Post Graduate Award

Two – Day Conference

25th & 26th October 2012

Conference Proceedings

MAURITIUS RESEARCH COUNCIL

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POST GRADUATE AWARD CONFERENCE

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at

Mauritius Research Council
Level 6, Ebène Heights,
34, Cybercity, Ebène

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FOREWORD

One of the objectives of the Mauritius Research Council is to 'foster, promote and co-ordinate research and development in all spheres of scientific, technological, social and economic activities'. The Council operates and funds a number of Research Grant Schemes to meet the above objective. One of them is the Post-Graduate Award (PGA) Scheme.

The PGA scheme was launched in 2005 and targets both unemployed and employed graduates to undertake part-time research studies at a local tertiary education institution, leading to an MPhil or PhD across a range of disciplines. These include: Ocean Technology and Marine Resources, Energy Efficiency and Renewable Energy, Waste Management and Waste Recycling, Biomedical and Biopharmaceutical Research based on indigenous resources, Science and Technology Education, Social and Economic Issues, Information & Communication Technology, Land & Land Use, Manufacturing Technology, Water Resources and Financial Services.

Currently, there are 28 registered awardees pursuing their research studies across the above mentioned disciplines. In October 2012, a PGA Conference was organised to provide these awardees with a platform to present their progress so far. They were assessed on a series of criteria and the best presentations were rewarded.

Presenters were also required to submit short papers of their presentations. These have been edited and compiled into this conference proceedings. This document is a collection of 20 research papers which will be disseminated.

I wish to end by thanking all those involved in this event; the awardees, their supervisors, the assessors and the staff of the Council who have all contributed to making the first MRC PGA Conference a success.

Dr A Suddhoo
Executive Director
Mauritius Research Council

SESSION 1 – BIOMEDICAL & BIOPHARMACEUTICAL

PRESENTATION 1

Contribution of the positional candidate gene *OXR1* to premature coronary heart disease and to type 2 diabetes in the Mauritian population

Mrs N Sem Fa

University of Mauritius

Mrs N Sem Fa is a PhD student in the Department of Medicine at the University of Mauritius. She received her BSc (Hons) First Class in Biomedical Sciences from the University of Mauritius. She was awarded a MRC postgraduate scholarship and her thesis is on the search for genetic factors to both premature coronary heart disease and Type 2 diabetes in the Mauritian population, more specifically in the 8q23 chromosomal region.

Introduction

Coronary heart disease (CHD) mortality in Mauritius is among the highest in the World (Vos et al, 1998). In 2006, 21.7% of total deaths in the Mauritian population were attributed to cardiovascular diseases. According to epidemiological survey carried out in 2009, prevalence of Type 2 diabetes (T2D) among adults aged 30-74 years in the Mauritian population was 26.9% (NCD report, 2009). Diabetic patients have a two to four times increased risk of developing cardiovascular diseases and a four-fold risk for CHD death (Haffner & Cassels, 2003).

CHD and T2D are both complex diseases involving interactions between genetic and environmental factors. Previous genome scan carried out in around 100 Mauritian families of North Indian origin had revealed several chromosomal regions that showed evidence for linkage to CHD (Francke et al, 2001) and these regions overlapped with chromosomal

regions that have been linked to type 2 diabetes in other populations. One particularly interesting chromosomal region was reported in the 8q23 region where microsatellite markers co-segregated with premature CHD, T2D and hypertension in the studied population (Francke et al, 2001)

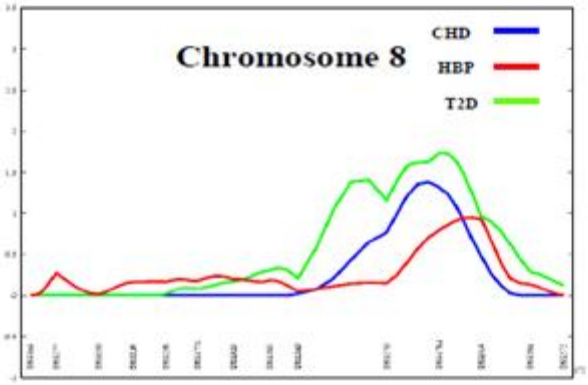


Figure 1 Multipoint analysis results for chromosome 8 showing overlapping between qualitative traits CHD, T2D and HBP in the Mauritian genome scan
(Maraj, 2002)

Within the 8q23 chromosomal region, there are several potential candidate genes for CHD and/or type 2 diabetes, which seem interesting, based on the biological functions of their proteins. Among them is the oxidation resistance 1 (*OXR1*) gene encoding for the oxidation resistance 1 protein. The expression of this gene was found to be induced by oxidative stress and the protein is involved in the protection against oxidative damage when localized in the mitochondria (Volkert et al, 2000).

Given the growing body of evidence that links oxidative stress to the pathophysiology of CHD (Ceriello & Moetz, 2004) and T2D (Gopaul et al, 2001), the *OXR1* gene appears as the best positional candidate gene in the 8q23 region.

Aim of the study

Our main objective was to investigate the contribution of the positional candidate gene OXR1 to susceptibility to premature CHD and/or to T2D in the Mauritian population.

Methodology

We used a population-based case control design to test for association between single nucleotide polymorphic (SNP) variants in the *OXR1* gene and CHD and /or T2D in a

Mauritian population of North Indian origin. Ethical clearance for the *OXR1* study was granted by the National Ethics Committee of the Ministry of Health & Quality of Life (Ref: MHS 458/33) in 2005.

Study samples

DNA samples used were from pre-existing resources collected between 1995 and 1997 for the study of premature CHD and the metabolic syndrome at the SSR Centre. CHD patients were recruited from two cardiac outpatient departments of the Ministry of Health, at the Victoria Hospital and SSR National Hospital. Controls were recruited among workers of several sugar estates.

The North Indian (NI) case-control groups selected from the original phenotypic databases included Muslims and Hindus from the Indo-Mauritian community, whose ancestors shared the same geographic origin, having migrated from the port of Calcutta in the North of India. This ensured a homogenous genetic background in our study population.

The patients group included 368 unrelated NI patients (294 men, 74 women) affected by premature CHD with or without T2D.

CHD status was characterized in previous study (Manraj, 2002) as being positive, based on the following criteria:

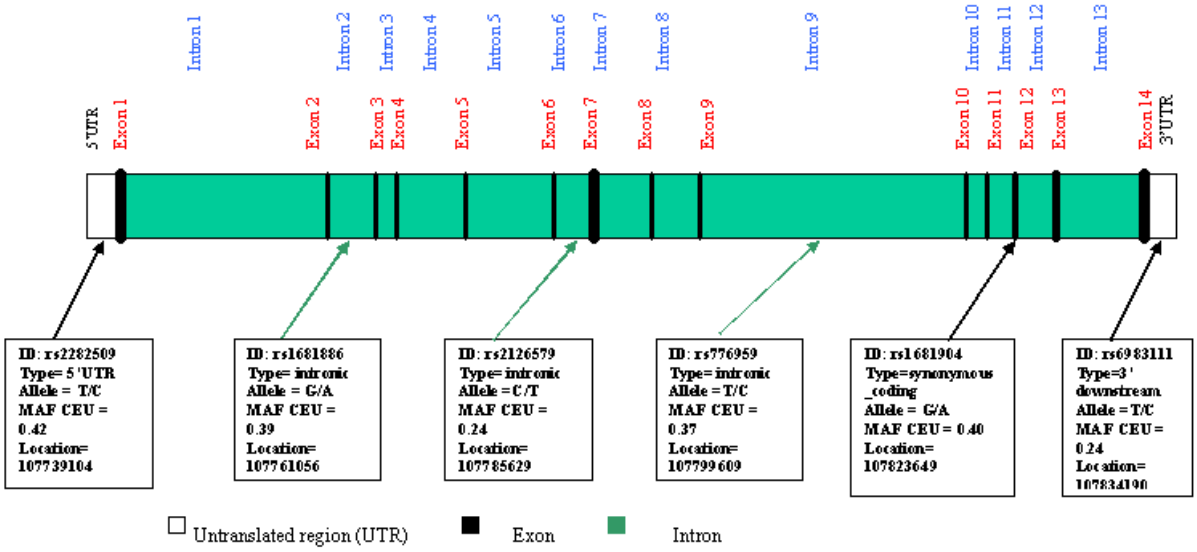
- Previous diagnosis of myocardial infarction
- History of revascularization procedures such as angioplasty or coronary artery bypass
- Following treatment for angina pectoris
- Glucose metabolism status was defined, based on fasting plasma glucose (FPG) and 2-hour plasma glucose values (2HPG), and on past history of type 2 diabetes, using the ADA 1997/WHO 1999 criteria (Gabir et al, 2000)
- Normal glucose metabolism: FPG **<**6.1 mmol/l and 2HPG < 7.8 mmol/l .
- Impaired fasting glucose metabolism (IFG): 6.1 < FPG < 7.0 mmol/l and 2HPG < 7.8 mmol/l
- Impaired Glucose Tolerance (IGT): FPG < 7 mmol/l and 7.8 < 2HPG < 11.1 mmol/l

- Type 2 Diabetes (T2D) if having a previous history of diabetes or FPG ≥ 7.0 mmol/l or 2HPG≥ 11.1mmol/l

The control group included 252 unrelated healthy NI individuals (160 men, 92 women) who do not show signs and symptoms of CHD and have a normal glucose metabolism (i.e. without T2D or IGT), confirmed by an oral glucose tolerance test.

SNP Genotyping

Using public available Ensembl Genome Browser and SNP browser, 6 SNPs were chosen so as to span the whole *OXR1* gene from the 5'upstream-untranslated region to the 3' downstream-untranslated region.



Genotyping was performed using pre-designed TaqMan SNP genotyping assay kits (Applied Biosystems, Foster City, CA). All PCR reactions were carried out in the Department of Biotechnology at the Mauritius Sugar Industry Research Institute (MSIRI) using a real-time PCR system (MJ 42 Research PTC 200, Chromo4 System). PCR conditions included an initial denaturation of 10 minutes at 950C, followed by 40 cycles of (denaturation at 950C for 15 seconds and primer annealing/extension at 600C for 1 minute) and a final extension of 5 minutes at 600C. 10% of the total no of samples genotyped were replicated and the results of quality control were 99.5% in agreement with the initial genotyping results.

Statistical analysis

Among the 6 SNPs genotyped, SNP rs2126579 yielded unreliable genotyping results and was thus excluded from our statistical analysis. Statistical analyses were carried out using EpiInfo™ (Version 3.4.1, CDC, Atlanta, July 2007).

We tested for deviation from Hardy-Weinberg Equilibrium (HWE) using the Pearson's Chi-Square goodness of fit test to check for genotyping errors or population stratification.

Allele frequencies and genotypes were compared using the Yates corrected Chi-Square test. Odds ratios (OR) and Cornfield 95 % confidence limits (95% CI) for OR were given for 2 x 2 contingency tables. Tables were stratified by sex so as to detect possible differences between genders in association between genotypes and phenotypes. Gene-gender interaction was searched for, by comparing 2x2 tables, using Mantel-Haezel Chi-square tests. We considered a p-value of <0.01 to be statistically significant after Bonferroni correction for multiple testing.

Individual SNP analysis was carried out for each of the 5 *OXR1* SNPs to look for association with premature CHD, T2D. When association or trend of association was observed, we further studied the associated SNP(s) in relation with risk factors for CHD and T2D which included the different components of the metabolic syndrome.

The SNPs were also analyzed in haplotypes for association with CHD and/or T2D using Haploview v3.32 software (Broad Institute, Cambridge, USA; June 2006).

Results

No difference in allelic frequencies was observed in both male and female groups except for SNP rs776959 (Table 1). The frequency of the common T allele was significantly higher in female CHD compared to female controls (CHD 69% v/s CT 58%; OR=1.63, 1.01<OR<2.64, p=0.045).

Similar trends were found when allele frequencies were compared in T2D patients and controls. Allele T of SNP 776959 was more frequent in diabetic women compared to women controls (OR=1.84, 1.05<OR<3.23, p=0.03) whereas in men the allelic frequencies were similar in diabetics and controls (OR=1.17, 0.80<OR<1.70, p=0.45).

Table 1: Comparison of allelic frequencies for the different OXR1 SNPs between CHD and control groups

SNP	Allele	NI Male (M)				NI Female (F)			
		CHD n=294	CT* n=160	OR (95% CI)	P value	CHD n=74	CT* n=92	OR (95% CI)	P value
		Allele frequency				Allele frequency			
rs2282509	C T	0.48 0.52	0.46 0.54	1.09 (0.82-1.45)	0.57	0.47 0.53	0.42 0.58	1.25 (0.79-1.97)	0.38
rs1681886	G A	0.43 0.57	0.40 0.60	1.15 (0.86-1.53)	0.37	0.34 0.66	0.36 0.64	0.92 (0.57-1.48)	0.8
rs776959	T C	0.65 0.35	0.63 0.37	1.1 (0.80 -1.47)	0.57	**0.69** **0.31**	**0.58** **0.42**	**1.63** **(1.01-2.64)**	**0.045**
rs1681904	G A	0.49 0.51	0.53 0.48	0.88 (0.66-1.17)	0.4	0.53 0.47	0.56 0.44	0.9 (0.57-1.42)	0.72
rs6983111	T C	0.14 0.86	0.15 0.85	0.98 (0.66-1.47)	1.0	0.20 0.80	0.14 0.86	1.62 (0.87-3.01)	0.14

**Controls were individuals with no signs and symptoms of CHD and with a normal glucose metabolism (ie. without impaired fasting glucose or impaired glucose tolerance)*

Genotype analysis showed no association between the 5 SNPs and CHD in men. In women, a trend of association was observed between SNP rs776959 and CHD (Chi-square=6.50, p=0.039) and no association with the other 4 SNPs (Table 2). Similar trends of association were observed with T2D in women (Chi-square=7.69, p=0.02).

We found that NI women with homozygous TT genotype had an increased risk of CHD (OR=2.28, 1.20<OR<4.32; p-value=0.017). Moreover, the heterozygous CT genotype tended to have a protective effect to CHD risk in the same female group (OR=0.52, 0.28<OR<0.98; p=0.06). When the male and female groups were compared, an interaction was found between gender and homozygous TT genotype (Chi-square=3.8, p=0.05) and heterozygous CT genotype (Chi-square=3.2, p=0.07) on CHD.

Similarly, homozygous TT genotype was found to confer a higher risk for T2D in women (OR: 2.72, 1.33<OR<5.58; p=0.0097) and a trend towards a protective effect of the heterozygous CT genotype on T2D in the female group only (OR: 0.45, 0.22<OR<0.91;

p=0.04). In addition, interactions were observed between gender and TT genotype (Chi-square=4.0, p=0.046) and CT genotype (Chi-square= 3.93, p=0.047) on T2D.

Similar trends were observed when SNP rs776959 genotypes were analyzed in relation to the metabolic syndrome and its different components (Table3).

Table 2: Study of OXR1 SNPs genotypes in relation to CHD

		NI Male			NI Female		
SNP	Genotype	CHD n=294	CT * n=160	p-value	CHD n=74	CT* n=92	p-value
rs2282509	CC CT TT	21.8% 53.4% 24.8%	23.1% 46.3% 30.6%	0.30	20.3% 54.1% 25.7%	18.5% 46.7% 34.8%	0.45
rs1681886	GG GA AA	18% 50% 32%	15% 49.4% 35.6%	0.61	12.2% 44.6% 43.2%	13% 46.7% 40.2%	0.92
rs776959	TT TC CC	41.8% 46.3% 11.9%	40% 45.6% 14.4%	0.74	**48.6%** **40.5%** **10.8%**	**29.3%** **56.5%** **14.1%**	**0.039**
rs1681904	GG GA AA	23.8% 51% 25.2%	28.8% 47.5% 23.8%	0.51	27% 52.7% 20.3%	32.6% 46.7% 20.7%	0.70
rs6983111	TT TC CC	2.4% 24.1% 73.5%	1.9% 25.6% 72.5%	0.89	1.4% 37.8% 60.8%	0% 27.2% 72.8%	0.17

**Controls were individuals with no signs and symptoms of CHD and with a normal glucose metabolism (ie. without impaired fasting glucose or impaired glucose tolerance)*

Table 3: Study of SNP rs776959 in relation with metabolic syndrome and associated traits in women

Phenotype	SNP rs776959 Genotype	NI Female		
MSIDF		MSIDF n=57	No MSIDF n=109	p-value
	TT TC CC	50.9% 40.4% 8.8%	31.2% 54.1% 14.7%	0.04
COIDF		COIDF n=91	No COIDF n=73	
	TT TC CC	39.6% 46.2% 14.3%	37.0% 53.4% 9.6%	0.54
TGIDF		TGIDF n=43	No TGIDF n=123	
	TT TC CC	53.5% 37.2% 9.3%	32.5% 53.7% 13.8%	0.05
HDLIDF		HDLIDF n=126	No HDLIDF n=39	
	TT TC CC	40.5% 48.4% 11.1%	28.2% 53.8% 17.9%	0.29
HBPIDF		HBPIDF n=78	No HBPIDF n=85	
	TT TC CC	46.2% 46.2% 7.8%	30.6% 52.9% 16.5%	0.06

MSIDF=metabolic syndrome, COIDF= central obesity, TGIDF= hypertriglyceridaemia, HDLIDF= low HDL cholesterolaemia, and HBPIDF= hypertension, as defined by the International Diabetes Federation, IDF (2002).

Among the five SNPs analyzed, we identified 7 haplotypes in men and 5 haplotypes in women with frequency >0.01 (Table 4). Haplotype analysis showed that the most frequent haplotype in men was haplotype H1 - CGTAC (0.3815) as compared in women where the most frequent one was haplotype H2 - TACGC (0.366). In addition, the haplotype H2 was associated with a decreased risk of CHD in women (OR: 0.60, 0.3<OR<0.96, p=0.025). Comparing the elements of the protective haplotype H2 with the other haplotypes in women, the C allele of SNP rs776959 seemed to be the protective determinant to CHD.

Table 4: Haplotypes in *OXR1* gene with frequency >0.01 in NI case-control group

		Male					Female				
Haplotype	SNPs 12345*	Frequency		χ^2	OR (95%CI)	P value	Frequency		χ^2	OR (95%CI)	P value
		CHD	CT				CHD	CT			
H1	CGTAC	0.387	0.376	0.101	1.05 (0.79-1.40)	0.751	0.340	0.346	0.012	0.97 (0.60-1.57)	0.913
H2	**TACGC**	0.320	0.347	0.704	0.88 (0.66-1.18)	0.401	**0.307**	**0.425**	**5.02**	**0.60 (0.37-0.96)**	**0.025**
H3	TATGT	0.139	0.152	0.29	0.90 (0.61-1.34)	0.590	0.187	0.122	2.69	1.65 (0.87-3.13)	0.101
H4	CATAC	0.083	0.073	0.341	1.18 (0.70-2.02)	0.559	0.120	0,064	3.255	2.0 (0.88-4.59)	0.071
H5	TGTAC	0.019	0.009	1.362	2.22 (0.59-12.34)	0.243	-	-		-	-
H6	TATGC	0.008	0.021	2.721	0.39 (0.10-1.43)	0.099	0.020	0.011	0.502	1.90 (0.21-2.96)	0.479
H7	TGCGC	0.016	0.004	2.665	5.56 (0.78-242.2)	0.103	-	-	-	-	-

** SNP 1: rs2282509 SNP 2: rs1681886 SNP 3: rs776959 SNP 4: rs1681904 SNP 5: rs6983111*

Discussion & Conclusions

It has been suggested that the candidate gene approach may be a practical and logical strategy to look for genetic variants influencing susceptibility to complex diseases including CHD or T2D (Tabor et al, 2002). We chose the Oxidation Resistance 1 gene as our best candidate gene in the 8q23 chromosomal region, given the increasing role attributed to oxidative stress in the pathophysiology of CHD (Ceriello & Moetz, 2004) and T2D (Gopaul et al, 2001).

Our study shows a trend of association between *OXR1* gene variant rs776959 and both CHD and T2D in our female population of North Indian origin but not in the male population. This trend of association is confirmed in haplotype analysis where the C allele (minor allele) of the variant within haplotype H2 is found to be associated with a decrease risk of CHD and T2D in women.

Up to now, no study has reported an involvement of the OXR1 gene in the pathogenesis of any disease. Haplotype analysis and individual SNP analysis in our study provide evidence of a gender-specific contribution of the OXR1 gene variant rs776959 to susceptibility to CHD, T2D and metabolic syndrome. Odds ratio of carrying TT genotype was 2.28 (95% CI=1.2-4.32) for CHD and 2.72 (95% CI = 1.33-5.58) for T2D in women, suggesting a significant effect size of SNP rs776959 in our female population, which might explain the nominal linkage signal obtained for both CHD and T2D in chromosome 8q23 in previous genome scan (Francke et al, 2001).

However, because of our small female sample size, we cannot exclude the possibility that odds ratio may have been overestimated (Nemes et al, 2009). This could be addressed by replicating this study in a larger female case control group of same ethnic origin (i.e. North Indians). Replication studies in other case control groups of different ethnic origin (namely South Indians) would also be interesting to confirm our findings. Even if association is validated in the replication studies, at this stage, we cannot speculate whether this SNP is the causal variant or whether it is in strong linkage disequilibrium with another unidentified variant located near. Further studies such as resequencing within region of the associated variant are needed to shed more light on the involvement of the OXR1 gene in the pathogenesis of CHD and Type 2 diabetes in women.

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PRESENTATION 2

Investigation into the textile potential of fibres extracted from '*Pandanus utilis*' leaf fibre

Mrs A V Soocheta

University of Mauritius

Mrs A V Soocheta is presently a Lecturer in the Department for Applied Sustainability and Enterprise Development, Faculty of Engineering at the University of Mauritius since 2001. Prior to that, she was lecturing at the College of Home Science, Textile and Fashion Technology Department, Bombay University, Mumbai, India since 1982. She was also associated as a visiting faculty at The National Institute of Fashion Technology in Mumbai, India (1996-2000) and Mauritius (2008-2009). Mrs A V Soocheta holds an M.Phil.(Home Science) degree. She is currently pursuing a Ph.D on 'Investigation into the Textile Potential of *Pandanus Utilis*'.

Introduction

Mauritius is a rich country in terms of indigenous plant density. Developing textile applications for a new or underused fibre is always valuable, especially when the fibre is natural and indigenous. The '*Pandanus utilis*' plant is commonly known as 'Vacoas', in Mauritius (Protabase Record display, no date). Originated in Madagascar and Mauritius, 'Vacoas' is a tropical tree, pyramidal, sometimes irregular and open, with a much-branched silhouette as in Figure 1. Large brace roots emerge from the trunk, several feet above the ground, helping to support the plant. It is capable of reaching 60 feet in height, but is not usually seen over 25 feet, with a spread of 15 feet. Growth rate is slow to moderate, depending upon fertilization and watering schedules (Plant Files: Detailed information on

Pandanus utilis, 2001). The fruit of *Pandanus utilis* as seen in Figure 2 is edible, although not flavourful to humans. The smooth, stout trunks are topped with full, graceful heads of long, thin leaves, 3 feet long and 3 inches wide, emerging spirally from stubby branches. The leaves are linear and edged with small red spines, with a spiral arrangement on the tree. The leaves of young un-branched trees are long and supple, whereas the leaves of older branched trees are rigid (Protaphase Record display, no date).

Care must be taken when handling the leaves because of their sharp spines (Tropical Plants Library Online, 1997). The leaves of *Pandanus utilis* have a spongy tissue with abundant fibres in bundles which may contain over 150 fibres.

Figure 1: '*Pandanus utilis*' plant, commonly known as 'Vacoas'

Scientific Classification

Binomial name:	*Pandanus utilis*
Kingdom:	Plantae
Division:	Magnoliophyta
Class:	Liliopsida
Order:	Pandanales
Family:	Pandanaceae
Genus:	Pandanus
Species:	P. utilis
Common name:	Pandano, Vacoas (Wikipedia, 2011)

Protologue: Voy. îles Afrique 2: 3 (1804)

Chromosome number: 2*n* = 60

Synonyms: *Vinsonia utilis* (Bory) Gaudich (1841)

Vernacular names: Common screw pine (En). Vacoa, baquois, vaquois (Fr). Pandano (Po)

Figure 2: Flowers, Fruit, Dried leaves (Tropical Plants Library Online, 1997**)**

The leaf plant tissues must undergo partial degradation before the fibres are mechanically extracted. They can be removed from the leaf by some form of decortication process. This allows the clean fibre bundles to be separated from the other leaf material more easily. A process commonly employed to separate fibres is 'retting', which is a process of submerging the leaves in water and soaking them for a period of time to loosen the fibres from the other components. Bacterial action attacks pectin and lignin, freeing the cellulose fibres to dissolve or rot away much of the cellular tissues and pectin surrounding fibre bundles, thereby facilitating separation of the fibres. They are then removed, washed, subjected to mechanical processing to remove the soft tissue and then dried. *Fibres* can also be *extracted* by *chemical* or enzymatic retting *processes.* Decortication processes vary and could use automated machinery which subjects the plant to mechanical stresses that physically rupture the bond between the fibres and the cortex. The machine then separates the fibres from extraneous matter. A process employing a combination of retting and decortication machinery may also be used to obtain fibres.

Objectives

- To investigate and optimise the extraction processes of fibres from dry and fresh *Pandanus utilis* leaves
- To investigate and devise mechanism for extraction of fibres from fresh leaves
- To analyse the leaf and fibre composition
- To study the physical characteristics and properties of the extracted fibres

- To study the scouring, bleaching and dyeing performance of fibres
- To investigate the conversion of fibres into yarns, cords and ropes
- To utilise the fibres for developing diversified products

Methodology

1. Extraction of fibres from *Pandanus utilis* leaves

Dry and fresh *Pandanus utilis* leaves were chosen for fibre extraction. The dry leaves that had reached maturity and fallen off the tree were collected. Fresh green leaves were gripped with gloved hands and pulled off the sheath end that is clasped at its base to the branch.

Mechanical decortication of dry leaves: Decortication process that show potential to extract fibres with high fibre yield was carried out to separate fibres and remove non-cellulosic material like lignin and pectin. Experiments were conducted under ASTM standard conditions; 20°C ± 2°C and 65% ± 2% R.H. Dry leaves were first measured lengthwise and weighed. The extracted fibres were oven dried and weighed to calculate the percentage yield for each method. The following experiments were carried out for separating the fibres from extraneous matter.

- Hand stripping
- Boiling in water
- Steaming in pressure cooker and steamer (Figure 3)
- Water retting (Figure 4)
- Retting using solar cooker (Figure 4)

Various tools, mallets, hand scraper blades, carder combs and brushes (as in Figure 5) were used to aid decortication and ease separation the fibres from the leaves.

Figure 3: Pressure cooker and steamer **Figure 4: Water and solar cooker retting**



Figure 5: Tools for decortication

Chemical and Enzymatic decortication: Chemical decortication was carried out with treatments using Sodium Hydroxide and Hydrogen Peroxide. Enzymatic decortication was experimented with alkaline pectinase, acidic pectinase and enzyme mixture.

Decortication of fresh leaves: Possible use of an existing hard fibre extracting machine of 'raspador' type was investigated for extracting fibres from *Pandanus utilis* leaves. Trials were carried out on a sisal fibre extraction raspador machine. Modifications were then made so that the machine could be suitable for extraction of fibres from *Pandanus utilis* leaves. Alterations, adjustment and calibrations were also made to the decorticator machine (Figure 6) to maximise percentage of fibre yield from fresh leaves.

Figure 6: Modified raspador fibre extraction machine for *Pandanus utilis leaves*

2. Characterization of fibre

Longitudinal and cross section of fibre: The morphological study of fibres extracted by various methods was studied with Scanning Electron Microscope (SEM). Orientation of fibres together with information concerning the nature of the bond between the fibre matrix interfaces was studied. Fourier transform infrared spectroscopy (FTIR) was used to investigate the chemical composition and analyse chemical changes during extraction.

Composition of leaf: The leaf was analysed using procedures referred in the Bureau of Indian Standards. Table 1 gives the protocols used to determine its composition.

Composition of the fibre: Lignin, alpha-cellulose, beta-cellulose and gamma-cellulose content of the extracted fibres were determined using TAPPI Standard (Reaffirmation of T222 om-06).

Table 1: Protocol for testing leaf composition

Test	References for the protocol
Moisture	BIS-7874 Part I
Fats	BIS-7874 Part I
Proteins	BIS-7874 Part I
Crude fibre	BIS-7874 Part I
Ash	BIS-7874 Part I
Carbohydrates	Wt of sample (g) - (Wt of protein (g) + Wt of fat (g))
Calories	BIS-7874 Part I
Calcium	BIS-7874 Part II
Sodium	By Flame Photometer
Iron	By AAS(Atomic Absorption Spectroscopy)
Iodine	BIS-7874 Part II

Tensile strength: Instron Model No: 4411 as in Figure 7 was used to determine the strength of the extracted fibres.

Figure 7: Instron Model No: 4411

Anti-bacterial activity: The fibres were tested for their anti-bacterial activity using the organism *Staphylococcus aureus* strain 3570 gram positive**.** Standard test method and evaluation procedures, compiled in the *American Association of Textile Chemists and Colorists – AATCC* 100 *were used.*

3. Scouring, bleaching, dyeing

The fibres were scoured to remove impurities and obtain cleaner fibres. They were bleached with sodium hypochlorite and hydrogen peroxide. They were dyed with direct, basic, acid, reactive, and vat dyes analogous to most commonly used dyes of cellulosic fibres. The amount of dye absorbed on the fibre and percentage fixation was calculated. The dyed fibres were evaluated for the depth of colour by reflectance method using 10 degree observer. The absorbance of the dyed samples was measured on Rayscan Spectrascan 5100+ equipped with reflectance accessories. The K/S values were determined. Evaluation of colour fastness to washing was carried out using ISO II methods (Trotmann, 1984) Dyed fibres were tested for colourfastness to light according to ISO 105/B02.

4. Yarn formation

Various conventional and unconventional techniques were experimented to convert fibres into yarns. The fibres were spun using simple tools such as a drill with hook, twirler, drop spindles and charkha as in Figure 8. Electric spinning machine (Figure 9) was also used. Single and ply yarns were made using Leonardo rope maker as in Figure 10. Fancy cords and ropes can be made with this rope maker, ranging from two to five ply yarns. The rope maker can be operated by hand or power drill with speed control.

Figure 8: Tools for spinning

Figure 9: Electric spinning machine

Figure 10: Yarn making

5. Diversified Product Development

Design through making approach was adopted for developing varied products. This process of design through making used craft knowledge as facilitator to develop and experiment products. Various craft techniques were introduced to use the fibres and make innovative prototypes. A wide variety of home products and fashion accessories were crafted that could serve as souvenirs. Braiding, weaving, twisting, coiling, macramé, crochet, matting (as in Figure 11) and other miscellaneous handcraft techniques were introduced.

Figure 11: Craft techniques

Results and Discussions

1 Extraction of fibres from *Pandanus utilis* leaves

Fibres can be extracted from both dry and fresh leaves. Mechanical decortication is labour intensive and is a slow tedious process of separating fibres by hand. It requires considerable amount of space and the waste material accounts for 95- 97% of the original weight of the leaves. Six to eight weeks were required for the fibres to be separated from the extraneous matter by water retting. The fibres can also be extracted by successfully by chemical decortication. Enzymatic decortication did not give satisfactory results and the fibres could not be separated easily as with water retting. Trials with *Pandanus utilis* fresh leaves using the modified prototype ensured that the machine operated correctly and safely. The machine executed a high yield and observations showed that the fibres extracted are clean and superior in terms of length, feel and colour. The fibre extraction machine gave a yield of 5 %. Steaming the leaves in a pressure cooker prior to extraction increased the fibre yield.

2 Characterization of fibres

Longitudinal and cross section of fibres: Figure 12 and 13 present the longitudinal and cross sections of mechanically removed fibres from fresh leaves by using the Scanning Electron Microscope.

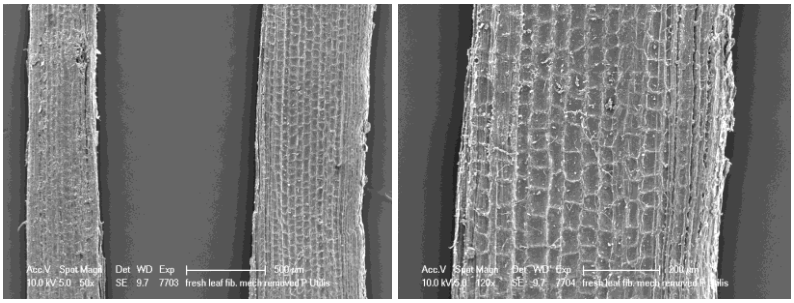

Figure 12: Longitudinal section of fibres removed mechanically from fresh *Pandanus utilis* leaves

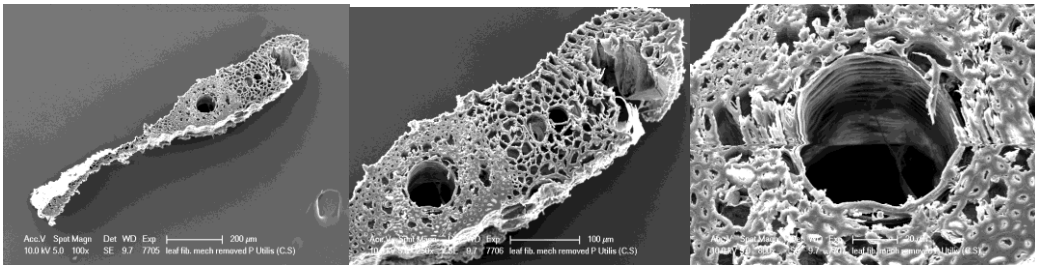

Figure 13: Cross section of fibres removed mechanically from fresh *Pandanus utilis* leaves

Composition of leaf: The results of the composition of the leaf are summarized in Table 2. It can be seen that the crude fibre accounts for 10.0%.

Table 2: Leaf composition

Test	Results
Moisture	73.55%
Fats	0.59%
Proteins	2.07%
Crude fibre	10.0%
Ash	1.72%
Carbohydrates	12.03%
Calories	62Kcal/100
Calcium	0.43%
Sodium	0.057%
Iron	0.008%
Iodine	Nil

Composition of fibres: The fibre is found to be lingo-cellulosic in nature containing 24% lignin. The cellulose content comprised 55% alpha cellulose, 21% beta cellulose and 24% gamma cellulose. Figure 14 shows a superimposed graph of the FTIR analysis of mechanically removed and retted *Pandanus utilis* fibres

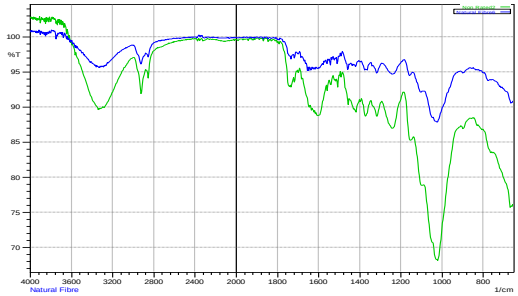

Figure 14: Superimposed Graphs of the FTIR Analysis of Mechanically Removed and Retted *Pandanus utilis* Fibres

Tensile strength: Table 3 shows that the wet strength is greater than the dry strength. It indicates that as the duration of water retting increases, the strength of fibre bundles is reduced.

Table 3: Water retting dry leaves

Duration	**Tensile strength**	
	Load (kg)	**Extension (mm)**
3 week retting	10.6757	3.113
6 week retting	7.15	2.774
Mechanically removed dry fibres	10.30764	4.932727
Mechanically removed, wet soaked for 30 min	11.14418	5.063636

Antibacterial activity: Table 4 shows the results of the antibacterial activity as 80.88%. Percentage Reduction = (A-B)/A X 100; A is the number of bacteria at 0 time contact with fibres and B is the number of bacteria after 24hrs time contact with the fibres as seen in Figure 15.

Table 4: Antibacterial activity *Staphylococcus aureus* strain 3570 Gram positive

Pandanus utilis fibres	0 hrs Contact (A)	24hrs Contact (B)	% Activity= (A-B)/A X 100
Number of Bacteria	272	52	80.88

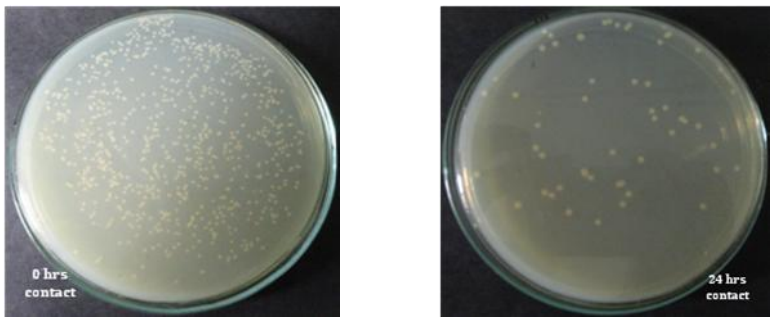

Figure 15: Number of bacteria

3 Scouring, bleaching, dyeing

The fibres were subjected to pre-treatment processes namely scouring and bleaching. Scouring loss was found to be 18 %. After bleaching the weight loss of 2 % was observed this might be because of discolouration and removal of lignin and natural colours in fibres. The fibres could be dyed with various colours and showed good colour depth and dye absorbance (Table 5). The dye fastness to light and washing were good (Table 6).

