since larval density was significantly different among the three farm systems and microclimate variables with water temperature being a significant contributor, significantly modified larval density in mixed and conventional farms, this could imply that both farms were very conducive in sustaining the lifespan of the larvae.

Table 7 Summary of regression analysis on larval density in mixed farms based on microclimate variables.

Predictor	Coef.	St Dev.	T-stat	P value
Constant	-41,881	16,904	-2.48	0.019
H_2O temp.	525.2	265.8	1.98	0.057
H_2O pH	2,161	1,757	1.23	0.228
H_2O turbidity	129.0	100.9	1.28	0.211

* S = 3,570; R-Sq = 24.6%; R-Sq (adj) = 7.4%.

Table 8 Summary of regression analysis on larval density in mixed farms based on rice canopy variables.

Predictor	Coef.	St Dev.	T-stat	P value
Constant	10,771	2,815	3.83	0.001
Rice Ht	-20.3	343.8	-0.06	0.953
Rice Till	-231.4	498.7	-0.46	0.646

* S = 3,694; R-Sq = 16.7%; R-Sq (adj) = 11.5%.

Table 9 Summary of regression analysis on larval density in conventional farms based on macroclimate variables.

Predictor	Coef.	St Dev.	T-stat	P value
Constant	-2805	36,960	-0.08	0.940
Rainfall	-580.3	319.8	-1.81	0.078
Humidity	-448.7	285.9	-1.57	0.126
Wind velocity	1,983.3	877.6	2.26	0.030
Ambient temp.	1,467.3	477.6	3.07	0.004

* S = 4,024; R-Sq = 51.7%; R-Sq (adj) = 46.0%.

Table 10 Summary of regression analysis on larval density in conventional farms based on miroclimate variables.

Predictor	Coef.	St Dev.	T-stat	P value
Constant	-134,062	25,811	-5.19	0.000
H_2O Temp	3,426.0	461.0	7.43	0.000
H_2O pH	8	1,939	0.00	0.997
H_2O Turbidity	240.36	98.01	2.45	0.019

* S = 3,203; R-Sq = 68.5%; R-Sq (adj) = 65.8%.

Table 11 Summary of regression analysis on larval density in conventional farms based on microclimate variables.

Predictor	Coef.	St Dev.	T-stat	P value
Constant	21,824	1,612	13.54	0.000
Rice Ht	-97.9	168.8	-0.58	0.565
Rice Till	-479.4	225.0	-2.13	0.040

*S = 2,993; R-Sq = 71.7%; R-Sq (adj) = 70.1%.

Water turbidity was found to significantly modify the larval density in conventional farms. Water turbidity is a consequence of fertilizer application. Fertilizers contain nitrogen, phosphorus and potassium [7]. Microorganisms in the soil decompose them in order to release the nutrients needed by the plants. Sources of organic fertilizers are green manure composed of decaying vegetation, crop residue or rice straw and animal manure. It takes three days for green manure to be decomposed, one month for crop residue and one week for animal manure. Whereas, inorganic fertilizers were being used in conventional farms take two to three weeks. In this study, fertilizers used by organic farms were processed poultry manure while mixed and conventional farms utilized inorganic fertilizer (registered brand name "Crop Giant 15-15-30") [7].

Water samples were analyzed for the presence of microscopic organisms. Results revealed the presence of filamentous green algae such as *Oedogonium*, *Microspora* and *Zygnemopsis*. Simple blue-green algae and filamentous blue-green algae were also found such as *Rivularia* and *Oscillatoria*, respectively. Likewise, unicellular zooflagellates such as Euglenoids, Ciliates (*Paramecium*, *Colpoda*) and Rotifers were seen.

Usually, fertilizers are applied in the flooded fields before transplanting the rice. Since inorganic fertilizers take a long time to be decomposed by the microorganisms, the presence of nitrogen, phosphorus and potassium in the water increase the growth of green and blue green algae that supply the food chain of mosquito larvae for their growth and development [4]. In addition, presence of these algae also supports the life of zooflagellates that also add to the water turbidity [7].

3.3 Rice Canopy Category

In general, rice canopy category significantly modified the larval density only in conventional farms. Specifically, the number of tillers per plant significantly contributed to the category. Number of tillers per plant serves as plant canopy for resting sites and protection from adverse elements including high temperature, low humidity and heavy winds. After feeding, female mosquitoes seek out resting places. After digesting the blood meal, the adult will oviposit in an appropriate habitat. Washino and Wood [8] studied characteristics of land cover in California which were dominated by low mosquito producing rice fields and high mosquito producing rice field using remote sensing. Probability of females completing the gonotrophic cycle could be estimated by the state of vegetation canopy development of the potential habitat.

3.4 Other Findings

Plenty of livestock that grazed around the farms were observed of which, the nearest grazing distance from the perimeter of the rice paddies was 30 meters. These animals were goats, swamp buffaloes, cattle, free range chickens and ducks. Similarly, residents around the farms also engaged in backyard piggeries. Other domestic animals living near the farms were dogs and cats.

The presence of livestock occupying the pastures near the rice paddies provides a dynamic support to *Aedes* spp. mosquito population. Soon after adult female mosquitoes emerge from the rice fields they will seek sources of blood meal to nourish their eggs after mating [9]. Since livestock is always available anytime as blood meal for these mosquitoes, there will always be eggs laid and larvae maintained until they develop into adults in the water paddies of these farms that have particular characteristics in their microclimate and rice canopy variables that support the life cycle of *Aedes* spp. mosquitoes [8].

In addition, *Aedes* spp. mosquitoes are mechanical or biological vectors of a number of diseases affecting animals such as dirofilariasis and fowl pox and a number of zoonotic pathogens that are transmitted to humans from animal reservoirs such as arboviruses causing encephalitis aside from the known human disease such as Dengue. Hence, the presence of livestock adds to the maintenance cycle of pathogens transmitted by *Aedes* spp. mosquitoes.

4. Conclusion

Larval density is a good monitoring index for mosquito density in evaluating environmental indices for integrated vector control. Rice paddies in mixed and conventional farms are better density culture grounds for sustaining larval development than organic farms. The variables were found to be significant contributor in influencing the larval density in mixed and conventional farms: macroclimate category with wind velocity & ambient temperature variables, microclimate category with water temperature & water turbidity and rice canopy category with rice height and number of tillers per plant as variables.

For mixed farms, a regression equation model using variables under microclimate category and rice canopy were created to predict larval density. For conventional farms, equation models using variables under the macroclimate, microclimate and rice canopy categories were created to predict larval density. No environmental exposure variables were identified as effect modifiers for larval density in organic farms.

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Decommissioning of Uranium Pilot Plants at IPEN-CNEN/SP: Facilities Dismantling, Decontamination and Reuse as New Laboratories for Strategic Programs

Paulo Ernesto de Oliveira Lainetti[1], Antônio Alves de Freitas[1], Francisco Mário Feijó Vasques[2], Robson de Jesus Ferreira[2], Marycel Elena Barbosa Cotrim[1] and Maria Aparecida Faustino Pires[1]

1. Instituto de Pesquisas Energéticas e Nucleares-IPEN-CNEN/SP, National Nuclear Energy Commission-CNEN, C. Universitária, Butantã, São Paulo-SP, CEP 05508-000, Brazil

2. Instituto de Pesquisas Energéticas e Nucleares-IPEN-CNEN/SP, National Nuclear Energy Commission-CNEN, C. Universitária, Butantã, São Paulo CEP 05729-090, Brazil

Abstract: From beginning of 90's, the Brazilian nuclear policy has been changed radically. This determined the interruption of most R&D fuel cycle activities and the facilities shutdown at Nuclear and Energetic Research Institute (IPEN). The existence of those facilities also implicated in the need of constant surveillance, representing additional obligations, costs and problems. The reasons to promote the dismantling of the IPEN's Nuclear Fuel Cycle Pilot Plants elapsed mainly from the need of physical space for new activities, since the R&D in the nuclear fuel cycle area were interrupted. In the last decade, IPEN has changed its "nuclear profile" to a "comprehensive and multidisciplinary profile". With the end of most nuclear fuel cycle activities, the former facilities were distributed in four different centers. Each center has adopted a different strategy and priority to face the D&D problem. The available resources depend on the specific program in each area's development (resources available from other sources, not only from Brazilian National Nuclear Energy Commission (CNEN). One of those new activities is the IPEN's Environmental Program. This paper describes the procedures, problems faced and results related to the reintegration of the former pilot plant areas as new laboratories of the Chemical and Environmental Technology Center—CQMA of the IPEN.

Key words: Decommissioning, dismantling, decontamination, pilot plants, reuse.

1. Introduction

Radical changes of the Brazilian nuclear policy, in the beginning of 90's, determined the interruption of most R&D fuel cycle activities and the facilities shutdown at IPEN. Those facilities already played their roles of technological development and personnel's training, with transfer of the technology for institutions entrusted of the "scale up" of the units. Most of the pilot plants had the activities interrupted until 1992-1993, due to the lack of resources for the continuity of the research. The appropriate facilities maintenance has been also harmed by the lack of resources, with evident signs of deterioration in structures and equipments. The existence of these facilities also implicates in the need of constant surveillance, representing additional obligations, costs and problems.

Since then, IPEN has faced the problem of facilities dismantling and/or decommissioning. Immediately after the nuclear R&D program interruption, the uncertainties related to an eventual retaking of the program created some political hesitation about the dismantling decision. As the retaking of the R&D Nuclear Program is now discarded, the decommissioning seems to be the obvious choice. The decommissioning strategy for the old facilities

Corresponding author: Paulo Ernesto Oliveira Lainetti, Ph.D., main research field: thermal treatment of wastes and nuclear materials.

dedicated to the technological domain of the Nuclear Fuel Cycle follows an approach of advancing gradually in dismantling, since the resources and technical conditions are available.

2. Reasons and Priorities for Dismantling and Decommissioning

The reasons of such approach are the need of political decisions related to the destiny of the facilities, lack of financial resources and of specialized personnel in the decommissioning issue, besides the fact that decommissioning is not an institutional priority in the present. As some facilities had the activities suspended for about twelve to fifteen years, also constitute relevant problems the equipment deterioration and personnel's loss, due retirements and transfers for other activities and increasing difficulties related to the availability of operational reports, drawings and descriptive memorials.

Some factors affecting the decision and the strategy of dismantling and decommissioning should be mentioned: the IPEN is located in the Sao Paulo City, in the Campus of Sao Paulo University, in an area of nearly 500,000 square meters; the space occupied by the old facilities constitutes a very valuable area; nowadays, the surroundings are a very populated area, in opposition to the past (when the facilities were built); the localization is an important aspect determining the reuse of the space and buildings of the former fuel cycle facilities.