Table 5: Dyeing properties

Dye class	Dyes	% Shade	% Exhaustion	% Fixation
Direct dye	solar red 5BI	0.5	88.42	85.12
		1	89.76	85.20
		2	89.80	88.28
	solar blue 5GLNI	0.5	63.83	76.69
		1	66.37	78.72
		2	69.28	79.65
Reactive dye	Reactive Difix red RBX	0.5	27.43	84
		1	30.64	87.40
		2	31.71	88.91
	Reactive difix orange ME2RL	0.5	27.13	68.27
		1	29.85	69.16
		2	35.91	72.62
	Basic Rhodamine B	0.5	57.45	79
		1	58.62	79.65

	(blch)	2	58.33	82.22
	Basic Rhodamine B (raw)	0.5	65.88	82.79
		1	66.70	83
		2	67.03	87.32
Basic dye	Basic Victoria blue (blch)	0.5	75.61	80.39
		1	76.82	83.80
		2	78.64	84.06
	Basic Victoria blue (raw)	0.5	87.89	84.74
		1	90.54	85.95
		2	90.70	84.32
	Acid lan orange (blch)	0.5	42.48	83.54
		1	47.85	85.60
		2	54.78	85.50
	Acid lan orange (raw)	0.5	58.82	92.08
Acid dye		1	63.57	92.18
		2	66.71	94.11
	Acid Navy blue (blch)	0.5	77.78	79.11
		1	78.56	81.53
		2	77.57	80.35
	Acid Navy blue (raw)	0.5	83.65	91
		1	85.27	88.90
		2	85.85	93.50
Vat dye	Vat brill blue	0.5	26.90	70.22
		1	32.78	68.85
		2	63.72	71.11
	Vat brill violet	0.5	26.34	78.33
		1	28.14	82.19
		2	44.8	84.54

Table 6: Colour value & fastness properties

Dye class	Dyes	% Shade	Colour values K/S	Wash fastness		Light fastness
				Change in colour	Staining	
Direct dye	solar red 5BI	0.5	12.2779	2	2-3	4
		1	12.3804	1-2	1-2	5
		2	14.6899	2-3	1	6
	solar blue 5GLNi	0.5	4.8941	1-2	4-5	
		1	5.8284	2-3	3	3
		2	7.2259	3	3	5
Reactive dye	Difix red RBX	0.5	3.4883	2	4	6
		1	4.4535	3	3	5
		2	5.9770	3-4	1-2	6
	difix orange ME2RL	0.5	6.8765	2-3	2-3	5
		1	8.4003	3	3	6
		2	10.564	3	1-2	7
Basic dye	Basic Rhodamine B (blch)	0.5	16.1086	1	2	2
		1	17.1035	1-2	2-3	2
		2	25.5206	3	1	2
	Basic Rhodamine B (raw)	0.5	11.7197	1-2	2	2
		1	16.9223	2	2-3	2
		2	21.9467	3	1	2
	Basic Victoria blue (blch)	0.5	24.2035	4	3	2
		1	31.2035	4	2	2
		2	32.1208	4-5	1-2	2
	Basic Victoria blue (raw)	0.5	11.2038	3-4	3	2
		1	16.6758	2-3	2-3	2
		2	19.0767	3-4	1-2	3
	Acid lan orange (blch)	0.5	7.1503	3	4	6
		1	8.9971	2-3	4	6

Acid dye		2	13.3277	4	3	7
	Acid lan orange (raw)	0.5	4.7239	1-2	3-4	6
		1	7.3855	4	3	7
		2	11.8073	2-3	4	7
	Acid Navy blue (blch)	0.5	6.1789	1-2	3-4	3
		1	7.9064	2	4	5
		2	8.6245	2	4-5	6
	Acid navy blue (raw)	0.5	3.69	1-2	4-5	3
		1	5.2986	2-3	4-5	5
		2	7.5227	2-3	4-5	6
Vat dye	Vat navinon brill blue	0.5	3.8019	4-5	5	6
		1	4.2424	4-5	5	5
		2	4.5641	5	5	7
	Vat navinon brill violet	0.5	6.8567	4-5	5	5
		1	7.7274	4-5	5	6
		2	8.0402	5	5	7

4 Yarn formation

The fibre may be classified as a hard fibre but is pliable and long to be spun into yarns (Figure 10). Ply yarns were spun using various tools.

5 Diversified product development

The design through making approach was used to develop prototypes. It gave the freedom to introduce innovative designs and amalgamate various craft techniques. This method contributed in design development as well as product development. The craft object demonstrates reconciliation between its maker's visions and outlines opportunities and constraints presented by the chosen materials and processes. Various prototypes were developed as in Figure 16.

Utility Products

Figure 16: Fashion accessories and utility products

Conclusion

The project establishes various techniques and procedures for extracting the fibres from *Pandanus utilis* leaves. Fibres from dry leaves can be removed successfully by retting, mechanical and chemical processes. The decorticator eases the fibre extraction process for fresh leaves. Morphology, composition, physical characteristics and properties of the fibre reveals its high fibrous nature, flexibility and strength. The fibre possesses anti bacterial properties presenting its option as a potential material for geo-textiles. The bleaching and dyeing potential of the fibres can be successfully used to maximum advantage and add aesthetic value. Yarns can be spun effectively using conventional and unconventional techniques and tools. Ply yarns can be used to diversify the plant's prospective utility. Whilst promoting its use as a potential fibre for various commodities, the study outlines traditional craft techniques to develop creative products**.** Simple and easy procedures, methods and skills can be adopted to craft these products. Diversifying the use of *Pandanus utilis* fibres provides an enormous potential to contribute towards sustainability from an environmental or economic perspective. The project endeavours in preserving, developing and promoting this native material for arts and crafts that can serve as a natural resource for income generating projects. Successful exploitation of the fibres can generate employment and utilization of waste agro-resources for value addition. The research opens up new avenues to take advantage of this indigenously available 'Vacoas' plant for the

textile sector and can catalyse innovation in small and medium industries dealing with crafts and textiles.

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PRESENTATION 3

Effect of iron and folic acid fortification on the sensory (colour), chemical and rheological properties of plain white flour in the Republic of Mauritius.

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Introduction

Food fortification is defined as the addition of one or more essential nutrients to a food (Allen *et al*., 2006), regardless of whether they occur naturally in the food or not. This may include addition of nutrients not normally associated with the food or addition to levels above that present in the unprocessed food (Fennema, 1996). The purpose of fortification is to correct a recognised population-wide micronutrient deficiency. Fortified food products are value added products and can be used as a marketing tool by the food sector to increase sales. As the world's population is becoming increasingly dependent on cereals for food, cereals are gradually replacing the more expensive nutrient rich animal food sources in iron and vitamin A (Wesley and Ranum, 2004).

Rationale

In a study carried out in the Island of Rodrigues in 1998 by the Sir Seewoosagur

Ramgoolam Centre for Medical Studies and Research in collaboration with the University of Mauritius, it was found that iron deficiency anaemia is a significant health problem affecting 35% girls and 16.6% boys in the Island of Rodrigues. The long term strategy to combat this problem in Rodrigues as recommended in this study was to fortify wheat flour. The flour fortification programme was meant to be initiated in the Republic of Mauritius since Rodrigues obtains flour from Mauritius (Deo *et al*., 1998).

In nutrition surveys carried out by the Ministry of Health & Quality of Life, it was found that 10.9% of adolescents aged 12 – 19 years were anaemic in 2004 while 16.4% of the same age group of adolescents was found to be anaemic in 2009. It is noteworthy that for the year 2004 14.6% of babies born were of low birth weight and a relationship with anaemia could be suspected (MOH, 2004). Also, in Mauritius for 14623 live births for the year 2009, 16.7% were reported to be of low birth weight compared to that for the year 2008 which showed a figure of 15.0% (MOH, 2010)

The problem of low birth weight babies and anaemia is of concern as we observe that figures are on the rise. This situation is present although aggressive nutrition campaigns are carried out by authorities concerned and an increase in the standard of living of Mauritians is noted. Also, we wanted to be in line with the millennium development goals set by the United Nations in the year 2000. The United Nations Millennium Development Goals are eight goals that all 191 UN member states have agreed to try to achieve by the year 2015 (WHO, 2011). If fortification of wheat flour is adopted in Mauritius, maternal health will be improved (goals 3 and 5) and micronutrient deficiency can be reduced further. This will lead to a decrease in the number of low birth a weight (which is rising in Mauritius) and prevent NTDs (goals 2 and 4).

Research Questions

Objectives of the study

The objectives of the study are:

- To study whether, addition of iron and folic acid changes significantly the colour of plain white wheat flour.

- To analyse the effects of addition of iron and folic acid on the chemical properties of plain white wheat flour.
- To study the effects of addition of iron and folic acid on the rheological properties of plain white wheat flour.

Literature Review

Dietary iron is very important in the prevention of anaemia. The major role of iron in the body is in the transport of oxygen from the lungs to body tissues and its storage in muscle (Fox and Cameron, 1995; WHO/FAO, 2004). Oxygen is transported in the blood attached to an iron containing protein complex called *haemoglobin*. It is also transported and stored in muscle attached to another iron containing protein complex called *myoglobin*. The body's ability to store iron is self-regulating, and iron balance is maintained by altering the amount of iron that is absorbed from food or pharmaceutical supplements such that, when the body needs more iron, more iron is absorbed, but this can happen only if the iron is not bound to other substances and is in a form that can be readily absorbed. Conversely, when the body is replete, the amount of iron absorbed is limited (Nestel & Nalubola, 2000).

A failure to meet iron needs can be due to either dietary factors or non dietary factors. The bulk of the cases of iron deficiency are however diet related (Nestel & Nalubola, 2000). Dietary iron requirements depend on the amount needed for growth and development as well as normal losses; thus, they also vary by age and gender. The need for iron is pressing when the body's blood supply expands during periods of rapid growth like early childhood, adolescence, or pregnancy. At the same time, blood loss due to menstruation and childbirth draws on iron reserves, and the requirement for iron increases in non-pregnant and pregnant women to compensate for these losses, respectively. Given these factors, the risk of iron deficiency and iron deficiency anaemia is greatest during those stages of life when iron requirements are highest, i.e., pregnancy, early childhood, and adolescence (Nestel & Nalubola, 2000; WHO, 2004; Mann & Truswell, 2007; Gropper *et al*., 2009). Other factors apart iron deficiency which causes anaemia include deficiencies of nutrients such as riboflavin, folic acid, vitamins A, B6, B12 and general infections and chronic diseases such as HIV/AIDS.

The risk of iron deficiency and anaemia is also increased in situations where individuals

are exposed to infections and parasites, such as malaria and helminthes (Nestel & Nalubola, 2000; WHO/FAO, 2004). Iron deficient populations around the world suffer from poor school performance, poor work performance, increased maternal mortality, smaller newborns, apathy and irritability, impaired mental development, and, poor growth (Maberly *et al*., 2002; WHO, 2011). In young children, iron deficiency and anaemia can have adverse effects on cognitive performance, motor development, coordination, language development, and scholastic achievement that are not always reversible. Iron deficiency anaemia also affects children's growth (Nestel & Nalubola, 2000; WHO, 2011).

The initial reason to include folic acid was to prevent the neural tube birth defects (NTD) of *spina bifida* and *anencephaly*. These can also occur if the mother has insufficient stores of folic acid during the first few weeks of pregnancy and supplements taken prior to conception will help prevent this. It is nearly impossible to get adequate intakes of folate from natural sources, particularly since the natural folates have only 60% of the vitamin activity of synthetic folic acid (Wesley and Ranum, 2004). Deficiency of folic acid in the body results in a number of diseases which includes megaloblastic anaemia, Neural Tube Defects (NTDs), risks of cardiovascular disease and colorectal cancer.

We observe that the staple food in Mauritius that is wheaten flour has been increasing compared to rice over the past eight years with a per capita consumption for rice and flour from 2002 (51.49 to 56.16kg/yr) to (70.98 to 75.55kg/yr) respectively (CSO, 2010). Based on these facts wheat flour was chosen as the vehicle for fortification and thus, it was highly desirable to investigate the impacts and consequences of wheat flour fortification.

Fortification when imposed on existing food patterns may not necessitate changes in the customary diet of the population and does not call for individual compliance. It can often be dovetailed into existing food production and distribution systems. For these reasons, fortification can often be implemented and be sustained over a long period of time, making it to be the most cost-effective way to overcome micronutrient malnutrition. Fortification has been recognized by many national governments as an important strategy to help improve the health and nutrition status of millions of people on a continuous and self-sustaining basis. The work productivity and learning ability of the nation as well as the cognitive capacity of the next generation can substantially be improved through

fortification. There are important micronutrients with public health significance and these include vitamin A, iron, iodine, B-Complex vitamins and zinc. (Garrow *et al.*, 2000). Currently 75 countries around the world have mandatory flour fortification with iron and /folic acid around the world (FFI, 2012)

The idea of fortifying the staple food in Mauritius may be justified as the situation of anaemia is severe especially among adolescent girls. That is why the study investigated the fortification of wheat flour using iron and folic acid. Data from the survey 2009 also draw attention towards the need to adopt appropriate measures to correct these non-communicable diseases. Optimal health for Mauritians can only be achieved when greater efforts are made in health promotion and prevention of illness; with nutrition as an integral part of these efforts.

Methodology

The methodology used for this research focused on the characteristics of fortified flour. They were subdivided as follows:

(i) Determination of the colour of various samples of the fortified plain white flour (using the Minolta Chromameter)

(ii) Chemical analysis of plain white wheat flour in terms of protein, moisture and ash content (AACC method 39 – 11) and determination of the level of α-amylase activity in fortified flour (AACC Method 56 – 81 B (1992)

(iii) Determination of the rheological properties of dough (using the AACC Method 54-30 (1999)).

Materials and Reagents 'A10' flour is soft wheat flour which is mainly used for bread making in Mauritius. It was used for this purpose of this study and it was kindly supplied by LMLC. All tests and reagents used for the analysis were provided and done at LMLC. Ferrous sulphate, ferrous fumarate, Iron EDTA and folic acid were used as fortificants were kindly supplied by Hexagon Nutrition, Mumbai. The level of fortificants added was based on the WHO (2009) recommendations according to the per capita consumption of wheat flour.

Findings

Sensory property -colour

Colour was measured in terms of 'l' (brightness) and 'b' (yellowishness) values and a significant difference ($p<0.05$) was noted upon the addition of the fortificants on colour values when compared to the blank. The mean range values were between 89.43 ± 0.0058 - 89.76 ± 0.0058 for 'l' values and 9.47 ± 0.01 -9.58 ± 0.006 for 'b' values. 'a' value is not an indicator for flour. Figure 1 shows the mean variability of parameter 'l'.

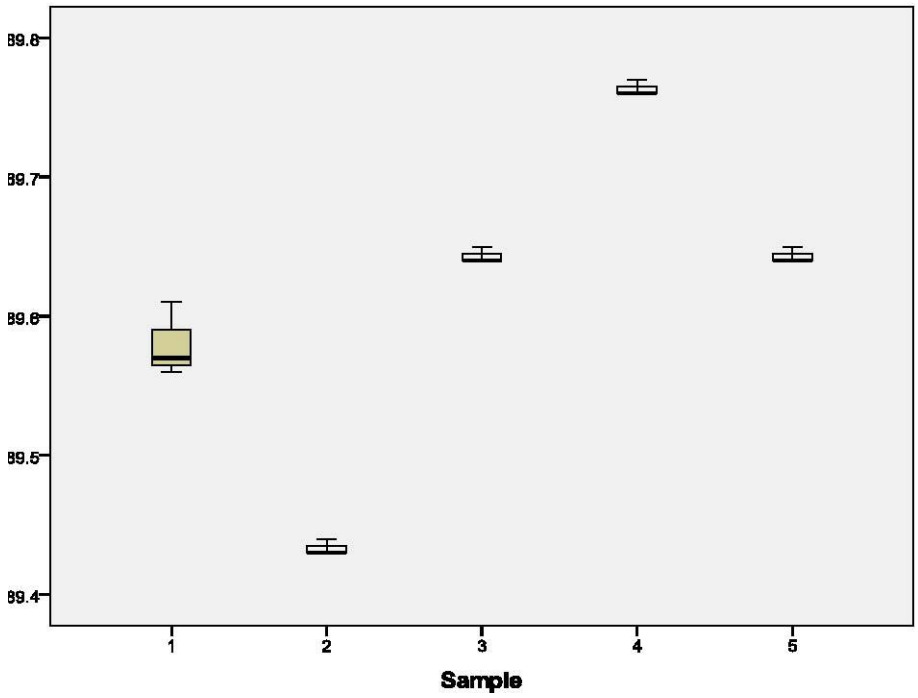

Figure 1: Box plots for 'l' parameter (whiteness)

Chemical tests: protein, ash, moisture and Falling Number Chemical properties (protein content, moisture content and ash content) and Falling Number were determined. No significant difference ($p>0.05$) was noted between the different parameters analysed when compared to the blank. Protein values obtained were between 11.6 ± 0.64% – 12.0 ± 0.38% , moisture content were between 13.5 ± 0.16% – 13.6 ± 0.22%, mean Falling Numbers lied between the range of 361 ± 19.16-375 ± 9.24 while for ash content the values were within the range of 0.65 ± 0.006 – 0.67 ± 0.015.

Rheological Properties -

P and L values

No significant difference was noted upon the addition of the fortificants on P/L ratio ($p>0.05$) when compared to the blank. The P/L ratio was found to be between the range of 1.6 ± 0.27 – 1.9 ± 0.32 for the various treatments.

Absorption values The mean absorption value obtained for the blank was 58.7% and no significant difference was noted upon the addition of the fortificants on absorption values ($p>0.05$). The absorption value was found to be between in the range of 58.5 ± 0.55% -58.8 ± 0.26% for the various treatments tested (figure 2).

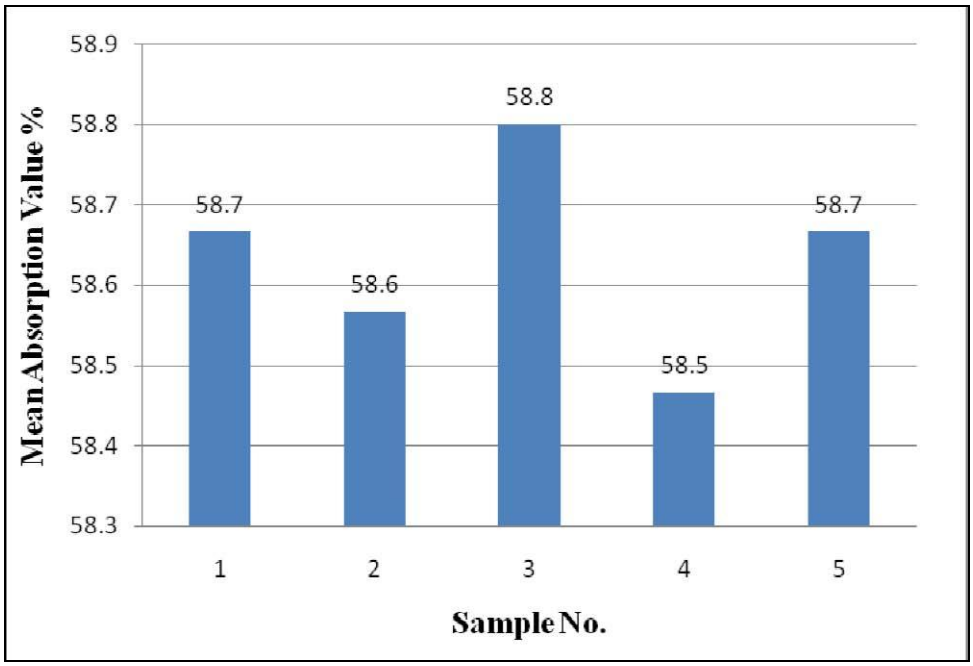

Figure 2: Mean absorption value

Discussion

Colour of fortified flour Colour is one of the most important attributes used by consumers when evaluating quality of a product. The ferrous sulphate used was greyish white in colour, while ferrous fumarate was reddish orange, iron EDTA was yellowish brown and folic acid was a yellow powder. Addition of these different fortificants significantly affects the colour of white flour in this study ($p<0.05$) especially the whiteness ('l' parameter).

However, the difference in colour is not visible to the naked eye and might not affect the acceptability of the products since minute quantities of the fortificants were added. The variability spread was very low with mean range values between 89.43 ± 0.0058 -89.76 ± 0.0058 for 'l' parameter.

In our study, ferrous sulphate and ferrous fumarate have been used at a level of 30 mg/kg while NaFeEDTA has been used at two different levels namely at 115mg/kg and 20 mg/kg. It is reported in literature that the addition of ferrous sulphate at 51 ppm produced a significant difference in the colour of flour. However they were not detectable by sensory evaluation. After three months of storage no significant change was noted in the total iron content and more than 90% of the folate was retained (FFI, 2009). Our results are in line with what has been reported. Nevertheless further in depth sensory evaluation of flour and the baked product needs to be investigated. Bioavailability of the added nutrients before and after baking and after a certain storage period needs to be investigated.

Chemical tests of fortified flour

Chemical tests namely protein, moisture ash and Falling Numbers were determined and no significant difference was noted in the various samples when compared to the blank ($p > 0.05$). An increase in the ash value was expected compared to the other nutrients since fortificants were based of iron, which is a mineral and folic acid which is a vitamin and in the determination of ash content, everything is burnt except minerals. However, no significant increase in the value was noted since minute quantities of fortificants were added.

The Falling Number is used to measure the level of α-amylase activity in flour. α -amylase is a naturally occurring enzyme in flour. Optimum α-amylase activity means adequate amount of fermentable sugars present which will be later fermented to give sufficient amount of carbon dioxide (Fox & Cameron, 1995). The mean Falling Number value obtained for the blank is 375. The addition of fortificants does not affect the Falling Number ($p>0.05$) when compared to the blank. This is so because all the fortificants used do not contain enzymes and the concentration of enzymes remains very low (same that in the blank). Enzymes namely α-amylases and fungal hemicellulase have been reported in

various studies to significantly affect Falling Numbers.

Table 1 gives a summary of the interpretation of the different Falling Number values. It should be noted that prior to the commercialisation of flour, regulators (containing enzymes mainly) are added to standardise the flour. The bakers at this level will add improvers which as its name suggests will improve all the parameters of flour and thus bread.

Table 1 -Interpretation of the different Falling Number

Falling Number	Indication
< 200	High α -amylase activity. Sprouted damaged wheat. Bread crumb firm and sticky
200-300	Optimum α -amylase activity. Bread crumb likely to be good
Above 300	Low α -amylase activity. Bread crumb is likely to be dried. And a reduced bread volume is obtained.

(Operation Manual 8600)

Rheological properties:

P & L values

Overpressure 'P' gives an indication of the dough to resistance to deformation. Usually normal dough has a dough resistance to deformation 'P' of 53. The 'L' value is usually used to determine the dough extensibility (Faridi & Rasper, 1987). L-cysteine is reported to increase dough extensibility (Stear, 1990). The more enzymes are available, the softer the dough becomes and the more extensible it is (Jood *et al.*, 2003). Flours for bread making usually have P/L values 1.3-1.5. The P/L value highly depends on the denominator that is 'L'. Blank flour and all the treatments have a P/L value > 1.5 (1.5 – 1.9). No significant difference was noted between the four treatments and the blank. The samples tested had added fortificants and not enzymes. Therefore the P/L ratio was not affected when

compared to the blank. Sudha & Leelavathi (2008) carried out a study on different fortificants (ferrous sulphate, iron EDTA and ferrous fumarate salts, calcium and other vitamins). Addition of these fortificants to wheat flour was found to have no significant effect on the farinograph, alveograph and micro-visco amylograph characteristics of wheat flour. Hence our results confirm that fortification of wheat flour is a feasible strategy. Bakers will not encounter problems of extensibility during bread making processes while using fortified flour.

Absorption values

Absorption is the amount of water required to centre the Farinograph curve on the 500-Brabender Unit (BU) line. This relates to the amount of water needed for a flour to be optimally processed into end products. Absorption is expressed as a percentage. No significant difference has been noted on absorption value upon addition of the fortificants at the various levels tested. Literature reported that fortification with iron (30-90 ppm) from different sources showed a marginal increase in water absorption (2%). Calcium ranging between 800 and 1,600 ppm did not show any influence on the mixing properties of the dough **(**Sudha & Leelavathi, 2008). In this study the fortificants did not influenced the absorption value since they were added in very low amounts and is thus insignificant. Accordingly, the addition of fortificants will not affect the absorption value and can be easily incorporated in different types of flours to be used. Bakers will not face any type of difficulty as an increase or decrease in the absorption value will not significantly affect the quality of the end product. As a consequence, using the fortificants at concentrations experimented in this study can be incorporated easily in the food chain by the mill itself.

Conclusion and recommendations

Fortification of flour using the different fortificants changed the colour of flour significantly but with very low range of variability. It was thus not detectable with the naked eye. Chemical analysis of the fortified flour showed that the addition of the fortificants did not change the rheological and chemical properties. This allows us to state that iron and folic acid fortification to the levels we have considered in this study is feasible and is also viable in the long term as “wheat flour” is well established in the local diet and is not likely to

change in the near future.

We thus strongly recommend the implementation of a national flour fortification programme in the Republic of Mauritius with iron and folic acid. Flour fortification with both iron and folic acid can be considered as the same vehicle which can be used to reach a larger population including adolescents and pregnant women.

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PRESENTATION 4

A study on the development of HLA antibodies in multiply transfused male patients in Mauritius

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Introduction

There is now a growing concern that a plethora of antibodies against human leucocyte antigen (HLA) could be allogeneically induced following multiple transfusions from different donors as well as in those exposed to a single donor blood or blood components

due to the fact that HLA epitopes are diverse in nature and thus are highly immunogenic. Whether this statement also holds true for the immunocompromised patients or not will have to be investigated. There is also little knowledge about the transient appearance of some of these antibodies. There is therefore a need to study the features of the induced HLA antibodies following red cells or platelet-rich plasma (PRP) or apheresis platelets or fresh-frozen plasma (FFP) or cryoprecipitates singly or in multiples or in combinations and correlates these data with the clinical settings: eg 1) the types of acute transfusion reactions such as febrile, allergic, anaphylaxis, hypotensive; 2) refractoriness to platelet transfusions; and 3) transfusion of blood and blood components that have been leucodepleted.

Research Questions

Several questions will have to be addressed namely:

- After how many transfusion episodes, these antibodies will be detected?
- How often these antibodies are present?
- For how long they will persist in the blood circulation?
- Is there any relationship or appearance of the antibodies with any side effects after transfusion?
- Is blood transfusion more likely to produce antibodies than transfusion of blood components like plasma or platelets?
- Is blood devoid of white blood cells less likely to produce antibodies?
- Is the appearance of these antibodies being subjective to the presence of antibodies against red cells?
- Is there a difference in diseased states requiring blood transfusion with the presence of **antibodies against white blood cells?**
- And will testing of the HLA antibodies be of any prognostic or diagnostic value in the long-term management of transfusion in our male patients.

These questions will set the parameters of the research project and will clarify exactly what this study is about and its long-term goal will improve management of transfusion in male patients.

Literature Review

HLA antibodies have been implicated in a number of diseased conditions requiring transfusion in males:

i. In the sera of 40 patients, with febrile non-haemolytic transfusion reactions, the frequency of the occurrence of HLA alloantibodies was quite higher than the platelet-specific antibodies and could be detected within 4 days after the serious event (75% v/s 5%; $p < 0.05$)[1].

ii. HLA Class II antibodies e.g. HLA-DR antibodies involvement in a severe non-haemolytic transfusion reaction including transfusion-related acute lung injury (TRALI) have been demonstrated in a 81 years old man with non-Hodgkin's lymphoma receiving a plateletpheresis unit[2]. There is now reason to believe that the prevalence of HLA Class I and II antibodies in 1138 male donors, irrespective of any history of transfusion, is indeed alarming (1.0% versus 1.7%; $p = 0.16$)[3]. Also, pooled buffy coat platelets diluted in as little as 10 - 20 ml of plasma, that contained 3 to 4 different HLA Class I-specific and Class II-specific antibodies to the patient's HLA type, could cause TRALI[4]. That is why testing of HLA Class I and II antibodies as well as HNA-3a antibodies is recommended in all suspected cases of TRALI[5,6].

iii. In a randomised controlled trial, 12.6 per cent out of 317 patients developed IgG HLA Class I antibodies after a single transfusion event with multiple red cells (RBCs) in cardiac surgery[7]. Moreover, the frequency of alloimmunisation was similar as to whether leucocytes-free RBCs before storage or leucocytes-free RBCs after storage have been transfused[7].

iv. Whilst, the rate of HLA alloimmunisation in 53 adult male surgical patients with RBCs alloantibodies was significantly higher than that in multiply transfused patients without RBCs antibodies (22.6% versus 7.8%; $p < 0.03$) so that in future HLA antibody screening would be mandatory for pre-operative patients with RBCs antibodies requiring platelets[8].

More data has been accumulated recently indicating:

i. the immunologic responsiveness (antibody producers or non-producers) of the recipient to donor HLA was dependent upon high- (HLA-A2, B40, DR4, HLA-DR6) and low-responder (HLA-B8, DR3) HLA haplotypes[9].

ii. within the high-responder HLA haplotype (50%), two immunizations were sufficient to produce antibodies, while others (50%) required three immunizations[9].

iii. most recipients with HLA-A3 phenotype (42%) readily formed antibodies sensitized against HLA-A1, A-10, A-11 or HLA-A1, A-10, whilst very few individuals (10%) with HLA-A1; HLA-A11 or both produced anti-HLA-A3 in multi-transfused platelet recipients[10].

Recent concerns over the detection of immunogenic β-2-microglobulin on red cells implying that multi-transfused patients will be exposed to HLA-A, B and C, despite having received leucocyte- and platelet-free RBCs and could explain:

i. why HLA-B7 was expressed on RBCs in donors with HLA-B7 positive lymphocytes as well as in 35 per cent with HLA-B7 negative lymphocytes[11].

ii. why 19 out of 60 thalassaemic patients, who routinely received washed RBCs, developed HLA antibodies, whilst 13 of them had both HLA- and platelet specific–antibodies[12].

Several lines of evidence also indicate that the expansion of the HLA alloantibody requires continued stimulus and could explain:

i. why in 19 highly sensitized patients with high levels of HLA Class I alloantibody, also have anti-idiotypic antibodies that could stimulate more B cells to produced more alloantibodies[13].

ii. the downregulation of HLA alloantibodies over time:

   a. in 67 per cent of 82 leukaemic patients that have continuously received random platelet transfusions resulting in the latter appearance of IgG anti-idiotypic antibodies that were reactive with the variable region of the HLA alloantibodies[14];

   b. also, in 36 per cent of these cases, the anti-idiotypic antibodies have been shown to possess paratope-related reactivity by destroying the ability of HLA alloantibodies to bind platelet membranes[14].

   c. disappearance of HLA alloantibodies has been demonstrated in 16 leukaemic patients in an elegant study involving 154 patients receiving continuous platelet transfusions[15].

Methodology

Sample characteristics

After prior approval from the Ethics Committee of the Ministry of Health and Quality of Life, 50 male subjects gave written informed consent to participate in this study. The exclusion criteria are: 1) Foetal and neonatal transfused subjects (due to their vulnerability and ethical issues); and 2) Subjects with an underlying autoimmune disease (to exclude autoreactive antibodies).

Blood sampling and Assays

Venous blood samples would be timely drawn for analysis as follows: Day 1- prior to transfusion; Day 2 - immediately following transfusion; Day 3 – three weeks after 1st transfusion or prior to next transfusion episode, whichever is less. The serum would be stored frozen at -20 °C until the batch analysis of HLA antibodies. A prospective analysis of HLA antibodies will be performed in sera once a week by an enzyme-linked immunosorbent assay (ELISA) method: LAT-M® (One Lambda/BMT) having sensitivity and specificity of 89.6 % and 97.5 % respectively for detecting Class I and 96.5 % and 98.4 % respectively for detecting Class II. IgM and IgG HLA antibodies will also be characterised using the ELISA technique.

Data Analysis

Pearson product moment correlation coefficients (r) would be used to assess the relationship among variables using SPSS 10.0. A p value of < 0.05 was considered statistically significant (2-tailed).

Safety

All laboratory work would be done according to the health and safety regulations.

Findings

It is highly predicted that the presence of HLA antibodies will be a common feature in multiply transfused patients and will significantly be induced after at least two

immunization events. Their level and specificity will become significantly more pronounced when transfusing RBCs and/or PRPs rather than FFP and cryoprecipitates.

Discussion

Understanding HLA antibody formation would be a breakthrough in the management of frequently transfused individuals not only by supporting medical decisions for having previously allowed HLA mismatches, due to the impossibility of getting a hundred per cent HLA-compatible allogeneic blood, but also would define non-harmful HLA antibodies in the sensitized patients. Therefore, it is imperative to clinically foster a better transfusion practice and significantly minimizing any untoward adverse transfusion reactions e.g. TRALI or PTP by knowing the HLA antibodies status of the sensitized recipients and by transfusing the appropriate blood and/or its components. Also, the clinical relevance of this study and its findings:

a) should establish common HLA antibodies that could be readily induced in the sensitized patients.

b) would confirm non-harmful HLA antibodies in the sensitized patients.

c) would lead into the compilation of a registry for patients having HLA antibodies.

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SESSION 2 – ENERGY EFFICIENCY & RENEWABLE ENERGY

PRESENTATION 5

Life Cycle Assessment of Solid Waste Management Options for Mauritius

Mr S A Rajcoomar

University of Mauritius

Mr S A Rajcoomar was graduated as Civil Engineer in the year 2002 at the University of Mauritius. He joined Sotravic Ltee in the same year as Site Engineer. Mr Rajcoomar has worked in several sewerage reticulation projects. In the year 2005 he joined the Ministry of Local Government as Technical Officer. He became a Registered Professional Engineer in 2006 and in the end of the same year he joined Sotravic Ltee again. Since then he is working as Deputy Landfill Manager at the Mare Chicose Landfill. Mr Rajcoomar is presently performing his MPhil/PhD research work on life cycle assessment of solid waste management options for Mauritius.

Introduction and Framework

Dealing with solid waste management is a complex and multi disciplinary problem that should be considered from technical, economic and social aspects on a sustainability basis. There is no single waste treatment system which is most appropriate for all waste fractions (Laimsanguan, 2008). To be able to manage solid wastes, each country should adopt its own strategy such as incineration, recycling, re use, and recovery that is most appropriate to their context. This is done using a life cycle approach. Life Cycle Assessment (LCA) is best defined as an objective process to evaluate the environmental burdens associated with a product, process or activity, by identifying and quantifying energy and materials used and

waste released to the environment. LCA evaluates and implements opportunities to allow environmental improvements (Barton et al., 1996). In this study, LCA methodology was used to compare different solid waste management system options and determine the most feasible system for the island of Mauritius. SimaPro 7.1 software developed by Pre Consultants (2010) has been used for the evaluation of the energetic and environmental impacts of the various processing steps. The eco invent database (Eco Invent 2000, (H)), in SimaPro 7.1 has been used and adjusted to the condition in Mauritius.

Description of the scenarios

In this paper, the waste collection system is investigated and eventually the following 2 scenarios were analyzed:

Scenario 1A: Wastes are delivered to landfill and gas produced is flared. This is the existing system that is being used in Mauritius. Wastes collected are transported either to a transfer station or directly to the landfill site. At the landfill, the waste is buried and upon degradation of organic material, under anaerobic conditions, landfill gas is produced. This mainly consists of methane (CH_4) and carbon dioxide (CO_2). Methane is captured through gas wells and eventually burnt in flares to convert the methane into mainly carbon dioxide.

Scenario 1B: This scenario is similar to scenario 1A except that in this scenario, the landfill biogas is being recovered to operate two gas engines to generate electricity. This scenario has been implemented already and would produce 110,000,000 kwh of electricity for 5 years (Joint Venture Sotravic/Bilfinger Berger, 2011).