Besides this, the reasons to promote the dismantling of the IPEN's Nuclear Fuel Cycle Pilot Plants as soon as possible elapses of three main aspects: need of physical space for new activities and priorities as, for example, the Fuel Cells Program, since the activities of R&D in the area of the nuclear fuel cycle were interrupted, not having perspectives of retaking of the Program; need to take advantage, as soon as possible, of the researchers' knowledge, mainly from those were indeed involved with the project, assembly and operation of the different facilities, since it comes happening a gradual loss of personnel for retirements and transfers; the long period since the interruption of the activities in above mentioned facilities has been taking to an increase in the difficulty of tracking documents and reliable information, besides to evident deterioration of structures, increasing the concerns related to the risk of liberation of radioactive compounds and/or risks for their chemical toxicities.

On one hand, in the beginning of the activities, it was considered the problem of the costs related to facilities maintenance/surveillance and of the gradual loss of knowledge accumulated (because of retirement or dispersion of the personnel former involved with the different nuclear fuel cycle processes). As the activities were interrupted in most facilities, IPEN has promoted a professional recycling of the remaining personnel with emphasis in other Institution different priorities such as radioisotope production or research reactor operation and fuel production or environmental applications of the existent experience (chemical processes). On the other hand, there was the problem of dismantling costs, mainly considering that there was no experience/expertise in this field at all at IPEN. Another problem was the evaluation of the facilities status in terms of chemical and radiological contamination levels for equipment/soil/buildings, after more than ten years since the facilities shutdown. Last, but not least, it should be mentioned the problem of the exhausted capacity of radioactive waste storage in the IPEN.

An aspect considered in the beginning of the activities was the lack of experience or expertise in the dismantling and decommissioning area at all at IPEN. Besides this, it was necessary to recovery reliable data/drawings about the facilities. It was very clear that would be necessary to improve all steps involving decommissioning, such as planning, regulatory requirements, cost estimating, cost-benefit analysis, need for and extent of decontamination, selection of decontamination techniques, assessment of the waste amount from the dismantling, dismantling techniques, staff training and so on.

In the last decade IPEN has changed its "nuclear profile" to a "comprehensive and multidisciplinary profile". During this period, IPEN has been restructured in 13 Research Centers. With the end of most nuclear fuel cycle activities, the former facilities were distributed in four different centers: Environmental and Chemical Technology Center, Fuel Cell Center, Materials Science and Engineering Center, Nuclear Fuel Center. Each center has adopted a different strategy and priority to face the D&D problem and to reintegrate the areas. The resources available depend on the specific program developed in each area (resources available from other sources, not only CNEN). In the Fig. 1, it can be observed the localization of the nuclear fuel cycle facilities in the IPEN plan.

3. Reuse of Dismantled Nuclear Facilities

Some Brazilian governmental and strategic programs are: Fuel Cells, Nanotechnology, Biomaterials, Environment and Polymers. Considering all aspects mentioned before, the old facilities, and the occupied area, constitutes a significant and useful resource, since they can be fully or partially reutilized for a variety of purposes and programs. Besides the full release of some facilities as "green areas" (priority programs), some buildings can also be used as interim storage facilities (for equipment and wastes). It should be mentioned that the decision regarding the reuse of the different facilities has been made on a case-by-case basis.

In 2000/2001, it was dismantled part of Thorium and UF_4 Production (aqueous route) Pilot Plants-Building 2/CQMA and in 2002/2003 it were dismantled the ADU Dissolution and the Uranyl Nitrate Purification Pilot Plants-Building 1/CQMA. In the Fig. 2, some pictures of the dismantling operations of the ADU Dissolution and Uranyl Nitrate Purification Pilot Plants are presented. The previous dismantling activities were described in [1-5].

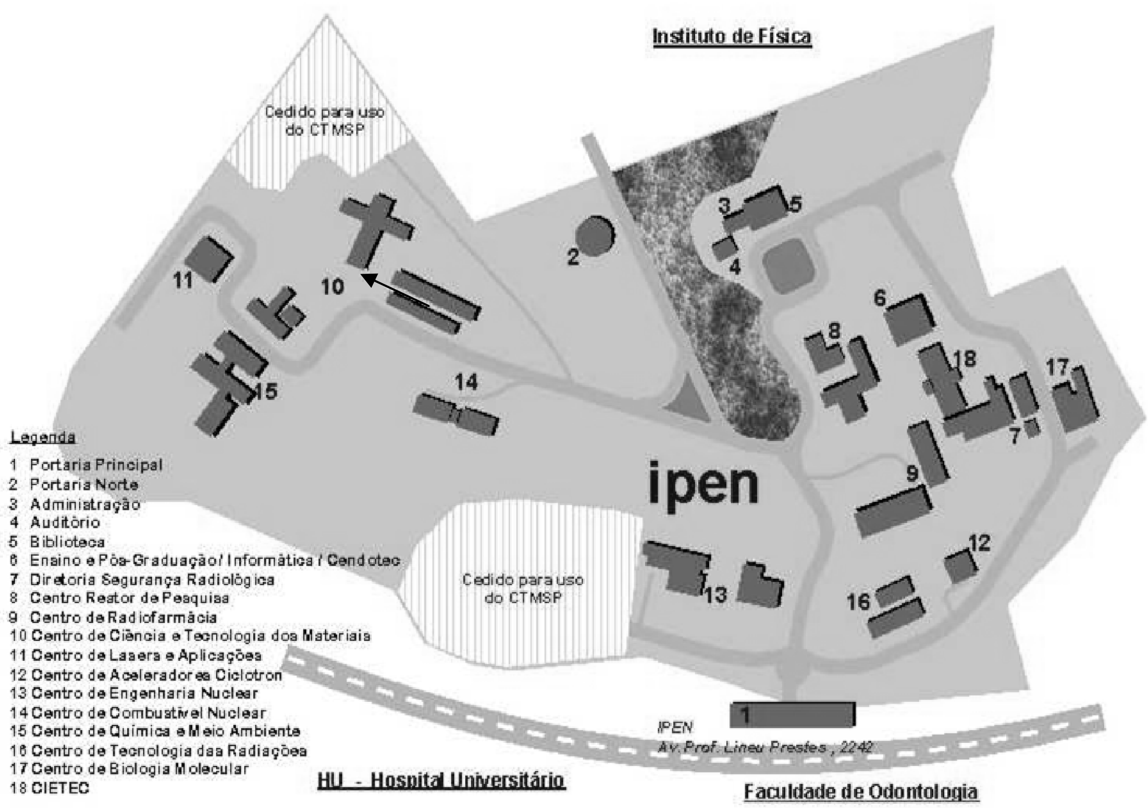

Fig. 1 Localization of the IPEN's fuel cycle facilities (left) and the ADU dissolution and uranyl nitrate purification building (arrow).

Fig. 2 Some pictures of dismantling operations of the ADU dissolution and uranyl nitrate purification pilot plants.

Fig. 3 Some pictures of facility decontamination.

The ADU Dissolution and Uranyl Nitrate Purification Pilot Plants have been reintegrated as the new laboratories of the IPEN's Environmental IPEN's program. The Thorium Pilot Plant and the UF_4 Production Pilot Plant (Aqueous Route) have been reintegrated as the new laboratories of the Polymers Program. In the Fig. 3, some pictures of floor and walls decontamination in the facility's building are showed.

4. Radioactive Wastes in the Operations

The main practical difficulty associated to the task of the dismantling and decommissioning of the old Nuclear Fuel Cycle facilities of the IPEN was the large amount of radioactive waste generated in the dismantling operations. The waste was mainly in the form of contaminated carbon steel structures. In the IPEN, the presence of contamination in the equipments, structures and buildings, although restricted to low and average activity levels, constituted an important concern due, on one hand, to the great volume of radioactive wastes generated during the operations. On the other hand, it should be outstanding that the capacity of stockpiling the radioactive wastes in IPEN found been exhausted. Basically, for the dismantling operations of the units, the main radionuclides of interest, from the radioprotection point of view, are U of natural isotopic composition and the thorium-232.

Several methods have been applied for the minimization of radioactive waste [6-10]. The choice of a coating removal process for radioactive material in the form of carbon steel pieces must have into account, among other factors, that it is not necessary a high quality of finishing, since the main objective is the release of the material as iron scrap. Different from other applications, where the main objective is to recover the component for reworking (appliances industry, for instance), the reduction of waste volume and the consequent need of expensive containers and space for storage are the driving forces.

It was decided to explore the former experience with molten salts in the thermal decomposition of radioactive organic wastes to investigate the possibility of its application as a potential method to solve the problem of the radioactive waste generated during the dismantling operations of the Nuclear Fuel Cycle Pilot Plants of the IPEN.

In spite of the use of molten salt has already been developed for some industrial coating removal process, it has not been found references in the literature about its use for radioactive superficial contamination removal. The molten salt stripping process relies on chemical oxidation of the coating by a molten salt bath. A new process for radioactive contamination removal from metallic surfaces was developed and a patent privilege request was submitted to analysis in the Brazilian Industrial Property Institut—INPI: related to the Process for Radioactive Decontamination of Parts Components and Metallic Structures in Molten Salt Baths

5. Conclusions

A private company was hired to the building decontamination activities, conditioning of the radioactive wastes and rebuilding. Beginning from the work to the end of the task, medical examination and clinic analysis for the personnel in charge of the job (from hired companies), in accordance with the requirements of IPEN. Besides this, a training of the company team was supplied by the IPEN's radiological protection staff.

During the pilot plant dismantling activities a new process for radioactive decontamination of complex steel structures was developed [11-14]. After the conclusion of the activities it was realized a radioactive monitoring of the laboratories and they were full released by Radiation Protection Area Dose ≤ 0.3 mSv.

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Building Sector: The Different Ways to Improve Their Energetic Efficiency

Clito Afonso and Ricardo Pereira

Department of Mechanical Engineering, Faculty of Engineering of Porto University, Porto 4200-465, Portugal

Abstract: The building sector has a significant weight in the global energy consumption in almost of the countries. So, there is a high potential for increasing its energy efficiency. With the enforcement of the energetic certification, it was tried to select different solutions that presents less energy consumption and waste, as well as an effective reduction of CO_2 emissions. This work fits in this perspective, since the main goal is to evaluate the contribution of passive and active solutions that can be used in buildings for the improvement of its energetic efficiency, as well as to evaluate the contribution of renewable energy sources. Contribution of solar systems for hot water heating and electric energy production has been studied, as well as cogeneration, Combined Heat and Power (CHP). The case studied is a hotel. To improve the building performance, there were proposed several changes, with the goal of evaluating the contribution of the different solutions proposed. It was concluded that they contribute to a reduction of thermal needs of 25.2% and avoided emissions of CO_2 is 30.4%. The analysis of the implementation of trigeneration, Combined Heat, Cooling and Power (CHCP) turns it executable. The payback period is less than 8 years.

Key words: CHP, CHCP, energy analysis, avoided CO_2 emissions, economic analysis.

1. Introduction

Hotels are buildings which have high energy demands and water consumption that decisively reflects in operating costs. In the tertiary sector, they have great potentials for improving energy efficiency.

Thus, it is essential to develop a sustainable strategy in the building sector to keep in account the environmental, social and economic impact of all and each one the parts that make up the building. In this sense, energy optimization and resources play a major role in driving the operation of buildings. These concerns must be present and reflect up from the design phase, that is, in the early stages of development of their project. The energy optimization is to select the solutions that promote the reduction of energy consumption, waste and a reduction of emissions of greenhouse gases (CO_2).

It should be noted that the energy optimization of a building does not pass only by mandatory large measures with high energy impacts and operating costs. Very often, the adoption of small actions only represents small impacts. However, the sums of all of them are of importance for the intended purpose-to reduce energy consumption and associated operating costs.

Despite the importance assumed by using renewable energies in the tertiary sector, cogeneration remains as the most effective technology on the conversion of primary energy (fossil or renewable sources) into electricity and heat [1, 2]. The application of cogeneration technologies on the third sector gains notability facing the rise of fuel prices and the need to ensure adequacy and comfort of space [3-6].

The micro-power generation, as an activity for low tension electricity production with the possibility of energy delivery to the public grid, it was regulated by several Decree-Laws [7, 8]. The actual ordinancestipulates that the electricity produced is destined predominantly for their own consumption, and the surplus that can be delivered to third parties or to the public, with 150 KW limit in the case of power

Corresponding author: Clito Afonso, mechanical engineer, Ph.D., professor. main research field: applied thermodynamics.

delivery to be made public. For the production of electricity on a large scale, using photovoltaics systems, the remuneration given to national electric system network is regulated by Decree-Law No. 225/2007 of 31 May [9]. Thus, the use of photovoltaic panels is becoming increasingly common practice more visible in several countries. So along with energy efficiency measures, the increasing integration of renewable energy in buildings, fits to aims to reach the 2020 targets stipulated. The energy consumption of the building is directly related to passive and active the solutions that will be analyzed.

In this work, a hotel located in Portugal was studied. The dynamic codes TRACE.700.v.6.2.5 and-Solterm-Térmico Solar in English: Solar Thermal-were used respectively for the evaluation of energy needs in HVAC-Heating Ventilation and Air Conditioning-system and for sanitary hot water demand. It was verified that the higher consumptions were on the electric ones, specifically the one of lightning (32.4%) and the equipment's (25.8%), followed by the HVAC, ventilation (11.6%) and cooling (10.8%). To analyze the contribution of different solutions, in order to increase the energetic efficiency of the hotel, there were made several changes on the transient computer model. The analysis of the technical/economic viability of the implementation of a cogeneration/trigeneration becomes at two levels, where the technologies tested were analyzed to adapt them to the thermal needs of the building. Among several solutions, namely micro turbines and fuel cells, it was chosen a system based on an internal combustion engine running on natural gas, with the help of an absorption chiller to produce the cooling load. The payback period of this solution is less than 8 years.

Parameters to be evaluated

- Payback time: is the project's operating time necessary to obtain the sum of revenue and expenditure flows that equalize the value of the investment in Eq. (1):

$$Payback = \frac{Initial\ Investment}{Annual\ \mathrm{Re}venues} \quad (1)$$

Energy Efficiency Index (EEI) (kgep·m^{2-}·year^{-1}). According to Decree-Laws already specified, there are several formulas to evaluate the EEI (not shown here) and deals with specific consumption for heating, cooling and lighting, for each typology. This parameter is important in order to define in which energy classes the building belongs.

- EEE (Equivalent Electrical Efficiency). By the Decree Laws in force, this parameter is given by Eq. (2):

$$EEE = \frac{E}{C - \dfrac{T}{0.9 - 0.2\dfrac{CR}{C}}} \quad (2)$$

Where,

E (KWh): electricity generated annually by the cogeneration system, excluding the consumption in internal auxiliary power generation systems;

T (KWh): useful thermal energy consumed annually from the thermal energy produced by cogeneration, excluding the consumption in the internal auxiliary power generation systems;

C (KWh): the primary energy consumed annually in the cogeneration system, evaluated from the lower heating value of fuel and other resources used;

CR (KWh): equivalent energy of renewable resources or industrial waste, agricultural or urban consumed annually in cogeneration facility.

EEE can assume the following values, according to the same Decrees-Laws:

EEE $\geq$ 0.55 for installations using natural gas as fuel, gas petroleum or liquid fuels with the exception of fuel;

EEE $\geq$ 0.50 for installations using fuel oil as fuel, alone or together with waste fuels;

EEE $\geq$ 0.45 for installations using biomass as fuel or residual fuels, alone or in conjunction with a fuel support a percentage not exceeds 20% annual average.

For the case study, it will not be analysed the contribution of renewable resources. Thus the formula for calculating the EEE is reduced to the Eq. (3):

$$EEE = \frac{E}{C - \frac{T}{0.9}} \geq 0.55 \quad (3)$$

For the CHP and CHCP the following parameter must also be evaluated.

- Electrical efficiency, $\eta_{electrical}$:
  $\eta_{electrical} = E_{grosselctricity}$/Total fuel consumed;
- Thermal efficiency, $\eta_{thermal}$:
  $\eta_{thermal} = E_{gross\ thermal}$/Total fuel consumed.
- E_{er}: maximum quantity of electricity to provide annually to the Electric System of Public Service not higher than the value given by Eq. (4):

$$E_{er} = \left(4.5\frac{E+T}{E+0.5T} - 4.5\right)E \quad (4)$$

(4) Saving Energy Index (SEI): ratio of the fuel economy obtained in the cogeneration engine when compared to the amount of fuel consumed in a conventional installation, i.e. an electrical plant with an efficiency η_c, a boilerwith an efficiency η_b and an electric chiller with a COP_{comp}. It is given by Eq. (5):

$$E_{er} = \left(4.5\frac{E+T}{E+0.5T} - 4.5\right)E \quad (5)$$

(5) Where, RCE and RFE are respectively the ratios between heat and electricity and the ratio between cooling and electricity in the CHCP.

2. Annual Thermal Analisys of the Hotel

In the base case, it was followed the RCCTE (Council Regulation of the Characteristics of the Thermal Behavior of Buildings). The U values of the internal and external envelope were calculated and are displayed in Table 1.

As already mentioned, the energy needs of the hotel were simulated with the dynamics codes TRACE700 v. 6.2.5 and SOLTERM-Solar Thermal-the results being displayed in Table 2. It is also shown the values of EEI as well as the emitted CO_2 associated with the energy consumption.

It must be noticed that the electric heating corresponds to the consumption of operation of heating systems, including pumps condensate, burner and control panel of the boilers. The gas heating corresponds to the consumption of boilers, with an efficiency of 83.3%, and cooling corresponds to the electrical consumption of chillers with a Coefficient of Performance (COP) equal to 3.2. The ventilation represents the consumption of the air handling equipment, while the pumps correspond to the consumption associated with all fluid pumping equipment.

The maximum thermal power loads for heating and cooling are respectively equal 1,775.8 KW and 1,920.1 KW. The values given above were obtained with a reference system composed of an electric air-to-air chiller (COP of 3.2) and a conventional boiler with an efficiency of 83.3%. It should be noted that the electric heating, represents the consumption of operation of heating systems, including pumps condensate, the burner and control panel of the boilers. The gas heating represents consumption of boilers and the cooling corresponds to the electrical consumption of chillers.

It is important to highlight the "parameters" which most contribute to the nominal consumption of primary energy are the lighting consumption and electrical equipment. Also, it is noted that the building presents elevated energy consumption, due to the fact it is a large service building. However, even in the base case on predefined conditions, the building is already within the minimum required by Regulation

Table 1 U values [$W \cdot m^{2-} \cdot {}^oC^{-1}$] for the base case.

		U values ($W \cdot m^{2-} \cdot {}^oC^{-1}$)
External envelope	Walls	1.80
	roof and floor	1.25
Internal envelope	Walls	2.00
	roof and floor	1.65

Table 2 Annual thermal needs of the hotel (base case).

			Useful thermal needs [KWh·year^{-1}]	Nominal primary thermal energy [kgep·year^{-1}]	EEI [kgep·m^{2-}·year^{-1}]	CO_2 emissions [tons CO_2]
H&C	Heating	Electric	19,724	5,720	0.27	6.9
		Gas	24,6731	21,219	1.0	25.3
	Cooling		521,389	151,203	5.19	181.4
Others	Lighting		1,141,168	330,939	15.61	397.1
	Electric equipment		909,071	263,631	12.43	316.4
	Gas equipment		439,081	37,761	1.78	45.3
	Ventilation		498,000	144,420	5.56	173.73
	Pumps		238,800	69,252	2.67	83.1
	Hydraulic equipment		4,729	1,371	0.06	1.6
	SHW	Gas	636,318	54,723	2.58	65.7
		Electric	10,143	2,941	0.14	3.5
	SPH	Electric	4,840	1,404	0.07	1.7
		Gas	161,678	13,904	0.66	16.7
	Mechanical equipment		6,572	1,906	0.09	2.3
	Total		4.84 [GWh·year^{-1}]	1,100 [tep·year^{-1}]	48.1	1,320.5

Table 3 The annual energy billing and associated costs.

	Total thermal load [MWh/year]	Fuel Bill [€/year]
Electricity	3,354.43	275,890
Gas	1,483.81	46,148
Total	4,838	322,038

Characteristics of the Thermal Performance of Buildings [10]. The annual energy bill and associated costs are shown in Table 3.

Due to the legislation in force, the hotel features an energy rating of B$^-$ (EEI nominal = 48.10 less than EEI reference value = 49.02 kgep·m^{2-}·year^{-1}). So it's mandatory to improve the building components in order to reach a higher rating class. This goes through in adoption of passive and active solutions.

2. Improved Passive Solutions

2.1 Opaque Envelope

The interior space of the building is physically separated from the outside by an envelope that is composed of opaque (walls, roof and floor) and a transparent part (glazing). Note that for this first analysis, to the glazed envelope have been given the maximum permissible values of solar factor and heat transfer, set out in Regulamento das Características de Comportamento Térmico dos Edifícios (RCCTE). In English: Regulation Characteristics of the Thermal Performance of Buildings [11]. In order to improve the efficiency of the building, regarding the opaque envelope, four alternatives were proposed. These ones are only due to changes of the U values of the internal and external opaque envelope due to the changes in thermal insulation. The alternatives are always according to RCCTE:

Alternative 1 (ALT 1): the U values are the reference ones;

Alternative 2 (ALT 2): 25% improvement on the reference values;

Alternative 3 (ALT 3): 50% improvement on the reference values;

Alternative 4 (ALT 4): 75% improvement on the reference values.

The alternatives are shown in Table 4.

Table 4 U values [$Wm^{2-}\cdot°C^{-1}$] for the base case and for four different alternatives.