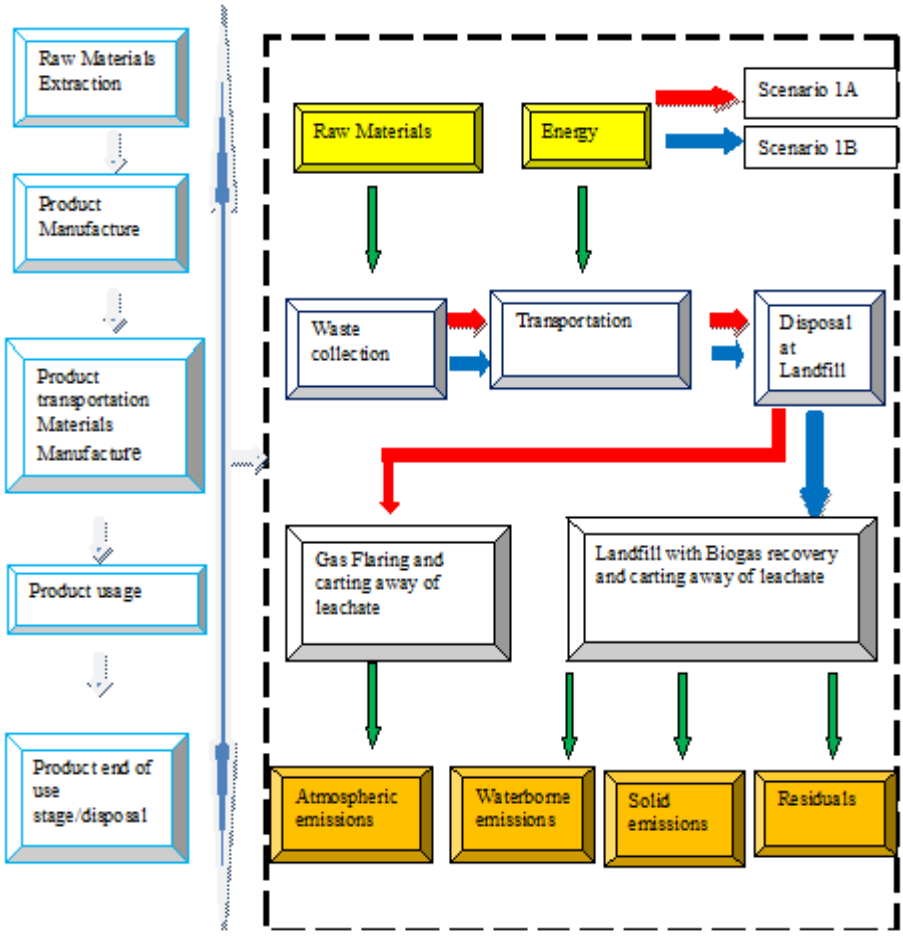

Figure 1: Flowchart for scenarios 1A/1B

We have assumed in this study that all wastes generated are being collected and disposed at the landfill site. There is no sorting being done although there are some unofficial practices at transfer stations, at commercial and public premises.

Other major assumptions/considerations from the Eco Invent database which have been considered in this study are listed below:

1. Degradability of each specified waste in a sanitary landfill is within the first 100 years.
2. Leachate concentrations for the first 100 years are assumed to be constant.
3. Leachate emissions for the first 100 years are collected, discharged to a sewer and treated in a waste municipal plant.
4. Average depth of waste of 20m has been assumed.

5. All landfill gas collected (47%) is flared. The remaining gas is emitted directly to the atmosphere.
6. Landfill models cover a time span of 60,000 years. Emissions are separated into short term emissions (first 100 years) and long term emissions (after the first 100 years).

Method of Analysis

The LCA methodology has been adopted to compare the environmental burdens of the different waste management scenarios to the existing system. This methodology which is described under ISO 14040(2006) and ISO 14044 (2006) consists of four major stages: goal and scope definition, life cycle inventory (LCI), lifecycle impact analysis and interpretation of results.

3.1 Goal and Scope Definition

The purpose and scope of the study is to evaluate and compare the environmental performance of the existing solid waste management system to other waste scenarios in Mauritius. The scenarios were developed based on the current municipal waste management system in the island. The results of the study can be used as technical support for decision making processes either by the public or private sectors.

The functional unit in this study has been taken as the management of municipal solid waste produced on the island in year 2010.

The system boundary of the study has been considered at the collection point of the solid wastes from the residential areas and includes the transportation of wastes until its disposal point.

3.2 Life cycle inventory

Data for life cycle inventory was gathered from the landfill operator, ministry, literature and database of the Sima Pro 7.1

3.2.1 Waste collection and transportation

Wastes throughout the island are collected either by the Local Authorities or the Private Scavenging Contractors. Wastes collected are transported to transfer stations where, they are reloaded in closed bins tipper truck or truck trailers or in open top truck trailers. The other stage is where the wastes are directly hauled to the landfill site. Transportation is done by road.

Table 1 - Waste Collection and transportation to Transfer Stations/Mare Chicose landfill (MoLG, 2010) – Private Companies

Location	No. of Lorries deployed	Capacity of Lorry (m3)	Average Dist.(Km) travelled per lorry per Day to the nearest transfer station/Mare Chicose	Total distance (km) covered during transportation
Beaches	10	139	241	2410
Housing Estates and Traffic Centres	14	162	157	2198
Villages	5	51	156	780
Total	**29**	**352**	**554**	**5388**

Table 2 - Waste Collection and transportation to Transfer Stations/Mare Chicose landfill (MoLG, 2010) – Local Authorities

Location	No. of Lorries deployed	Capacity of Lorry (m3)	Transfer Station	Average Dist.(Km) travelled per lorry per Day to the nearest transfer station/Mare Chicose	Total distance (km) covered during transportation
Municipal Council of Quatre Bornes	13	75	St Martin	30	390
Municipal Council of Curepipe	15	88	La Brasserie	15	225
Municipal Council of Port Louis	21	106	Roche Bois	7	147
Municipal Council of Vacoas/ Phoenix	14	80	La Brasserie	35	490
Municipal Council of Beau Bassin/ Rose Hill	24	189	St Martin	15	360

Black River District Council	Not Applicable		St Martin		
Pamplemousses/Riv.du Rempart D.C	26	117	P. D'or	40	1040
Grand Port Savanne D.C	16	78	Mare Chicose Landfill	80	1280
Moka Flacq D.C	20	103	La Brasserie & La Laura T.S	70	700
Total	**149**	**836**		**392**	**4632**

3.2.2 Diesel Consumption

Diesel is consumed when tipper or compactor trucks collect and transport the wastes. The consumption is about 0.5l/km. During the collection stage diesel consumption is normally higher compared to during transportation of the wastes to nearest facility. Lorries of 3.5–7.5T and 16-32T of the eco invent database have been considered. Diesel consumption, vehicle operation and maintenance, and construction of roads are already included in the study as they exist in the eco-invent data base.

At the transfer stations and the landfill site, diesel is consumed during high pressure cleaning of trucks. Diesel consumption for this has not been considered during computation as it is negligible.

3.2.3 Electricity Consumption

Electricity at the transfer station is consumed for:

- Pressing of wastes in close bins

- Street and office lightning

At the landfill site electricity is consumed for:

- Gas flaring
- Street and office lightning
- Pumping of leachate

Eco invent database from Sima Pro 7.1 has been used for this study.

3.3 Life cycle impact assessment

In this study, SimaPro 7.1 software, developed by PRé Consultants (2008) has been used for the evaluation of the energetic and environmental impacts of the various steps. Two characterization methods have been chosen; CML 2 baseline 2000 and Eco-Indicator 99 (H).

Results and Discussions

The LCIA has been carried out at the following two levels::

1. Mid-point level

At the mid-point level, the impact assessment has been done according to the CML 2 baseline 2000 method

2. End-point level

In this level, the impact assessment has been carried out according to the Eco-indicator 99 method in the egalitarian formulation. Eco-indicator is a damage oriented end point analyzing tool.

4.1 LCI and LCIA using mid-point category

4.1.1 Scenario 1A - Lifecycle of land filling without energy recovery

Figures 2 shows the normalization results of landfilling without energy recovery (1A). Major contributions to the impact categories are due to transportation of wastes compared to landfilling and electricity consumption in the operation of the various infrastructures. Normalization results at the midpoint level show that the landfill scenario without energy recovery has a high impact on abiotic depletion (due to fossil fuel use in transportation), climate change, and human and ecotoxicity. Scenario 1A contributes to toxicity (human,

terrestrial, marine and water) due to landfill gas, leachate, presence of heavy metals in leachate and collection and transportation of wastes.

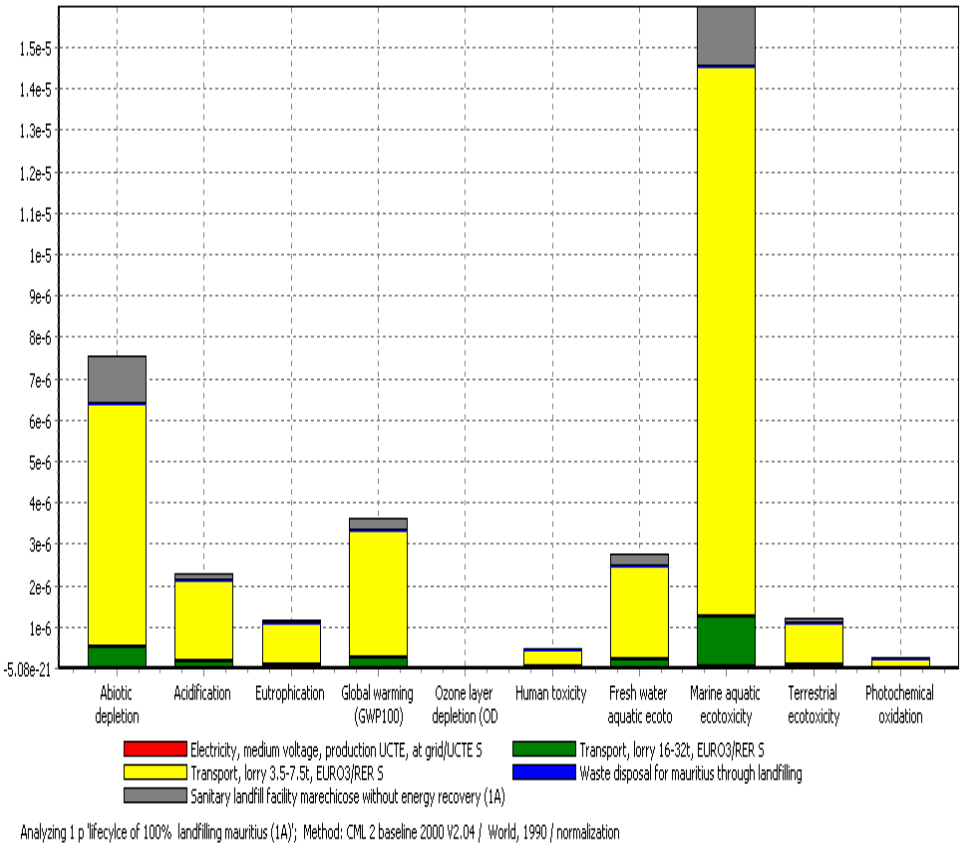

Figure 2: Normalization result of scenario 1A using CML 2000

4.1.2 Scenario 1B - Lifecycle of landfilling with energy recovery

Figure 3 shows the normalization results of the LCIA. There is a negative contribution with regards to aquatic and terrestrial ecotoxicity due to the energy recovery from the landfill biogas.

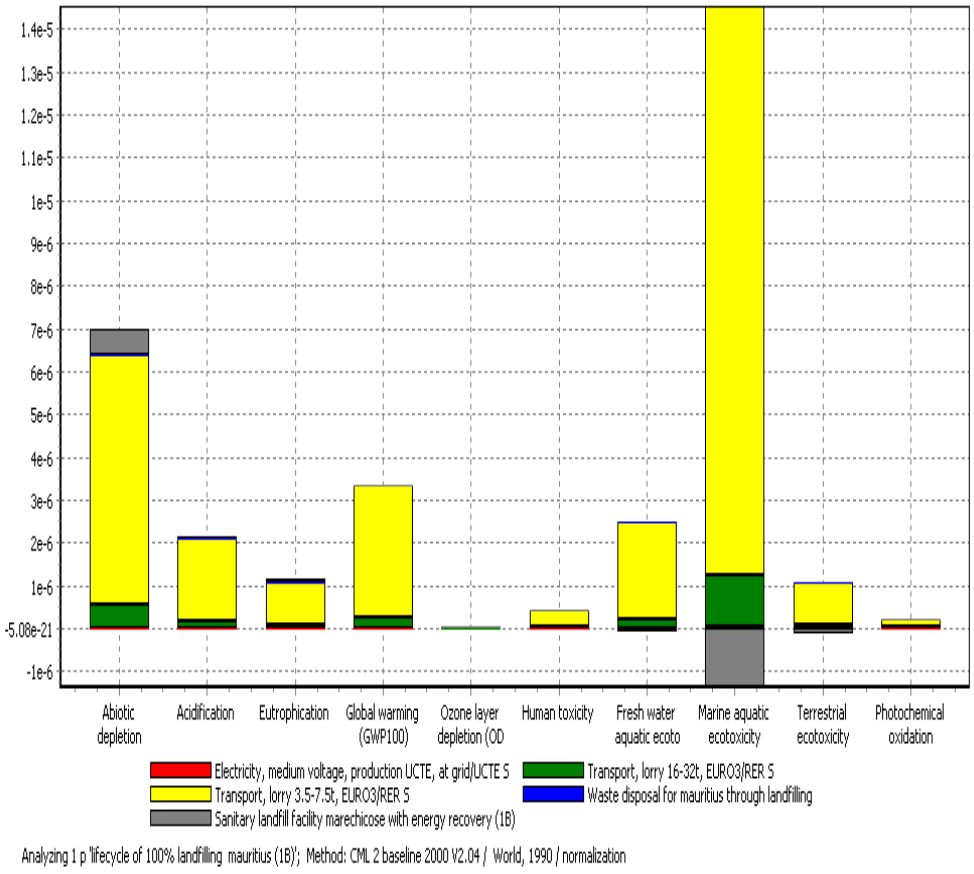

Figure 3: Normalization result of scenarios 1B using CML 2000

4.1.3 Comparing life cycle of both scenarios

The net contributions to each impact category that each scenario produces are reported in Table 3. The contributions of abiotic depletion, acidification, global warming, ozone layer depletion, human toxicity, water and marine ecotoxicity, terrestrial ecotoxicity and photochemical oxidation, as expected, is higher in scenario 1A (landfilling without energy recovery) than in scenario 1B (landfilling with energy recovery). There are however not much significant differences between the two scenarios. In this study an avoided electricity of 22,000,000 Kwh has been considered based on the local data.

Table 3: Net contribution to impact categories for each scenario using CML 2000 method

Impact category	Unit	Scenario 1 A - Lifecycle of 100% landfilling mauritius (1A)	Senario 1B - Lifecycle of 100% landfilling mauritius (1B)
Abiotic depletion	kg Sb eq	1.19E+06	1.11E+06
Acidification	kg SO2 eq	7.43E+05	6.88E+05
Eutrophication	kg PO4--- eq	1.54E+05	1.51E+05
Global warming (GWP100)	kg CO2 eq	1.59E+08	1.47E+08
Ozone layer depletion (ODP)	kg CFC-11 eq	2.68E+01	2.63E+01
Human toxicity	kg 1,4-DB eq	2.86E+07	2.64E+07
Fresh water aquatic ecotox.	kg 1,4-DB eq	5.72E+06	4.93E+06
Marine aquatic ecotoxicity	kg 1,4-DB eq	1.21E+10	9.97E+09
Terrestrial ecotoxicity	kg 1,4-DB eq	3.14E+05	2.51E+05
Photochemical oxidation	kg C2H4	2.59E+04	2.37E+04

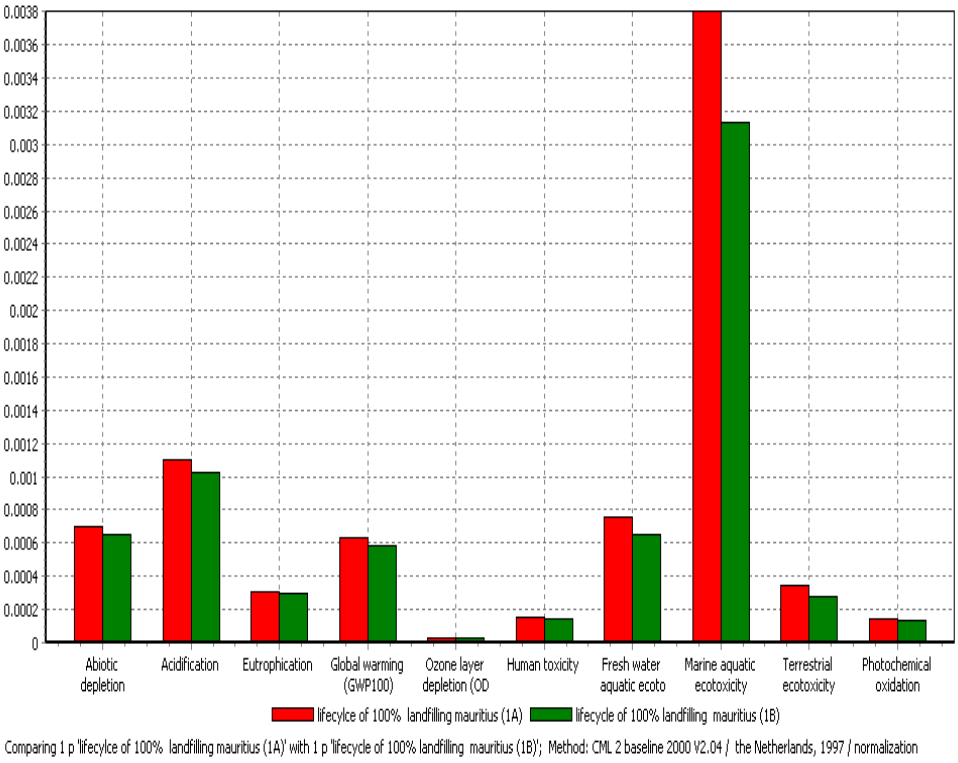

Figure 4: Comparative Normalization result of scenarios 1A and 1B using CML 2000

4.2 Results using end-point category

Figures 5 below illustrate the normalisation results for each impact category and Figure 6 illustrates the single score result for human health, ecosystem and resources. From the normalization results, scenario 1B is relatively a better than scenario 1A as its contribution to the impact categories is less. The major impact is on fossil fuel use followed by climate change and respiratory inorganics. This is due to the significant use of diesel during transportation of the wastes. This is reflected in the single score results where Resources use is the major end-point impact. The normalised values for each impact categories is shown in table and it can be seen that fossil fuel has the maximum normalised value with 4.02×10^4 and 3.93×10^4 for scenarios 1A and 1B respectively.

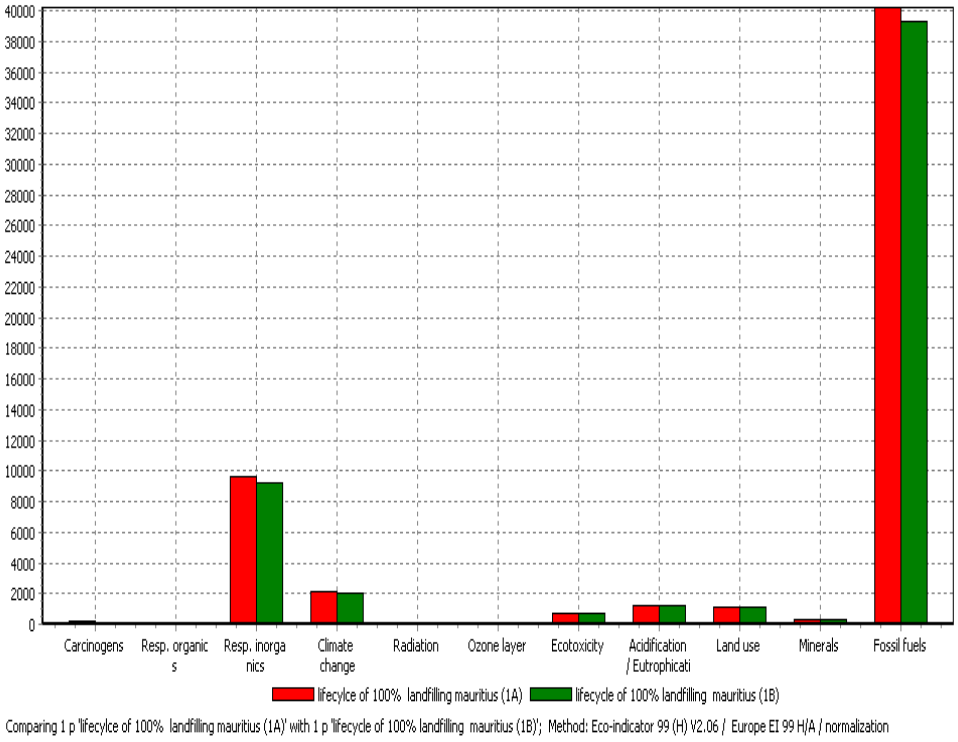

Figure 5: Normalization result of scenarios 1A and 1B using Eco Indicator 99

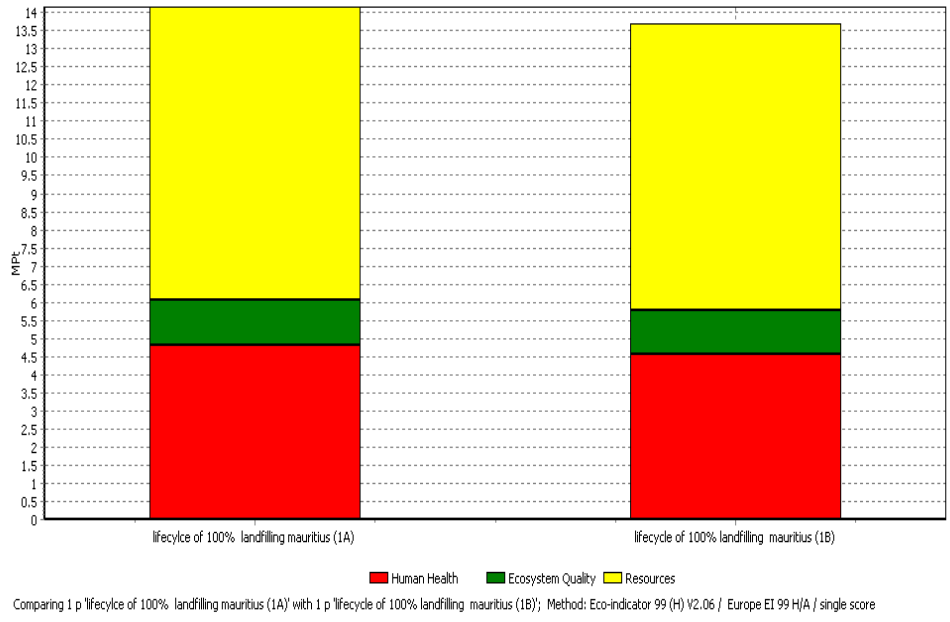

Figure 6: Single score result of scenarios 1A and 1B using Eco Indicator 99

Table 4: Net contribution to impact categories for each scenario using Eco Indicator method

Impact category	lifecycle of 100% landfilling mauritius (1A)	lifecycle of 100% landfilling mauritius (1B)
Carcinogens	2.05E+02	1.49E+02
Resp. organics	1.40E+01	1.39E+01
Resp. inorganics	9.65E+03	9.26E+03
Climate change	2.17E+03	2.01E+03
Radiation	2.45E+01	1.19E+01
Ozone layer	1.83E+00	1.80E+00
Ecotoxicity	7.19E+02	6.99E+02
Acidification/ Eutrophication	1.24E+03	1.21E+03
Land use	1.10E+03	1.09E+03
Minerals	2.84E+02	2.74E+02
Fossil fuels	4.02E+04	3.93E+04

From the results, scenario 1B, is slightly more beneficial with respect to environmental evaluation impacts. This is in line with studies performed by Bovea and Powell (2006) and Cherubini et al (2008) where they concluded that scenarios with energy recovery achieve better environmental performances than scenarios without energy recovery.

However scenario 1B does not have a major significant improvement compared to scenario 1A given that transport weighs the most in contribution to the impact categories and both scenarios studied use the same amount of transport. Hence, there are other possibilities like recycling, incineration that need to be further considered to achieve a more sustainable waste management option.

Conclusions

The literature review shows that LCA can be successfully applied to MSW management systems as a decision support tool. Application of the LCA methodology to the environmental assessment of municipal waste management systems is a practice that has started to be applied in several countries in recent years. Several studies have shown that neglecting the effects of collection and transport might result in a severe underestimation of the environmental impacts of a waste management system. The LCIA shows that Scenario 1B, is slightly more beneficial from an environmental point of view compared to scenario 1A. Moreover, the LCIA from both the mid-point and end-point methods show that transportation has the largest impact through the use of resources in the form of fossil fuels. Neglecting the effects of collection and transport might result in a severe underestimation of the environmental impacts of a waste management system, especially as refers to depletion of fossil fuels, emission of respiratory inorganics and climate change. To reduce the environmental impact of waste management systems, an accurate optimization of waste transport is required.

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PRESENTATION 6

Energy Management - A Strategic Business Issue for Top Management in Mauritius

Mr M Ramdoo

University of Mauritius

Mr M Ramdoo is currently working as an Aviation Coordinator for Total Mauritius Ltd since April 2009. His job placement is at the SSR International Fuel Depot and is responsible to ensure an effective management w.r.t the policies established by the company, the airport authorities and the international regulations. He has been on the job market since 2006 and has gained experiences in the shipping industry (Maersk Mauritius Ltd) and in the engineering sector (Sotratech Ltd). Mr Ramdoo brings more than 6 years of educational expertise through the University of Mauritius and holds a degree in Chemical & Environmental Engineering, a Master of Science in Industrial Engineering with Management and since October 2010, has enrolled for a Doctor of Philosophy in the field of Energy Management. Mr Ramdoo is on a mission to make the Mauritian Community aware of the worldwide energy crisis and to adopt an energy efficiency culture.

Introduction

One of the main challenges in the years to come will be to ensure the continued economic development of the country while at the same time striving to achieve an increased degree of self-sufficiency in the energy sector by means of energy savings and more renewable energy. Like other small countries, Mauritius has difficulty with this energy problem. Elahee (2008) in his workings on "Energy Policy: Time for coherence and action", recommended a white paper on energy for the adoption of long-term policies and strategies on a national level. He also believes that Energy Management should prove to be

vital for sustainable development and Mauritius has the perfect conditions to emerge as a leading promoter of Energy Management in the region. Even the United Nation Development Programme (UNDP) in a press release, has suggested a supporting development for an energy policy for Mauritius. Ideally, to provide an integrated approach to business sustainability, it is strongly recommended that energy management be incorporated into existing systems.

Research Questions

The research will provide a vital argument that energy management concept can prove to be a tool for sustainable development to accompany technically and financially businesses during the time period of turning to green and must be considered as a strategic business issue for decision-making in the future.

Literature Review

Energy is essential – without it no organisation can operate!

The Primary Energy Requirement (PER) of Mauritius has increased steadily over the past decade and is expected to continue its rise in the future, especially as the country seeks to increase its economic output (Deenapanray, S, 2006). Total energy requirements by 2020 will be around 1.5 M TOE. Electric power requirement is estimated at (3.5 - 4.0 X 10^9) KVA out of which about 30% could be generated mainly from bagasse. Improving generation efficiency and energy saving would result in a reduction of 30% of imported sources. Kassiap Deepchand [2001]. Therefore all businesses must manage energy, if only to ensure routine operational needs. However, beyond the basic need for energy there is opportunity for savings and broader business strategy and position along with market opportunities. Energy cost and availability can influence what time the shifts operate, capital equipment choices, and actual facility location, along with basic operational efficiencies. An unsystematic approach that is not based on fact could result in bad business decisions and missed opportunities. Barney L. Capehart [2008]. Even though there is not a single strategy that will work for every organisation there is a proven systematic approach that combines the technical aspects of energy management and the basic business decision processes to provide proven results. That approach is represented by ANSI/MSE

2000:2008. The system creates a bridge within the organisation to address energy management as a strategic business issue and provides the necessary metrics for tactical decision making. The flexible nature of the standard makes it applicable to all organisations no matter their business or size.

Methodology

Step 1:

The planning phase (Initial Assessment) includes:

- Policy and Goals
- Resources
- Energy Data Management

Step 2:

The doing phase (Design the Process) includes:

- Communication
- Documentation
- Training
- Energy assessments
- Energy projects

Step 3:

The checking phase (Evaluate Opportunities) includes:

- Corrective and Preventive action
- Monitoring and verification

Step 4:

The acting phase (Implementation) includes:

- Management Review
- Process control
- Reviewing and updating energy data
- Reviewing and updating energy projects

Findings; Case Study I – The SSR International fuel depot

The SSR International Airport fuel depot in the only unique depot that supply the Airport of Mauritius Limited with JET A-1 for ALL their aircrafts. The new depot has been in full operation since 2008 with a 24/7 operation and the industry is a highly electrical energy dependence. An Energy Planning Ledger was conducted in the SSR airport fuel depot on the 15th January 2012. The objective of conducting this walkthrough survey is to identify the energy saving potential that exist in this fuel depot as well as the potential Green House Gas emission saving that could be achieved by implementing energy saving and conservation measures. After the energy planning ledger has been carried out and the required data in relation to energy calculations collected, an action plan has been developed in order to achieve the objectives of the project.

LEVEL	POLICY AND SYSTEMS	ORGANISATION	MOTIVATION	INFORMATION SYSTEMS	TRAINING AND AWARENESS	INVESTMENT
4	Formal energy / environmental policy and management system, action plan and regular review with commitment of senior management or part of corporate strategy.	Energy / environmental management fully integrated into management structure. Clear delegation of responsibility for energy use.	Formal and informal channels of communication regularly exploited by energy /environmental manager and staff at all levels	Comprehensive system sets targets, monitors materials and energy consumption and wastes and emissions, identifies faults, quantifies costs and savings and provides budget tracking	Marketing the value of material and energy efficiency and the performance of energy / environmental management both within the organisation and outside it.	Positive discrimination in favour of energy / environmental saving schemes with detailed investment appraisal of all new build and plant improvement opportunities
3	Formal energy / environmental policy, but no formal management system, and with no active commitment from top management	Energy / environmental manager accountable to energy committee, chaired by a member of the management	Energy / environmental committee used as main channel together with direct contact with major users	Monitoring and targeting reports for individual premises based on sub-metering / monitoring, but savings not reported	Programme of staff training, awareness and regular publicity campaigns	Same pay back criteria as for all other investments. Cursory appraisal of new build and plant improvement opportunities.

		board		effectively to users		
2	Unadopted / informal energy / environmental policy set by energy / environmental manager or senior departmental manager	Energy / environmental manager in post, reporting to ad-hoc committee but line management and authority are unclear	Contact with major users through ad-hoc committee chaired by senior departmental manager	Monitoring and targeting reports based on supply meter /measurement data and invoices. Env. / energy staff have ad-hoc involvement in budget setting.	Some ad hoc staff awareness and training	Investment using short term pay back criteria mostly
1	An unwritten set of guidelines	Energy / environmental management the part-time responsibility of someone with only limited influence or authority	Informal contacts between engineer and a few users	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department	Informal contacts used to promote energy efficiency and resource conservation	Only low cost measures taken
0	No explicit policy	No energy / environmental	No contact with users	No information system. No accounting	No awareness raising of energy	No investment in increasing environmental

		manager or any formal delegation of responsibility for env / energy use.		for materials and energy consumption and waste	efficiency and resource conservation	performance / energy efficiency in premises

Table 1: The Energy Management Matrix for the fuel depot

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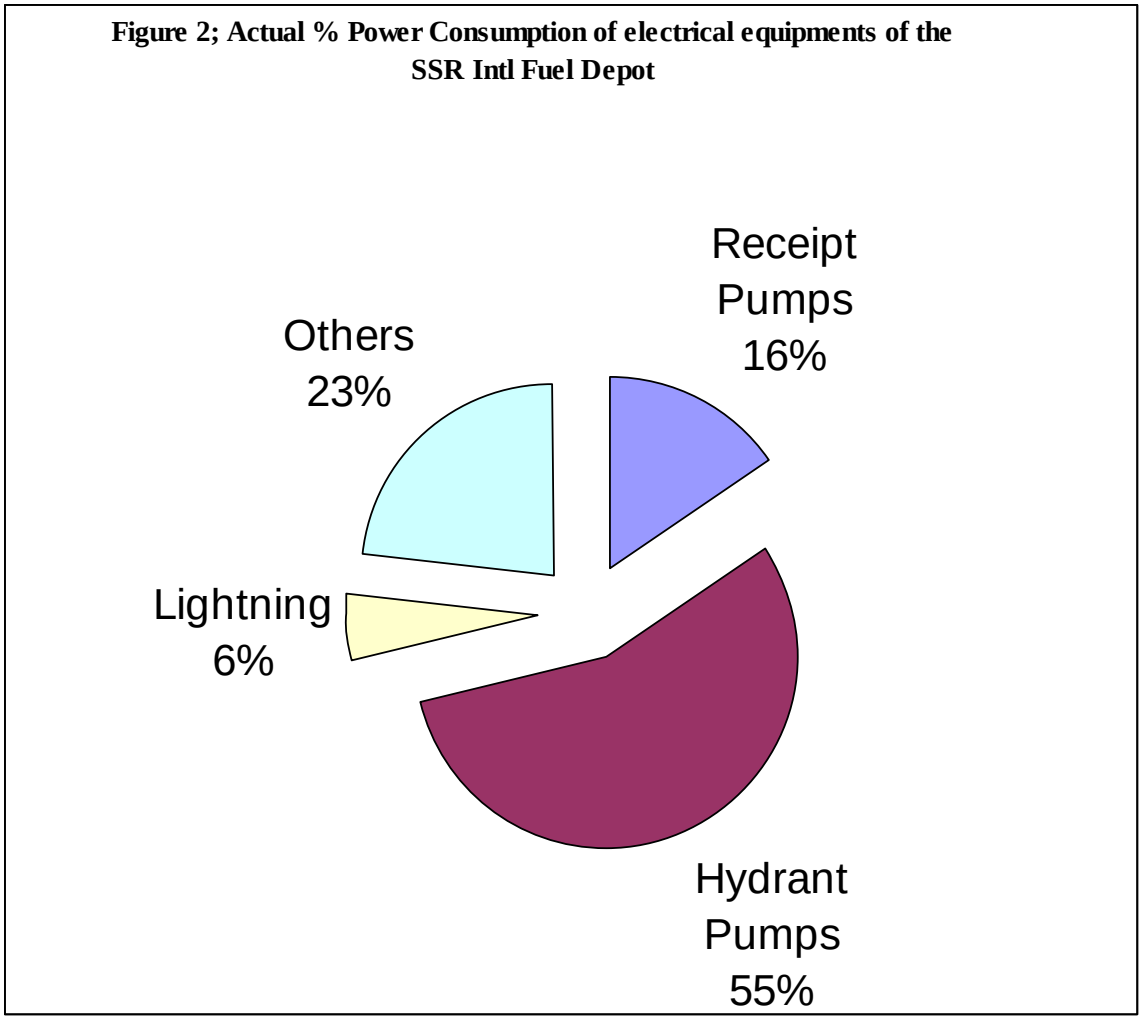

Figure 1: Actual % Power Consumption of Electrical Equipments of the SSR Intl Fuel Depot

After further investigation on the worldwide market price of implementing a renewable system on the fuel depot for the whole power requirements, we found that the cost of investment at first sight will be too high and the pay-back period too long for a single model of green technology. We, finally, decided to opt for an off-grid PV system for lightning purposes only based on the pricing of supply, testing and commissioning of the PV system related directly to the modeling & sizing, the hot and sunny conditions prevailing throughout the year and the space available for the PV system. We shall go for the wind turbine system for the pumping system as they require a quite high starting load.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mauritius Total Power Consumption, GWh	2100	2150	2400	2500	2600	2750	2850	3000	3100	3250	3300	3500	3750
Distributive Trade Power Consumption, GWh	673	680	748	793	819	866	898	945	976	1024	1039	1102	1181
Mauritius Total CO_2 Emissions, t	1,970	2,017	2,251	2,345	2,439	2,580	2,673	2,814	2,908	3,049	3,095	3,283	3,518
Fuel Depot Power Consumption, GWh	352	358	382	434	430	455	471	496	512	538	545	578	620
Total Fuel Depot CO_2 Emissions, t	330	333	374	403	404	427	441	464	479	502	509	539	577
Total Fuel Depot Cost Power Consumption, Rs X 10^3	2708	2759	2895	3310	3125	3300	3412	3587	3699	3881	3930	4161	4455