		Base case	Alt 1	Alt 2	Alt 3	Alt 4
External envelope	Walls	1.8	0.7 (61%)	0.525 (25%)	0.35 (33%)	0.175 (50%)
	Roof and floor	1.25	0.5 (60%)	0.375 (25%)	0.25 (33%)	0.125 (50%)
Internal envelope	Walls	2	1.4 (30%)	1.05 (25%)	0.7 (33%)	0.35 (50%)
	Roof and floor	1.65	1 (39%)	0.75 (25%)	0.5 (33%)	0.25 (50%)

Table 5 Annual thermal needs of the hotel: base case simulation and alternatives for the opaque envelope.

		Base case	Alt 1	Alt 2	Alt 3	Alt 4	
Heating	Electric	0.27	0.25	0.24	0.22	0.22	
	Gas	1	0.36	0.27	0.2	0.15	
Cooling		5.19	4.59	4.53	4.48	4.45	$Kgep\cdot m^{2-}\cdot year^{-1}$
Ventilation		5.56	4.99	4.97	4.87	4.91	
Pumps		2.67	1.41	1.38	1.37	1.37	
$EEI_{nominal}$		48.1	44.99	44.77	44.53	44.49	
Consumption		1,100.4	1,029.5	1,026	1,021.6	1022	$tep\cdot year^{-1}$
Total Energy		228	211	210	209	208	$KWh\cdot m^{2-}\cdot year^{-1}$
CO_2 emissions		1,320.5	1,235.4	1,231.2	1,225.9	1,223.4	tons CO_2 equiv$\cdot year^{-1}$
Costs		-	104.5	189.4	316.4	845.5	[$€\cdot 10^3$]
Payback time		-	5.6	9.6	15.1	40.4	Years

The values in parenthesis correspond to the reduction of heat transfer coefficients between the alternatives. From this analysis it is emphasized that the greatest reduction occurs between the base case and alternative one.

The optimization process of the opaque envelope goes through the analysis of its contribution to the energy consumption of the building. Table 5 shows the annual energy consumption of the hotel regarding the alternatives for the opaque envelope as well as the values of EEI and the emitted CO_2 associated with the energy consumption. There are also shown the total costs and the payback time of all alternatives.

The baseline for this analysis is the opaque envelope, the base case from which follows that it is not relevant to improve the U value of the opaque envelope beyond the reference values stipulated by RCCTE, since the decrease of the U values of the opaque envelope, beyond the benchmarks, do not translates into a significant improvement of the final value of the primary energy consumption (Table 5, consumption: between Alt 1 and Alt 4 the difference is 0.73%). As can also be observed in the same table, it is apparent that the transition of the U values of the opaque envelopewhen compared with the alternative one (ALT 1), presents a decrease in the consumption, both for heating (4.27%) and cooling (14.3%) and consequent reduction of ventilation and pumping systems. As can be seen, alternative 1 is the best one when compared to the base case, even due to the payback time. Besides these benefits there is no improvement in the energetic classification of the hotel (to reach class B the EEI should be less than 44.1 $Kgep\cdot m^{2-}\cdot year$).

2.2 Glazing Envelope

As the best solution for the opaque envelope is alternative 1, the values were fixed in order to evaluate the alternatives for different types of glazing and frames. With the code Calumen of Saint-Gobain there were analyzed four different alternatives of double glazing regarding the Solar Factor (SF):

Alternative 1 (ALT 1): SF = 0.45;

Alternative 1 (ALT 2): SF = 0.4;

Alternative 1 (ALT 3): SF = 0.35;

Alternative 1 (ALT 4): SF = 0.3.

For each alternative, there were analyzed different frames being them metallic with or without thermal cut or of wood or plastic. The energetic and economic analyses are displayed respectively in Table 6 and Table 7.

From the results of the analysis, it is concluded that a window with a low solar factor there is a reduction in thermal cooling requirements. However, it causes increased heating requirements, leading the need to find an optimal point associated with the improvement of the glazed envelope. It was chosen a glass with a solar factor 0.40, since this solution becomes attractive in terms of payback time.

3. Active Solutions

3.1 Solar Thermal Panels for Sanitary hot Water and Swimming pool and PV's for Electricity Production

Decree-Law No. 79/2006 turns out the compulsory installation of solar panels for hot water in new buildings or major rehabilitation of buildings. In this

Table 6 Cost savings using glazed envelope with different frames.

Double glazing Frame	SF	Type of consumption	Annual energetic consumption [MWh·year^{-1}]	Annual energetic costs [€·10^3·year^{-1}]	Total [€·10^3·year^{-1}]	Cost savings [€·10^3·year^{-1}]
Base case (0.56)		Electricity	3,157	262	303.4	-
		Gas	1,327	41.6		
Metal without thermal cutting	0.45	Electricity	3,105	258	300	3.6
		Gas	1,329	42		
	0.4	Electricity	3,068	255	297	6.2
		Gas	1,332	42		
	0.35	Electricity	3,036	253	295	8.3
		Gas	1,336	42		
	0.3	Electricity	3,005	251	293	10.4
		Gas	1,338	42		
Metal with thermal cutting	0.45	Electricity	3,118	259	300	2.9
		Gas	1,321	41		
	0.4	Electricity	3,084	257	298	5.2
		Gas	1,322	41		
	0.35	Electricity	3,118	259	300	7.6
		Gas	1,323	41		
	0.3	Electricity	3,020	252	294	9.7
		Gas	1,325	42		
Wood	0.45	Electricity	3,131	260	301	2
		Gas	1,318	41		
	0.4	Electricity	3,097	258	299	4.5
		Gas	1,318	41		
	0.35	Electricity	3,064	255	297	6.8
		Gas	1,318	42		
	0.3	Electricity	3,031	253	294	9.1
		Gas	1,319	41		
Plastic	0.45	Electricity	3,139	261	302	1.5
		Gas	1,317	41		
	0.4	Electricity	3,100	258	299	4.3
		Gas	1,317	41		
	0.35	Electricity	3,066	255	297	6.7
		Gas	1,317	42		
	0.3	Electricity	3,033	253	294	9
		Gas	1,318	41		

Table 7 Payback time of different kinds of windows.

	Total costs [€·10^3]	Increase in investment [€·10^3]	Payback time [years]
SF			
Base case (0.56)	332	-	-
0.45	362	30.2	8.4-19.7
0.4	377	45.3	7.3-10.6
0.35	407	75.4	9.1-11.3
0.3	422	91	8.7-10.0

Table 8 Comparison between solar thermal panels: amorphous silicon and polycrystalline silicon.

Amorphous silicon panels							
Power peak [KW_p]	-	3.68	10	20	30	100	150
Solar capture area [m^2]	-	62.92	171.6	343.2	500.5	1,716	2,516.8
Nº of modules	-	44	120	240	350	1,200	1,760
Produced energy [MWh·year^{-1}]	-	6.6	18.3	36	53	186	268
$EEI_{nominal}$[Kgep·m^{2-}·year^{-1}]	44.25	44.16	44	43.8	45.6	42	41
Polycrystalline silicon panels							
Power peak [KW_p]	-	3.68	10	20	30	100	150
Solar capture area [m^2]	-	28.9	76.9	147	368	736	1,088
Nº of modules	-	18	48	92	230	460	680
Produced energy [MWh·year^{-1}]	-	6.9	19	35	89	182	270
$EEI_{nominal[}$[Kgep·m^{2-}·year^{-1}]	44.25	44.16	44	43.8	41	42	41

hotel they will be used for sanitary hot water and swimming pool. The main characteristics of the solar thermal panels are: optical yield of 0.74, a solar capture area of 2 m^2 and a thermal loss coefficient a_1 = 3.9 W/m^2/K and k_2 = 0.013 W/m^2 /k^2.

An economic study was also done, similar to the previous cases. For the building under consideration, if using a solar capture area higher to 200 m^2, the system is no longer economically viable because the payback time is greater than the lifetime of the equipment. It should be noted that the selection criteria of this type of equipment cannot be only based on an economic assessment. It should also be taken into account the energy contribution that this type of equipment has to each situation under review. The lower payback time is around 8 years which corresponds to an area of 25 m^2. For this situation, the EEI is 41.5 Kgep·m^{2-}·year^{-1} and becomes less than the reference value, 44.1 Kgep·m^{2-}·year^{-1}. So the hotel can be included in class B.

The PV panels, in despite of the high initial investment, is ecologically clean, with long life and do not require great care in terms of maintenance. For the contribution of this technology in the building, the analysis was done according to the maximum power peak of the photovoltaic system to be used, where it was tested the contribution of three different types of panels, such as amorphous silicon ones, the polycrystalline silicon and their integration in the facades (BiPV). The results of the comparison between them are shown in Table 8. The BiPV was discard from the analysis because the modules are arranged vertically which harms much the production of these panels.

From the results obtained for the two types of photovoltaic panels, it was concluded that for the same peak power, the annual energy produced by amorphous silicon panels and the poly-crystalline silicon is quite similar between them, which is reflected in a decrease the overall consumption of the building in a very similar manner. Although these two different types of panelshas for the same peak power a very similar annual energy production, the amorphous silicon panels arepenalizedbecause they require more than twice the solar capture area. So it was chosen for the following analysesthe polycrystalline silicon panels-92 modules with a power pick of 20 KW_p. The EEI is 42 Kgep·m^{2-}·$year^{-1}$ which maintains the hotel in class B, beside the benefits were shown in Table 8.

3.2 Others Improvements

Several other improvements were taken into account. In order to not repeat the same kind of tables, only the final results of each one will be shown in this subsection. Ventilation devices

In order to improve the efficiency of ventilation equipment, consideration will be given to influence of HVAC systems with and without heat recovery, as well as the influence of consumption of the equipment associated with them. Between several options, the final one was that the air velocity in the batteries (heating and cooling), did not exceed 2.5 m·s^{-1} whit the respective reduction of the total pressure drop in ducts and with heat recovery. Comparing with the base case, the percentage of the total energy saved is 2.9%, and the avoided CO_2 emissions represent 4.1%. The EEI value is 42.79 Kgep·m^{2-}·year, less than the reference value.

Lighting control equipment-dimmers. The control of artificial lighting in a building aims to maximize the use of natural lighting, requiring only lighting and occupancy sensors in the spaces. These detect the presence of space lighting power, comparing it with the preset. If it is not achieved by natural lighting is driven artificial lighting. The TRACE.700.v.6.2.5 software has an algorithm that allows the inclusion of the concept of natural light into the building, creating in each space a variable named daylight factor, defined by the ratio between indoor luminance and the horizontal exterior luminance. The implementation of such control system reverts in a reduction of the annual energy bill of around 7%. The contribution to this decrease comes from the electricity consumption that is reduced considerably due to lower power consumption in the building using this technology. The payback time is 1.3 years.

Chillers using heat recovery of hot water from the condensers to heat the sanitary hot water (SHW). After an energetic and economic analysis, it was found out that using this technique, there is an expected increase in power consumption by the latter, by the reason ofits contribution to the SHW (there is a significant reduction in nominal power to SHW). The greatest contribution of this equipment to satisfy the SWH takes place in the cooling season (summer), since in this period the chillers are running permanently (feeding the cooling batteries).

They take advantage of the flue gas which from the combustion Condensing boilers. The use of condensing gas boilers leads to a decrease in overall building consumption due to their better performance when compared to conventional boilers.

3.3 Overall Solutions

Taking into account the better solutions for each active solution shown before, it's possible to compare them with the initial conditions. Table 9 displays the overall results of the best choices in order to reduce the energy consumption of the building.

As can be seen, with the features inherent in the initial solution (base case) when compared to the optimal solution set, the differences in all consumption levels decrease in a meaningful way. The reduced overall consumption of the building is approximately 25%. For the base case an according to the Portuguese legislation, theenergy rating of the hotel was B^- category. Therefore, after the changes carried out the building was rated to class A.

3.4 Cogeneration (CHP) and Trigeneration (CHCP)

Depending on the electrical power of the engineto be used and of the annual operating hours of the system, it's possible to evaluate the electricity produced annually by the equipment. In turn, the useful thermal energy depends on the thermal requirements of the

Table 9 Results of the final solution.

		Final solution		Initial solution		Reduction of energy consumption	Avoided emissions of CO_2
		[kgep·m^{2-}·year^{-1}]	tons CO_2	[kgep·m^{2-}·year^{-1}]	tons CO_2	% [-]	% [-]
Heating	Electric	0.27	6.8	0.27	6.9	1.6	
	Gas	0.36	9.1	1.0	25.3	64.2	
Electric cooling		4.49	157	5.19	181.4	13.5	
Lighting		12.95	329	15.61	397.1	17.1	
Electric equipment		12.43	316.4	12.43	316.4	-	
Gas equipment		1.78	45.3	1.78	45.3	-	
Ventilation		2.62	85.8	5.56	173.73	52.9	
Pumps		0.52	16.9	2.67	83.1	80.7	
Hydraulic equipment		0.03	0.08	0.06	1.6	46.5	
SWH	Electric	0.54	13.7	2.58	65.7	79.1	
	Gas	0.14	2941	0.14	3.5	0.9	
SPH	Electric	0.07	1.7	0.07	1.7	5.4	
	Gas	0.52	13.1	0.66	16.7	21.9	
Mechanical equipment		0.09	2.3	0.09	2.3	0.1	
Solar thermal		-0.32	-8.1	-	-	-	
PV		-0.48	-12.1	-	-	-	
Total		36	918.8	48.1	1320.5	25.2	30.4

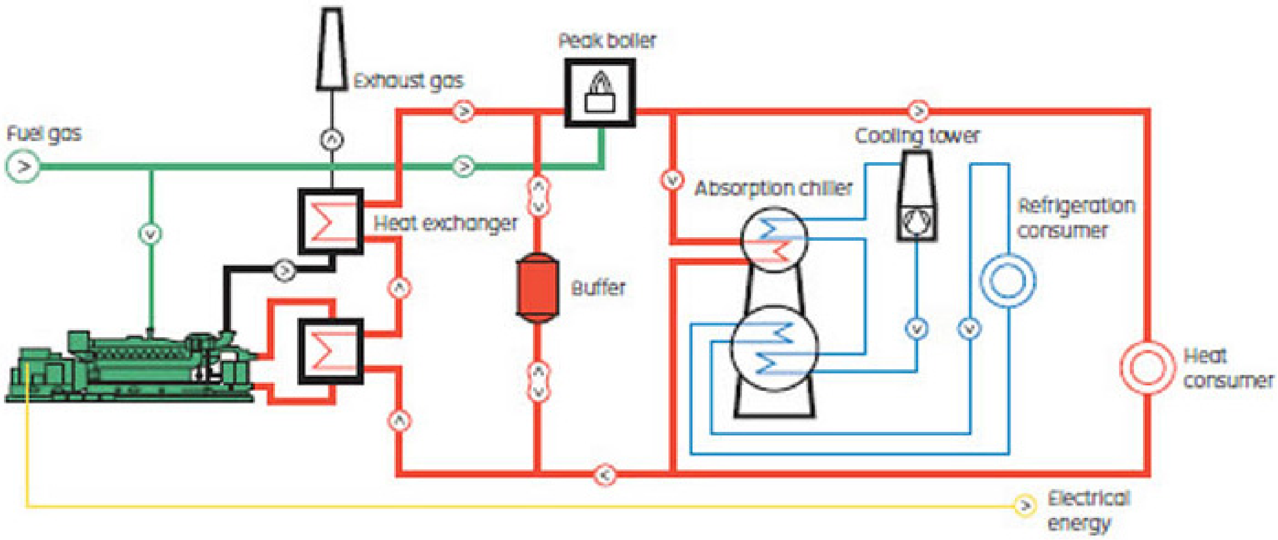

Fig. 1 General principle of a CHCP system.

building, because such a system only produces heat (besides the electricity). To be able to produce coolingit is necessary to have an absorption chiller that runs with the heat generate by the CHP. In this case such systems are designated as trigeneration systems—Combined Production of Heat, Cooling and Power (CHCP). In the case study, due to the involved thermal needs, is interesting to couple an absorption chiller for the cooling needs. A general sketch of a CHCP is shown in Fig. 1.

There were analyzed several types of cogenerations systems, namely four strokes engines running with natural gas, micro turbines and fuel cells. Among them, the one that better fits to the thermal needs of hotel is a specific one with the following characteristic as shown in Table 10.

Table 10 Characteristics of the CHP engine.

Electric power [KW]	Thermal power [KW]	Gas consumption [KW]	Electric efficiency[%]	Thermal efficiency[%]	Global efficiency [%]
330	363	851	38.78	42.66	81.43

Table 11 Contribution of the CHCP for the energetic needs as a function of the running hours per year.

Thermal needs	CHCP	Conventional system	CHCP	Conventional system	CHCP	Conventional system
	%		%		%	
Heating	94.28	5.72	70.97	29.03	41.75	58.25
Cooling	39.32	60.68	39.22	60.78	41.12	58.88
Annual operating hours	8,760 h·year^{-1}		6,205 h·year^{-1}		4,380 h·year^{-1}	

It should be noted that the operating system defined for the system CHCP is that the heat produced by the system first meets the heating needs, and only suppliesheat to the absorption chillers to satisfy the cooling demandswith the surplus heat not used in heating.

In order to verify the feasibility of this type of system, it is necessary to define its annual operating hours, which for the case study will be analyzed three different possibilities. It runs 24 hours a day (8,760 h/year), or from 7 am to 24 hours (6,205 h/year) because this schedule eliminates much of the super-peak and standard empty electricity (uninteresting of the remuneration level), or from 10 am to 21h (4,380 h/year). Table 11 shows the contribution of the CHCP when compared to the base case.

For the chosen engine, the EEE value is checked (EEE ≥ 0.55) using just one or two engines. It is also be concluded that the use of this engine and its hours operation, there is the economic viability of this technology as well as the obligation to use it (payback time < 8 years.)

4. Conclusions

In this work, it was carried out an energetic and economic analysis of the contribution of passive and active solutions for buildings in order to reduceits energy consumptionas well as the avoided CO_2 emissions. The contribution of renewable energysources and the assessment of the contribution of a CHCP system were also studied. For that, dynamic codes were used to obtain all the thermal needs of a hotel located in Portugal.

The simulations with nominal conditions (base case) showed thatthe total energy consumed in the building is 4.84 GWh/year. Where, under the conditions set for this model, it achieved a $EEI_{nominal}$ of 48.1 kgep·m^{2-}·year^{-1}, indicating that the building features an energy rating of B^{-} [$EEI_{nominal}$ (48.10) < $EEI_{reference}$ (49.02) kgep·m^{2-}·year^{-1}. Regarding the emission level of CO_2, this building would emit 1,320.5 equivalent tons of CO_2 per year. The consumption of HVAC (heating, cooling, ventilation and pumps), represents 35.7% of primary energy consumption, lighting 30.1%, consumption on the equipment is 27.6% and 6.6% referred to sanitary hot water and swimming pool water.

At a passive level, a sensitivity analysis to the base case was also done. Regarding the changes in the opaque envelope, the best solution was ALT1 shows a decrease in the consumption, both for heating (4.27%) and cooling (14.3%) and a consequent reduction of ventilation and pumping systems. The avoided CO_2 emissions are 6.4% and the payback time is 5.6 years. Regarding the glazing envelope and from the results of the analysis it is concluded that a glass with a solar factor of 0.40 is the best one, since this solution becomes attractive in terms of payback time in the range of 7.3-10.6 years as a function of the different types of frames that can be used.

At an active level it was analyzed the use of solar thermal panels for hot water heating. The lower payback time is around 8 years. For this situation, the EEI is 41.5 Kgep·m^{2-}·year^{-1} and becomes lower than the reference value, 44.1 Kgep·m^{2-}·year^{-1}.Also two types of photovoltaic panels were analyzed: amorphous silicon and poly-crystalline silicon. It was concluded that the amorphous silicon panels are penalized because they require more than twice the solar capture area. So it was chosenthe polycrystalline silicon panels whit 92 modules. The power pick is 20 KWp andthe EEI is 42 Kgep·m^{2-}·year^{-1}. With this solution, it was concluded that they contribute to a reduction of thermal needs of 25.2% and avoided emissions of equivalent tons of CO_2 of 30.4%. Regarding the use of CHCP the best solution chosen was a four stroke internal combustion engine running with natural gas, and coupled to an absorption chiller.The contribution of this type of engine to fulfill the heating requirements of the building lies in the range of 44% to 94% and for cooling the range is 39%-61% (depending upon the working system profiles). It is also concluded that, the use of this engine and its operatinghours, there is the economic viability of this technology as well as the obligation to use it (payback time < 8 years).

Therefore, after all the changes carried out, the building was rated to class A.

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Short-term Intensive Sustainable Restoration of Grasslands and Prairies Invaded with High Densities of Nitrogen-fixing Weeds: A Test with the Invasive Plant *Lespedeza Cuneata*

Jack Cornell and Alexander Wait

Biology Department, Missouri State University, Springfield, MO 65897, USA

Abstract: This study examines management strategy for restoring grassland and prairie communities that have become degraded due to high density stands of invasive nitrogen-fixing plants. The novel management applications minimize the use of herbicides and maximize the competitive interactions of native species. The management method included in two seasons application of organic fertilizer (4-1-4), an initial herbicide (PastureGard, DowAgro) application, and mowing. Where, mowing was a necessary treatment to control secondary growth in prairie habitats, to control high density patches of *Lespedeza (L.) Cuneata*, in a completely randomized factorial experiment. The herbicide was effective in reducing *L. Cuneate* stem density to 0 stems/m^2 from initial 88 stems/m^2 with cover reduced to 0% from 16%. The fertilizer only treatment reduced *L. Cuneata* percent cover to 6% from initial cover of 16%, but did not reduce the number of stems. The management strategy is an effective first step, in restoring a native prairie invaded by a nitrogen-fixing plant.

Keywords: Legumes, nitrogen-fixing plants, *Lespedeza Cuneata*, prairie/grassland restoration, invasive species, sustainable management.