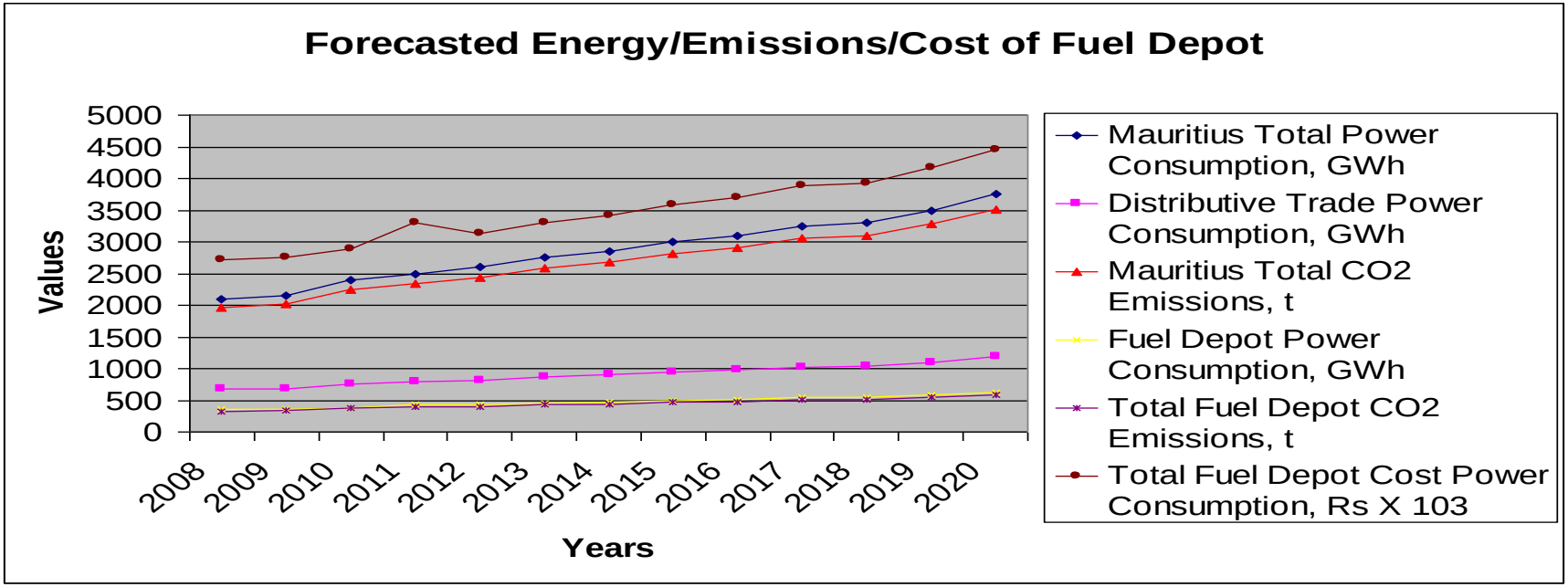

Figure 2: The Future Demand in energy and related emissions as well as cost of the fuel depot.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fuel Depot Power Consumption, GWh	352	358	382	434	430	455	471	496	512	538	545	578	620
Receipt Pumps Power Consumption, GWh	56	57	61	69	69	73	75	79	82	86	87	92	99
Hydrant Pumps Power Consumption, GWh	194	197	210	239	237	250	259	273	282	296	300	318	341
Lightnings Power Consumption, GWh	21	21	23	26	26	27	28	30	31	32	33	35	37
Others, GWh	81	82	88	100	99	105	108	114	118	124	125	133	143

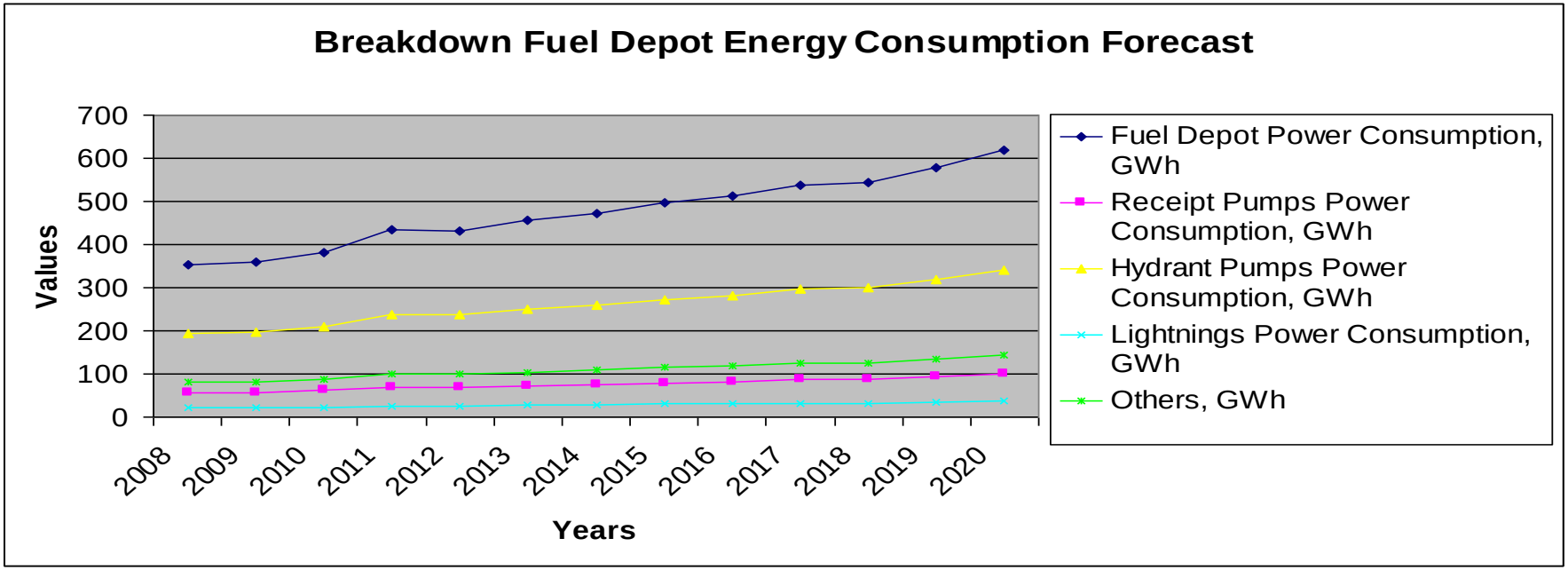

Figure 3: The breakdown forecasted energy demand for the electrical equipments of the fuel depot.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total CO_2 Emissions, t	330	333	374	403	404	427	441	464	479	502	509	539	577
CO_2 Emissions w.r.t Receipt Pumps, t	64	65	68	76	75	79	81	85	87	91	92	97	103
CO_2 Emissions w.r.t Hydrant Pumps, t	189	192	204	230	228	241	249	261	269	282	286	302	323
CO_2 Emissions w.r.t Lightnings, t	32	32	34	36	36	38	39	40	41	42	43	44	47
CO_2 Emissions w.r.t Others, t	86	88	93	104	103	108	111	117	120	125	127	134	143

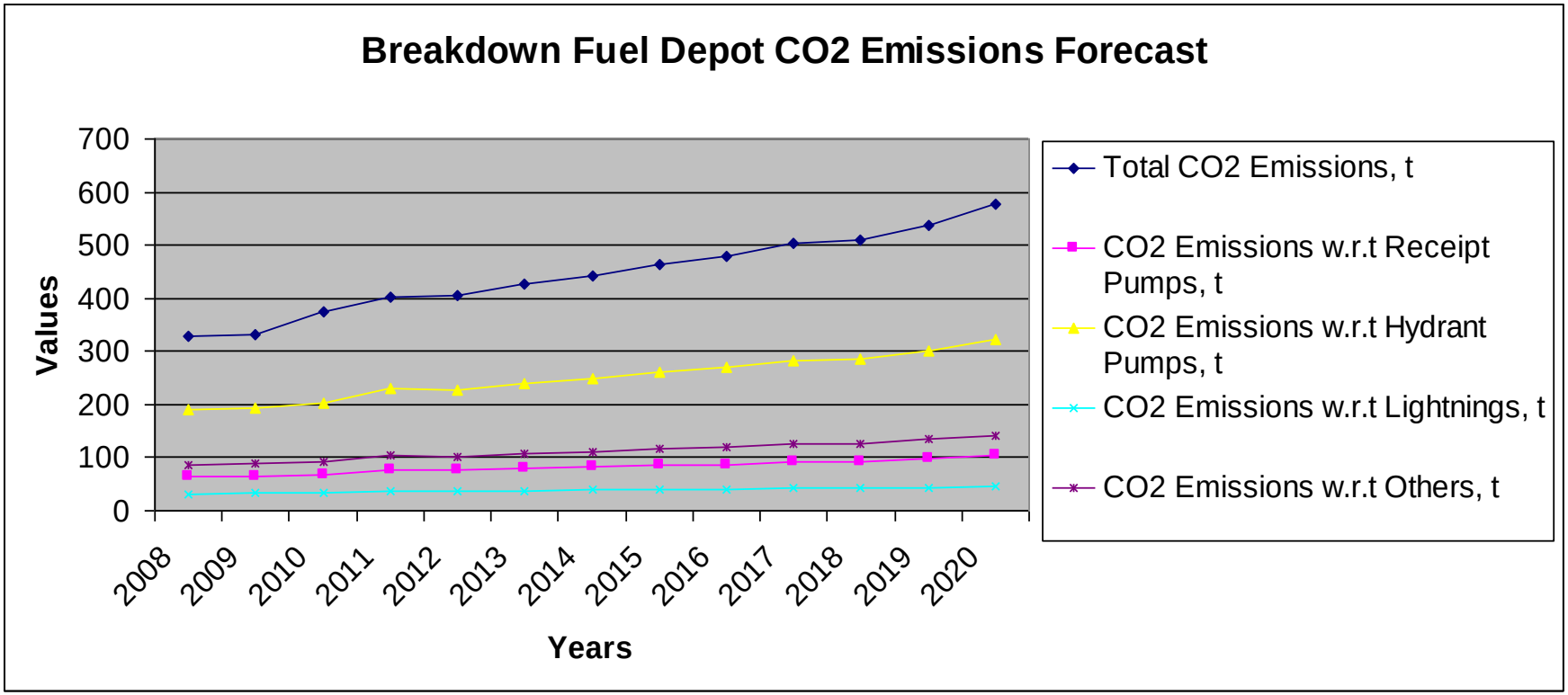

Figure 4: The breakdown forecasted CO_2 emissions related to electrical equipments of the fuel depot.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Cost Power Consumption, Rs X 10^3	2708	2759	2895	3310	3125	3300	3412	3587	3699	3881	3930	4161	4455
Receipt Pumps Cost Power Consumption, Rs X 10^3	509	516	543	601	597	625	643	671	689	718	726	763	810
Hydrant Pumps Cost Power Consumption, Rs X 10^3	1470	1493	1586	1786	1771	1867	1929	2025	2086	2186	2213	2340	2502
Lightnings Cost Power Consumption, Rs X 10^3	263	266	276	297	296	306	313	323	330	341	344	358	376
Others Cost Power Consumption, X 10^3	682	692	730	814	807	848	873	914	939	981	993	1046	1113

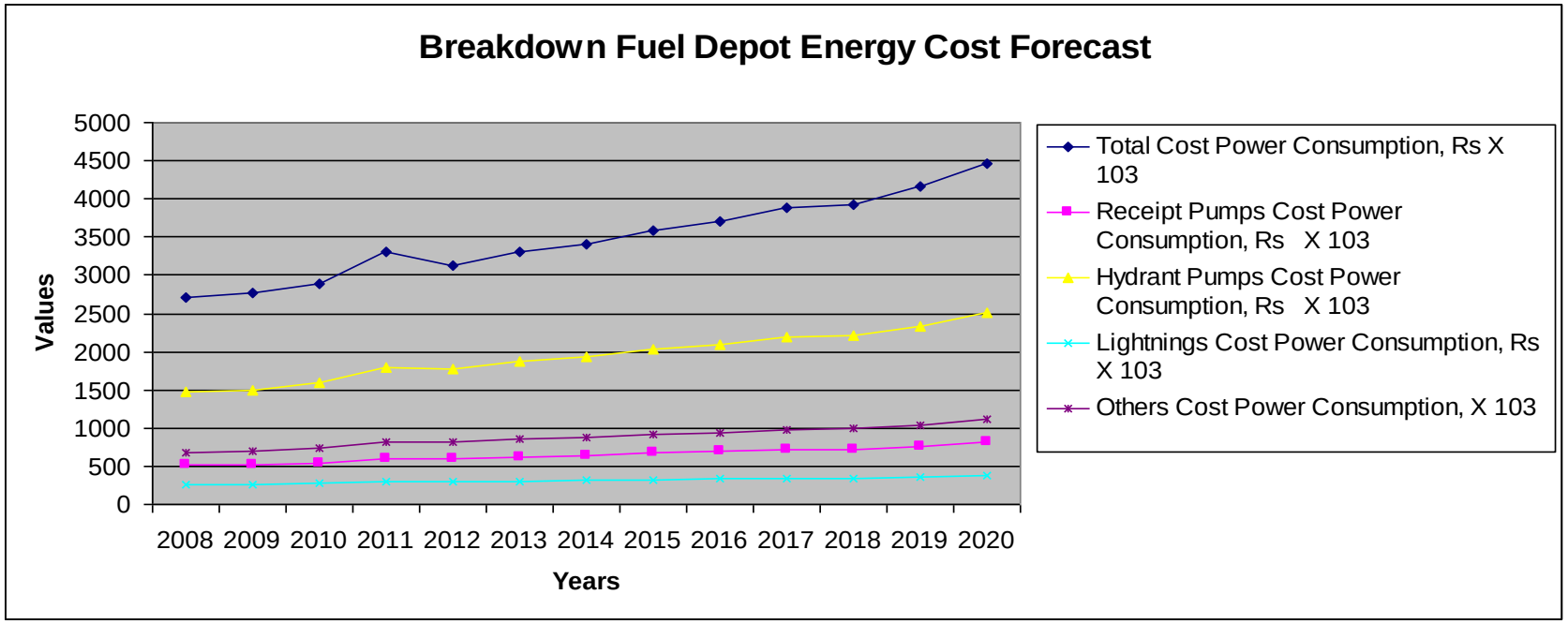

Figure 5: The breakdown forecasted electricity costs related to electrical equipments of the fuel depot.

The energy model for each system has been designed and simulated using the MATLAB software. A rough estimate has been made on the cost of implementation of the PV system prior to the price obtain from the internet or pricelist of the supplier. Same have been done for the wind turbine-generator system as well

Estimation Costs of Renewable Energy Installation		
Solar PV System		
	Qty	Price, MUR
Panel REC235PE	10	102207
Battery LiFeP04	24	7267680
MPPT 150/70	2	71400
Solar Switch	2	48804
Inverter 24/5000	2	213612
Solar Cablings	100	113400
		7817103
Wind Turbine-Generator System		
	Qty	Price, MUR
GWL 225 KW	2	9450000

Table 2: The estimates for green technology on the fuel depot

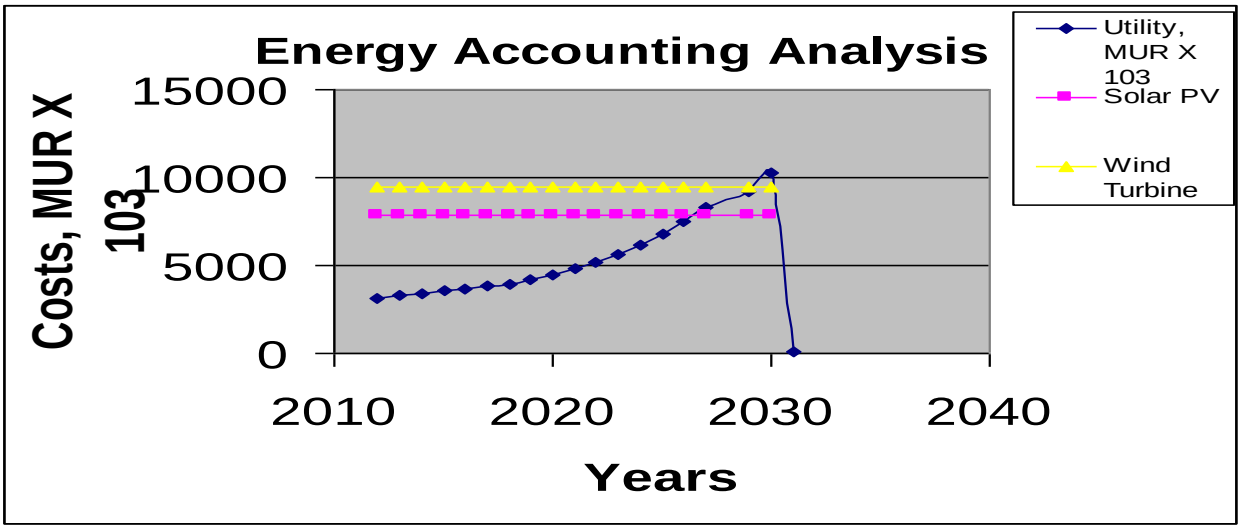

Figure 6: The pay back sequence for the renewable energies

Discussions

Before describing a system to improve energy management, the barriers to effective management must first be identified and understood. While most experts argue that energy management is a technical problem that must be addressed with technological solutions, the framers of the energy management standard, ANSI/MSE 2008, formulated a management solution that incorporates both management and technical solutions to the problem. Whatever the technology identified by an organisation to address their energy needs, it still must be implemented by people, and to optimise the outcome people have to be managed. The ANSI/MSE 2008 standard was formulated to address barriers that frequently inhibit organisational ability to manage energy. These issues are lack of organisational commitment, insufficient resources, lack of energy data, shifting priorities, results not sustained, correcting symptoms instead of problems, and narrow focus.

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PRESENTATION 7

Energy Efficiency Analysis of the Cold Chain in the Food Industry in Tropical Regions

Mr D Sooben

University of Mauritius

Mr D Sooben holds a Bachelor of Technology in Mechanical Engineering from the Institut Superieur de Technologie and registered as part time MPhil/Phd Student at the University of Mauritius. He obtained a Post Graduate French Scholarship in the year 2002 and he is also a member of ASHRAE (American Society of Heating Refrigerating and Air Conditioning Engineers) and a member of IOR, UK (Institute of Refrigeration). In addition, Mr Sooben has a Diplôme d'études Supérieures Spécialisées in Génie Mécanique et Productique from the Ecole Nationale d'Ingénieur de Metz, France and a Specialisation in Refrigeration and Air Conditioning, DSFI from the Institut Français du Froid Industriel et du Génie Climatique de Paris, France. Mr Sooben is currently working as a Mechanical Engineering Lecturer at the Institut Superieur de Technologie.

Introduction

The main focus of my research is to improve and maximize the efficiency of refrigeration systems (laying emphasis on industrial refrigeration, refrigeration in transport and commercial refrigeration) in the cold chain of the food industry with special bearing on the climatic conditions prevailing in tropical regions. Given that the cold chain is quite complex, with many operations and operators in the sector, for the scope of this research project, emphasis is being laid essentially on industrial refrigeration, refrigeration in transport and commercial refrigeration with a per sector approach.

My research methodology is empirical and consists of three phases. The first phase comprises the assessment of the food refrigeration sector in Mauritius. In order to evaluate the current situation of the cold chain in Mauritius, certain basic information in terms of level of sophistication of equipment and data on energy use in this sector is being gathered. The collaboration of the Winner's chain of supermarket has been obtained as far as the commercial refrigeration sector is concerned. Winner's is the largest integrated chain of supermarket in Mauritius, with 19 stores strategically located in various parts of the island. A preliminary survey in the 19 supermarkets around the island has already been carried out.

Moreover, the collaboration of IBL Frozen Food Ltd has also been sought and will be considered for the transport and industrial refrigeration part of the research work. IBL Frozen Foods is a major HACCP certified importer and distributor of a wide variety of frozen and chilled products. With a storage capacity of 5000 metric tons, IBL Frozen Foods owns and operates the biggest cold storage facility. Its sale and delivery are carried out by a fleet of 20 refrigerated lorries across the island.

As per the initial timeline drawn for the research, the first six months have been devoted to a critical review of the literature. In addition, the first phase of the data gathering has been conducted in the commercial refrigeration sector as a means to assess the current situation of this sector. To this end, certain basic information in terms of level of sophistication of equipment, and data on energy use in this sector was required. To facilitate data collection, initially the collaboration of the Winner's chain of supermarket was sought. However, in order to have a more representative sample, negotiations with other stakeholders in the sector are under way.

The preliminary survey as well as the meteorological data collected in different regions around the island has helped to identify which refrigeration installations required a more in-depth study. As such, a detailed survey is currently being conducted in a few supermarkets around the island. In view of conducting the above, the necessary equipment, namely temperature and relative humidity data loggers have been ordered and received.

Literature Review

Refrigeration Systems in Supermarkets

Over the past decade, electricity demand in Mauritius has grown at an average annual cumulative rate of over 8 %. The Central Electricity Board (CEB) forecasts that energy generation requirements will increase by approximately 60 % over the next 10 years, equivalent to an average cumulative annual growth rate of over 4.5 % and a peak demand increase by 17 MW per year between 2004 and 2013. Air conditioning and mechanical ventilation from commercial and residential buildings are contributors to this growth, and currently account for a load of 40 MW during the day and 30 MW at night, well over 10 % of the peak demand. (United Nations Development Programme, Global Environment Facility, Removal of Energy Barriers to Energy Efficiency and Energy Conservation in Buildings).

The contribution of the commercial and industrial refrigeration sector as far as energy consumption is concerned has not been looked into. With the constant increase in the number of supermarkets and hypermarkets on the island and the expansion of the food processing sector, the contribution of the refrigeration sector to the growth of the electricity consumption in Mauritius may not be negligible.

The environmental impact of supermarkets is high due to their high electrical energy consumption, and CO_2 emissions from the power stations, indirect emissions, and the direct emissions, arising from refrigerant leakage, to the atmosphere. According to a recent study (Brian A. Fricke: 2010), the continual operation of a supermarket refrigeration equipment accounts for approximately 50 % of the total electrical energy consumption of a typical supermarket.

In developed countries, supermarket chains account for between 3% and 5% of the total electrical energy consumption (Tassou et.al. 2011). In the UK, supermarket refrigeration accounts for between 30% and 60% of electrical energy consumption, depending on the size of supermarket, type of refrigeration system used and balance between food and non-food and refrigerated and ambient (non-refrigerated) products sold (Campbell et al., 2006).

Supermarket chains cover the market with different store formats. The store formats and average surface of stores are significantly different in different countries. The typical surface areas of supermarkets and hypermarkets in different countries are given in the table below.

Table 1: Typical surface area of supermarkets and hypermarkets in different countries (Source: UNEP, 2002)

	Brazil	**China**	**France**	**Japan**	**USA**
Average Surface Area of Supermarkets (m^2)	680	510	1500	1120	4000
Average Surface Area of Hypermarkets (m^2)	3500	6800	6000	8250	11500

The recent developments in supermarket refrigeration systems reflect the factors shaping the supermarket industry: severe competition, small profit margin, high energy cost, high refrigerant price, regulatory pressures, and public perception and image.

The purpose of refrigeration systems in supermarkets is to provide storage and display of perishable food prior to sale. Food is stored in walk-in storages before the transfer to display cases in the sale area. There are two principal temperature levels in supermarkets, namely medium temperature for preservation of chilled food and low temperature for frozen products. Chilled food in supermarkets is kept at 1°C to 14 °C, while frozen food is kept at -12 °C to -18°C, depending on the country. In Mauritius, chilled food is kept between 1°C and 4 °C and frozen food is kept at a temperature ranging from -18 °C to -20 °C.

The evaporation temperature, for a medium temperature system, varies between – 15 °C and 5 °C, and for a low temperature system, the evaporation temperature is in the range of -20 °C to -40 °C. The variations in evaporating temperature are dependent upon products, display cases and the refrigeration system.

Three main types of refrigeration systems are used in supermarkets in Mauritius: stand-alone equipment, condensing units, and centralized systems.

The stand-alone or plug-in equipment is often a display case where the refrigeration system is integrated into the cabinet and the condenser heat is rejected to the sale area of the supermarket. The purpose of plug-in equipment is to display ice cream or cold beverages such as beer or soft drinks.

Condensing units are small-size refrigeration equipment with one or two compressors and a condenser installed on the roof or in a small machine room. Condensing units provide refrigeration to a small group of cabinets in convenience stores and small supermarkets.

Centralized systems consist of a central refrigeration unit located in a machine room. There are two types of centralized systems: direct and indirect system. In a direct system, racks of compressors in the machine room are connected to the evaporators in the display cases and to the condensers on the roof by a piping system.

In an indirect system, the central refrigeration unit cools a secondary fluid that circulates between the evaporator in the machine room and display cases in the sale area. The use of an indirect system has been adopted in order to lower refrigerant charge and minimize potential refrigerant leakage.

The quest for increased energy efficiency and the phase out of ozone depleting substances have considerably affected refrigeration systems design in supermarkets. However, in Mauritius, following the survey actually being carried out, it has been found that only direct refrigeration systems are used in commercial refrigeration. Since the use of direct refrigeration system involves leakages, the associated consequence as far as energy efficiency and environmental impact are concerned can be looked into.

It has been noted that the traditional CFC and HCFC refrigerants are being replaced progressively by R404A, which has been found to be the most widely used refrigerant in supermarkets that have been surveyed up to now.

Energy Usage in Supermarkets

In the United States and in France, the electricity consumption of large supermarkets represents about 4 % of the national electricity energy consumption, of which around 50 to 70 % is due to air conditioning and refrigerated display cases (M. Orphelin 1997).

The energy consumption in supermarkets is normally specified in kWh/m^2 sale area per year and can be defined as the energy intensity of the supermarket. The energy intensity

can be used to compare supermarkets that merchandise similar quantities of ambient and refrigerated food products, and non-food products.

According to a study conducted in the UK (Tassou et al. 2011), the investigation of 2570 retail food stores covering a whole range of retail food outlets from convenience stores to hypermarkets shows that a wide variability exists in the electrical energy intensity of these stores even within the same category and the same retail food chain. The average electrical intensity for a sample of 640 convenience stores of sale area between 80 m^2 and 280 m^2, varies from around 700 kWh/m^2 per year to 2900 kWh/m^2 per year. The wide variability is mainly due to the business practices employed and equipment used. The same study shows that the electrical energy intensity reduces from around 1000 kWh/m^2 per year to 600 kWh/m^2 per year, as the sale area increases from 1400 m^2 to 5000 m^2.

The typical electric energy usage in a grocery store in the US and in a supermarket in Sweden is shown in the figures below. The same exercise is being conducted to study the trend for a supermarket in Mauritius.

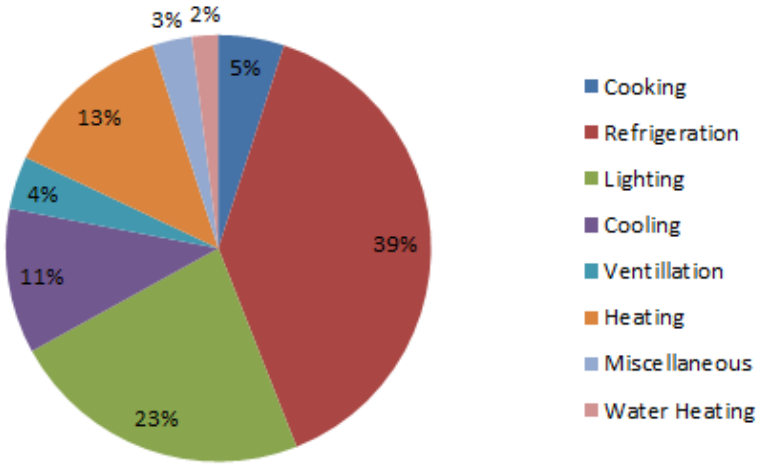

Figure 1: Typical Energy Usage in a grocery store in the US (Source: Energy Star, 2003)

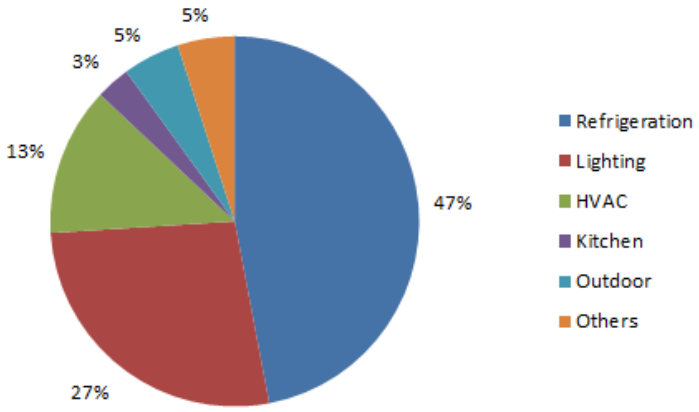

Figure 2: Typical Energy Usage in a supermarket in Sweden (Source: Lundqvist, 2000)

Food Transport Refrigeration

Food transport refrigeration is a critical link in the food chain not only in terms of maintaining the temperature integrity of the transported products but also in terms of its impact on energy consumption and CO_2 emissions. Road transport refrigeration equipment is required to operate reliably in much harsher environments than stationary refrigeration equipment. Due to the wide range of operating conditions and constraints imposed by available space and weight, transport refrigeration equipment are less efficient than stationary systems. There has been considerable increase in the use of refrigerated transport arising from the much wider range of transported goods, home delivery and greater quality expectations. The reduction in energy consumption cannot compromise the temperature control of the transported food products which is governed by legislation.

In Mauritius, most refrigerated road vehicles fall into two basic categories. Firstly, there are semi-trailers, with refrigeration units that can be run independently of the tractor unit. Secondly, there are rigid-bodied vehicles of various sizes, which may have independent refrigeration units, or may have units driven from the vehicle engine or axles. Most of these vehicles use diesel engines with optional electrical alternatives. These vehicles cover long distances or bulk movements, generally with one or more destinations, with varying journey times, for supermarket distribution.

Field Measurements

In order to set targets for improvement on energy use by stakeholders involved in commercial and industrial refrigeration sector, it is necessary to obtain data on energy use. The surveyed data will be useful to develop a benchmark. Benchmarking the energy performance of these installations will provide a means to compare the energy intensity of installations and current practices. The steps that will be involved in the benchmarking process will enable the definition of the most critical parameters to measure and track.

Field measurements in 19 supermarkets of the Winner's chain of supermarkets around the island have been carried out. The preliminary survey has been carried out to evaluate the refrigeration equipment being used and the level of sophistication. A more exhaustive examination of the systems and components is being conducted to evaluate energy efficient technologies and energy consumption in supermarkets.

Several parameters such as indoor and outdoor temperatures, moisture, air temperature in cabinets, energy usage in lighting, cooling and refrigeration are being logged at pre-set time intervals, to see the interaction of different subsystems with the effects of different energy measures.

In this context, temperature and humidity data loggers have been ordered to record these measurements in the supermarkets. The same data loggers will eventually be used for transport and industrial refrigeration.

The preliminary survey that has been carried out has allowed the collection of data about the following:

1. Shop Floor Sale Area
2. Number of display cases (or linear meters of chilled cabinets)
3. Number of Deep Freeze Cabinets(or linear meters of deep freeze cabinets)
4. Number of cold rooms
5. Refrigerant being used for medium and low temperature refrigeration
6. Type of compressors being used for medium and low temperature refrigeration
7. Existence or not of a heat recovery system
8. Whether power monitoring equipment are present on the refrigeration installations
9. Total capacity of air conditioning units installed in the supermarket sales area
10. Electricity consumption of the supermarkets

The above information is being correlated with the meteorological data that have been obtained from the meteorological station for the respective regions.

A more detailed survey is under way (since the end of April 2012) based on this information and field measurements of the energy consumption of different supermarkets around the island and a hypermarket. Further to the initial inventory of refrigeration equipment conducted in the commercial refrigeration sector in Mauritius, a number of supermarkets have been identified for a more in-depth investigation. The selection has been based on their location, type of equipment in place, and similarity in terms of linear metres of chilled and frozen cabinets in the sale area. However, although it would have been most appropriate to take into consideration another important parameter: the daily volume of chilled and frozen foods sold, this has not been possible due to unavailability of the required information.

Another variable that was taken into account was climate. Indeed, a study conducted in Sweden by Arias and Lundqvist (2000: 9) clearly shows the strong influence of higher outdoor temperatures and humidity on compressor power and temperatures in display cases. In the light of what Arias and Lundqvist (2000) have highlighted, it was deemed important to conduct the field measurements over both seasons: summer and winter, and to bear in mind the specificity of the Mauritian climate: its diurnal daily temperature variation.

Up to now, the detailed survey has been carried out in five supermarkets located in different regions around the island, namely in the west, the inland northern region, the coastal northern region and the central plateau. The initial preliminary survey was conducted essentially in the Winners' Chain of supermarket. However, given the fact that the refrigeration equipment used in its different outlets are quite similar, it was considered important to extend the survey to other supermarkets. Minimarkets and hypermarkets were also found to be interesting to investigate given the difference in size. This was done in order to have a more reliable and therefore generalizable source of information. As such, access to other supermarkets and hypermarkets was sought. Consequently, it has been possible to get field measurements from one hypermarket while negotiations are still under way with other stakeholders.

Data logging in the different supermarkets involve looking into the potential impact of certain parameters such as ambient temperature and relative humidity, among others, on the efficiency of the refrigeration system. The compressor power measurement is being carried out with the use of a power quality energy analyser of the Kyoritsu make. The instantaneous value of the voltage, current, active power, reactive power, apparent power, power factor and phase angle on each phase are being recorded on a 5 minutes interval over a period not exceeding 72 hours due to the limited availability of the energy analyser. In addition, measurements of refrigerant temperatures on the circuit are being conducted simultaneously for both the medium temperature and low temperature system.

A more in-depth analysis of a typical supermarket is actually being done. Measurements of the above mentioned parameters are being monitored over a longer period.

Initial Presentation of Findings and Discussion

Supermarkets are intensive users of energy in all countries. Electricity consumption in large supermarkets in the US and France is estimated to be 4% of the national electricity use (Orphelin 1997). In the US, typical supermarkets with approximately 3700-5600 m^2 of sale area consume about 2-3 million kWh annually for total store energy use (Baxter 2003). The national average electricity intensity of a grocery store in the US is about 565 kWh/m^2 per year (Energy Star 2003).

The same preliminary exercise shows that in Mauritius, a typical supermarket of mean sale area of 750 m^2 consume about 600,000 kWh per year for the total store energy use. The corresponding average electricity intensity is therefore about 800 kWh/m^2 per year, which is 41.6 % higher than in the US. This figure however needs to be taken with caution as this has not been correlated with parameters such as type of equipment used, sale area etc. A better understanding of this average electrical intensity will be possible once a more in depth examination of the surveyed installations is carried out.

In addition, supermarkets present a unique space conditioning challenge because of the interaction between the air conditioning system and the refrigerated display cases. The display cases provide significant sensible cooling and increase the latent load fraction of the air conditioning system. In all supermarkets that have been surveyed to date, the two systems are controlled independently.

Conclusion

As per the initial timeline drawn for the research, in addition to the critical review of the literature conducted initially, the first part of the study which consisted of a preliminary survey has almost been completed. This survey together with meteorological data collected for different regions has helped to identify which refrigeration installations required a more in-depth study. As such, a more detailed survey is currently being conducted in certain specific regions of the country. Initially, the survey was restricted to supermarkets of the Winners' Chain. However, in order to have a more representative sample of the commercial refrigeration sector, negotiations with other stakeholders in the sector is under way. The absence of energy metering devices on the refrigeration installations has made the detailed survey very difficult. An energy analyser has therefore been installed to obtain the energy consumption of the different refrigeration equipment in the supermarkets. However, due to the limited availability of the energy analyser which has been obtained on loan from a local company, the energy consumption is being monitored only for a short period of time. The results obtained to date has shed light on a number of issues and the preliminary results obtained as for now is being analysed.

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SESSION 3 – FINANCIAL SERVICES

PRESENTATION 8

Impact of exchange rate volatility on trade in goods and services (tourism) - an African perspective

Mr S Polodoo

University of Mauritius

Mr S Polodoo has about nine years of experience in the financial services sector. He started his banking career as Credit Analyst at the Ex-South East Asian Bank (Now Bramer Bank) and gradually got promoted to the rank of Manager. He held various management positions at the Ex-First City Bank Ltd, the Mauritius Leasing Company Limited and recently Dolberg Asset Finance Limited. He is now a Freelance Lecturer in Finance and Economics at University of Technology, Mauritius, UOM Trust, Middlesex University, Glamis Business School and Vatel Business School. He is holder of a Masters degree with Distinction from the UTM as well as a (PGCHE) Post Graduate Certificate of Higher Education from IFS School of Finance, University of Kent and now studying for Mphil/Phd at the University of Mauritius in the field of exchange rates.

Building Blocks

Following the floating of the US dollar in 1973, liberalization of capital flows and the associated intensification of cross-border financial transactions during the last three decades important volatility and uncertainty in exchange rates have emerged. This has raised eyebrows among policy makers and researchers as regards the impact of exchange rate movements on exports. Arguments, both theoretical and empirical are divided as to the results of the relationship between exchange rate variability and exports/trade flows, that is, whilst some models advocate that volatility in exchange rates foster uncertainty and

increases risks and therefore hamper growth in foreign trade, some other models postulate otherwise.

An analysis of the impact of exchange rate volatility on trade to Mauritius and other African countries is deemed pertinent as they have had recently experienced negative shocks in their terms of trade owing to the phasing out of the Multi-Fiber Agreement in 2004, cuts in sugar price under the Lome Convention by the European Union in 2006 and skyrocketing world oil and commodity prices. Given the prevailing situation in the eurozone, there are two areas for concern: the first being the level of indebtedness of some European countries and the exchange rate of the Euro, which has been sliding against other major currencies. This is directly impacting on African exporters (including Mauritius) and potentially the tourism sector as countries in Europe introduce measures to counter the crisis.

African exports have always been vulnerable to real exchange rate variability, but exchange rate risk hedging facilities in the continent are virtually nonexistent. Although hedging facilities are available, they are considered as expensive for small exporting firms. As a result, exporters bear the consequences of unexpected changes in the exchange rates. So far, despite some studies have been carried out in some developing countries, there has been very few studies carried out to analyse the impact of exchange rate volatility on trade of goods and services. The study thus closes a significant gap in the literature and is intended to have important policy implications as it shall help informed decision making about policy makers in formulating their exchange rate policy with a view to stimulate our exports. It can also be a case for exporters can argue their case to Government by lobbying for an export-friendly macroeconomic environment and assist them to plan their export activities more effectively.