1. Introduction

Lespedeza (L.) Cuneata is a long-lived perennial legume that has become a pervasive problem in old fields and prairies throughout parts of the United States [1-6]. For example, areas invaded by *L. cuneate* have lower plant and animal diversity than areas dominated by native grasses and forbs [5, 7]. To promotemuchhigher plant and animal diversity, there is a strong interest in restoring natural ecosystemsand therefore, there is a demand for techniques that both control a given invasive species and improve the establishment of native flora and fauna [5, 8-11]. Since the introduction of *L. Cuneata,* it has become a successful invader and colonizes and once it is established, it shades native plants and reduces soil nutrient levels [3, 10, 12]. *L. Cuneata* also has allelopathic effects that reduce seed production and growth of native plants [12]. It is a model invasive nitrogen-fixing plant [1]. Typical tallgrass prairie management and restoration strategies of mowing and burning to remove secondary growth and promote species diversity have facilitated the spread and dominance of *L. Cuneata* [12]. For example, early spring burning and mowing allow for more direct sunlight favored by *L. Cuneata*, while spring burns increase *L. Cuneata* germination rate via seed scarification [3, 10].

L. Cuneata is typically managed by the application of herbicides, typically along roadsides, in animal food plots, and in areas being restored to a native prairie [5, 10]. Studies have indicated herbicide applications increase native plant biomass and reduce *L. Cuneate* cover and stem density [5, 6, 13]. While

Corresponding author: Jack Cornell, master, research field: plant biology.

low density stands of *L. Cuneata* have been successfully controlled by spot spraying, fields that have become heavily invaded require repeated applications of herbicide [4], which can be both expensive and not conducive to sustaining a diverse healthy ecosystem. Clearly, an alternative control method for high density stands of a nitrogen fixing weed like *L. Cuneata* needs to be developed.

Fertilization is a relatively novel treatment for nitrogen-fixing plants like *L. Cuneata*, in which the soil is enriched to promote competition of native species [14]. For example, the application of ammonium nitrate to provide nitrogen (N) has been shown to lower the competitive advantage of *L. Cuneata* by significantly reducing cover, stem density, and biomass [2, 12]. Nitrogen applications have also been shown to have a detrimental effect on legume nodule formation and subsequent nitrogen uptake, as well as compensate for the negative effects of the allelopathic chemicals released by the plant [7, 12]. Therefore, adding N to old fields and reclaimed prairies that typically have poor soil fertility may help native species compete with *L. Cuneata* [2, 12, 14, 15]. However, a few experiments where N has been applied, N was applied at very high concentrations [2, 12, 14, 16, 17], which is not cost effective or environmentally sustainable. Current tall grass management strategies, using prescribed fire and fuel management to manage natural resources, have been successful in reducing and maintaininga low abundance of woody growth, but have not been successful in reducing *L. Cuneata* dominance [13, 18, 19]. The goal of this research was to examine whether an applicationof an herbicide and low nitrogen concentration organic fertilizer along with management required mowing regimes to reduce woody plant stems would facilitate the restoration and management of native prairies that have become almost completely dominated by *L. Cuneata*.

Specific questions addressed by this study were: (1) What are the effects of an initial application of a herbicide that is marketed for controlling *L. Cuneata*, PastureGard (Dow AgroSciences), and the application of low nitrogen concentration organic fertilizer, and schedule mowing on *L. Cuneata* stem density, cover, and importance value? (2) How does an initial application of herbicide followed by two years of organic fertilization and mowing affect cover of desired and undesired tallgrass prairie species and species richness after two years?

2. Methods

2.1 Study Site

Wilson's Creek National Battlefield (WCNB), which is located in Southwestern Missouri in the United States of America (37º06'56.04" N, 93º25'12.17" W) is a 708 hectare park that contains 172 hectares of remnant tallgrass prairie and agricultural area [20, 21]. In 1960, the area was made a National Park and has maintained to the physical environment which existed in 1861 during the Civil War battle using periodic burns and removal of secondary growth by mowing [20, 22].

The soil in the restored tallgrass prairies in the WCNB include Wilderness cherty silt loam, Goss cherty silt loam, and a Gasconade-Rock outcrop complex [21]. There are 126 herbaceous and shrub species found within the park; the predominant native tall grass prairie species include big bluestem (*Andropogon gerardii*), and Indian grass (*Sorghastrum nutans*) [21]. The prairies of the park are heavily managed to reduce invasive exotic species, such as *L. Cuneata* (sericea lespedeza) and *Rubusfruticosus* (blackberry), which reduce the cover and presence of native species. This study focused on a 53 ha unit of tallgrass prairie habitat in the northwest part of the park that contained high density stands of *L. Cuneata* (98.2 ± 40.3 stems m^2) that had an average cover of 54.8%, which was managed using fall mowing and spring burns. The Prairie Cluster Long-term Ecological Monitoring Program, carried out by the National Park Service Heartland Inventory and Monitoring Network, performed a four year study (1997-2000) at WCNB that found the relative cover of exotic species across the park was 30.37%, and the relative cover of native species was 69.88% per 10 m^2 [21].

2.2 Study Design

A fully factorial random block design was used to assess the effectiveness of mowing, herbicide, and fertilization in controlling high density stands of *L. Cuneata* to a manageable density (six blocks, eight treatments, replicated in each block for 48 plots total). An area of 720 m^2 within the 53 ha prairie unit was haphazardly demarcated on a grid map of WCNB. The map was then demarcated into 24-30.0 × 30.0 m blocks; six blocks were then chosen randomly using a random number generator (Minitab 15). Each block was demarcated into 36-5.0 × 5.0 m plots; 8 out of the 36 plots within each block were selected using a random number generator (Minitab 15). A GPS coordinate was recorded for the center of every plot using a Garmin GPS map 76 CSx (position accuracy 1-5 m) along with stacking the corners of each plot.Within a block each of the eight plots received a randomly selected treatment (control, herbicide (H), fertilization (F), mowing (M), M × H, M × F, H × F, M × H × F).

2.3 Treatments

Triclopyr ester and fluroxypyr (PastureGard, 0.02 kg L^{-1} active ingredient) was used as the herbicide to control *L. Cuneata* following manufacturer's instructions. The herbicide was only applied in the first growing season of the study in mid-July on the entire assigned 5 m^2 plot. The fertilizer used was "Perfect Pasture and Farm" developed by Bradford Organics, which is ideal for areas where high inorganic nitrogen fertilization would be prohibited for environmental reasons (e.g., nutrient runoff) and expensive. The ratio of nitrogen, phosphate (P_2O_5), and potash (K_2O) in the organic fertilizer is 4-1-4. This fertilizer is an alfalfa-based organic fertilizer which also contains molasses, sulfate of potash, Humate (Humic acid), and meat meal. There was a total of 26.68 kg of fertilizer (1.067 kg of nitrogen, 0.2668 kg of phosphate, and the 1.067 kg of potash) applied each July and August of the 2-year treatment period on a total area of 600 m^2,or 444.6 kg/ha. Mowing (typical management strategies for tall grass prairies) was applied during the flowering stage of *L. Cuneata* to prevent seed formation. Plots were mowed to a height of 0.1-0.2 m only in the first growing season in early August.

2.4 Measured Variables

The assessment of *L. Cuneata* stem density was determined by counting the number of stems in four randomly chosen 0.25 m^2 areas within each 5 m^2 plot. Daubenmire cover values were used for accessing the species cover for every species that was rooted within each 5 m^2 plots [23]. Every species was then categorized as Native or Nonnative and classified by growth habit (Woody, Herbaceous and Grass), to identify if the species is desired or undesired for a tallgrass prairie. Species richness was accessed by the count of the number of species rooted within each 5 m^2 plot.

The National Park Service's division of Heartland Network Inventory and Monitoring and Prairie Cluster Long-term Ecological Monitoring Program methodology was used to characterize the treatment effects on the *L. Cuneata* population within each treatment level [21]. First there was an assessment of the relative cover of *L. Cuneata* (% cover of *L. Cuneata*/% cover or all other species), and then the relative frequency of *L. Cuneata* (# of occurrences/total species richness) was used to calculate the % Importance Value ([relative cover/relative frequency] × 100).

The data for each variable was collected with three pretreatment measurements taken from April to early May in the first year of the study. Post treatment measurements were taken late May, June and

September of the first year of the study and again with two measurements during the second year in May and June. The post treatment data presented reveals the effects of herbicide (applied only in the first growing season), fertilizer (applied in the first and second growing season) and mowing (applied in the first growing season).

Analysis of variance using a general linear model was used to assess a main treatment effect across all measurements. A Tukey Simultaneous Test utilizing a pairwise comparison among treatments was used to assess statistical differences of individual treatments, which was appropriate because the main treatment effects were statistically significantly different ($P < 0.05$).

3. Results and Discussion

3.1 Treatment Effects on L. Cuneata

L. Cuneata was effectively controlled across all treatments that included Herbicide (H, HxF, HxM, and HxFxM) (Fig. 1 and Table 1). Other studies have demonstrated that the active chemicals triclopyr ester and fluroxypyr ester found in the herbicide PastureGard (Dow AgroSciences) control *L. Cuneata* [5-6, 13] and this study confirms it is effective.

The organic fertilizer only treatment did not significantly increase *L. Cuneata* stem density, but did significantly reduce *L. Cuneata*mean percent cover of 4.2 ± 6.3 (Table 1; Tukey $P = 0.3907$) (Fig. 1). The fertilizer only treatment reduced *L. Cuneata* importance value to 16.8% compared to 29.4% in the control (Table 1). This is evidence that a slow release organic fertilizer can reduce the dominance of *L. Cuneata* and allow the other native species to compete better without the use of herbicide [2, 15]. Fertilizer combined with mowing only reduced *L. Cuneata* stem density by 1.3% compared to the control; however, it did reduce *L. Cuneata* percent cover to 4.6 ± 1.6 (Fig. 1 and Table 1). The importance value reduction by 48% also reflected that fertilizer combined with mowing was an effective mode of control for *L. Cuneata* (Table 1). The reduction of *L. Cuneata* importance value may be attributed to mowing opening up the canopy, and fertilizer enabling all other species to better compete with the faster growing invasive legume. The mow only treatment did not significantly affect *L. Cuneata* cover with only a 6.1% reduction (Tukey $P = 0.9951$), but did significantly increase stem density by 28.8% (Tukey $P = 0.0007$) (Table 1). The highest importance values for *L. Cuneata* were in the control (29.4%) and mow only treatments (29.2%); therefore, mowing alone did not successfully control *L. Cuneata*, which is consistent with the findings of Brandon and Middleton [12].

3.2 Treatment Effects on Other Species

Desired species had the highest percent cover in HxM, HxF and herbicide only treatment with values of 66.2%, 47.4%, and 46.8% respectively. Although not statistically significant, the desired species in the fertilizer only treatment had 11.4% greater percent cover than the control. The desired species percent cover was at or below the control value (24.2%) in the treatments of $H \times F \times M$, Mow and $F \times M$. Identifying treatment effects on desired species is important for factor for accessing the success of each restoration plan [5].

To understand the relationship that treatments had on the undesired species, the percent cover of *L. Cuneata*was separated from the remaining undesired species shown in Fig. 1. It is important to create a management strategy to restore native plant communities that reduce *L. Cuneata* dominance, but that do not result in other undesired species gaining importance, which is known as the invasive treadmill effect [24]. Herbicide only treatment and the $H \times F \times M$ had the highest percent cover of undesired species with percentages of 61.7% and 56.2% respectively. Similar to Brandon and Middleton [5], our prairie management treatments did not affect the percent cover of undesired species (Fig. 1). Most importantly, herbicide alone increased species cover of undesired species, but HxF

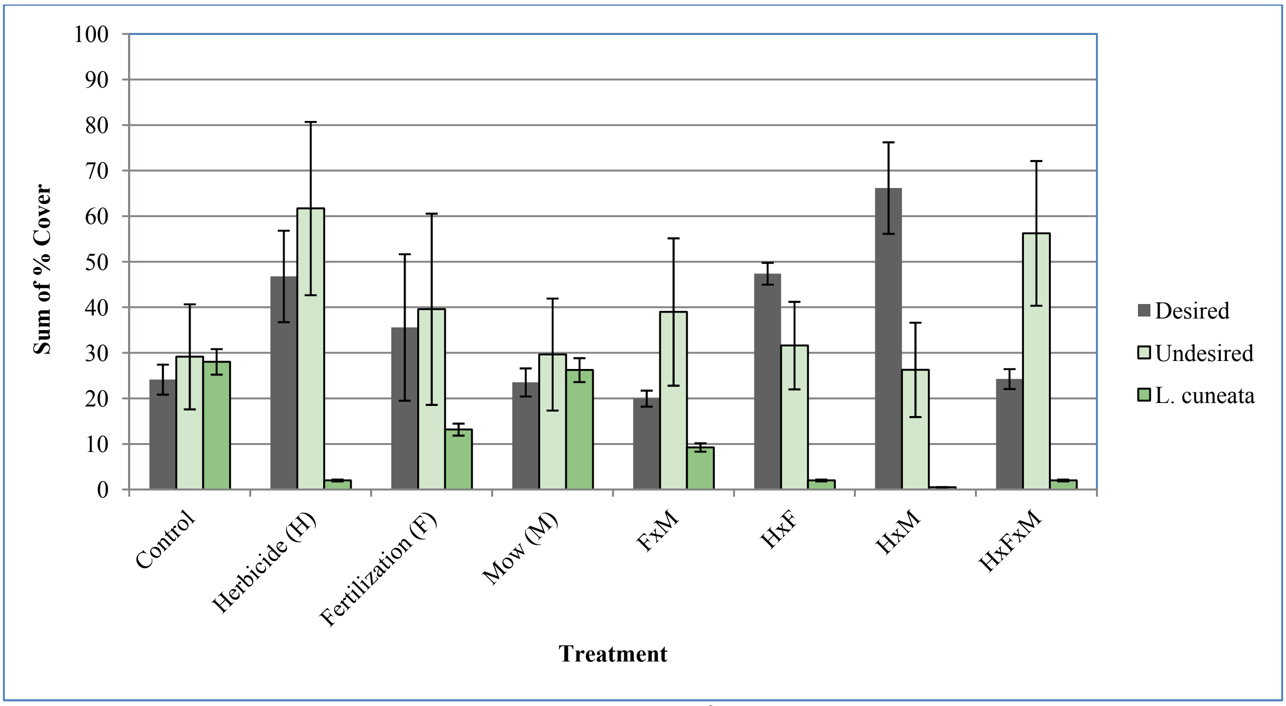

Fig. 1 Summation of all species accessed in percentage per 5 m^2 using the Daubenmire cover value scale in the post treatment period. Species were categorized into Desired (native grasses and native herbaceous plants), Undesired (Native woody, nonnative grasses, nonnative herbaceous, nonnative woody), and *L. Cuneata*.

Table 1 Post treatment data for *L. Cuneata* stem density (number of *L. Cuneata* stems in four 0.25 m^2 sub-plots with in the 5 m^2 plot) and Importance Value Percentage for *L. Cuneata* ([relative cover/relative frequency] × 100).

Treatment	*L. Cuneata* stemdensity (Mean ± SE)	Importance value (%)
Control	87.7 ± 18.1	29.40
Herbicide (H)	0.0 ± 0.0	2.55
Fertilizer (F)	100.0 ± 14.0	16.84
Mow (M)	117.2 ± 16.9	29.19
FxM	85.8 ± 8.6	18.08
HxF	0.1 ± 0.1	1.28
HxM	0.0 ± 0.0	4.25
HxFxM	0.0 ± 0.0	1.57

increased desired species cover. Therefore, the restoration method should facilitate competitive ability of desired species into the future and the efficacy of seeding post treatment [8].

3.3 Species Richness

PastureGard significantly reduced species richness in every plot that it was applied (Table 2). This confirms what Koger, C., et al. [5] reported that PastureGard not only targets *L. Cuneate*, but also inhibits the growth of woody species, herbaceous species, and does not promote an increase in species richness. Although not significant, the fertilizer only treatment had the highest species richness of desired species (Table 2). An increased diversity of species can prevent ecosystem nutrient loss and increase ecosystem productivity [12, 20]. The remaining non-herbicide treatments and treatment combinations also did not have a significant effect on species richness. This may be attributed to only being a short term study, a common problem in invasive plant control experiments [11].

Table 2 Post treatment data for Species Richness (all species rooted within each 5 m^2 plot).

Treatment	Species Richness (Mean ± SE)
Control	8.8 ± 0.5
Herbicide (H)	7.6 ± 0.6
Fertilizer (F)	9.3 ± 0.9
Mow (M)	8.5 ± 0.6
FxM	9.3 ± 0.5
HxF	6.7 ± 0.8
HxM	7.4 ± 0.4
HxFxM	6.9 ± 0.4

4. Conclusion

This study illustrated that the herbicide PastureGard was an effect means to control *L. Cuneate*; however, the herbicide did not significantly reduce other undesired species from filling the ecological niche that *L. Cuneata* left behind. However, by adding the organic nitrogen treatment and standard mowing, initial restoration goals were met. Fire was not allowed in the study, but it can be hypothesized that if fire was added, the restoration goals would have been more completely met. The restoration method will also allow effective seeding of desired species as it opened up niches. The restoration method was more successful than the methods used previously in this prairie and is suggested for the initial treatment of highly invaded grasslands and prairies.

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The Prospect and Feasibility Assessment of Brine Shrimp (*Artemiafranciscana*) Culture in Bangladesh

M Niamul Naser, Rajib Hasan, Sharmin Akter Nipa and Harun Or Rashid
Department of Zoology, University of Dhaka, Dhaka 1000, Bangladesh

Abstract: A laboratory-based work was conducted on development, biometry (cyst diameter, hatching efficiency and hatching percentage) and survival rate of *Artemiafranciscana* at 35 ppt using natural brine water under constant aeration facilities. The experiment was carried out for both chorionic and decapsulated cysts. There was a significant increase in hatching output of the decapsulated cysts than the chorionic cysts. The survival rate was counted only for the chorionic cysts because nauplii hatched from decapsulated cysts died after four days of incubation before reaching the adult stage. Untill now the Artemia cysts are import from abroad. Though the prospect of mass production of *Artemia* in Bangladesh is feasible but there needs to be more studies done.

Key words: Cyst diameter, hatching output, decapsulation, survival rate.

1. Introduction

Artemia, also known as brine shrimp, is a minute crustacean, has become an easy and most convenient food items among the live diets used in aquaculture of fishes. Over the course of time it has gained much popularity in many aquaculturists because of its multiple usages in fish culture with various forms such as *Artemia*nauplii, decapsulated *Artemia* cysts and on-grown *Artemia* [1]. Likewise the rearing of such highly nutritious feed item is quite easy.

In most intensive aquaculture system, the newborn fish larvae rely on live food items. But the culture and collection of highly nutritious natural food such as crustaceans for rearing the fish are not only always economically feasible but also poorly available. Crustaceans occur naturally on hypersaline water which acts as the predominant factor for prohibiting *Artemia* populations from being present in humid climatic conditions like Bangladesh [2].

Artemia is being used in large scale in the hatcheries of Bangladesh since it is one of the key items in shrimp and fishery hatcheries. However, because of its unusual occurrence and the difficulties of collecting cysts, *Artemia* cysts are being commercially imported from abroad countries to meet up the increasing demand where the mass production of cysts of *Artemia* in Bangladesh is still at the premature stage. Although a number of fundamental works have been conducted on *Artemia* under laboratory condition, only a few preliminary works on mass *Artemia* production have been reported. Some major studies were conducted on the production of *Artemia* biomass and cysts from the traditional solar salt beds of coastal areas of Bangladesh [3-5]. Results revealed that the modified solar salt beds of Bangladesh have suitable water quality that can be used for salt *Artemia* production in winter season. So the present 12,000 ha of salt farming area of Bangladesh can be used to produce 180 metric tons of dry cysts and 2,400 metric tons of biomass per annum [6]. In Thailand, *Artemia* is produced in modified salt pans integrated with shrimp production. So there is a potentialprsopect in our country to get mass *Artemia* production by using 275,583 ha shrimp farming area if proper initiatives are taken carefully.

In this present study the development, hatching and survival of *Artemia franciscana* were closely examined

Corresponding author: Rajib Hasan, research assistant, research field: conservation biology and zoology (fisheries science).

on the laboratory reared animals. Besides these observations, water quality parameters such as water temperature, salinity and pH were measured carefully.

2. Material and Methods

2.1 Hatching of Artemia Cysts

Simple aquarium tanks were used for hatching of nauplii from *Artemia* cysts. Unpurified brine water was used as culture media. Salinity level was adjusted by using tap water. The culture media was then oxygenated by an aerator pump, and placed it in front of a fluorescent light (60 watt) until the study period ended. Continuous aeration was provided to keep the cysts in suspension and to provide enough oxygenation. Since *Artemia* is a specific filter feeder, the nauplii were fed with natural phytoplankton known as Spirulina.

2.2 Decapsulation

For decapsulation, 0.1 gram of dry cysts were taken in a conical, transparent plastic container and incubated in salt water for 1 to 2 hours to ensure the complete hydration. After 2 hours, 0.5 gram of bleaching powderwas added to the salt water and the media was aerated. Ice was added to the media to maintain the temperature not beyond of 40 ℃. The color of the cysts was observed carefully. When the color of the cysts changed from dark brown to orange, the cysts were filtered from the decapsulation solution and rinsed with cool tap water until no chlorine smell persisted. The sample of decapsulated cysts were then incubated for determining hatching efficiency and hatching percentage [7].