Based on the foregoing, the main aims of this paper are:

(a) To analyse the impact of exchange rate movements on Mauritian trade of Goods.
(b) Examine the effect of exchange rate movements on the Trade of Servces, more specifically, tourism in Mauritius.

After analyzing the impact of exchange rate volatility on trade and tourism for Mauritius, the study will be extended to Africa. The two other objectives will thus be as follows:

Analyse the impact of exchange rate volatility on trade in goods in Africa as well as investigate the nature of the causality between exchange rate volatility and trade in Africa.[1]

(c) Analyse the impact of exchange rate on trade in services, more specifically, the tourism sector in Africa as well as investigate the nature of the causality between exchange rate volatility and tourism flows in Africa.

Review of Literature.

Since the floating of the US dollar in 1973, several theories have been developed to explain the channel through which exchange rate volatility affects trade. The theories propounded have been broadly classified into two channels. The first one concerns channels through which only exchange rate influence trade- the partial equilibrium theory- to put it in the words of Côté (1994). Here, the impact of exchange rate volatility on trade is explained and dependent on the following: the risk profile of exporters, the presence/absence of hedging, the market structure, costs and pertinence of hysteresis in trade, alterations of production volume and export destination, assuming that the only variable that influence trade is the exchange rate. A second channel, more technically known as the general equilibrium theory Côté (1994) explains the channel through which exchange rate volatility impacts on trade by combining all the probable factors that might influence trade. All the channels through which exchange rate volatility influences trade are discussed below. In addition to trade in goods, the focus in recent years has been the impact of exchange rate volatility in trade of services.

[1] Countries to be included in the sample embrace Kenya, Tanzania, Zambia, South Africa, Botswana, Namibia, Uganda, Rwanda, Morocco and Mauritius.

Empirical Literature

The existing empirical literature has been classified and critically analysed with a view to providing an idea about gaps and subsequently to form an assessment of potential methodologies to be applied in the thesis.

In the theoretical literature chapter, a review of the theory underpinning the impact of exchange rate volatility on trade is made and equivocal results are uncovered thereto such that a proper direction and nature of the link is rather hard to gauge. That said the impact of exchange rate volatility on trade and vice versa is an empirical issue which is addressed in the empirical literature chapter. Numerous studies, viz Hooper and Kohhagen (1978), De Grauwe (1988), Mc Kenzie and Brooks (1997), Dekle and Fukao (2011) among others have found differing results pertaining to the impact of exchange rate volatility on trade.

The objective is to review the empirical literature as regards the impact of exchange rate volatility on trade. There are a number of matters in the literature that helps explaining the ambiguity in the results as regards the impact of exchange rate volatility on trade. These are: the type of trade flows (whether they are bilateral, multilateral or sectoral), the way exchange rate is measured or type of exchange rate (nominal or real exchange rate), the models applied in the literature, econometric method applied, the nature of the economies studied, endogeneity or exogeneity issues as well as the type of data used (whether panel or time series).The studies vary in terms of their results; whilst some studies reveal a negative impact of exchange rate volatility on trade, others reveal no impact or positive impact of exchange rate volatility on trade.

Differences in Trade Flows

Empirical evidence as regards the impact of exchange rate volatility on trade differs widely in terms of the underlying trade flows. Whilst some studies use aggregate or multilteral trade, others use bilateral or in some cases, sectoral trade to examine the impact of exchange rate volatility on trade. In any of the studies, results are mixed with some studies revealing a positive impact whilst others give a negative impact and others give significant impact. This section gives a review of the empirical literature as regards the underlying trade flows, deemed to be one of the most important features explaining the differences in results pertaining to the impact of exchange rate volatility on trade.

Most of the earlier studies, viz Hooper and Kohlhagen (1978) as well as recent ones like, Arize et al (2000), Duasa (2007), Todani and Munyama (2005), Rey (2006), Aziz (2008), Ibikunle and Akhanolu (2011) employ aggregate trade data to examine the impact of exchange rate volatility on aggregate trade. The results are not conclusive given that some authors find either positive or negative impact others find no impact or both.

The use of aggregate trade flows has been subject to extensive criticism. In this vein, Mc Kenzie (1999) postulates earlier that the impact of exchange rate volatility on trade is not the same for each country as same would depend on the export market as well as the nature of the good. Chit et al (2008) point out that data regarding aggregate trade flows give weak empirical findings. Their views are based on the fact that exchange rate volatility may have both positive and negative impact on bilateral trade for an economy with its different trading partners and that at aggregate level these positive and negative effects tend to offset each other. According to Godany (2011), the ambiguous results obtained when aggregate trade flows are employed are due to the assumption that the impact of exchange rate volatility on international trade is the same in each country, which is untrue in real life situation. Nevertheless, as we shall see below, the results regarding the impact of exchange rate volatility on trade is also mixed. According to Cushman (1986), bilateral trade flows ignore third country effect, subsequently leading to the model being misspecified. Despite the foregoing, there has been a shift in the way the impact of exchange rate volatility on trade is studied towards more bilateral frameworks and some studies nowadays even test for 'Third Country Effects'.

Despite the fact that bilateral trade flows are preferred to aggregate trade flows, the various studies conducted using bilateral trade flows have been criticised on various grounds. For example, according to Cushman (1986), most studies employing bilateral trade flows ignore 'Third Country' effects. Clark et al (2004) among others postulate that studies using bilateral trade flows may still lead to aggregation bias Also, Chit et al (2008) stipulates that, given that markets are heterogeneous, exchange rate volatility may lead to different impact on different export markets. According to Auboin and Ruta (2011), aggregate trade data also assumes identical income elasticity, price elasticity and exchange rate volatility across countries, a situation where pertinent information are not captured in the analysis. Based on the foregoing limitations, there is nowadays a shift in emphasis to

disaggregated trade flows in analysing the impact of exchange rate volatility on trade (Sekkat and Varoudakis, 1998; Todani and Munyama, 2005; Caglayan and Di, 2008; Hosseini and Moghaddasi, 2010, Huchet-Bourdon and Korinek, 2012 among others). Studies regarding sectoral trade flows are broadly segregated into the impact of exchange rate volatility on agricultural trade, manufacturing trade and trade in services.

Agricultural Trade

Studies regarding the impact of exchange rate volatility on agricultural trade are done by Adubi and Okunmadewa (1999), Sheldon (2003), Bittencourt et al (2006), Todani and Munyama (2005), Kandilov (2007), Sarker and Villanueva (2007), Gunduz (2010), Fogarasi (2010), Hosseini and Maghaddassi (2010), Serenis et al (2011), Sheldon et al (2011), Huchet-Bourdon and Korinek (2012) among others.

Manufacturing Trade.

Studies regarding the impact of exchange rate volatility on trade are provided by Campa and Goldberg (1993), Samson et al (2003), Aguirre et al (2007), Hayakawa and Fukunari (2008) among others. For instance, Campa and Goldberg examine the impact of exchange rate volatility on US manufacturing sector trade using annual sectoral data for the period 1972 to 1986. The authors employ real exchange rate and two measures of exchange rate volatility in their study; the coefficient of variation and the standard deviation of the first differences of the logarithm of exchange rate over the twelve previous quarters. The authors employ a panel investment equation and apply in the first instance Two Stage Least Squares to take into account endogeneity problems. The equation is also regressed with fixed effects and for robustness purposes, GMM is applied. The empirical findings reveal that for the period 1972 to 1983, exchange rate volatility led to a fall in investment in the manufacturing sector and hence trade. However, for the period 1984 to 1986, there was an increase in investment in the manufacturing sector and hence trade.

Trade in Services

Studies pertaining to the impact of exchange rate volatility on trade in services are rather scant. Authors who have directly or indirectly studied are Hung and Viana (1995), Wang

and Barett (2002), Barcellina and Molero (2003), Baggs et al (2008) and Mahagaonkar et al (2009).

Hung and Viana (1995) model U.S services trade flows, in particular tourism and other private services. They employed export import price equations for both tourism and other private services and use to time series econometrics viz cointegration and error correction model approach to model tourism and other private services. The empirical findings reveal that tourism is much less responsive to exchange rate change but instead to foreign economic growth. Similar finding is found for other private services. Moreover, Wang and Barett (2002) examine the impact of exchange rate volatility on international trade of all sectors in Taiwan. The authors employed monthly sectoral and market specific data for the period 1989 to 1998 and use multivariate GARCH in mean estimator as a measure of exchange rate volatility. According to the authors, the employment of aggregate data assumes that the effect of exchange rate volatility is homogenous across sectors and markets and that disaggregated data captures differences in exchange rates across sectoral trade. In view thereof, a multivariate GARCH-M model is employed to capture aggregation bias. The empirical findings reveal that exchange rate volatility is insignificant in explaining service sector trade flows in Taiwan, contrary to agricultural flows, for which exchange rate volatility has a positive significant impact.

Furthermore, Barcellina and Molero (2003) use annual data for the period 1976 to 2000 for 15 European countries to study service export firm. The authors employ an imperfect substitute model with export demand equations for real services, which are a function of relative prices, foreign income and exchange rate. Employing time series econometrics and after applying unit root tests, cointegration and error correction modelling techniques, the equations are regressed by including two lags to variables in first differences to capture lagged effects after which the variables in difference having t values of less than one are dropped. The empirical findings reveal cointegration between the explained and explanatory variables and that the impact of exchange rate on services exports is positively significant for eight countries only. Barcellina and Molero (2003) find negative and perverse impact of exchange rate on services exports for Belgium and Italy.

One penultimate paper is provided by Baggs et al (2008), who examine the impact of exchange rate changes on service trade in Canada using annual and sectoral data for the period 1990 to 1995. The authors employ real exchange rate and change in trade weighted exchange rate to measure any appreciation or depreciation of the currency. They developed functions relating to profit, survival, sales and leverage and employ panel data econometrics, viz ordinary least squares and Tobit estimation procedure. Baggs et al(2008) find significant negative impact of exchange rate movement on the profit, survival, sales and leverage of the service firms.

More recently, Mahagaonkar et al (2009) examine the impact of exchange rate volatility on manufacturing and service sectors for 14 OECD countries using annual sectoral data for the period spanning 1987-2003. The authors employ real exchange rate, GARCH as measure of exchange rate volatility and use two export functions; one function having export share in production as dependent variable and the other having export-import ratio as dependent variable. As regards methodology employed, Mahagaonkar et al (2009) employ unbalanced panel random effects as well Instrumental variable random effects panel regression and find significant negative impact of exchange rate volatility on research and development intensity and thus exports of both service sector and manufacturing firms.

Measures of Exchange Rate and its Volatility

Besides trade flows, another important aspect in the empirical literature is the measure of exchange rate and its volatility. Although some authors like Clark et al (2004) mentions that it makes no difference as to whether we use nominal or real exchange rate, some studies employ either nominal only or real only. Yet for sensitivity analysis, and there are also studies that employ both measures of exchange rate. As regards exchange rate volatility, there is a plethora of models developed to date. Here also, some studies employ only one measure whilst others employ more than one measure

Trade Models

The various empirical studies regarding the impact of exchange rate volatility on trade also vary a lot in terms of trade models. There have been various trade models employed in the

literature, which include inter alia, export functions, gravity models, import functions, import functions, and trade balance functions. Most studies, however, are conducted using export demand functions and gravity models. It is noteworthy that the empirical findings are very responsive to the trade model employed in the study.

Countries Covered

The empirical literature also differs a lot in terms of countries covered. Whilst some studies are done in small island developing states like Mauritius, Singapore, Fiji, New Zealand among others, other studies are done in other African countries like Sub Saharan African countries, South Africa, Nigeria, Kenya and so forth. For the developed world, most studies are done in US.

Econometric Issues

The various empirical literature regarding the impact of exchange rate volatility on trade have been conducted using either time series or panel data econometrics. Pursuant to the advancement in econometric literature, there has been several development in the estimation methods over the years, be it in terms of time series or panel data, rendering, according to the authors more consistent and efficient estimates. One additional issue of interest in recent years has been the question of tackling endogeneity issues, both in time series and panel estimations.

Conclusion and Proposed Methodology

The contributions to the literature regarding the impact of exchange rate volatility on trade on both goods and services are reviewed. It is found in the literature that empirical results are inconclusive. Whilst some findings reveal significant negative impact, others show significant positive impact or insignificant results. The ambiguity regarding your results is explained mostly by differences in frequency of data, differences in the nature of trade flows, type of exchange, measure of exchange rate volatility, the model employed as well as the econometric methodology employed together with various econometric issues such as endogeneity.

As far as frequency of data is concerned, we note that whilst some studies are conducted using annual data, there are some other studies that are carried out either using monthly or quarterly data. The most important issue found in the literature is the choice of exchange rate volatility measure. There is no golden rule per se as to the exchange rate volatility measure to be used. As we have seen, there is a plethora of measures that have been employed so far in the literature. However, most studies are conducted using two or three measures for robustness purposes.

Moreover, there have been several models developed so far to investigate the impact of exchange rate volatility on trade, viz export demand function, import function and gravity models. The studies conducted use either of these models, although there are few studies that have employed two models to check for robustness of their results.

Further, an important issue found in the literature, especially for the small island economies is failure for account for nature of causality between trade and exchange rate volatility. So the endogeneity of the variables becomes an important issue.

Based on the findings of the empirical literature, a brief of the proposed methodologies to be applied in the study are provided hereunder:

Impact of exchange rate volatility on Trade in Goods in Mauritius.

-In order to avoid aggregation bias, annual sectoral data will be employed. We shall employ agricultural trade data as well as manufacturing trade data. Although studies regarding the manufacturing sector have been done and scant, studies regarding agricultural trade and exchange rate volatility have never been done for Mauritius.

- More than one exchange rate volatility measure will be employed for robustness purposes. The study will employ newer measures that have not yet been employed in studies conducted for Mauritius such as the coefficient of variation, a measure that is deemed to give a better approximation than the standard deviation or mean. For robustness purposes, newer measures not yet employed in studies for Mauritius will be used such as the z-score, the Max-Min and the absolute percentage change in the exchange rate will be employed.

-As far as model specification is concerned, instead of using solely an export equation, the study shall also employ an import demand equation as well as a trade balance equation so that an investigation of not only net trade is done but individual import and exports of agricultural and manufacturing goods. An Exchange rate equation will also be created so as to investigate the nature of causality.

-Regarding methodology, time series econometrics will be employed whereby a blend of methods comprising ARDL bound testing and generalised Variance Decomposition. Despite the fact that the ARDL bound testing does not require pre testing for unit root, this study shall first conduct several unit root tests such as the ADF test, the Phillips Perron test using eviews software. Given that presently there are no studies conducted that have tested the nature of causality between trade and exchange rates, this study shall employ instrumental variables procedures as well as granger causality tests for that purpose.

The Impact of Exchange Rate Volatility on Trade in Service (Tourism) in Mauritius.

- Instead of using either annual, monthly or quarterly data, the data employed will be seasonally adjusted given that tourism trade is seasonal having its peak season in summer in Mauritius.

- Several newer measures of exchange rate volatility will be employed and an investigation as to whether the results are robust to these measures will be made.

-Instead of using import and export equations as in most studies, we shall employ a gravity model as tourism trade flows depends on country size, geographical distance, income, land areas among others. Such factors can only be factored in a gravity model. An Exchange rate equation will also be created so as to investigate the nature of causality.

- As far as econometrics is concerned, time series econometrics will be employed. So far the impact of exchange rate volatility on tourism trade flows in Mauritius is yet to be explored. In view thereof, using eviews software, newer unit root tests such as Elliot-Rothernberg-Stock test will be done and compared to traditional ADF as well Phillips Perron tests.

Cointegration techniques will be used and Vector Error Correction, if applicable. In order to test for the nature of causality, granger causality tests will be done and instrumental variables will be employed.

The Impact of Exchange Rate Volatility on Trade in Goods in Africa.

This part will be an extension of the study that will be conducted for Mauritius. However, instead of using time series econometrics, the study shall use panel data econometrics. Thus, as in the case of Mauritius, annual sectoral data will be employed-agricultural trade data as well as manufacturing trade data. Also, the coefficient of variation, z-score, the Max-Min and the absolute percentage change in the exchange rate will be employed exchange rate volatility measures that will be employed.

Regarding methodology, as already mentioned, panel data econometrics will be employed. A blend of methods comprising panel OLS, random effects, fixed effects, GMM and random coefficient estimations will be employed. The random coefficient estimates, also known as Time Varying Model, as explained earlier, is a much better methodology than the GMM or OLS as there is no need to include dummy variables, controls for endogeneity, measurement errors and unknown functional forms. This methodology is employed by Hondroyiannis et al (2005) for industrialised countries but to our knowledge no studies in Africa has yet employed such tools in analysing the impact of exchange rate volatility on trade. To investigate the nature of causality, we make use of panel Vector Autoregression techniques (VAR) which enables to further address endogeneity issues by allowing endogenous interactions between the variables. In this study, the VAR approach allows to check for bidirectional causality between trade and exchange rate volatility. In other words, the VAR approach takes into account the fact that exchange volatility can impact on trade and vice versa, that is trade impacts on exchange rate volatility. After doing panel unit root tests, panel cointegration techniques will be applied. Once the VAR estimates are obtained, we compute the impulse response functions describe the response of an endogenous variable over time to a shock in another variable in the system. Variance decompositions will also be carried out to know the contributions of each source of shock to the (forecast error) variance of each endogenous variable, at a given forecast horizon.

The Impact of Exchange Rate Volatility on Tourism Trade in Africa.

This part also will be an extension of what will be conducted for Mauritius. The data employed will be seasonally adjusted given that tourism trade is seasonal having its peak season in some time of the year. In such a case, countries facing summer solstice simultaneously during a given year will be taken.

Several newer measures of exchange rate volatility such as the coefficient of variation, z-score, the Max-Min and the absolute percentage change in the exchange rate will be employed and an investigation as to whether the results are robust to these measures will be made. Panel data techniques will be used as in 4.3.

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PRESENTATION 9

Financial policies and corporate capital structure in developing countries: the case of Mauritius

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Introduction

The main aim of this paper is to model the influence of external financing on corporate capital structure choice in a small island economy like Mauritius. In light of the different theoretical evolution over the years, there are still no clear-cut answers to the determinants of corporate capital structure. Even in their extensive and thorough surveys, Harris and Raviv (1991) have missed the relationship between external financing and

corporate capital structures. Hence, we use a unique firm level database across different sub-sectors and industries in a Small Island Developing States (SIDS) like Mauritius to test the impact of financial policies on corporate capital structure. We differentiate between the impact of financial liberalisation and financial sector development on corporate finance. Moreover, we test for a joint interaction between firm investment, liquidity and leverage under asymmetric financial markets and liberalized finance, which is estimated via a dynamic panel data model with the Generalised Method of Moment (GMM) estimates. Many authors have missed the inter-relationship amongst these three variables (dividend, liquidity and leverage).

Literature review

The literature on capital structure has been wide and ranges from the traditional Net Income Approach, the Net Operating Income Approach, the Modigliani and Miller (MM) (1958) Irrelevance Theories, MM (1963) Tax theory and the Static Trade-Off theory. Based on the principle of information asymmetry, Myers and Majluf (1984) developed the Pecking Order Hypothesis, where firms basically make use of internal finance. According to the Signaling theory of capital structure, good firms distinguish themselves from bad ones by sending a credible signal about its quality to capital markets. Under the Legal Environment theory of capital structure, different legal environments are expected to influence firm's financing decisions. In a sample of nine developing countries, Singh and Hamid (1992) argued that firms made significantly more use of external finance, particularly equities, to finance their growth, than is typically the case in the industrial countries. Huary and Song (2002) concluded that the static TOH explained the financial structure of Chinese listed companies better than the POH. However, Tang and Green (2004) supported the POH by using data from Chinese companies. Abar (2008) compared the capital structures of public quoted firms, large unquoted firms and SME's in Ghana using panel data regression model, as well as in a sample of three different groups. He showed that quoted and large unquoted firms exhibited significantly higher debt ratios than SME's. However, short-term debt constituted a relatively high proportion of total debt of all the sample groups. Seetanah and Padachi (2002) investigated the link between stock market development and firm capital structure for 38 listed firms on stock exchange of

Mauritius over the period 1994-2008 and showed that stock market development increased debt for non-financial firms while this was not the case for listed financial firms.

Capital Structure Analysis

An analysis of the gearing ratios of the top 100 companies over the period 1994 to 2008 illustrates that there is a wide variation in the ratio among companies both within the same and across different industries. Almost all industries are highly geared and the overall gearing ratio of firms has shown an increasing trend over the years.

Augmented model

On the basis of theoretical underpinnings, we estimate an augmented model as follows:

$$LEV_{it} = \beta_0 + \beta_1 TANG_{it} + \beta_2 PROF_{it} + \beta_3 SIZE_{it} + \beta_4 LIQUIDITY_{it} + \beta_5 AGE_{it} + \beta_6 NDTS_{it} + \beta_7 RISKS_{it} + \beta_8 GROWTH_{it} + \beta_9 FINLIB_{it} + \beta_{10} FINDEV_{it} + e_{it} \quad (1)$$

Empirical strategy

For a more comprehensive analysis of debt/equity choices of firms in Mauritius, we undertake sensitivity analysis in different sub-samples. We have collected data from an unbalanced sample of 298 firms across different sectors and classified them according to good corporate governance, poor corporate governance, those in group structure v/s independent companies, international and domestic enterprises and listed v/s unlisted companies. We further sub-divided the sample into the top 100 companies and 'other companies'. To conduct a sectoral analysis, we undertake the study in the banking, insurance, hotels, manufacturing, construction, leasing, retail/distributive trade and oil industry.

We apply the new STATA software 10.0 to estimate the above model. In order to reinforce the robustness of our results, we test whether our variables are stationary using the panel unit root tests (table 4). Data has been collected from the financial statements of

companies. Some other pertinent data have been obtained from the SEM FactBook 2008 and the top 100 Companies Magazine 2008 Edition.

Analysis of results

As dependent variable in our hypotheses, we use corporate leverage (debt/equity ratio), measured as the sum of short term and long-term liabilities of companies to equity. We believe that this is a better measure of corporate debt, as it envelops firms' ability to borrow in the external market. The independent variables included are described in the table below. We report results in the different sub-samples. The different models applied are rightly specified with appropriate coefficient of determination across the different sub-samples, which are either estimated with OLS or GLS estimates.

Definition of variables used

Variables	Indicator used
Leverage	Summation of short and long term liabilities
Tangibility	Amount of fixed assets
Size	First difference of total assets
Net-Liquidity	Cash flow plus short-term illiquid investments and any liquid asset for which there is a readily available market.
Age	Number of years since existence
Non-debt Tax Shield	Corporate tax relief available
Risks	Variability in annual turnover
Growth	Growth in turnover
Profits	Earnings before interest, depreciation and taxes
Financial Liberalisation	Financial Liberalisation Index computed from the PC method. It is also decomposed between the index of capital account liberalisation and the index of money market liberalization
Financial Development	The following sensitivities: the ratio of M2 over GDP, total bank credit over GDP, market capitalization over GDP, total amount of corporate loans disbursed by insurance companies over GDP, investment in leasing activities over GDP, ratio of total

	investment by venture capitalists over GDP and total loans disbursed by government bank over GDP.

Source: Author

We have disaggregated the overall financial liberalisation index (FINLIB) into the index of capital account liberalisation (ICAL) and the money market liberalisation index (IMML) and included in our regression. The different indices have a positive but insignificant impact on corporate leverage. Financial liberalisation programmes cannot explain corporate leverage in Mauritius.

In contrast, the overall financial development index has a positive and significant relationship with leverage. Development of the financial sector allows firms a wider choice of financial instruments and products and they increase their liabilities accordingly. The coefficient of broad money liabilities over GDP positively impacts of the debt/equity ratio and more money into circulation allow more credit in the financial system. In the same vein, the higher the amount of credit disbursed towards the private sector by banks, they more the debt amount of banks and firms in Mauritius prefer to use bank loans rather than other sources such as equity financing.

They also make use of leasing finance, which has a significant and positive impact on corporate leverage. Our result is therefore different from Singh and Hamid (1992). The coefficient of stock market capitalization over GDP is insignificant across the different sub-sectors to explain corporate leverage. Many companies also resort to government loans such as from the DBM, which positively impact on their debt/equity ratios. The other institutions, such as venture capitals and insurance companies are still at their infancy in explaining the debt/equity ratio of firms.

We test the hypothesis that there is joint interaction between firms' liquidity, investment and leverage under asymmetric financial markets and liberalized finance. By and large, there is also an indirect relationship between investment and dividend behaviour. We thus formulate a dynamic simultaneous equations framework that is composed of a liquidity

equation, a leverage equation and an investment equation as follows:

$$LIQ_{it} = \alpha_0 + \alpha_1 LIQ_{it-1} + \alpha_2 L_{it} + \alpha_3 L_{it-1} + \alpha_4 INV_{it} + \alpha_5 INV_{it-1} + \alpha_6 PROF_{it} + \alpha_{7i} PROF_{t-1} + FILIB_{it} + FLIB_{it-1} + FINDEV_{it} + FINDEV_{it-1} + e_{it} \quad (A)$$

$$L_{it} = \beta_0 + \beta_1 L_{it-1} + \beta_2 LIQ_{it} + \beta_3 LIQ_{it-1} + \beta_4 PROF_{it} + \beta_5 PROF_{it-1} + \beta_6 INV_{it} + \beta_7 INV_{it-1} + \beta_8 SIZE_{it} + \beta_9 FILIB_{it} + \beta_{10} FLIB_{it-1} + \beta_{11} FINDEV_{it} + \beta_{12} FINDEV_{it-1} + v_{it} \quad (B)$$

$$INV_{it} = \delta_0 + \delta_1 INV_{it-1} + \delta_2 LIQ_{it} + \delta_3 LIQ_{it-1} + \delta_4 L_{it} + \delta_5 L_{it-1} + \delta_6 PROF_{it} + \delta_7 PROF_{it-1} + \delta_8 FILIB_{it} + \delta_9 FLIB_{it-1} + \delta_{10} FINDEV_{it} + \delta_{11} FINDEV_{it-1} + u_{it} \quad (C)$$

Each equation is determined jointly by the other equations with liquidity, investment and leverage as endogenous variables. The above is a set of simultaneous equation model, with a set of predetermined variables with each equation containing one period lagged variable (liquidity, profitability, leverage, financial liberalisation index, financial development index and investment). The endogenous variable in one equation appears as an explanatory variable in another equation in the system.

The above models have a lagged dependent variable. We estimate the above simultaneous equation model with the GMM estimates with lagged variables as instrumental values. Such a model yields better and more robust results than individual estimates of the equations separately as there are joint interactions among variables.

We report results from a full sample of 298 firms. For robustness check, we also report results on the different sub-samples (firms in group structure; independent firms; banks; insurance companies; leasing companies; hotels; manufacturing firms; oil; distributive trade and those in the construction industry). These results provide better estimates for the different coefficients of the different models as each coefficient is estimated while taking into account the behavior of the other variable(s), with which there is a simultaneity relationship.

The equations are simultaneously determined and the results are reported with equation A (dependent variable: liquidity) in the first column, equation B (dependent variable: leverage) in the second column, while equation C (dependent variable: investment) is reported in the third column.

In all the three equations, A, B and C, it is observed that both lagged and current period FL index has an insignificant impact of liquidity, leverage and investment. This reinforces our previous results on the influence of FL on investment and leverage. In contrast, it is observed that the coefficients of both lagged and actual period financial sector development index have positive and significant coefficients on liquidity, leverage and investment. Development of the financial sector thus allows firms to improve their liquidity conditions through increased leverage. This in turns has a positive impact on corporate investment.

A crucial simultaneity relationship is observed in the above analysis. When firms make profits and there is a profitable investment opportunity available, they curtail dividend payments and save out the funds in terms of internal liquidity[2]. This is in turn used to finance the investment project. Hence, an inter-play among internal liquidity, dividend payment, investment and external debt is observed.

Conclusion

This chapter has provided additional evidence on the relationship between financial liberalization and development on corporate capital structures. A wide variation in the gearing ratio among companies within the same industry as well as across different industries is noted. High volatility of capital structure choice is also observed and almost all industries are highly geared with increasing gearing ratios. We have divided the sample of firms differently, as well as across different sectors and used an improved measure of internal liquidity. Results from a stationary panel data from an augmented capital structure model, with macroeconomic financial variables have shown different results. The

[2] And hence lower external debt.

main determinants of corporate leverage are asset tangibility, firm size, firm growth, age, growth, risks, profitability and liquidity. However, the relative impact of each of these variables varies across the different sub-samples. Firms in groups and international companies operate an internal financial market and easily obtain finance. This is also the case for those with good banking ties. Further results have shown a nil effect of financial liberalization on capital structure decisions, unlike financial sector development. It has also been proved that the stock market does not influence capital structure choice, results contrary to what Hamid and Singh (1992) found for developing countries. We found that subsidized Government financing and leasing companies increases corporate leverage but other institutions such as private venture capitalists, insurance companies cannot explain leverage. Results from a simultaneous dynamic panel data model comprising of a leverage equation, a liquidity equation and investment equation confirmed joint interaction between these parameters firms retain profits in terms of internal cash flow (liquidity) in order to finance investment. They also borrow less in the market. Myers (1984) PO hypothesis is thus reinforced and we have an indirect proof that firms also curtail dividend payments in order to finance current investment projects.

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SESSION 4 – SCIENCE & TECHNOLOGY EDUCATION

PRESENTATION 10

Sugarcane yellow leaf virus: genetic diversity studies, effect on yield and inheritance of resistance in sugar cane

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Mr N Joomun obtained his BSc (Hons) degree in Agriculture from the University of Mauritius in 1999. He then spent a year as trainee researcher at the Agricultural Research and Extension Unit (AREU). In 2001, he was awarded a scholarship by the Department for International Development (DFID), UK to follow an MSc course in Natural Resources (Plant health and protection) from the Natural Resources Institute, University of Greenwich, UK, which he completed in 2003 with distinction.

He joined the Mauritius Sugarcane Industry Research Institute in 2003 and has since been working in the field of molecular diagnostics. His research interests include the following:

- development and application of molecular techniques for sensitive detection of plant pathogens (especially real-time Taqman PCR and Muliplex PCR)
- characterisation of genetic diversity of sugarcane pathogens
- application of DNA fingerprinting test for sugarcane varieties which has achieved ISO 17025: 2005 accreditation by MAURITAS
- the application of DNA barcodes for identification of sugarcane insect pests.

Introduction and Literature Review

In the late 1980s, a sugarcane disease of unknown etiology was described in Hawaii (Schenck, 1990). Intense yellowing of the midribs occurred and it gradually progressed until the whole leaf turned yellow, hence the name yellow leaf syndrome. Similar symptoms, though, had been reported previously in eastern Africa by Ricaud (1968) and was termed yellow wilt. In a few years, the disease was reported in a number of sugarcane growing countries including USA and Brazil (Comstock et al., 1994), Mauritius (Saumtally and Moutia, 1997), Australia (Smith et al., 1995) and South Africa (Bailey et al., 1996). The causal organism was first identified as a Luteovirus and named Sugarcane yellow leaf virus (SCYLV) (Scagliusi and Lockhart, 1997). Recently, this virus has been assigned as a member of genus polerovirus of the luteoviridae family (D'Arcy and Domier, 2005).

In many countries, the sugarcane yellows phytoplasma is also associated with similar yellowing symptoms in sugarcane (Cronjé et al., 1998; Aljanabi et al., 2001; Arocha et al., 2005). Rott et al. (2005) proposed new names to distinguish the disease caused by these two organisms - Sugarcane leaf yellows caused by the phytoplasma and Sugarcane yellow leaf caused by SCYLV. SCYLV is transmitted mainly by infected cane setts and the aphid vectors Melanaphis sacchari and Rhopalosiphum maidis (Scagliusi and lockhart, 2000). It is believed that the international transfer of infected cuttings during exchange of germplasm for breeding purposes greatly facilitated its spread at a time when appropriate diagnostic techniques were unavailable. SCYLV is now present in all sugarcane growing areas of the world (Lockhart and Cronjé, 2000).

Since yellowing of leaves can also be caused by other biotic and abiotic factors such as water stress, and that the virus often occurs at low titres, improved detection techniques were required for its diagnosis. Initially polyclonal antiserum were developed and DAS - ELISA (Scagliusi and Lockhart, 1997) and Tissue Blot immunoassay, TBIA (Schenck et al., 1997) were used. The development of a Reverse Transcription Polymerase Chain Reaction (RT-PCR) test offered increased sensitivity especially for application at quarantine level (Comstock et al., 1998). Infected quarantine clones had to be destroyed to prevent spread of the virus, but since the early 2000s tissue culture techniques are available to clean virus-infected sugarcane plants (Chatenet et al. 2001; Parmessur et al. 2002). Real-time Taqman

® RT-PCR (Korimbocus et al. 2002) and molecular beacons (Goncalves *et al*. 2002) have been recently developed for improved detection of SCYLV.

Highly susceptible cultivars are severely affected, e.g. cultivar SP 71-6163 in Brazil where up to 25% yield losses have been reported and in USA, Grisham et al. (2009) observed loss in cane and sugar yield and sugar content in commercial cultivars. In commercial fields in Mauritius, more than 50% infection was observed in 13 varieties out of 21 surveyed using TBIA (Anon, 2008). This figure may be even higher if a more sensitive detection technique is applied.

At genetic level, considerable genetic diversity has been reported for SCYLV. Moonan and Mirkov, (2002) found that the geographical origin of the SCYLV isolates from the Americas may be responsible for the diversity observed. Similarly, Abu-Ahmad et al., (2006a) described genotypes of SCYLV from Brazil (BRA), Peru (PER), Réunion (REU) and Cuba (CUB) as well as cases of mixed infection of more than one genotype. With further genetic studies worldwide, other genotypes are also reported, namely HAW from Hawaii (Elsayed *et al*. 2011), IND from India (Viswanathan *et al*., 2008), CHN1 (Wang and Zhou, 2010 and CHN2 (Wang *et al*., 2012) from China. In a study of selected germplasm clones in Mauritius, genotypes REU, BRA-PER and CUB have been detected (Joomun and Saumtally, 2010).

Study of the variation of the virus is important since differences in infection capacity and virulence have been reported among the different genotypes reported (Abu-Ahmad *et al*. 2007a,b). Moreover, a sequence deletion of 48-54 nt in ORF1 (coding for gene silencing suppressor and RNA-dependent RNA polymerase) was observed in SYCLV sequence from susceptible plants as opposed to those from resistant plants (Elsayed et al., 2011). These authors suggested that this deletion is the reason for the high proliferation rate of SCYLV in susceptible plants.

Hot water treatment of infected setts is not effective for the elimination of the virus and even if clean tissue culture material is used for propagation, field re-infection is very common. Therefore, the use of SCYLV resistant varieties remains a better solution.

Breeding for resistance to SCYLV has not yet been undertaken in Mauritius and in order to assess the reaction of individuals in a sugarcane population, it is important to devise a reliable, quantitative assay for the virus so that varieties can be rated for their reaction to the disease.

Research Questions

The proposed overall aims of this study consist of the following:

- Assessing the genetic diversity of SCYLV in Mauritius
- Developing specific real-time RT-PCR for each strain and the possibility of designing a multiplex RT-PCR assay
- Assessing the reaction of commercial varieties to different SCYLV genotypes
- Devising a resistance index for SCYLV based on real-time RT-PCR
- Studying the inheritance of resistance to SCYLV
- Studying the effect of various SCYLV genotypes on cane and sugar yield

Methodology

Genetic diversity of SCYLV in Mauritius

Leaf samples, with or without symptoms, were collected from commercial fields from different sugarcane growing regions during the period February-July 2011. Total nucleic acids were extracted using the Hot CTAB method as described in Joomun and Saumtally (2010) following which RT-PCR were performed using primers YLS462/111 (Irey, unpublished), that amplify a 352 bp fragment from SCYLV positive plants.

Genotype specific primers for CUB, REU and BRA-PER genotypes have been designed by Abu-Ahmad *et al*., 2006b (Table1) and the RT-PCR optimized by Joomun and Saumtally (2010) for use with total nucleic acids was used in this study.)

Table 1: primer pairs used for detection of SCYLV genotypes REU, BRA-PER and CUB

Genotype	Primer	Sequence (5'-3')	Product (bp)	Reference
BRA-PER	PER-F	AAC TGC TGC GTC AGG CCC A	362	Abu-Ahmad *et al.*, 2006b)
	PER-R	GAC GAG CTT GCG TTG TTT TTC T		
CUB	CUB-F	GTG CTT CTC CCG GCG GTT CAC T	450	
	CUB-R	ATT CGA GAA CAA CCT CCG CCT C		
REU	REU-F	CAA GCT TCT AGC GGG AAT C	905	
	B-REV	CAG TTG CTC AAT GCT CCA CG		

Multiplex RT-PCR for genotypes of SCYLV

In addition to the use of single RT-PCR for the various genotypes, tests were performed in order to develop a sensitive multiplex RT-PCR test to detect 3 genotypes of SCYLV in a single test

Development of genotype specific real-time RT-PCR for each genotype

It is desirable to have specific and sensitive assays for diagnosis of sugar cane diseases especially at quarantine level, and if possible to be able to detect all variants in one test. From sequence data available in Genbank, specific primers and probes were designed for CUB genotype using primer 3 and blast combination from the NCBI website. Optimisation of the real-time RT-PCR were performed and tested using the samples collected during the survey.