2.3 Hatching Efficiency and Hatching Percentage

80 mL of salt water was taken in 250 mL measuring conical flask. The media was then aerated and 250 mg cysts were added. After one hour, the 100 mL volume was made by adding salt water. Continuous aeration and light illumination were provided. After 24 hours and 48 hours of incubation, 5 subsamples containing 0.25 mL were taken from the conical flask. Then the number of nauplii and unhatched cysts were counted. The two parameters were determined using Eqs. (1) and (2) (Sorgeloos and Kulasekarapandian 1984):

Hatching efficiency = Number of nauplii per gram of cysts (1)

Hatching percentage (%) = Number of nauplii×100/number of nauplii+number of unhatched cysts (2)

2.4 Diameter of Cysts

The diameter of both chorionic and decapsulated cysts were measured under microscope (at 10 X magnification) using an ocular micrometer. The cysts were collected after 2 hours of incubation. From the mean diameter, chorionic thicknesses were measured using Eq. (3) [8]:

Chorionic thickness = Mean diameter of chorionic cysts-mean diameter of decapsulatedcysts/2 (3)

2.5 Water Quality Parameters

Water quality parameters such as pH, salinity and water temperature were observed during the experiment at different day intervals.

2.6 Survival Rate

Survival rate was determined at water renewal on days 8th, 12th, 15th, 20th and 23th. The rate was determined on the basis of the number of developing larvae survived on the representative days.

3. Results

3.1 Development

After hydration the biconcave cysts became spherical and the embryos became visible under microscope after 9 hours to 10 hours of incubation when they started to protrude through the fissure. Prior to hatching, the embryos are found to be hanging from the cyst shells (Fig. 1). The embryo, following the hatching, developed into an oval shape having a single naupliar eye and covered by a thin membrane through which it was attached to the cyst shell (Fig. 2).

Within a short period of time the free-swimming first naupliar (instar I) stage (Fig. 3) came out through the rupture of the embryonic membrane. It is the non-feeding stage with a mean body length of 0.502 ± 0.0156 mm. The nauplii are brownish orange in color because of their yolk reserves. A few hours after the hatching of first instar, it developed into the second larval stage (instar II) having a mean length of 0.614 ± 0.0183 mm. The instar I could be differentiated from the instar II by the quick lashing movements of the instar II larvae. The third larval stage was observed on the third day of incubation with a mean length of 0.822 ± 0.0115 mm. This larval stage was persisted for the next few hours and then molted into the fourth larval stage having a body length of 0.90 ± 0.094 mm.

During the next few days, the naupliihad undergone several molting and reached into the adult stage. The adults were observed from the 20th day after incubation with a mean body length of 8.46 ± 0.074 mm (Fig. 4).

The larval stages with their days of observation and body lengths are summarized in Table 1.

3.2 Physico-Chemical Parameters

Physico-chemical parameters like water temperature, pH and salinity were recorded on different days of observation. There was a gradual increase of salinity from 35 ppt to 54 ppt onwards with the culture system.

Fig. 1 Embryo on hatching.

Fig. 2 Oval-shaped pre-nauplius.

Fig. 3 1stnaupliar stage (instar I).

Fig. 4 Adult (male).

No significant variation was observed in case of pH and remained within a range of 7.4 to 7.7. The temperature showed a little fluctuation, the lowest temperature recorded was 26.4 °C and the highest was 31.5 °C (Table 2).

Table 1 Bodylength of larval stages.

Name of larval stages	Specific days of observation	Body length (mm) (Mean ± SE)	Name of larval stages	Specific days of observation	Body length (mm) (Mean ± SE)
1st Larval stage	20 hours	0.502 ± 0.0156	6th Larval stage	8th	1.46 ± 0.024
2nd Larval stage	2nd day	0.614 ± 0.0183	7th Larval stage	9th	1.95 ± 0.074
3rd Larval stage	3rd day	0.822 ± 0.0115	8th Larval stage	13th	2.84 ± 0.143
4th Larval stage	6th day	0.90 ±0.094	Juvenile	16th	5.32 ± 0.259
5th Larval stage	7th day	0.992 ± 0.0048	Adult	20th	8.46 ± 0.074

Table 2 The physico-chemical parameter of water during the different days of observation.

Water parameters	Specific days of observation												
	1th	2th	3th	6th	8th	9th	10th	12th	15th	17th	18th	20th	23th
Salinity	35	35	35	36	38	40	41	43	46	48	51	53	54
pH	7.4	7.4	7.4	7.5	7.5	7.6	7.5	7.5	7.6	7.7	7.6	7.4	7.4
Temperature (℃)	26.4	26.5	26.5	26.6	26.4	27.1	26.8	27.8	29.5	31.5	26.8	26.6	26.5

Table 3 Determination of chorionic thickness.

Diameter of chorionic cysts (µm) (Mean ± SE)	Diameter of untreated cysts (µm) (Mean ± SE)	Chorionic thickness
242.2 ± 1.90	213.5 ± 3.167	14.35

Table 4 Hatching efficiency and hatching percentage of chorionic and decapsulated cysts.

Cyst type	Hatching efficiency (N/gm cysts)		Hatching percentage (%)	
	24 hours	48 hours	24 hours	48 hours
Untreated cysts	5.6×10^4	8.96×10^4	36%	48%
Decapsulated cysts	1.02×10^5	1.42×10^5	56%	90%

Table 5 Survival percentage of *Artemiafranciscana*.

	Specific days of observation				
	8th	12th	15th	20th	23th
No. of nauplii	133	107	100	97	92
Survival percentage (%)	100%	80.45%	75.18%	72.93%	69.17%

3.3 Cyst Diameter

The mean values for chorionic and decapsulated cysts were 242.2 ± 1.90 µm and 213.5 ± 3.167 µm respectively. The chorionic thickness was measured from the mean diameter of chorionic hydrated and decapsulated cysts and the value is 14.35 µm (Table 3).

3.4 Hatching Efficiency and Hatching Percentage

The results of hatching efficiency and hatching percentages are presented in Table 4. Where, the differences are noticeable in both hatching efficiency and hatching percentages. The hatching efficiency and the hatching percentages of decapsulated cysts were higher than that of chorionic cysts.

3.5 Survival Percentage

During the experiment, the survival rate of *Artemia*nauplii was also determined at water renewal on days 8th, 12th, 15th, 20th and 23th to study the effect of salinity on survival of *Artemia*. The number of the developing embryo was 133 on the 8th day of the experiment. There was a gradual decrease of the number of larvae onwards with the culture periods. On the 23th day, about 92% growing larvae were observed and the survival percentage was 69.17%.

4. Discussion

The growth, survival, metabolism and number of instars of *Artemia* are critically dependent on environmental factors. This extremely euryhaline animal grows well when the salinity, temperature and pH are favorable. The effects of these water quality parameters on the survival, reproduction and morphology have been studied by many authors. A study found that the survival temperature of *Artemia* is ranging from 15 ℃ to 55 ℃ [9]. Cyst hatching output is greatly compromised at pH below 5 [10]. The effect of pH on the hatching percentage, survival and reproduction of *Artemia* strains was studied [11]. *Artemia* can withstand salinity 3 ppt to 300 ppt [9]. Under laboratory condition, development of *Artemia* at salinity 35 ppt showed a good result in the experiment [12]. In the present study, the culture was done at a salinity of 35 ppt, showed a good result in survival, development and hatching output of *Artemiafranciscana*. Temperature (26.4 ℃ to 31.5 ℃) and pH (7.4 to 7.7) were also optimum during the study period.

In the present study, *Artemia* reached the adult stage on the 20th day and the adults were 8.46 ± 0.07 mm in length. When *Artemia* was cultured in salt ponds it reached adult stage in 16th to 19th days [13]. *Artemia* reached adult stage on the 19th day at salinity 20 ppt and on the 18th day at salinity 45 ppt [14]. *Artemia* reached adult stage on the 13th day with a body length of 11.86 ± 0.09 mm when cultured in natural sea water [12]. Another study observed that *Artemia* living in natural environment was usually smaller than laboratory reared [15]. Most of the report says that the adult *Artemia* size was 10 mm. However, *Artemia* reached 12 mm when it was reared in sea water followed by brackish water (9 mm) and freshwater (4 mm) [16].

The differences in hatching efficiency and hatching percentage of cysts are noticeable where more nauplii hatched out from the decapsulated cysts than the untreated cysts since the nauplii had to spend less energy to hatch from the cysts. The decapsulated cysts contain muchhigher energy content, since they do not have to expend energy in breaking out of shell [17]. If the decapsulated cysts are incubated for hatching as instarInauplii, the hatchabilityis also improved, again because no shell breakout is required. However, the number of hatched nauplii determining the hatching efficiency and hatching percentage are sensitive to environmental factors and varying condition prior to and at cyst harvesting, cyst processing and storage [18, 19].

A study observed 17 populations where the mean diameter for chorionic cysts ranged from 221.0 µm to 284.9 µm, and the values for decapsulated cysts ranged from 208.2 µm to 258.8 µm, with the chorionic thickness ranged from 4.7 µm to 13.3 µm [20]. The mean diameter for chorionic cysts ranged from 247.63 ± 11.47 µm to 259.34 ± 11.36 µm; and the values for decapsulated cysts were 231.29 ± 10.43 µm to 251.6 ± 11.24 µm, with the chorionic thickness ranged from 1.31 µm to 9.37 µm were found [21]. A study found the mean diameter for untreated cysts ranged from 262.7 µm to 286.6 µm, decapsulated cysts ranged from 258.6 µm to 274.4 µm, with the chorionic thickness ranged from 1.2 µm to 9.3 µm [22]. In the other study of the same population, the mean diameter of untreated and decapsulated cysts ranged from 249.8 µm to 280.7 µm and 218.4 µm to 259.8 µm, respectively. The chorionic thickness ranged from 2.7 µm to 15.6 µm. The variation between the mean diameter of untreated and decapsulated cysts, as well as, in chorionic thickness may be due to the cause of seasonal fluctuation in physico-chemical parameters and food availability [23]. These differences may be found in a site at different periods of time [21].

The present study on determining survival rate indicates that under laboratory condition a salinity of 35 ppt can greatly influence the survival of *Artemiafranciscana.*

5. Conclusion

At present, Bangladesh is showing better performance in aquaculture and day by day the land occupied by aqua farming is increasing with the increasing of protein demand. Since most fish and shrimps rely on live diets in the early larval stages, there is always a need for nutritious diets. Among those live diets, *Artemia* has become the most reliable and absolutely necessary food items. Study revealed that the modified salt beds of Bangladesh can successfully be used for culturing *Artemia* during winter months [6]. But the question remain sunanswered whether the culture of *Artemia* only during winter months will meet the requirement for live diets or not? Apparently, the aquculturists must focus on indoor hatching process of *Artemia*. Furthermore, the culture of *Artemia* is easy and requires fewer materials. The aquaculturists can easily feed their fish larvae with newly hatched nauplii, decapsulated cysts, dry cysts in powdered forms and also adults, according to the nutritional requirements.

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