SCYLV Resistant X SCYLV Susceptible crosses

Variety M 1176/77 is known to be resistant/tolerant to SCYLV and both R570 and R579 and highly susceptible to the virus. The crossing seed bank of the Plant Breeding Department of MSIRI was screened for crosses involving these varieties. Crosses R570 X R579 (susceptible x susceptible) and M 117677 X R 579 (resistant x susceptible) were available and seeds were sown in trays in the glasshouse. Four hundred and six (406) seedlings of M 1176/77 X R 570 and 143 seedlings of R 579 X R 570 were available and

have been transplanted in the field in Réduit in April 2012. These will be used for studying inheritance of resistance to the virus

Findings and Discussion

SCYLV genotypes in Mauritius

Part of the work done so far on the samples collected during the survey is currently presented in Table 2. Out of the ten field samples, 7 tested positive for SCYLV. Variety M 1176/77 is resistant/tolerant to SCYLV and was tested SCYLV free. As expected from the geographical grouping of SCYLV genotypes described by Abu-Ahmad *et al*. (2006), Genotype REU is prevalent in Mauritius due to proximity with Réunion Island. Genotype BRA-PER has been observed to be more aggressive in Réunion Island and Guadeloupe (Abu-Ahmad *et al*., 2007b). The BRA-PER Genotype was detected only in R579 and interestingly this variety has previously been reported to be highly susceptible to SCYLV in Mauritius (Khoodoo *et al*., 2010). The detection of BRA-PER genotype in field samples is of concern due to its aggresivity and needs to be closely monitored.

Table 2: Status of SCYLV infection in selected clones and genotype detected using RT-PCR with specific primers.

	Variety	SCYLV status	Genotype Identified	Location
1	R 579	+	BRA-PER and REU	Mon Desert Alma
2	M 1672/90	-	-	
3	R 570	+	REU	
4	R 573	-	-	
5	M 1400/86	+	REU	
6	M 703/89	+	REU	
7	M 1176/77	-	-	
8	M 387/85	+	REU	Savannah
9	M 695/69	+	REU	
10	R 579	+	BRA-PER	

Multiplex RT-PCR

Optimisation tests have been performed to integrate the three genotypes-specific tests into a single multiplex assay. A duplex RT-PCR was optimised for detection of CUB and BRA-PER genotypes (Figure 1). The BRA-PER genotype was detected in Lanes 1 and 10 (corresponding to variety R579) as observed in single RT-PCR. The extracts in lanes 3, 5, 6, 8, and 9 have previously been tested positive to SCYLV genotype REU (data not shown). It was difficult to integrate the 905 bp REU fragment in this multiplex, may be due to its larger size since it is known that small fragments are preferably amplified in multiplex PCR.

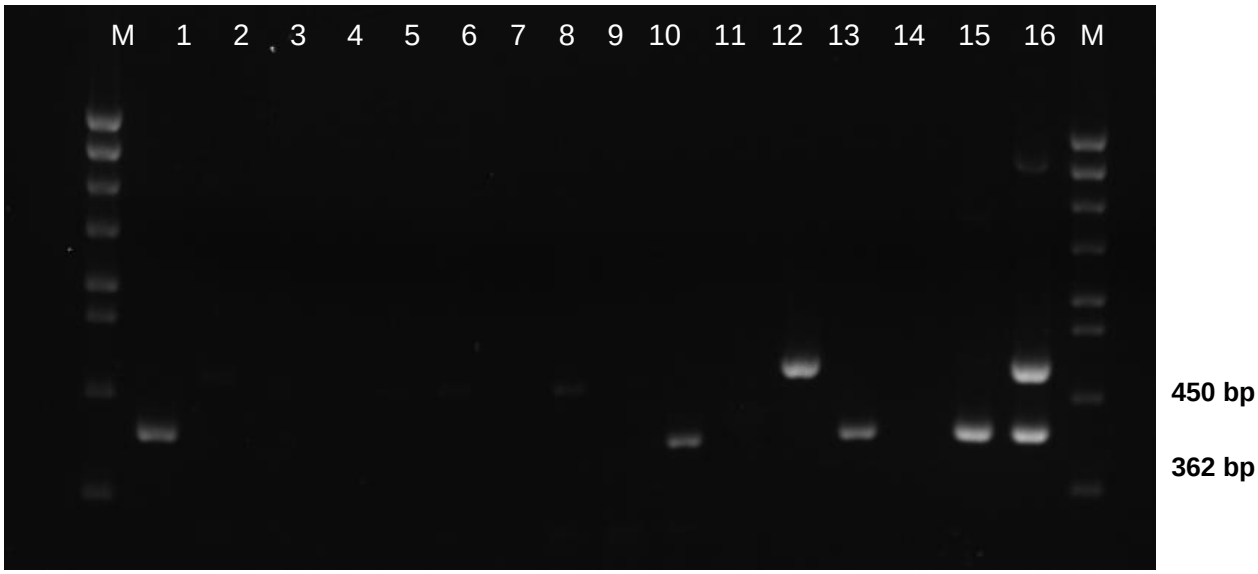

Figure 1: Duplex RT-PCR for detection of CUB (450 bp) and BRA-PER (360 bp) fragments

Lanes 1-11: Total nucleic acids from survey samples 1-10 (as per Table 1)

Lane12: Total nucleic acids from SYCLV infected plant (Genotype CUB)

Lane : 13 Total nucleic acids from SYCLV infected plant (Genotype BRA-PER)

Lane 14: Water Control, Lane 15: Plasmid with BRA-PER insert, Lane 16: Mix (Plasmid witBRA-PER insert/Plasmid CUB insert), M: Molecular weight marker

Taqman real-time RT-PCR for CUB genotype

Real-time RT-PCR assay is being developed for detection of the CUB genotype. Using the 452 bp CUB fragment from Co 6304 (Genbank Acc GQ907001), one common forward primer (CUB-F1) and Probe (CUB) was designed along with three reverse primers (CUB-R1, CUB-R2 and CUB-R3). The specific amplification of the CUB genotype from variety Co6304 was possible using all three primer pair combinations. No amplification was observed with nucleic acids from SCYLV infected plants belonging to REU and BRA-PER genotypes. This test will be applied for samples collected during the survey. The internal Taqman probe specific to CUB is an additional guard against non-specific annealing and also this test allows the possibility of integration of the o-met internal positive control (IPC) developed by Korimbocus *et al*. (2002).

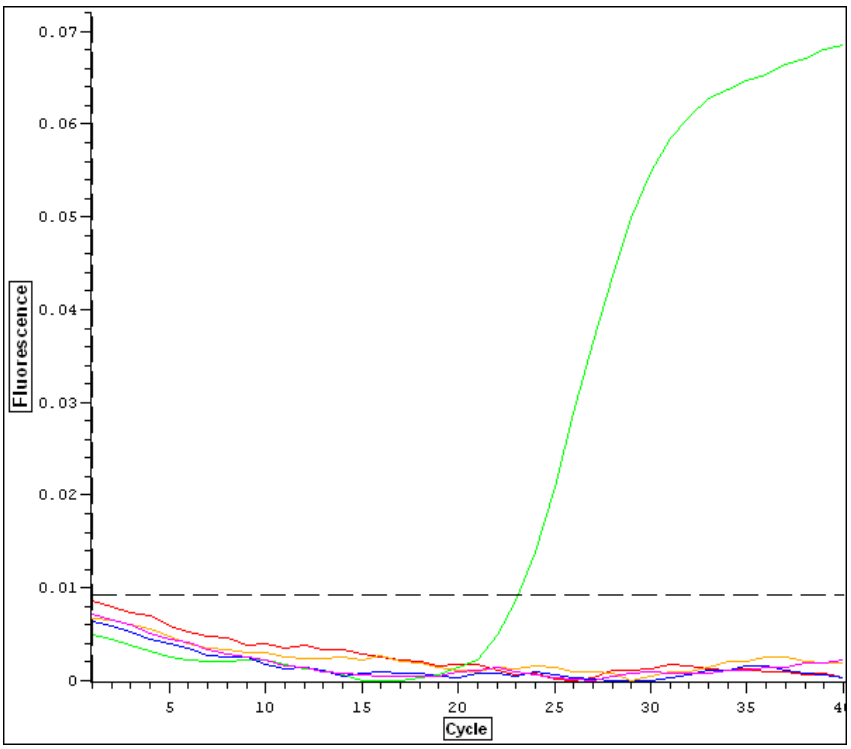

Figure 2: Specific amplification of CUB genotype using real-time Taqman RT-PCR

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SESSION 5 – OCEAN TECHNOLOGY & MARINE RESOURCES

PRESENTATION 11

Lagoonal thermal stress physiology and mortality responses in scleractinian corals of Mauritius using fluorescence technique

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Mrs S Mattan-Moorgawa has over 10 years experience in the field of education, science popularization, solid waste management, environmental engineering, and marine/ environmental sciences. She graduated at the University of Mauritius in Year 2000 with a Bachelor in Biology and Environmental Sciences, and in Year 2003 with a Masters in Environmental Engineering. After graduation she works at the Solid Waste Management Unit, Ragiv Gandhi Science Centre and the Ministry of Environment & Sustainable Development before moving to the University of Mauritius in 2010.

In her current role as Lecturer, she is involved in teaching marine sciences, oceanography, environmental pollution, monitoring and management, and environmental engineering. Her main research interests include coral bleaching, climate change, marine pollution marine, biofouling and sustainable development.

Introduction

The coastline of the island of Mauritius is a complex region where human settlement, recreational activities and development are concentrated. The coral reefs of Mauritius surround most of the island as fringing reefs except with breaks on the Southern and Western coasts. Our coral reefs are, thus, exposed to a lot of environmental stress arising from inshore (point source) and inland (non-point source) anthropogenic activities, such as

hotel development, development of marinas, sewage disposal, effluent discharge, seepage, terrestrial runoff, coastal erosion and sedimentation (Moorgawa et al. 2012). The reefs are also regularly impacted by cyclones, and there is good evidence that the lagoon patch reefs seasonally exhibit partial bleaching during the summer months (Fagoonee et al. 1999) due to increased sea surface temperatures. Massive coral mortality could eventually result in socio-economic impacts, including a decrease in lagoon fish stocks, greater coastal erosion and a possible decline in tourism. It is therefore crucial that the degree of bleaching and the current health of the coral reefs in Mauritius are determined, in order that adequate management measures can be undertaken to encourage recovery of the coral reefs. This study deals essentially with a survey of the bleaching phenomenon and an assessment of the cholophyll-*a* stress physiology in selected species of hard corals at selected sites around the coasts of Mauritius by use of fluorescence technique namely the Pulse-Amplitude Modulated (PAM) fluorometer.

Aim

Investigate the mortality responses of eight different species of hard corals to lagoon stress factors.

Objectives

- To investigate percentage mortality among 8 different hard corals at Belle Mare lagoon during the study period October 2008 – March 2009 in response to lagoonal stress factors.
- To determine the differential susceptibilities among the eight species of scleractinian corals in response to increasing sea surface temperature during the study period.

Literature Review

Coral reef bleaching originally referred to as the loss of pigment by corals (Yonge & Nichols 1931) is characterized by the loss of algae (Hoegh-Guldberg & Smith 1989a; Glynn & D'Croz 1990; Lesser et al. 1990; Le Tissier & Brown 1996) and/or loss of photosynthetic pigment

(Kleppel et al. 1989). This phenomenon is a common stress response of corals usually associated with anthropogenic and natural disturbances, for instance, extreme low/high temperatures, solar irradiance, sedimentation, xenobiotics (Cu, herbicides and oil), subaerial exposure, inorganic nutrients (nitrate and ammonium), freshwater dilution, and pathogens. Since the zooxanthellae increase the fitness of their host by enhancing calcification, mediating elemental nutrient flux and providing photosynthetically fixed carbon, their loss results in a loss of fitness (Jones & Berkelmans 2011) and often mortality.

Recent studies have shown that zooxanthellae densities within the coral host vary in relation to exogenous factors such as nitrogen enrichment (Muscatine et al. 1989), copper enrichment (Jones 1997a), iron enrichment (Harland & Brown 1989), cyanide (Cervino et al. 2001), starvation and osmotic shock (Titlyanov et al. 2001a), increases in sea water temperature (Coles & Jokiel 1978), lowered seawater temperature (Gates et al., 1992), ultraviolet light (Jokiel et al. 1982) and Photosynthetic Active Radiation (PAR) (Titlyanov et al. 2001b). Furthermore, field studies have shown that there are seasonal cycles in zooxanthellae densities in response to variations in environmental factors (Fagoonee et al. 1999). The leading factors responsible for large-scale coral reef bleaching are increased sea temperatures and solar radiation (Stone et al. 1999; Glynn 1993; Brown 1997).

Coral bleaching and subsequent mortality is becoming more frequent worldwide. The coral bleaching process takes place due to the breakdown of the photosynthetic machinery (photosystem II, PSII) of the endosymbiotic dinoflagellates (genus *Symbiodinium*) commonly called zooxanthellae, which is then released from the coral host, leaving behind the whitish coral animal (Warner et al. 1999). Differential bleaching/ mortality of corals have also been documented. Baird and Marshall (2002) reported that whole colony mortality due to thermal stress was high in *A. hyacynthus* (88%) and *A. millepora* (32%) and partial mortality rare*, Platygyra daedalea* and *P. lobata* took longer to bleach, longer to recover and longer to die. Mortality data after thermal stress experiments (Bhagooli & Hidaka 2004) indicated differential bleaching susceptibilities in *Seriatopora caliendrum*, *Montipora digitata*, *Porites cylindrica* and lastly *Platygyra ryukyuensis* in order of most susceptible to least.

Coral reefs of Mauritius escaped the widespread mass coral bleaching/mortality phenomenon in 1998; however, temperature records from this study indicated that the surface seawater temperature in Belle Mare lagoon on the eastern coast of Mauritius was at least 30^{o}C in March 2009.

Methodology

Firstly, a coral bleaching survey were carried out on a monthly basis from October 2008 to December 2009 during both winter and summer seasons at Belle Mare lagoon. The coral bleaching survey were carried out using the line transect method, the quadrat method and by using an underwater digital camera. The field survey was facilitated by use of a glass bottom boat and snorkeling and/or skin diving. The GPS (Global Positioning System) coordinates were recorded at each station and sampling was repeated at each station on a monthly basis. Coral bleaching and recent mortality was quantified, with special focus on eight coral species: *Acropora cytherea, A. hyacynthus, A. formosa, A. sp., Pocillopora damicornis, P. eydouxi, Galaxea fascicularis* and *Fungia sp.*

Secondly, selected coral species (visibly bleached (B), partially-bleached (PB), Pale (P) and non-bleached (NB) were sampled at each station along four permanent transect line running across the lagoon from the beach to the reef. The observed conditions were based on the visual estimates of the extent of bleaching as compared to coloured photographs of the normal states of corals. Thus, partially bleached condition is less than 30% of the colony; pale condition indicates overall paling of the colony; bleached condition indicates >90% of the colony bleached; non-bleached condition means healthy looking colonies with normal coloration. Coral tips 2 – 3 cm were collected by a hand corer by snorkeling and skin-diving. Coral samples were preserved at low temperature in seawater in 250 ml sampling bottles in ice packs in the dark for about 6 hours. After this dark adaptation, Chlorophyll *a* fluorescence ratio, Fv/Fm, was recorded in partially bleached (PB), pale (P), bleached (B) and non-bleached (NB) corals using a Pulse-Amplitude-Modulated (PAM) fluorometer (Teaching PAM). The initial fluorescence (Fo) was measured by applying pulses of weak red light (< 1 µmol quante m-2 s-1) and a saturating pulse (8000 µmol quanta m-2 s-1, 0.8-s duration) was applied to determine the maximal fluorescence (Fm).

The ratio of the change in fluorescence (Fv= Fm-Fo) caused by the saturating pulse to the maximal fluorescence (Fm) in a dark-adapted sample, has been shown to be a good measure of the maximum quantum yield of Photosystem II (PS II).

Physico-chemical parameters such as temperature, salinity, pH and dissolved oxygen were measured in-situ at each station over the study period. Samples of seawater were also collected in triplicates at each station and refrigerated for further analysis of nitrate and phosphate in the laboratory. Nitrate determination was done by the cadmium reduction method (Wood et al. 1967) and analysis of inorganic phosphate in seawater by the colorimetric method by Murphy and Riley (1962).

Measured data for the maximum quantum yield for the 4 different conditions (PB, P, B AND NB) in the 8 species of corals was arcsinsqrt transformed and analysed by One-way ANOVA followed by Post Hoc Tukey Test using the Statistica (version10.0) software.

Main Findings

Temperature records from January 2009 till March 2009 showed that the surface seawater temperature in Belle Mare lagoon was at least 30^{o}C. The recorded physical parameters in May 2009 indicated a temperature, dissolved oxygen, salinity, and pH of 27.52±0.33 ^{o}C, 20.38±0.77 mgL^{-1}, 33.5±1.45 $^{o}/_{oo}$, and 7.10±0.15, respectively (Fig 1).

Eight coral species namely *Acropora cytherea, A. hyacynthus, A. formosa, A. sp., Pocillopora damicornis, P. eydouxi, Galaxea fascicularis* and *Fungia sp.* were observed. PS II functioning, measured as *Fv /Fm*, was lower in partially bleached (PB), pale (P) and bleached (B) samples as compared to the non-bleached (NB) ones in *A. cytherea* and *A. hyacynthus*. In *A. formosa* PB and B were lower than the NB *Fv/Fm*, except for the P. In *A.* sp., *Fv/Fm* was lower in P compared to NB samples. However, the pale colonies of *P. damicornis* and *G. fascicularis* did not differ from their non-bleached ones. All the *Fv/Fm* measured in *P. eydouxi* and *Fungia* sp. was normal and no recorded bleaching occurred. The tabular corals, *A. cytherea* and *A. hyacynthus*, showed the highest levels of recent mortalities. While *A. formosa* and *A. sp.* exhibited high levels of partial colony mortalities and *P. damicornis, P. eydouxi*, *G. fascicularis* and *Fungia* sp. did not show any signs of mortality. These results,

taken together, suggest that the tabular corals, *A. cytherea* and *A. hyacynthus* are the thermally most vulnerable while *P. damicornis*, *P. eydouxi*, *G. fascicularis* and *Fungia* sp. are among the most tolerant coral species in the studied lagoon.

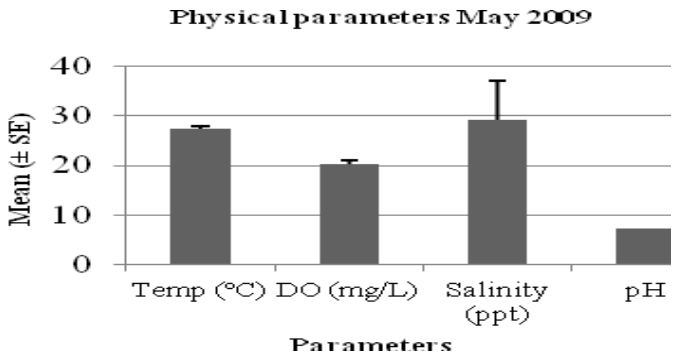

Figure 1: Mean values of physico-chemical parameters (temperature, dissolved oxygen, salinity and pH) measured *in situ* in May 2009. (*Source: Moorgawa et al. 2012)*

It was also observed that nitrate concentrations were at or below 0.2 mg/L throughout the sampling period from October 2008 to May 2009. Observations also indicated a decrease in nitrates with distance from the shore. Concentrations of phosphate above 0.04 mg/L have been implicated in coral stress (Connel & Hawker 1991). Results indicated phosphate levels in samples less than 0.04 mg/L. Detailed data not presented in this paper.

Sea surface temperature results indicated a gradual increase from September 2008 to February 2009 where they peaked at 31.5ºC, and then decreased to 27.4ºC by May 2009. (Fig 2)

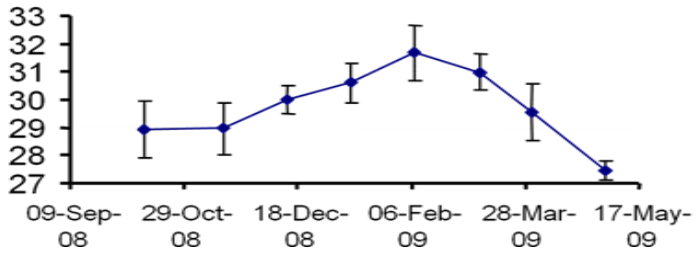

Figure 2: Temperature (ºC) recorded at Belle Mare lagoon from October 2008 till May 2009. (Source: Moorgawa et al. 2012)

In situ survey of coral bleaching from October 2008 to May 2009 revealed some 70% bleaching and some 40 - 50% mortality of corals were recorded between January and March 2009. The tabular corals, *A. cytherea* and *A. hyacynthus*, showed the highest levels of recent mortalities. While *A. formosa* and *A*. sp. exhibited high levels of partial colony mortalities and *P. damicornis, P. eydouxi*, *G. fascicularis* and *Fungia* sp. did not show any signs of mortality (Fig. 3). Complete mortality was highest in *A. hyacynthus* and highest partial mortality in *A. cytherea*, *A. formosa* and *Acropora* sp. whilst relatively no mortality was observed in *P. damicornis*, *G. fascicularis*, *Fungia* sp. and *P. eydouxi.* (Fig. 3)

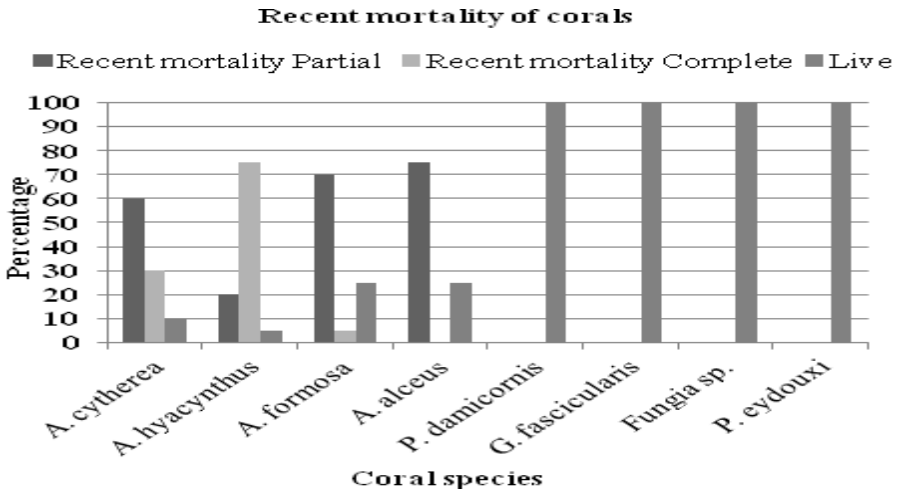

Figure 3: Percentage recently partially and completely dead colonies and live (out of 20 observed colonies) of the eight studied coral species at Belle Mare in May 2009. (Source: Moorgawa et al. 2012)

Maximum quantum yield (F_v/F_m) was highest (0.6) in non-bleached colonies in the eight species under study and lowest in bleached colonies of *A. cytherea, A. hyacynthus* and *A. formosa*, indicating direct relationship between chrorophyll *a* fluorescence and bleaching (Fig. 4). There is no significant difference in Fv/Fm in pale and non-bleached colonies of *P. damicornis (p>0.05,* one-way ANOVA test*)* and *G. fascicularis (p> 0.05,* one-way ANOVA test*)*. Pale colonies in *A. hyacynthus*, *A. formosa* and *A. sp*. showed $F_v/F_m \leq 0.4$. The pale colonies of *P. damicornis* and *G. fascicularis* did not differ from their non-bleached ones ($p>0.05$, one-way ANOVA test).

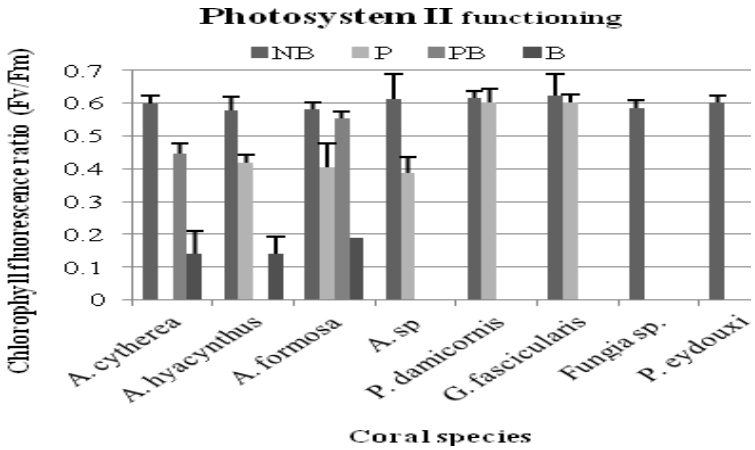

Figure 4: Maximum quantum yield (F_v/F_m) in non-bleached (NB), pale (P), partially bleached (PB), and bleached (B) coral samples (n=4-11) in eight studied coral species at Belle Mare in May 2009. (Moorgawa et al. 2012)

PS II functioning, measured as F_v/F_m, was lower in partially bleached (PB), pale (P) and bleached (B) samples as compared to the non-bleached (NB) ones in *A. cytherea (p<0.05,* Post Hoc Tukey test*)* and *A. hyacynthus (*p<0.05, Post Hoc Tukey test*)* (Fig 4). For *A. cytherea*, there was significant differences between NB and B (p<0.05,Post Hoc Tukey test), PB and B (p<0.05, Post Hoc Tukey test), and no significant difference between PB and NB conditions (p>0.05, Post Hoc Tukey test). In *A. hyacynthus*, there were significant differences among and between all conditions (p<0.05, Post Hoc Tukey test).

In *A. formosa* PB, B and P were lower than the NB F_v/F_m, , with significant differences between B and NB (p<0.05, Post Hoc Tukey test), PB and NB (p<0.05, Post Hoc Tukey test), but no significant differences between P and PB (p>0.05, Post Hoc Tukey test) In *Acropora* sp., F_v/F_m was lower in P compared to NB samples. No visual bleaching was recorded in *Fungia* sp. and *P. eydouxi.* All the F_v/F_m measured in *P. eydouxi* and *Fungia* sp. was normal (Fig. 4)

Discussion

Although bleaching of corals is a general response to stress, much of the extensive bleaching observed in the field is thought to be due to elevated seawater temperatures

which in turn increase the susceptibility of symbiotic dinoflagellates to high irradiance (Warner et al. 1996; Brown, 1997). This study demonstrates the variable susceptibility to coral bleaching among eight different species in the Belle Mare Lagoon, Mauritius.

Our results suggest that the tabular corals, *A. cytherea* and *A. hyacynthus* are thermally the most susceptible to bleaching while *P. damicornis*, *P. eydouxi*, *G. fascicularis* and *Fungia* sp. are among the most tolerant reef-building coral species in the studied lagoon. This is observed in May 2009 results for coral mortality where 100% of *P. damicornis*, *P. eydouxi*, *G. fascicularis* and *Fungia* surveyed exhibited live colonies. *A. cytherea*, *A. hyacynthus*, *A. formosa and A.* sp showed varying conditions (NB, B, P and PB) or susceptibities to thermal stress (Fig 4). Maynard et al. (2008) found that coral genera generally most susceptible to thermal stress (*Pocillopora* and *Acropora*) showed the greatest increase in tolerance between bleaching events (2002 v/s 1998). Dunne and Brown (2001) found similar results in the Andaman Islands in 1998 as compared to 1995. The range in bleaching tolerances among corals inhabiting different thermal realms suggest that at least some coral symbioses have the ability to adapt to much higher temperature fluctuations than they originally experience (Maynard et al. 2008; Coles & Brown 2003; Riegl 2002).

Reduction in the photosynthetic capacity of *in hospite* zooxanthellae under thermal stress has been reported in several coral species (e.g. Warner et al 1999; Bhagooli & Hidaka 2002). Warner et al. (1999) also reported the temperature-dependent loss of PSII activity from naturally and experimentally bleached corals as well as in cultured zooxanthellae treated at 32^0C. These findings strongly suggest that damage to photosynthetic apparatus in zooxanthellae is a determinant of coral bleaching.

The results show that the most susceptible corals (tabular and branching *Acropora*), zooxanthellae had the lowest F_v/F_m (< 0.2) in bleached (B) corals indicating damage to their photosynthetic machinery in the B corals. However, zooxanthellae of lightly pale (P) corals of *P. damicornis* and *G. fascicularis* had normal F_v/F_m level when compared to NB condition, thus indicating non-selective release of zooxanthellae with respect to their PSII functioning.

The above findings also suggest that the symbionts as well as the host play an equally important role in its resistance/ susceptibility to bleaching. Baird et al. (2008) suggested that the coral host has several potential ways to reduce UV and light flux to symbionts, including production of fluorescent pigments, acquisition of mycosporine-like amino acids, and several antioxidant systems and stress enzymes to deal with oxygen stress originating in the animal cell. The differences among the host species in their capacity to utilize these mechanisms might therefore determine differences among species in response to stress.

Also, differences in sensitivity among corals are determined, in some species, by the symbiont. Oliver and Palumbi (2011) reported that physiologically distinct lines of dinoflagellate symbionts, *Symbiodinium spp*., may confer distinct thermal tolerance thresholds on their host corals. If a coral host may alternately host distinct symbionts, changes in their *Symbiodinium* communities might allow corals to better tolerate increasing environmental temperatures. The *Symbiodinium* genotype was not examined in this paper. However, Baker et al. (2004) reported that only 3% of the coral colonies in Mauritius in years 2000 – 2002 contained Clade D and that corals containing thermally tolerant *Symbiodinium* Clade D are more common on reefs after episodes of severe bleaching and mortality. Mc Clanahan et al (2005) reported most scleractinian corals (Acroporidae, Pocilloporidae, Oculinidae, Poridae and Agariciidae) contained *Symbiodinium* Clade C from the northeast coast of Mauritius, except one sample of *Galaxea fascicularis* containing *Symbiodinium* Clade D from the north-west coast, indicating that the observed differences in response among coral taxa and sites were unlikely to be affected by the type of symbiont they contain. Rowan (2004) reported that *Pocillopora* spp. living in frequently warm (more than 31.5ºC) habitat host only *Symbiodinium* D and perhaps explains why those living in cooler habitats predominantly host *Symbiodinium* Clade C. The diverse response of corals to thermal anomalies has been related to host and/or symbiont factors but the combined physiology of the two organisms likely determines the tolerance range of the holobiont (Sampayo et al, 2008).

Conclusion

The results of this study highlight the variable responses among the eight studied coral species. The order of susceptibility/ mortality is as follows: Tabular *Acropora* > Branching *Acropora* > Massive-like Corals/ Solitary Corals.

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PRESENTATION 12

Mapping Genetic Diversity of Microalgae in the Lagoons of the Republic of Mauritius

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Ms S B Sadally has a BSc (Hons.) degree in Biology from the University of Mauritiusand she has received the Best Poster Award for the National Ocean Science Forum in 2007. After her degree, she has been working as Research Assistant at the Mauritius Institute of Education and followed the Educator's License course there. She has also worked as RA at the University of Mauritius (2010). She is a beneficiary of the MRC Postgraduate Award and has been enrolled as MPhil/PhD student since 2009 under the supervision of Dr N Taleb-Hossenkhan and Dr R Bhagooli, based at the Department of Biosciences, Faculty of Science, University of Mauritius. Ms Sadally is currently doing her research in the field of marine and molecular biology. She has attended several national and international conferences, including the WIOMSA International Symposium in 2011. Moreover, she has followed several short courses, including, SPSS Intermediate (2010), Exploring our Marine Biodiversity (2010), Writing Skills for Researchers (2010), Seaweed Biodiversity and Biogeography (2011), and Coral Reef Ecosystem in a Changing Environment (2012), among others.

Introduction

Microalgae, as a part of the phytoplankton communities, are microscopic photosynthesizing organisms at the base of any marine food chains and food webs, and are thus the determinants of population dynamics of heterotrophic organisms, including fishes. Fisheries income, which nationally represents about 1% of the gross domestic product (GDP), is dependent on microalgae since the latter is one of the most important components in the diet of fishes. Thus, any change or disturbance in the species distribution and abundance of microalgae may have a negative impact on fish production, or even cause the whole ecosystem to collapse.

Microalgae represent a potential marine resource that can contribute to sustainable development in Mauritius but before exploiting these resources, there is a need to have a baseline study on the diversity and distribution of microalgae in our lagoons.Scientific data on specific types, distribution and seasonal variability of microalgae in the Mauritian waters is limited, with almost no genetic characterization done so far. Given the recent developments that have occurred along the coastal shoreline in the recent years, there is an imperative need to perform an in-depth investigation of the abundance and distribution patterns of the various species of microalgae within our lagoons.

So far, studies focused mainly on microscopic examination but this type of identification singly is not always reliable. Thus, there is an urgent need to revise the current status of the microalgae dwelling in our lagoons through the use of molecular genetic tools. The potential applications of microalgae are diverse but to achieve these goals, correct identification at the molecular level is an absolute pre-requisite. The use of molecular genetic tools enables us to specifically identify specimens, which are morphologically identical and which may have been classified as belonging to a single species using traditional classification systems. The present study lays emphasis on the use of well-established molecular genetic tools to verify morphological identification in an effort to correctly map the species distribution of microalgae in the Mauritian waters.

Research Questions:

- How can microalgae species be identified using molecular genetic tools?
- Do microalgae show seasonal variation?
- Does microalgae distribution vary from the coast to reef?
- Does aquaculture have an effect on microalgae biomass and distribution?
- Do microalgae vary according to tide?
- Do microalgae vary among different ecosystems?

Literature Review

Microalgae, being at the base of marine food chains and webs (Bhadury and Wright, 2004), support many marine organisms, including zooplankton and fishes, which are dependent on them as their source of food and energy (Lugomela and Semesi, 1996). Microalgae represent a potential marine resource that can contribute to sustainable development in Mauritius, such ad in the production of biofuels (Li *et al*., 2008). The potential applications of microalgae are diverse, such as in the cosmetic (Spolaore*et al*., 2006), pharmaceutical (Apt and Behrens, 2002) and medical industry (Wijffels, 2007). However, some harmful microalgae may be the root of fish poisoning and food poisoning. These may release toxic substances which may cause death of invertebrates and fish, as well as, be harmful to human health (Gönülol and Obali, 1998).

Scientific data concerning characterization and distribution of microalgae are limited. Most of the studies carried out in the waters of the Republic of Mauritius focused mainly on identification based on morphological characteristics, using the light microscope. However, this traditional method has been found to underestimate species diversity (Knowlton and Weigt, 1997) and this type of identification may be misleading because identical specimens may be genetically different while same species may vary morphologically (Knowlton, 2000). Analysis of the genetic material of microalgae and the use of genetic markers will facilitate their specific identification and this will allow the differentiation of morphologically identical specimens.

In the last decade, the rRNA genes have been largely used for molecular work (Borne*et al.*, 2004).Auinger*et al.* (2008) made use of the small subunit (SSU) rRNA gene to characterize microalgae, while Lyra*et al.* (2001) and Nubel*et al.* (1997) examined the 16S rRNA genes to genetically characterise cyanobacteria. This study made use of the ITS regions (ITS1 and ITS2) to characterize diatoms and dinoflagellates while the 16S rDNA is used to identify cyanobacteria.

Methodology

Microalgae samples were collected formolecular characterization and its study on seasonal variation at Flic-en-Flac (FEF) and BM (BM).Primers for each microalgae group were designed to amplify the ITS regions (for diatoms and dinoflagellates) and the 16 rDNA (for cyanobacteria). DNA of microalgae was extracted using tested protocols and the target regions were amplified through PCR, followed by cloning. Plasmid containing the desired insert were then extracted and purified for sequencing. Snapshot studies were also carried out on the distribution of microalgae from the coast to the reef flat at FEF and BM (March 2010), microalgae in an aquaculture set-up (November 2010), the effect of tide on microalgae (August and November 2011 and photo-physiology of microalgae in different ecosystems (Pointe D'Esny mangrove area, Blue Bay sandy beach and coral area, Le Goulet Estuary and Mahebourgseagrass bed) around Mauritius (February 2012). Analysis of water samples for nutrients (Greenberg *et al*., 1992) and chlorophyll *a*(Jeffrey & Humphrey, 1975) were also conducted, while physico-chemical parameters were recorded *in-situ*. Microalgae samples for enumeration and identification were preserved and microalgae were categorized into three broad groups, namely diatom, dinoflagellate and cyanobacteria.

Results

DNA extraction, PCR amplification of the targeted regions, cloning of the PCR products, as well as, extraction and purification of the plasmid containing the insert was successful, confirming the effectiveness of the designed primers and the tested protocols.

Total microalgae showed seasonal variation with highest concentration being recorded in the summer months. Diatom was the most abundant microalgae group, followed by dinoflagellates and cyanobacteria. Chlorophyll *a* concentration and physico-chemical parameters also vary according to seasons. Microalgae were positively correlated with nutrients and higher chlorophyll *a* was recorded at higher microalgae density.

The study on the distribution of microalgae from the coast to the reef flats showed that higher density was recorded near the coast, followed by the lagoon and lowest density was recorded near the reef flat. A study on microalgae in an aquaculture set-up revealed higher diversity and distribution of microalgae within the set-up with a total of 35 genera recorded. Nutrients and chlorophyll *a* also followed the same trend.However, no algal bloom was recorded during the study and the other surrounding stations remain unaffected.Tide had an effect on microalgae density such that higher density was recorded at low tides compared to high tides

Total microalgae density in water column were higher in mangrove ecosystem compared to the other ecosystems (seagrass, sandy beach, coral reef and estuary) while highest density was recorded in the sediment from the sandy beach ecosystem. Silicate was highest in the estuarine area while higher nitrate was recorded in estuary, followed by mangrove ecosystem. However, no significant difference in phosphate concentrations was recorded among the different ecosystems, except in the sandy beach area, where phosphate concentration was lowest. Diatoms dominated the microalgae population in both water column and sediment samples, followed by dinoflagellates and cyanobacteria. There was no significant variation in photo-physiology of microalgae for water column and sediments at coral reef area, sandy beach area and mangrove area. However, microalgae in the water column of the seagrass bed area and the estuarine area had a much higher photosynthetic activity than those present in the sediments.

Discussion

Successful amplification of the ITS1 and ITS2 regions using the designed primers yielded a 371 bp and 416 bp PCR products, respectively. Cloning of the PCR products and successful

extraction and purification of the recombinant plasmid for sequencing (in process) confirmed the effectiveness of these methods for characterization purposes.

Seasonal variation in phytoplankton abundance and distribution is a result of seasonal changes in physico-chemical parameters, as well as, nutrients (Davies *et al*., 2009) and this is in accordance to the present study since higher microalgae density was obtained at higher nutrient concentration. Abiotic (nutrients (Furuya*et al*., 1986) and physico-chemical parameters) and biotic factors (trophic interactions) has been found to govern phytoplankton abundance and composition (Meesukko *et al.*, 2007).Productivity of plankton is dependent on the ecological balance of these factors (Chowdhury*et al.,* 2007), such that a higher density and diversity of phytoplankton was recorded in months where higher nitrite-nitrate concentration and temperature was recorded (Chowdhury*et al*., 2007).

Higher nutrient concentration near the coast, as a result of run-off events, accounted for the higher microalgae density there (Sadally *et al*., 2012). Higher microalgae density in the middle of the aquaculture set-up is due to the released of nutrients derived from fish feed which increase primary productivity near the fish cages (Dalsgaard and Krausejensen, 2006). However, these nutrient input did not have any effect on the surrounding stations because primary productivity has been found to decrease with increasing distance from the fish cages (Pitta *et al*., 2009). The good flushing system is due to the presence of a channel at the site of the cages, which sweeps away or dilutes the excess nutrient derived from the fish feed. This water exchange system not only ensures a good water quality environment around the fish farm but also prevents occurrence of harmful algal bloom.Moreover, higher density of microalgae at low tides is attributed to the stability of water and the concentrations of nutrients.

Higher microalgae density was recorded in the water column of the mangrove ecosystem due to the high concentration of nutrients, which is exported from the mangrove swamp (Akamatsu*et al*., 2009) or by the decomposition of litter. The difference in photo-

physiology of microalgae in water column and sediment samples in different ecosystems is due to their varying degree of adaptation to different light intensity.

Conclusions:

- Use of molecular genetic tools is the most reliable method to characterise microalgae.
- Microalgae vary according to season.
- Microalgae are more abundant near the coast and least abundant near the reef.
- Microalgae are higher in aquaculture set-up.
- Microalgae show tidal variation.
- Mangrove ecosystems harbor higher density of microalgae and their photophysiology vary according to varying degree of light adaptation.

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SESSION 6 – CLIMATE

PRESENTATION 13

A geostatistical approach to forecasting rainfall over Mauritius

Mr R Dhurmea

University of Mauritius

Mr R Dhurmea has a Diploma in Applied Science and Technology, a BSc (Hons.) in Physics and a Post Graduate Diploma in Meteorology. In view to pursue further studies he embarked on research program at the University of Mauritius with a view to work on a rainfall model for the island and he has already completed his work at an MPhil level and has upgraded for a PhD. Mr Dhurmea is presently working as a meteorologist at the Mauritius Meteorological Services.

Introduction

Measured rainfall data are important to many problems in hydrologic analysis and design. Estimates of the amount and spatial distribution of precipitation are critical inputs to a variety of ecological, agricultural, and hydrological models. These include model of water supply, water quality, drought severity, crop production and others. The accurate estimation of the spatial distribution of rainfall requires a very dense network of instruments, which entails large installation and operational costs. Also failure of the observer to make the necessary visit to the gauge may result in lower sampling density. Furthermore if provision could be made to increase the density of gauge in flat areas, this is not the case over mountainous terrain. The demand for precipitation fields on a regular grid and in digital form is growing dramatically as models become increasingly linked to geographic information systems that spatially represent and manipulate model output.

Mauritius, although being a small island, has a rainfall distribution greatly influenced by its topography. For instance, orographic lifting plays a great role in the spatial distribution of rainfall. Different parts of the island benefits from varying amount of rainfall from various forms of weather systems due to their topographic features. If the density of gauges in accessible areas is very reasonable in Mauritius, this is not the case in mountainous and inaccessible regions. Thus it is necessary to estimate point rainfall at unrecorded locations from values of surrounding sites. Furthermore, since there is a total dependence of the agricultural sector on rainfall, an efficient use of its limited arable land and rainfall catchment areas is of prime economic importance. As the distribution of precipitation is a variable phenomenon, it is not likely to be effectively studied by purely prescriptive method but rather statistical approach is required that will take into account the geography of the island. One of the most promising approaches to this study is the use of geostatistics. This work will introduce the methods used in geostatistics and will focus towards a systematic geostatistical study that can provide an appropriate tool in forecasting the distribution of precipitation on the island.

Background

The spatial distribution of precipitation is heavily influenced by temperature, especially by its vertical lapse rate (Γ), which dictates the local height and rate of condensation. In the absence of detailed (small-scale) temperature information, elevation could be used as its surrogate, at least as a first approximation especially for the case of a spatially constant lapse rate.

The lapse rate can be defined as $\Gamma = \frac{\partial T}{\partial z}$, and a more useful approximation is that temperature varies linearly with height: $T = T_0 + \Gamma z$, where z is the height and T_0 is the value of temperature at z=0

The primary effect of orography on a given mountain slope is to cause precipitation to vary strongly with elevation. This phenomenon, commonly called the orographic effect, is evident worldwide. Depending on its size and orientation, a mountain or range of mountains can increase the intensity of precipitation by retarding the rate of movement of

clouds and causing forced uplift of the airmass. In summer, the orographic effect may trigger a conditional or convective instability in an otherwise stable airmass, producing local redistribution of precipitation over the higher grounds. The orographic effects may operate at relatively large spatial scales, responding to smooth topographic features rather than detailed variations in terrain. Relationship between measured precipitation and elevation are sometimes strengthened when the elevation of each data point is given in terms of its height on a smooth terrain. The relationship between precipitation and elevation varies from one slope face to another, depending on location and orientation of the terrain slope.

Local increases in precipitation with elevation approximate a linear form in many regions. Under some conditions the relationship between precipitation and elevation may be best describe by log-linear or exponential functions. In subtropical regions, limited vertical cloud development causes the precipitation maximum to occur below the crests of higher mountains. In contrasts, the climatological precipitation at midlatitudes usually occurs at or near the crests of the topographic barrier. There are exceptions, however. In large-scale precipitation situations, a spatial displacement of the precipitation maximum upwind of the crest may occur over very broad barriers as a result of lifting and condensation in the upstream flow before the barrier is reached.

Furthermore atmospheric variables such as pressure, humidity and wind speed and direction also have a marked influence on the precipitation distribution. Lower state variables of more significance include the specific humidity and the horizontal wind components especially from the surface up to the 700-hPa levels. Lower- atmosphere state variables, although known at a very small number of locations, provide a picture of the large- scale state of the lower atmosphere, which is expected to be related to observed precipitation at the local scale.

Also, the weather of Mauritius is affected by different climate systems, such as disturbances in trade winds, tropical cyclones, frontal systems and sea breeze that have different inherent rainfall pattern. What determines the different amount of precipitation is the

amount of rain bearing clouds associated with them. Cloud top temperatures can be used to estimate the amount of rain associated with the different weather systems along with the effect of sea surface temperature.

Approaches in estimating rainfall

The general circulation model usually provides predictions of precipitation, but its utility is limited because of their coarse spatial resolution. The use of limited area models is gradually emerging as a mean for enhancing the accuracy of rainfall predictions at regional scales. Dynamic downscaling using limited area models yield multiple relevant variables, including precipitation, that are physically and dynamically consistent. However, dynamic downscaling is computationally expensive and is not error free, because of limited spatial resolution and model parameterizations.

Statistical interpolation of rainfall based on rain gauge data still provides one of the basic analysis tools for constructing rainfall maps at regional scales. There is a wide choice of interpolation techniques for mapping rainfall; these techniques range from the inverse distance technique (Tabios and Salas 1985) to more complex methods such as krigging (Journel and Huijbregts 1978). The simplest approach consists of assigning to the unsampled location the record of the closest gauge (Thiessen 1911). This method amounts to drawing around each gauge a polygon of influence with the boundaries at a distance halfway between gauge pairs, hence the name Thiessen polygon for the technique. Another method is the inverse square distance technique whereby the unknown rainfall depth is estimated as a weighted average of surrounding values, the weight being reciprocal to the square distances from the unsampled locations. However, these two abovementioned methods do not cater for factors such as topography that can affect the catch at a gauge. To overcome this deficiency, the isohyetal method was designed whereby the location and catch for each gauge as well as knowledge of the factors affecting these catches are used to draw lines of equal rainfall depths (isohyets). The amount of rainfall at the unsampled location is then estimated by interpolation within the isohyets. However, a limitation of the technique is that an extensive gauge network is required to draw isohyets accurately.

Geostatistics, which is based on the theory of regionalised variables, is increasingly preferred because it allows one to capitalize on the spatial correlation between neighbouring observations to predict attribute values at unsampled locations. Several authors (Tabios and Salas, 1985; Philips et al, 1992) have shown that geostatistical prediction techniques (krigging) provide better estimates of rainfall than conventional methods. Furthermore krigging techniques provide a measure of prediction for error (krigging variance) and also allows for sparsely sample observations of the primary attributes to be complemented by secondary attributes that are more densely sampled. For instance, for rainfall, secondary information can take the form of weather radar observations. A multivariate extension of krigging, known as cokrigging, has been used for merging rain gauge and radar rainfall data (Creutin et al., 1988; Azimi-Zoonooz et al., 1989). Another valuable and cheaper source of secondary information that can be considered is a digital elevation model (DEM). A straightforward approach consists of estimating rainfall at a DEM grid cell through a regression of rainfall versus elevation (Daly et al., 1994). More sophisticated approaches, like cokriging, have been used to incorporate elevation into the mapping of rainfall (Hevesi et al., 1992).

In the context of mapping precipitation using rain gauge data, the variable most frequently used for enhancing interpolation, especially over mountainous region, is terrain elevation (Hevesi et al. 1992). Terrain-derived characteristics, such as slope aspect, as well as other variables such as latitude, longitude, and distance from the coast can also be accounted for in the mapping of rainfall (Wolting et al. 2000). Although the above variables enhance the predictability of spatial distribution of precipitation, they donot account directly for orographically induced rainfall.

Simple regional models with limited atmospheric physics and dynamics focus on lower-atmosphere state variables that steer storms and dictate the pattern and movement of air masses (Alpert 1986). Examples of such variables include wind speed and direction as well as specific humidity integrated over several pressure levels (Pandey et al. 1999). The important link of such lower-atmosphere characteristics with precipitation lies in their interaction with local terrain (Andrieu et al 1996).

The objectives of this research will be to:

- Develop a precipitation model, using geostatistics, for spatial interpolation of precipitation for Mauritius using rain gauge data and integrating the terrain characteristics and lower-atmosphere state variables such as wind and humidity.
- Locate for redundancy of gauges and their relocation.
- Use cloud top temperatures and sea surface temperatures to identify rain bearing clouds and estimate rainfall associated with them.
- Determine the magnitude of displacement in the precipitation maximum from mountain crests.
- Explain the rainfall anomalies in certain regions of the islands
- Forecast rainfall from associated with different climate systems ahead of time.
-

Methodology And Work To Be Undertaken

A survey of the work conducted in this area will be done. The basic aim of geostatistics is to estimate values for some quantity in areas or at a point where actual sampling has not been conducted. The trends in the daily, monthly and long-term rainfall distribution for all stations of the island will be examined. Long term variation is seen in the monthly mean precipitation as well as in the longer term means. Shorter-term variations will be seen in the daily distribution and will bear a correlation with the prevailing weather.

Using the rainfall data, a variogram will be computed and plotted. This variogram, which is a statistic of the data observations, will be compared with theoretical variogram models namely the spherical model, the Gaussian model, the exponential model and the power law model, and the one with the best fit will be chosen. This model will then be used for estimation. Spatial interpolation of rainfall will then be done using only raingauge precipitation data.

Orographic effect and precipitation: The scale at which orographic effects are observed will be of great importance in this study, as it will aim towards the use of a DEM (digital elevation model) as a GIS (geographical information system)-compatible source of spatially

gridded elevation data. Depending on computing resources available, attempts will be made to get finer resolution of the DEM, such that it closely matches the elevation of the grid cell at that point. To effectively model the spatial pattern of orographic effect over complex terrain, topographic regions will be identified and isolated. This will aim towards dividing a mountainous landscape into different topographic faces, or 'facet' each assumed to be experiencing a different orographic regime. The orographic elevation of each precipitation station will be estimated using a DEM at appropriate latitude-longitude grid spacing. Each DEM grid cell will then be assigned to specific topographic facet after assessing the slope orientation. After developing a precipitation-DEM elevation regression function from nearby rainfall stations on the cell's facet, precipitation at each DEM cell will be estimated and also predicted. Prediction interval for the estimate will also be calculated to indicate approximately the uncertainty involved.

Wind and precipitation: The aspect of orography will be treated using the vertical wind components. Interpolated horizontal wind components will be used to calculate the vertical components of winds w_s due to orographic lifting at the local scale. This terrain induced vertical motion is defined as the inner product of directional elevation gradients with the corresponding horizontal wind components, (Alpert 1986)

$$w_s = -v.\nabla h = -\left[u\left(\frac{dh}{dx}\right) + v\left(\frac{dh}{dy}\right)\right]$$

where $v = (u, v)$ denotes the wind vector with local horizontal components u and v, and dh/dx, dh/dy denotes the local gradients of elevation along the same directions. The vertical wind speed values at different locations will then be correlated with rainfall measured by the gauges.

Humidity and precipitation: It is established that for a saturated parcel of air ascending with vertical velocity, w_s, the rate of condensation of water vapour, C, is very close to the rate of change of the saturated moisture content and which can be expressed as

$$C = -\frac{d\left(\rho q^{sat}\right)}{dt} \approx -\frac{\partial\left(\rho q^{sat}\right)}{\partial z}\frac{dz}{dt} = -w\frac{\partial\left(\rho q^{sat}\right)}{\partial z}$$

where ρq^{sat} is the mass of water vapour per unit volume in a saturated air parcel and which can be written as

$$\rho q^{sat}(z) = \rho_0 q_0^{sat} \exp(-z/H_m)$$

where z is the height and q^{sat} is the saturation specific humidity. H_m is a scale height for atmospheric moisture. For typical atmospheric values, H_m is approximately 4 km in the tropics and 2 km at high latitudes.

Hence, the variation of humidity with height will be determined from available humidity values using interpolation technique and with the interpolated vertical velocities calculated the rate of change of saturated moisture content of a parcel of air could be determined. Spatial interpolation of rainfall will then be done using rain gauge data in addition to low-atmosphere variables and their interaction with the terrain.

Cloud top temperatures and precipitation: The rainfall amount can be estimated from cloud top temperatures using images from geostationary satellite. Different methods are available for estimating area rainfall using images of visible (wavelength between 0.4 and 0.7 μm) and infrared (wavelength between 10.5 and 12.5 μm) region of the electromagnetic radiation. The visible channel measures the short wave radiation backscattered by the atmosphere and the earth. This channel gives the albedo of the reflecting body and high brightness implies a highly reflecting cloud. This albedo gives an indication of the temperature of the cloud.. The infrared channel measures the thermal radiation emitted by the cloud and this is related to the temperature of the emitting cloud by the Planck's radiation law. In general cold cloud are assumed to be deep and rain bearing.

The TAMSAT (Tropical Application of Meteorological Satellites) rainfall-estimating technique will be used, as it is relevant to the type of climate prevailing over the Indian Ocean. The TAMSAT technique is entirely pre-calibrated, i.e. it is calibrated against historical gauge data. Half-hourly or hourly infrared images will be used from analysis. In the TAMSAT approach, rain gauge values are related to the CCD (Cold Cloud Duration) using the following linear relationship,

R= a1CCD+3.4a0 R = 0 when CCD = 0

Where R is the rainfall, $a_1$and a_0 are constants to be determined by comparing CCD images with raingauge data.

Furthermore, PCA (Principal Component Analysis) and image processing techniques will also be used to identify rain-bearing clouds.

Time Plan

Year 1: Literature review. The general circulation of the southwest Indian Ocean and associated weather systems will be reviewed. The physics of rainfall and clouds microphysics will be reviewed. A compilation of the complete precipitation data over a long time interval will be made available from the Mauritius Meteorological Services. Other parameters like wind, temperature and humidity will be collected.

Year 2: A detailed study of the mathematical formulation of geostatistics will be undertaken to come up with a geostatistical model that will be applied to the data collected.

Year 3: The models will be firstly used for daily and monthly mean analysis of precipitation throughout the island. An M.Phil dissertation will be written up.

Year 4: Study will be extended to include cloud top temperatures and sea surface temperatures to study different climate systems and modeling of the different climate systems will be done. Rainfall from different systems will be estimated and compared to actual values.

Year 5. Model will be validated and dissertation will be written.

Expected Output

1.It is expected to provide geostatistical modeling that can be applied to provide an adequate interpolation for those regions, which are under sampled and locate gauges that are redundant and that can be relocated in more appropriate areas.

2.Recommend new sites for installation of rain gauges.

3.A better understanding of the science of local precipitation associated with the various weather systems namely disturbances in the trade winds, tropical cyclones, frontal systems and sea breeze, and supported by appropriate computational template in which modeling of the following weather systems will be possible.

4. Produce forecasts of general trends in daily, monthly, and longer terms precipitation.

5. Derived an improved model equation for precipitation that will give the best precipitation map for the island.

Supervisor

Prof. S.D.D.V. Rughooputh (main)

Dr R. Boojhawon

Funding Required

Literature: Rs 20,000 per year

Unforeseen: Rs 10,000 per year

Field trips and small equipments: Rs 30,000

Computer: Rs 30,000

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PRESENTATION 14

Novel topography based limited area model for Mauritius

Mr R Virasami

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Mr R Virasami is a meteorologist at the Mauritius Meteorological Services and also a PhD candidate at the University of Mauritius. His field of specialization is in regional modeling and he has a decade of experience as an operational weather forecaster. IT is a field where he excelled especially where it comes to meteorology, numerical weather prediction and climate modeling.

Introduction to NWP (A brief history):

In 1904, the Norwegian hydrodynamist V. Bjerknes suggested that the weather could be quantitatively predicted by applying the complete set of hydrodynamic and thermodynamic equations to carefully analysed initial atmospheric states. Then afterwards,a British mathematician named Lewis Fry Richardson spent three years developing Bjerkness techniques and procedures to solve these equations but lack the computational facilities . He envisaged that some time in future there would a forecast factory with 26,000 accountants doing the calculation to determine the weather patterns around the world. In 1948, a young meteorological theoretician, Jule Charney, succeeded to derive simplified mathematical models of the atmospheric motions, based on the quasi-geostrophic approximations. These equations would be able to forecast the large scale flow in spite of minor inaccuracies in the initial analyses. After several decades, meteorological

observation, research, and technology struggled to reach the level necessary to make the computations envisioned by Richardson. In April 1950, the first one-day, nonlinear weather prediction was made but required the round-the-clock services of the modelers and, because of several ENIAC breakdowns, more than 24 hours to execute. However, this first forecast was successful in proving to the meteorological community that numerical weather prediction was feasible. Since then development of improved and new NWP followed rapidly as computer technology improved

Research objectives:

- The main aim behind this study is to adapt a high resolution limited area model for Mauritius. The model should have sufficient number of grid points so as to compare the different meteorological parameters with the actual observations over the island.
- This work is targeted towards developing a regional model for the island taking into the consideration the elevation and the size.
- To apply novel information technology techniques and, at the same time, assuring the soundness of the physics and mathematics for running such a model..
- To make use of model output statistics so as to increase the precision of the dynamic outputs of the regional model.
- To study the climate of the island with respect to those small scale events especially which are topography related

Synopsis of research:

The responsibility of any National Meteorological Centre is to provide information for a specific area of responsibility. This is usually done through analysis of local meteorological parameters and also interpretation of forecast products from global meteorological centres. A suitable tool, which with adequate computer power, can provide additional and more region specific information is a limited area model. In spite of very high level of sophistication of the existing global and hemispheric forecasting systems, more refined short range forecasts of the smaller synoptic scales and the associated processes such as

frontal systems, meteorological variables distribution and effects of topography can be obtained with limited area models which is of higher resolution and with more careful design of the schemes for simulation of the important local phenomena. With topography-based modifications, the limited area model can be used for the simulations/studies of atmospheric phenomena and, in addition, the development and application of complex forecasting systems will stimulate scientific efforts on the national level. Moreover, one of the significant weather events that affects the regions are tropical cyclones but, as compared to the other ocean basins, research work in the field of high resolution numerical weather prediction for this weather system in the South West Indian Ocean is scarce. So with the help of model outputs statistics, high resolution numerical weather prediction model helps to improve the skills for forecasting of tropical cyclones for this part of the globe in terms of track, intensity, maximum gusts, precipitation and their predictability.

The Limited Area Model used for this research was the High-resolution Regional Model (HRM) developed by the Deutscher Wetterdienst (Germany) and adapted to the region of the South West Indian Ocean. The case study consisted of Tropical Cyclone Daniella, which passed at its nearest point about 40 km to the South West of Mauritius in early December 1996. The maximum gust recorded was of the order of 170 km/h.

The model was run on a High Performance Computer at the University of Mauritius. The server had open source software installed, Scientific Linux as OS, MPICH for parallel processing and Grads for visualizations among others.

Results:

It has been found that the model performed well on the synoptic scale and for the case study of tropical cyclone Daniella, its track as well as its intensity was quite realistic when compared to the actual scenario.

Over the island, the HRM output of precipitation and wind captured the microscale signals but, however, lacked the precision in magnitude. It is must be noted that it is the first time

that a study of the effect of a tropical cyclone at this resolution over the island of Mauritius is being carried out using a hydrostatic model.

Moreover, a lot of effort was also made for setting up the server with the appropriate software and running this model as the server at the University was provided in the beginning of year 2009 without any operating system or software. All work were carried out initially on laptop and then started from scratch again using the server.

The concept of parallel processing using MPICH is a first at the University and was successfully implemented on the server, thus optimizing the time for the running the model at 5-7 km.

Future works:

Mauritius is affected by different weather systems which is at times small scale. These weather events will be studied separately using input data from DWD global systems in an attempt to find the model strengths and weaknesses when dealing with small islands. Additionally, the large scale interaction between the planetary systems and the small scale phenomena over Mauritius will also be studied using a non-hydrostatic model and the results between these two models will be compared.

Additionally, model output statistics will be applied to enable the study of the localized effects of meteorological parameters like ,excessive rainfall, associated to these events.

The topography plays an important role in atmospheric variables such as pressure, temperature, humidity and wind speed and directions, precipitation distribution over the island. The high resolution dynamic modeling approach along with model output statistics can help to study these different parameters with respect to small to micro scale phenomena. The precipitation distribution over the island will be extracted from a local statistical precipitation model which is related to the topography and a correlation will be carried between the dynamic and statistical results.

The correlation will be used to incorporate elevation and also other atmospheric variables and to develop models which will be implemented which will be using artificial neural networks.

Given the importance of the effects of tropical cyclones in South West Indian Ocean, the studies will put more emphasis on the predictability (development and tracking) of such systems. Data and information from ECMWF, Era-Interim, and HRM will also be utilized in this endeavor.

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SESSION 7 – INFORMATION & COMMUNICATION TECHNOLOGY

PRESENTATION 15

Will IPv6 change the life of Mauritians?

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University of Mauritius

Mr A Durbarry has received his Bachelor Degree from the University of Mauritius in Information Systems in 2007 and his Master of Business Administration (MBA) in 2010 with the University of Sunderland. He is also a Professional Member of the Association for Computing Machinery and a professional member in the British Computer Society (MBCS). Currently Assadullah is the Managing Director of ATech Group and doing his MPhil/PhD at the University of Mauritius.

Introduction

IPv6 forms the back bone of next generation internet. Even though the initial aim was to obtain a solution for shortage of internet address space, but because of new technologies with always-connected devices such as DSL, cable, networked personal digital assistants [PDAs], 2.5G/3G mobile telephones, etc., the demand on multimedia and multimedia communication through streaming video and audio is becoming essential. It can be said that our current best-effort internet (IPv4) is not offering Quality-of-Service (QoS) guarantees as it is expected. It is also a fact that QoS is compulsory for better performance, especially in the field of media from the end-user perspective (Kalonov B, 2002). Even with the introduction of the classless network redesign, it was not sufficient to prevent IPv4 address exhaustion and more changes to the Internet infrastructure were needed (K.Tantayakul et al., 2008). However, very little is known about IPv6 network. (I. Manthos et al., 2006, J. Welch et al., 2006).

Literature Review

The main reason for the deployment of IPv6 is due to the scarcity of Internet address. The main features of IPv6 that are important for the future growth of mobile wireless network are as follows: sufficient number of IP address, mandated security header implementation, destination options for efficient rerouting, address auto configuration and avoidance of the access filtering penalty (Bob Hinden, 2008).

Overview

The design of Mobile IP support in IPv6 (Mobile IPv6) represents a natural combination of the experiences gained from the development of Mobile IP support in IPv4 (Mobile IPv4), together with the opportunities provided by the design and deployment of a new version of IP itself (IPv6) and the new protocol features offered by IPv6. In mobile IPv6 three operation entities are defined: mobile node (MN), correspondent node (CN), home agent (HA); four new IPv6 destination options are defined: binding update option, binding acknowledgement, binding request and home address option; two ICMP message are defined for 'Dynamic Home Agent Address Discovery': ICMP home agent address discovery request message and ICMP home agent address discovery reply message; two new IPv4 options for 'Neighbor Discovery': advertisement interval option and home agent information option. (Alfredo Matos, 2007)

Mobile IPv6 Protocol

The main goal of Mobile IP is that a mobile node is always addressable by its home address, whether it is currently attached to its home link or is away from home. A care-of address is an IP address associated with a mobile node while visiting a particular foreign link. The association between a mobile node's home address and care-of address is known as a "binding" for the mobile node. While away from home, a mobile node registers one of its care-of addresses with a router on its home link, requesting this router to function as the "home agent" for the mobile node. The home agent has the responsibility to use proxy Neighbor Discovery to intercept any IPv6 packets addressed to the mobile node's home address on the home link, and tunnel each intercepted packet to the mobile node's primary care-of address. To tunnel each intercepted packet, the home agent encapsulates the packet

using IPv6 encapsulation, with the outer IPv6 header addressed to the mobile node's primary care-of address (D. Johnson, 2004 and W. Haddad, 2008).

Mobile IPv6 Mechanism

Mobile IPv6 provides a mechanism, known as "dynamic home agent address discovery", that allows a mobile node to dynamically discover the IP address of a home agent on its home link with which it may register its care-of address while away from home.

Mobile IPv6 also defines one additional IPv6 destination option. With IPv6, a mobile node can inform each of its corresponding nodes of its care-of address. The Optimization functionality allows direct routing from any correspondent node to any mobile node, without needing to pass through the mobile node's home network and be forwarded by its home agent, and thus eliminates the problem of "triangle routing" present in the base Mobile IPv4 protocol (D. Johnson, 2004 and W. Haddad, 2008).

QoS

QoS (Quality of Service) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on the ability of a network to deliver predictable results. The fundamentals of network performance within the scope of QoS often include availability, bandwidth, jitter, error rate and data loss (R. Braden, 1997).

QoS involves prioritization of network traffic. QoS can be found at a network interface, towards a server or router's performance, or in specific application.

QoS Protocol

Two architectures have been defined for IP QoS support: Integrated Service (IntServ) ((Hemant Chaskar, 2002 and Minghai Xu 2003) and Differentiated Service (DiffServ) (Jyh-Cheng Chen, 2000 and Minghai Xu 2003). QoS can also be based on hybrid architecture of both.

The IntServ architecture tries to provide absolute guarantees via Resource Reservation protocol (RSVP) (RFC 2205) (R. Braden, 1997) the paths that the traffic class follows. The main protocol that works with this architecture is the Reservation Protocol which has a complicated operation and also inserts significant network overhead. In particular, all the

messages that are exchanged in order to initialize, terminate, or update the status of a resource reservation, create a network overhead and additionally a computational overhead to the nodes of the network.

On the other hand, DiffServ architecture is more flexible and efficient as it tries to provide Quality of Service via a different approach. It is based on prioritisation and is a reservation-less protocol. It allocates a network's bandwidth according to the application's QoS class and bandwidth management policy criteria.

Conclusion

Summarizing the observations made, I presented a preliminary hypothesis which still needs to be tested. Cultural and regional peculiarities may be considered factors, but political drivers prevail in the deployment of IPv6. Economic forces might favor more market-oriented solutions which aim towards a market for IP addresses and transfers of IP address blocks as a service in such markets. IPv6 will also boost the usage of internet in Mauritius as it will allow more people to be connected with a faster speed and at a lower cost.

Future Works

The challenge is to provide appropriate Quality of Service to applications on mobile devices. Thus more exploration is needed on the following:

- Discover re-configuration Techniques based on Network bandwidth availability to sustain QoS in mobile IPv6 applications.
- Develop a network scheduling Protocol of Mobile Networks that will use:
    - Fair-Share scheduling
    - Deadline based scheduling
- Sustain QoS for soft real-time application.

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SESSION 8 – LAND & LAND USE

PRESENTATION 16

Biology, ecology and management of *Maruca vitrata* (F.) (Lepidoptera: Pyralidae) on *Phaseolus vulgaris* (l.) in Mauritius

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Mrs L Unmole completed a degree in Crop Science and Production at the University of Mauritius in 1990. She worked as a Technician in the Food Science Laboratory at the University of Mauritius during 1990-1991. She joined service at the Ministry of Agriculture as Technical Officer in the Extension Unit in November 1991 and shifted to the Entomology Division until 1997. In 1992, she completed a Diploma in Management studies at the University of Mauritius. As from 1998, she is working as Researach Scientist at the Entomology Division of Agriculturral Research and Extension Unit (AREU). She worked on an MPhil/PhD project (at post) at the University of Mauritius during May 2006-February 2011 and was awarded a degree in Doctor of Philosophy in January 2012. Mrs L. Unmole has so far published nine scientific papers from her research work.

Introduction and Literature Review

Bean (*Phaseolus vulgaris* L.) is an important cash crop grown on about 360 hectares by small farmers in Mauritius (Anonymous, 2008). The area under bean production is likely to increase in future to attain self-sufficiency in production of green pods and pulses. However, three species of pod borers (*Maruca vitrata* F., *Lampides boeticus* L. and *Etiella zinckenella* Tr.) have been reported to cause damage to flower buds, flowers and pods (Moutia, 1955). Their larvae remain concealed at feeding sites and their control poses special challenges. The heavy reliance of farmers on synthetic pyrethroids and other broad-

spectrum insecticides tends to threaten safe bean production, sustainability, human health and the environment. This study represents a pioneer work on the biology and ecology of *M. vitrata* for development of a sustainable pod borer management strategy in bean cultivation in Mauritius.

Methods and Results

As a prerequisite for the development of such a strategy, the economic importance of the three pod borer species was first determined during a 12-month survey in four major bean growing areas. *Maruca vitrata* was found to be the major species and constituted 99.6% of the field collected larvae. *Lampides boeticus* and *E. zinckenella* were not important as the former constituted only 0.1% of the collected larvae and the latter was not even recorded. Furthermore, larvae of the tomato fruitworm, *Helicoverpa armigera* Hub., were recorded on bean flowers and pods but at a very low percentage (0.3%). *Helicoverpa armigera* had not been previously recorded on bean in Mauritius. Pod damage by *M. vitrata* was determined in untreated bean fields during five crop cycles. It varied from 33% to 57% within a crop cycle with an average of 41.9 $\pm$ 3.0% for the five crop cycles.

A novel and cheap method was developed to rear *M. vitrata* in the laboratory. Four types of cages were tested for their suitability to hold adult moths, and five types of materials as oviposition substrates for egg recovery from cages. The small cylindrical plastic container (20 cm x 15 cm diam.) was found to be most suitable to rear adult moths and the white muslin cloth (24 cm x 24 cm) to collect eggs. Mung bean sprouts (*Vigna mungo* (L.) Hepper) were used as a larval diet. The effect of two types of diets (mung bean sprouts and bean flowers and pods) on the growth and development of *M. vitrata* was determined. Larval survival on mung bean sprouts was found to be higher (87.5%) than that on bean flowers and pods (52.5%). Females raised from larvae reared on sprouts were more fecund (241.3 $\pm$ 54.6 eggs/female) than those issued from bean flowers and pods (127.5 $\pm$ 30.3 eggs/female). They were also as fecund as those reared on semi synthetic diets. The improved performance of larvae and moths raised on mung bean sprouts during the second generation indicates that mung bean sprout is a suitable larval diet. This is a first report of rearing *M. vitrata* on mung bean sprouts.

The host range of *M. vitrata* was established. *Maruca vitrata* was recorded on eight out of the nine legumes studied. These legumes have different flowering patterns upon which *M. vitrata* maintains a population throughout the year. It was most abundant on *Phaseolus vulgaris*, *Phaseolus lunatus* L. and a cover crop (*Pueraria phaseoloides* (Roxb.) Benth.) and least abundant on *Pisum sativum* L., *Vigna unguiculata* (L.) Walp., *Cajanus cajan* (L.) Millsp., *Arachis hypogea* L. and a fodder crop (*Macroptilium atropurpureum* (DC.) Urb.). *Maruca vitrata* was recorded for the first time on *P. lunatus*, *P. phaseoloides* and *M. atropurpureum* in Mauritius. Nowhere else has *M. atropurpureum* been reported as a host of *M. vitrata*.

Four types of biocontrol agents (egg and larval parasitoid, entomopathogenic nematode and pathogenic fungus) were recovered during a survey of natural enemies of *M. vitrata*. The two species of larval parasitoids; *Bracon* sp. and *Eiphosoma annulatum* Cress., induced low levels of parasitism (2.4%). Freshly laid *M. vitrata* eggs on bean plants were exposed in the field to detect the presence of egg parasitoids (as per Arodokoun, 1996). The trichogrammatid parasitoid, *Trichogramma chilonis* Ishii was recovered from exposed eggs. This is a first record of *T. chilonis* on *M. vitrata* eggs in Mauritius and even worldwide. Likewise, pupae of *M. vitrata* were exposed in a bean field to detect the presence of entomopathogenic nematode (as per Bedding and Akhurst, 1975). An unidentified entomopathogenic nematode species was recovered from exposed pupae and which was found to be pathogenic to healthy larvae in laboratory. A pathogenic fungus (*Metarhizium* sp.) was detected from diseased *M. vitrata* larvae collected from *P. phaseoloides*.

Three biopesticides (two commercial formulations of azadirachtin, *Bacillus thuringiensis* var *kurstaki* Berlinger and *Beauveria bassiana* Balsamo) and three IPM compatible products (chlorantraniliprole, spinosad and indoxacarb) were tested for their efficacy against *M. vitrata* as alternatives to broad-spectrum insecticides in laboratory and in the field. In dose response bioassay in the laboratory, *B. thuringiensis* (Dipel® 16000 I.U./mg) at the rate of 2.0 g/L, induced more than 70% mortality in young and mature larvae within seven days. Spinosad (Tracer® 480 SC) at the rate of 0.25 g/L induced 100% mortality in young and mature larvae within three days. Pod damage in bean fields treated with azadirachtin (Bioking® 0.15% EC) at the rate of 5 mL/L was significantly lower (30%) than

untreated ones (57%). On the other hand, chlorantraniliprole (Coragen® 200 SC) at the rate of 0.25 mL/L and indoxacarb (Steward® 30 WG) at the rate of 0.25 g/L gave 100% larval control on flowers in two successive applications. Pod damage in chlorantraniliprole and indoxacarb treated plots was significantly lower ($\leq$ 2.5%) than that in untreated ones (30.8%). The pathogenic fungus, *B. bassiana* (Biofix larvo-guard® 2 x 10^9 CFU/mL), was not effective against *M. vitrata* larvae.

Field experiments were conducted to determine the attractiveness of four promising synthetic pheromone lures to males of *M. vitrata*. The lures were formulated by Natural Resources Institute (NRI), and consisted of a major component (EE 10,12-16: Ald) alone or in combination with one or both of two minor components (EE 10, 12-16: OH and E 10-16: Ald). Two of these lures are reported to be effective in Africa (one in Benin and Ghana and the other in Burkina Faso). The four lures were tested in three types of traps in treated and untreated bean plots in Mauritius. Males of *M. vitrata* did not respond to any of the four NRI lures in the field but were attracted to caged virgin females. This indicates that the synthetic lures were not similar to the pheromone released by virgin females and that the *M. vitrata* in Mauritius can be a population geographically distinct from those in Benin, Ghana and Burkina Faso.

Laboratory and field studies were carried out to study the biological parameters of *T. chilonis* developed from eggs of *M. vitrata* and its potential in inducing egg mortality in *M. vitrata*, *H. armigera* and *P. xylostella*. *Trichogramma chilonis* females lived for about 8.5 $\pm$ 0.7 days in laboratory and produced an average of 42.4 $\pm$ 1.3 eggs during their life time. They laid 80% of their full complement of eggs within four days after emergence. However, the number of eggs laid was highest on the first day. The sex ratio of emerging progeny was 1:2.2 (M:F). One-day old *M. vitrata* eggs were preferred for oviposition whereas 2 and 3-day old eggs for feeding. No parasitism was observed in 3-day old eggs. The combined effect of egg parasitism and feeding resulted in more than 77% mortality in one and two-day old eggs. Only one *T. chilonis* adult emerged from a parasitized egg. In the choice test, *T. chilonis* females showed a preference for parasitizing eggs of *H. armigera* to *M. vitrata* but did not parasitize eggs of *P. xylostella*. In the no-choice test, parasitism in eggs of *H.*

armigera and *M. vitrata* was significantly higher than that in eggs of *P. xylostella*. Exposed eggs of *M. vitrata* and *H. armigera* in the field were parasitized by *T. chilonis* while those of *P. xylostella* were not.

The toxicity of five selected IPM compatible insecticides and a commonly used synthetic pyrethroid, lambda-cyhalothrin, on immature and adult *T. chilonis* were determined in laboratory. The six insecticides showed a marked difference in their toxicity to *T. chilonis* females, parasitism and wasp emergence from treated eggs. Based on the evaluation criteria of the International Organistaion for Biological Control, chlorantraniliprole and indoxacarb were found harmless to *T. chilonis* whereas the other four insecticides were either slightly toxic or toxic to female wasps and affected parasitism and wasp emergence from treated eggs but with reduced effect in 1-day residue test.

Results were considered valuable for the scientific and farming community and were communicated at International Neem Conference in India (Unmole, 2007), National Research Week Forum in Mauritius (2008) and in the Women in Science Competition organised by CTA and FARA in Burkina Faso (Unmole. 2011). Research results on management of pod borers on bean, laboratory rearing of *M. vitrata*, response of males *M. vitrata* to pheromone lures and on biology of *T. chilonis* were published in the peer-reviewed *Journal of the University of Mauritius* (Unmole 2009a, Unmole 2009b, Unmole 2009c, Unmole 2010). Farmers were made aware of the results through a radio talk (2008) and Technology Review Meetings with Extension officers of AREU (2009). Control recommendation for the management of *M. vitrata* was updated in the *Guide Agricole 2010* (Abeeluck *et al*., 2010).

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PRESENTATION 17

E-waste disposal in Mauritius – An assessment of its environmental impacts and an evaluation of the risk potential

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Introduction

In the past decade, rapid strides in technology and software have made the use of computers and other electronic products nearly ubiquitous in most developed countries and desires among consumers have heightened for newest and fastest equipment. In fact, the rapid growth in the use of computers and the incorporation of electronic features in a wide array of consumer products have been among the most important driving forces of the Mauritian economy during the last decade. In addition to producing better products, the improvements in technology have created growing volumes of obsolete products to be managed as waste.

Electronic waste (e-waste) is the most rapidly growing segment of most municipal waste stream.

Disposal of e-waste is an emerging global environmental issue, as these wastes have become one of the fastest growing waste types in some parts of the world, including the U.S and Europe (National Safety Council, 1999; Global Futures Foundation, 2001; Schmidt, 2002). Management of these products as waste is alarming in part because of their volume, but more importantly because they contain large amounts of heavy metals and other toxic substances. Hedemalm *et al*, 1994, have described different element compounds contained in electric and electronic products, and claimed that brominated flame retardants (BFR), cadmium, chloro-paraffins, chromium, copper, lead, mercury, nickel, PCB's and silver compounds are the main toxic substances detected in electrical products. Concerns have been raised that toxic chemicals will leach from these devices when disposed (Yang, 1993; Lee et al., 2000; White et al., 2003).

BFRs in landfill leachate could be released back to the environment through sewage sludge if the leachate is sent to a wastewater treatment plant. The mobility of the heavy metals and BFRs that e-wastes contain, also pose a potential risk to groundwater and water quality surrounding a landfill. BFRs have been found in human breast milk, human blood serum, animal tissue, air, water, sediments and sewage sludge (de Boer et al., 2003; de Wit, 2002; Watanabe and Sakai, 2003). BFRs have also been found in body fat of many wildlife species including sperm whales in the Atlantic Ocean (de Boer, 1998). Studies have found increased levels of BFRs in electronics disassembly workers (Sjodin et al., 2001). Potential locations at which BFRs may enter the environment include the plants where they are manufactured, the plants where they are added to products, the locations where the products are used and the locations where the products are disposed. Another reason for the concern is the recent disclosure of toxicological data which demonstrate that some BFRs have serious health effects, such as thyroidogenic, estrogenic, and dioxin like activities (Bergman and Ultika, 2001). Therefore, the emerging problem is whether environmental levels of BFRs will continue to increase and possibly cause toxic effects to humans.

As evidence has mounted on the harm caused to human health and the environment by chemicals used in information-age products, worldwide activism against these toxins has also grown, culminating in stringent new regulations for the proper management of e-wastes. The European Union (EU) has enacted two directives related to e-wastes namely the Waste Electronics and Electrical Equipment (WEEE) and the Reduction of Hazardous Subsatnces (RoHS). The WEEE directive deals with the recycling of e-wastes whilst the RoHS restricts the use of particular substances in electronic equipment. Mauritius has adopted the Basel Convention regarding the Control of Transboundary Movements of Hazardous Wastes and their Disposal in November 1992, thereby restricting the export, import and transit of hazardous wastes and other wastes for final disposal and for recovery.

The Mare Chicose Sanitary Landfill is currently the unique ultimate repository of Mauritius. To date around 2,600,000 tons of domestic waste have been placed and compacted in the landfill. In Mauritius, "e-waste" is a relatively new concept about which very little is known and which has not been given much priority to date. Apart from the Basel Convention, there is currently no direct legislation monitoring e-waste's handling, recycling and disposal, because it has not been identified as a waste stream in any of the characterization studies that have been regularly carried out on municipal waste streams. According to a local survey on the ownership, use and disposal of common household appliances (Jeenally, 2005), a majority of households dump their e-wastes into their dustbins whereas the others have been storing them in some inconspicuous place for years. The survey also illustrated that most distributors of electronic appliances who also provide after sale services by reparation of the appliances, have been throwing away their e-wastes together with municipal wastes whereas the rest have been keeping them and are waiting for better options. Used electronics markets are not well developed in Mauritius, apart from few business and organizations, which specialize in computer refurbishment for resale of cloned computers (Jeenally, 2005).

Research Objective

In view of the emerging environmental problems caused by e-wastes, and given that most of the e-wastes in Mauritius are dumped together with municipal wastes which are ultimately

landfilled, the environmental impacts of e-waste disposal at the Mare Chicose landfill have been assessed throughout this project.

Methods

A groundwater risk analysis has been conducted in the vicinity of the Mare Chicose landfill since the landfill is located in a region of high rainfall and hence there is a potential for high leachate generation. Groundwater and surface water samples were collected around the Mare Chicose landfill and heavy metals (Copper, Zinc, Lead, Cadmium, Chromium, Manganese, Nickel, and Iron) have been tested in the samples using the Atomic Absorption Spectroscopy. The trace metals level analysed in ground water and surface water were compared with Drinking Water Standards and the Guidelines for Inland Surface Water Quality respectively (as per the Environment Protection Act 2002).

Grab samples of leachate have been collected in summer (intense rainfall season) and winter (low rainfall seasons) for analysis of heavy metals. Leachate samples were collected at two sites namely the Leachate Pond and the Well B1.

Leachate samples were also collected from the Leachate Pond and leachate well B1 for analysis of Brominated Flame Retardants (BFRs). BFRs have been analysed from raw leachate samples using the extraction procedure, based on continuous liquid – liquid extraction. PCB – 2,3,3/ - trichloro- 1,1/ Biphenyl, Hexabromocyclododecane (HBCD), Tetrabromobisphenol A (TBBPA) and Polybrominated diphenyl ethers (PBDE) were used as internal standards. Extracts were evaporated to 0.2ml using a rotary evaporator and at a temperature of 70^{o}C and were diluted with Dichloromethane (DCM) and Hexane (HX) and centrifuged for 10 minutes before being run on a 0.25mm diameter column, gas chromatography apparatus.

A water balance at the landfill has been carried out to predict moisture movement within the Mare Chicose landfill and to determine the amount of leachates generated.

Preliminary Results

Considerable amounts of lead, cadmium, iron, chromium, nickel and manganese in groundwater exceeding the Drinking Water Standards (Environment Protection Act 2002), have been noted. Elevated levels of lead, cadmium, chromium, and nickel (exceeding the Guidelines for Inland Surface Water Quality, EPA, 2002) were detected in surface water samples. Highest concentrations of pollutants were recorded downstream of Feeder Tibere, (K003/05) and boreholes BH21, BH22, BH29, G3, and G4.

The levels of most heavy metals in the leachate samples at the two sites were found to be below the permissible limits (Standards for Effluent Discharge Regulations and the Standards for Effluent Discharge into the Ocean (Regulations 2003). The leachate chemistry has been found to be dominantly composed of iron, and cadmium which exceeded the EPA standards (standards for Effluent Discharge into the Ocean).

The water balance model (WBM) indicated high leachate production during heavy rainfall in summer seasons. Leachate production was also affected by evaporation from refuse and soil. Leachate generation has been found to be increasing since the operation of the landfill.

A considerable amount of tetrabromobsphenol-A was detected in all the samples of leachates collected from well B1 through the selective ion monitoring (SIM) and full scans. The mixture DCM/HX resulted better extraction. Hexabromocyclododecane (HBCD) was not detected in samples analysed.

The detection of BFR in the leachate sample confirmed the fact that as other developing and developed countries, e-waste is becoming a complex problem to manage in Mauritius. The results obtained throughout this project has compensated for the dearth of information on e-waste management in Mauritius. This would certainly present policy-makers with an introduction to the impacts that e-wastes disposal might have on the environment and to the multiple factors that have to be considered when deciding the best measures to adopt in order to tackle the e-waste problem locally.

Results obtained throughout this study also reveal that the quality of the groundwater resource underlying the Mare Chicose landfill site has been impacted by migration of leachate from the body of the landfill. These results show that there is necessity for leachate treatment at the landfill site to prevent further contamination to surface and groundwater.

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PRESENTATION 18

Assessing polluting potential of hydroponic effluents and developing methods for Reuse

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Introduction

Food crop production in Mauritius is characterized by an intensive production system, mainly because of the limited land resources available for agricultural purposes on the island and the increase in food demand to satisfy the increasing population and tourist industry. Food crop agriculture is mainly dominated by small scale farming with an average holding of 0.25 ha and few large farms that are greater than 10 ha. A wide range of crops are cultivated including potatoes, onions, tomatoes, chillies, crucifers, garlic and ginger. The annual domestic demand for food crops ranges from 90 000 to 110 000 tonnes and a large amount of processed food is imported on a regular basis to meet local demands.

However, the constant worry in agricultural development has always been the low production and yields.

With the rise in standard of living, purchasing power and with the development of the tourist industry and more sophisticated marketing channel, there is an increasing demand for quality produce in terms of appearance and nutritive values. These can be achieved by adopting vegetable production under hydroponics which will improve both quality and yield per unit area.

Presently, the area under hydroponics in Mauritius is around 12 hectares and is expected to increase by approximately 8 hectares in the years to come following the agricultural diversification programme of the government. However, one major concern with this type of culture is the volume of liquid effluents and nutrients particularly nitrates, phosphates and other micro elements which may contribute to adverse effects to the surrounding environment. This is mainly due to the movement and leaching of nutrients contaminating groundwater, surface water and soil. Despite the polluting potential of the hydroponic effluents no methods have so far been devised in Mauritius to address this issue.

Research Questions

The purpose of this research was to assess the hydroponic effluents potential as a waste diversion strategy. The benefits of this project will be described into two fold, (i) firstly diverting the hydroponic effluents from groundwater, surface water, and soil; (ii) secondly producing a valuable resource beneficial to growers, at the same time protecting the natural environment. This study initiated at the University of Mauritius in collaboration with the Agricultural Research and Extension Unit (AREU) to collect data on hydroponic effluents in an attempt to assess their use as fertiliser. With an increasing scarcity of freshwater, due to indiscriminate use and a changing climate with extreme weather events of drought and flooding, there is an urgent need to cater for the management of this resource.

Up to now, no technical project to study the management of hydroponic effluents from greenhouses as a route for disposal of waste water to the natural environment has been initiated in Mauritius. In Mauritius hydroponic effluents are allowed to drain out of the

system as, up to now no laws/regulations have been formulated. Research has revealed that 50% of fertilizer applied in hydroponic culture is lost through leaching (Choi et al., 2001). Hence this project falls well in line with control of environmental pollution. Another reason for carrying out a study on the hydroponic effluents would be to use the latter as a partial substitute for chemical fertilisers in agriculture. At the present moment, in Mauritius, around 57,000 tonnes of inorganic nitrogen containing fertilisers are imported on an annual basis. However, its use related to the nitrate levels in future may contaminate the water sources and exceed the maximum limit of 50 mg/l permitted for drinking water (EPA, 2002).

Literature Review

Hydroponic systems are generally divided into liquid culture and substrate culture systems. The former are commonly referred to as water culture, whereas the latter are named according to the medium used, such as sand, gravel, rockwool, perlite, pumice, zeolite, sawdust, coconut coir and other organic materials. In most cases, open or run-to-waste systems rather than "closed" or recirculation systems have been adopted (Savvas et al, 2002).

Open systems are the easiest form of hydroponics to manage. In open system; once the nutrient solution is delivered to the plant roots, surplus water and unused essential elements solution are allowed to run into a waste collection area or more often the superfluous nutrient solution leaches freely into the ground and surface water (Maloupa, 2002). In a closed system; the surplus solution is recovered, replenished and recycled back to the system (Jones, 1997). All the ions entering the system are either absorbed by the plant roots or they remain in the solution and increase the salinity.

In Mauritius, the most common type of hydroponics cultures are the open systems where the hydroponic effluents are discharged in drains, undoubtedly leading to environmental problems such as potential contamination of water bodies, aquifers and human health link to the use of groundwater for domestic purposes. This has been evidenced by Bilgehan et al. (2006) who reported that the situation will be worsen in future as agriculture must

intensify through the use of excessive agricultural chemicals to satisfy the demand for food by the increasing human populations.

Moreover, the threat from hydroponic effluents is significant because of usually very large amounts of fertilizers used for vegetable and ornamental plant fertigation in greenhouses. For example, for roses grown in soilless culture, a total of 2,990 Kg N ha-1 was applied. At present the annual average application of nitrogen in Poland is 70 Kg N ha-1. Thus, greenhouse fertigation represents a very large and potentially important loss of nutrients and source of environmental pollution (Bres, 2009). Also, as stated by Wysocki (2004), the disposal of hydroponic effluents is a major problem. This fact has also been reported by Gagnon et al. (2010) and Park et al. (2008) that hydroponics cultures generate large amount of wastewater highly concentrated in nitrate (200-300 mg/l) and phosphate (30-100 mg/l). This is in line with Fernandez (2009) who also reported that nitrates and phosphates found in the hydroponic effluents can get easily leached and contaminates rivers, soil and groundwater.

In Netherlands, there have been laws and regulations put in place requiring greenhouse operations to collect any nutrient effluent originating from their location as laws prohibit growers to dispose the excess nutrient solutions in the environment due to surface and groundwater pollution (Runnia et al. 2001). This is in agreement with Raviv et al. (1998) who pointed out that strict environmental regulations against groundwater pollution originating from fertigation effluents produced in greenhouses, are primarily responsible for enforcing growers to adopt nutrient solution reuse.

At the same time as the excess solution is leached down the soil or surface water it can directly affect our water sources like groundwater, river water if the greenhouses are located in the vicinity of these sources. As reported by Bilgehan et al. (2006) groundwater is the source of drinking water for many people around the world, especially in rural areas. Already more than 98% of the world's fresh liquid water supplies occur underground and there is plenty of room for more (FAE, 2003).

Methodology

The growers' survey was based on a quantitative methodology involving a sample population of 120 growers. The growers' awareness was assessed in the survey and

descriptive analysis was performed on the survey data using statistical program SPSS (statistical Package for the Social Sciences), version 12.0 and Excel software (Excel, Microsoft, 2000).

Hydroponics water and hydroponic effluents under different agroclimatic conditions were collected on a fortnightly basis from 27 greenhouses namely; cucumber, sweet pepper and tomato. Data was collected throughout the crop cycles to analyse different parameters as well as the potential impacts of pollution.

Microbiological studies included bacterial count and the determination of the presence of total coliform. Samples of influents and effluents from each culture namely; tomato, sweet pepper and cucumber were randomly selected from different greenhouses for enumeration of bacteria and determination of total coliform. Serial dilution was carried out till 10^{-6}. Viable bacteria count in water samples were carried out as described by ISO 4833: 2003 (E). Inoculated plates were incubated at 30^{o}C for 72 hours. After incubation, the bacterial colonies were counted to determine the viable count (CFU/ml) of each specimen. Concerning the coliform test, after preparing sterile Mac Conkeys agar plates, they were inoculated with a sample of the microorganisms that were to be cultured respectively. Four different 10 fold dilutions were prepared and tested.

The study furthermore focuses on assessing the potential of using the hydroponic effluents as a source of nutrient and water in bean "*Phaseolus vulgaris*" production. The aim was to evaluate the difference in yield of bean under different fertilization regimes. The treatment were as follows: (T1) control- no fertiliser and no hydroponic effluents, (T2) hydroponic effluents only (no mineral fertiliser), (T3) 25% mineral fertiliser + hydroponic effluents, (T4) 50% mineral fertiliser + hydroponic effluents, (T5) 75% mineral fertiliser + hydroponic effluents and (T6) 100% mineral fertiliser as per recommended rate (Guide Agricole, AREU). The experimented design for the trial was a random block design with six treatments replicated 4 times. Statistical analysis of data using ANOVA two factor without replication and least significance difference test were used to test difference among treatments.

Findings

In the survey conducted, 96% of the respondents highlighted that the hydroponic effluents were allowed to drain and only 4% of the respondents regularly use the hydroponic effluents for cultivation of other crops. This was mainly due to the fact that growers were not aware of the economic value of the hydroponic effluents.

Among others, nutrient analysis also demonstrated that nitrate and phosphate concentration in samples of hydroponic effluents were above the critical limit of 50 mg/l and 10 mg/l respectively. The nitrate levels recorded range between 24 and 202 mg/l while phosphate levels were between 22 and 52 mg/l. Overall, the electrical conductivity of the hydroponic effluents was high enough. This relationship suggests that EC and nutrients concentration are interacting in such a way that perhaps an increase in EC will automatically lead to an increase in nutrients concentration (Figure 1 & 2).

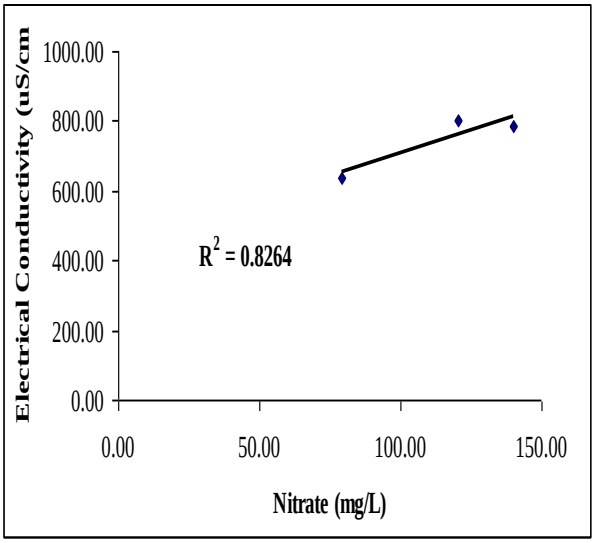

Figure 1

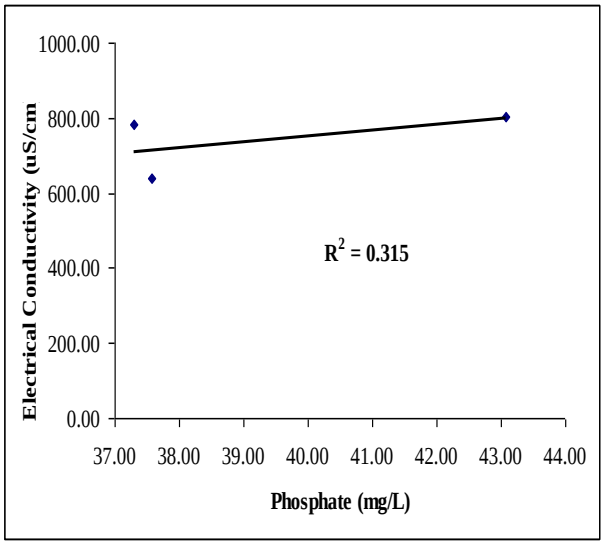

Figure 2

Out of the 60 samples employed in this study (30 samples hydroponic influents and 30 samples hydroponic effluents) the bacterial population was higher in the effluents. The higher population could be as a result of the solution being left aside after successive supply to the plants in the greenhouses. The lowest percentage of culturable bacteria on Potato Carrot Agar was found as 29% in the samples taken from the hydroponic effluents and the highest percentage noted was 71%. Both the total viable counts and the total

coliform test revealed that the hydroponic effluents were below the critical limit.

Pot trial revealed that bean yield obtained with hydroponic effluents combined with 75% recommended mineral fertiliser rate was not significantly different from that obtained with 100% recommended mineral fertiliser rate. The results clearly indicated that the nutrient available in the hydroponic effluents combined with recommended fertiliser rate can be put to beneficial use for improving plant growth and reducing fertiliser application rate by at least 25%.

Table 1: Mean plant height, weight of bean pods and ratio: yield/seed weight under different treatments

Treatments	**Plant height (cm)**	**Yield (kg/no of plants)**	**Ratio**
T1: Control	30.78±0.18^{e}	0.83±0.04^{e}	0.11±0.02^{a}
T2: H.E only	46.20±0.14^{b}	1.26±0.07^{d}	0.17±0.04^{a}
T3: 25% Mineral fertiliser + H.E	35.50±0.13^{d}	2.01±0.08^{c}	0.26±0.04^{ac}
T4: 50% Mineral Fertilizer + H.E	44.85±0.10^{c}	2.74±0.05^{b}	0.36±0.03^{ab}
T5: 75% Mineral Fertilizer + H.E	49.50±0.07^{a}	4.89±0.16^{a}	0.64±0.08^{a}
T6: 100% Mineral Fertiliser	45.13±0.06^{c}	4.76±0.11^{a}	0.59±0.09^{a}

± Standard Deviation

Note: *Means followed by the same letter are not significantly different at 5 % significant level by using the Least Significant Difference test (**LSD** $_{0.05}$)*

Discussion

The result achieved from this study provides important information about the sanitary evidence of the hydroponic effluents. Both the total viable counts and the total coliform test revealed that the hydroponic effluents were below the WHO standards. The study has also revealed that fertilization of bean with hydroponic effluents has numerous beneficial effects in terms of higher yields (fresh weight) and on soil properties. Data on soil nutrient concentrations have also shown that continual application of hydroponic effluents appears to raise the soil nutrient content with regards to phosphorus and potassium. From a sustainable point of view, for optimum yield while at the same time limiting any damage to the environment, application of 3/4 mineral fertilizer rate and hydroponic effluents is more suitable. Therefore, economically adopting treatment T_5 (75% mineral fertilizer + hydroponic effluents) may be more profitable as a result, decreasing to a great extent the heavy dependence on chemical fertilizers. Based on these results hydroponic effluents may be seen a potential alternative to be exploited in the local context.

Overall, this study has demonstrated that hydroponic effluents have a potential to improve plant growth, however this finding has been restricted to pot studies on bean only and partial conclusion has been obtained. Prior to reach a conclusive finding it is important to validate the observations and upscale the study at field level to test the reliability of the hydroponic effluents. Hence it is being proposed to repeat the pot experiment on a leafy crop of economic importance "lettuce" and the crops to be tested at field level would be lettuce, bean and fodder. Furthermore, a study will also be carried out on the storage lifetime of the hydroponic effluents. The upscaling of this project could be used as a basis to gather guidelines for management of hydroponic effluents as a measure to protect the environment.

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PRESENTATION 19

An investigation on the production of best quality compost from biowaste and lignocellulosic wastes to be used as substrate for the cultivation of the Pleurotus sajor caju mushroom

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Ms Y Mihilall has a Bachelor's Degree in Agriculture with Environmental Science from the University of Mauritius. She was recently upgraded from her MPhil Degree to an ongoing PhD Degree at the Faculty of Engineering from the same University. She has a total of four international publications, two of which have been presented during the ORBIT conference in China (2009) and France (2012). She was selected to participate in the Doctoriales 2012, May 21-27, Reunion and received the second prize of 1500 € for the mini project "Creation of an Innovative Company in Two days". Also, Ms Mihilall recently became member of the regional Higher Education and Research Network of the countries of the Indian Ocean Commission.

Introduction

The oyster mushroom (*Pleurotus sajor caju*) is the second most cultivated edible mushroom worldwide after the button mushroom (*Agaricus bisporus*) (Sánchez, 2010). This white-rot basidiomycete is progressively gaining ground for both gastronomic and medicinal reasons. It is rich in proteins, vitamins, fibres, carbohydrates, several minerals and has a low fat content (Bonatti *et al.,* 2003). Both fruiting body and mycelium contain compounds with a wide ranging antimicrobial activity and have been extensively used in

traditional medicine for curing various types of diseases since it also has antiviral, anticancer, antitumor, anti-inflammatory, immunomodulating activities and inhibits cardiovascular diseases (Akyüz *et al.*, 2010). Common in Chinese cuisine, the oyster gourmet mushroom is progressively being popularised in other countries. It is typically served raw, in soups or stir-fried with soy sauce. *Pleurotus sajor caju* grows primarily on hardwoods and numerous composted and non-composted lignocellulosic wastes. It has an extensive range of temperature adaptability. Since its introduction in Mauritius, bagasse from sugar cane (*Saccharum officinarum*), has remained the sole substrate used to cultivate the oyster mushroom commercially. Growers are increasingly facing difficulties in acquiring this substrate because it is being diverted to thermal power stations as input for the generation of electricity. Therefore, a rise in commodity price and a drop in mushroom production is predictable.

Research Question

To find an alternative substrate for growing the *Pleurotus sajor caju* mushroom, which is as performant as bagasse, using the local feedstocks available.

Review of Literature

Mushrooms are the reproductive organs of the largest and most complex fungi. Despite the fact that the mushroom neither belongs to the animal nor to the plant monarchy, it is more closely related to Kingdom Animalia than to Kingdom Plantae (Goli, 2009). According to Peerally and Sutra (1972) and Peerally (1979), several mushrooms have been identified and cultivated in Mauritius are shown in **Table 1**.

Table 1: Mushrooms identified and cultivated in Mauritius

Mushroom	**Remarks**
Lepiota morgani Peck.or Lepiota esculenta Massee	Poisonous
Volvariella volvacea (Fr.) Singer	Edible. Usually culitvated on bagasse, residue from aloe (*Furcraea gigantea*) factory, cotton wastes, banana leaves, mix of 5% bran and 5% limestone.
Protohydnum gelatinosum (Fr.) Karst	Edible
Tricholoma spectabilis	Grows in sugar cane fields. Edible after cooking.
Tricholoma mauritania	

Adapted from: Peerally and Sutra (1972) and Peerally (1979)

Compared to *Agaricus* and *Lentinula*, *Pleurotus* mushrooms are the easiest, fastest and cheapest to grow, require less preparation time and production technology (Mandeel *et al.*, 2005). The *Pleurotus sajor-caju* mushroom belongs to Phylum Basidiomycota. Being saprophytic, it grows primarily on hardwoods and numerous composted and non-composted lignocellulosic wastes.

The present local substrate formulation for growing the oyster mushroom is fundamentally, fermented bagasse which is then moistened until 70% water content is achieved. Supplements are then mixed with the substrate until a homogeneous mixture is obtained. Polypropylene bags are then filled with the resultant mixture and heat treated for 3 to 4 hours. After cooling, the bags are inoculated with the mycelium spawn in a sterile area, and then disposed horizontally on wooden or metal shelves to allow substrate colonization. The contribution of bagasse in cogeneration is expected to increase over the coming years with the local mushroom industry facing inevitable shortage of the substrate. Composted biowaste and lignocellulosic wastes, using the locally available discarded agro-industrial resources, are being presently envisaged as the future substratum. This prospect is anticipated because it would partly substitute the bagasse substrate while providing an

environmentally sustainable solution towards the reduction of wastes hauled to the Mare Chicose sanitary landfill (MCLS), the only landfilling site in Mauritius. This site presently receives about 1217 tons of wastes per day, part of which is sent to the novel Solid Waste Recycling Company. However, this figure is far from what the MCLS was expected to accept (400 tons/day) and so, the landfill is already near saturation. The country's solid waste composition is mainly 45% yard wastes, 25% food wastes and 6–15% mixed paper wastes with 70% of the solid waste stream in the country is suitable for composting. Engineered composting systems are considered as an effective way of refuse reprocessing, resulting in the generation of a truly recycled and sanitised organic product. This creates an optimum decomposing environment thus accelerating the process to optimise biological stabilisation and achieving sanitisation while reducing the emission of odours and gases. In the end, a more consistent compost of quality standard is obtained in as little as a couple of weeks. Subsequent utilisation of the resultant substrate for oyster mushroom cultivation will no doubt solve the problem of oyster mushroom growers while minimising the influx of wastes to the MCLS. This option not only provides an environmentally sustainable solution towards alleviating the load of refuse sent to the MCLS but also encourages the country towards self-sufficiency in food production. Most African countries are addressing food shortage through the production of highly alimentative protein-rich biomass using locally available waste materials. As such this strategy can be integrated in the present Mauritian agricultural system to enhance farmer income on a sustainable basis.

Methodology

The in-vessel composting of locally available lignocellulosic substrates, termed as the BGCW mix, was carried out. Oxygen was provided by active aeration with a constant airflow. Several composting parameters were tested for careful monitoring to ensure that the process was taking place within the required standard. Nearly all experiments, moisture content (MC), wet bulk density (BD_w), particle size, water holding capacity (WHC), porosity, pH, electrical conductivity (EC), volatile solids (VS), and ash content were carried out on a weekly basis. Exceptions were for temperature monitoring on a daily basis at a fixed time (9 a.m.) in the morning and compost maturity, tested over four consecutive days per week. The heavy metals (Lead, Cadmium and Zinc) content and nutrient content

(Nitrogen, Phosphorus and Potassium) of the compost were carried out after the 3-week composting. In the second phase, the BGCW compost alongside with bagasse were packed in heat resistant bags and pasteurised. The cooled bags were inoculated with the oyster mushroom spawn (*CC 114* strain) and incubated at temperatures ranging from 23°C to 27°C.

Findings & Discussion

The average temperature monitored, was 46.2°C with a maximum of 56.5°C on day 8 thus satisfying the EPA guidelines of temperature more than 55°C for a minimum of five days. The physicochemical characteristics show the final composted BGCW mix having a lower MC, 57.7% compared to bagasse (58.1%). Conversely, BGCW had a higher BD_w, particle size, WHC, EC, pH and ash content compared to bagasse. Porosity and VS were superior in bagasse. The heavy metal contents for Pb, Cd and Zn of the BGCW mix were within the range of 0.01 and 0.002 mg/L with respect to the Mauritian Standards. The final carbon dioxide evolution rate concluded the processed mix as stable compost. The nutrient content for the BGCW compost for nitrogen, phosphorus and potassium was higher compared to bagasse. The spawn run on the substrate could be observed from the fifth day of incubation on bagasse and BGCW compost. Primordia formation appeared earlier on the bagasse substrate (14 to 18 days of incubation) in comparison to the BGCW compost (21 to 32 days of incubation). Mushrooms were harvested three to five days later after primordia formation on both substrates. The total yield of fructifications harvested from the three pickings was 950.30 g for bagasse and 810.60 g for the BGCW compost. Consequently, the average biological efficiency on bagasse was 42.23 ± 4.4% as compared to the BGCW compost which was 36.03 ± 5.3%. Figures 1 and 2 shows the growth of the *Pleurotus sajor caju* mushroom on the BGCW compost and that of bagasse.

Fig. 1. Growth of *P.sajor caju* on BGCW

Fig. 2. Growth of *P.sajor caju* on Bagasse

It is envisaged that the BGCW compost be supplemented to bagasse for the cultivation of the *Pleurotus sajor caju* mushroom. Hence, introduction of the oyster mushroom in present agricultural systems can be a profitable economic venture, since Mauritian farmers or any trained freelance can readily convert the free waste resources into a value-added product. The major future work will be to modify the composting process with respect to the end use of the final compost; therefore, as mushroom substrate in this case. The perspective is to develop the oyster mushroom cultivation on a large scale basis in terms of building design, with particular reference to temperature, humidity and air exchanges, growing room requirements and waste recycling system.

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PRESENTATION 20

Life Cycle Assessment of Electricity Generation in Mauritius

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Ms R Brizmohun has been working as Scientific Officer at the Ministry of Environment and Sustainable development since 2003. She has also gained working experience at the UNDP GEF Small Grants Programme and at the International Atomic Energy Agency in Austria. She is a holder of a B.Eng (Hons) Chemical and Environmental Engineering at the University of Mauritius and a MSc in Environmental management at the University of Nottingham, UK.

Introduction

Energy, in all its forms, is a vital part of our daily lives. The global energy consumption is expected to increase steadily over the next twenty years, and the largest increase in energy use will occur in the developing world. Mauritius, being a rapidly developing country, will not be spared by this wave. Electricity, the major form of energy, fuels our everyday activities at home and at work and also drives the national economy, since it is a significant input into the production of goods and services. To meet the challenge of satisfying the increased demand of electricity, it is imperative that there be an efficient and sustainable production of electricity.

In Mauritius, the main sources of electricity come from fuel oil, bagasse, coal and hydropower. Electricity generation is provided by both utility and non-utility sources, that is, by the Central Electricity Board, which is the sole national electricity supply corporation, and the Independent Power Producers (IPP) respectively. All the IPPs are associated with the sugar sector and this allows for the efficient use of bagasse as a local and renewable

biomass fuel for energy generation. The CEB produces around 40% of the country's total power requirements and the IPPs produce the remaining electricity requirements for the island.

The generation of electricity, and the consumption of energy in general, result in consequences to the environment and human health. To determine which electricity generation system is more environmentally acceptable, the environmental impacts caused by each electricity generation system have to be looked into. In this respect, the most appropriate tool that can be used is Life Cycle Assessment (LCA). It should also be noted that when carrying out LCAs, electricity is a building block in any assessment as it is a major environmental impact on its own. The study was carried out to undertake a Life Cycle Inventory (LCI) for electricity generation by fuel, bagasse, coal and hydro and make a comparison of their environmental burdens from a life cycle perspective and to model the life cycle inventory (LCI) for electricity generation in Mauritius for the reference year 2007. The intended application is to use the data sets as background data in other LCA case studies. The LCI of the electricity mix will provide appropriate data for other LCA studies in Mauritius since electricity is one prime impact in the life cycle of products and services. In addition the environmental impacts of the different sources of electricity will be determined. It can also help in developing criteria for environmental labelling, such as 'green energy' or 'eco-friendly' schemes. Moreover, the electricity data obtained can be considered for strategic decisions in policy making.

Research Questions

1. What are the environmental implications associated with the generation of electricity in Mauritius?
2. Which fuel source provides the most environmental benefits

Literature Review

What is Life Cycle Assessment?

Life Cycle Assessment is a tool to assess the potential environmental impacts and resources used throughout a product's life-cycle, i.e from raw material acquisition, via production and

use phases, to waste management (ISO, 2006). The waste management phase includes disposal and recycling and the term "product" includes both goods and services. LCA is a comprehensive assessment and considers all attributes or aspects of the natural environment, human health, and resources (ISO, 2006). The unique feature of LCA is the focus on products in a life-cycle perspective.

Structure and Components of LCA

The International Organisation for Standardisation (ISO) has standardized the LCA framework within the ISO 14040 – 14043 series. The four separate but interrelated components of life cycle assessment, as structured by the SETAC LCA framework and based on the ISO standard, are:

- Goal definition and scope
- Inventory analysis
- Impact assessment and
- Improvement analysis

The following diagram shows the framework for Life Cycle Assessment:

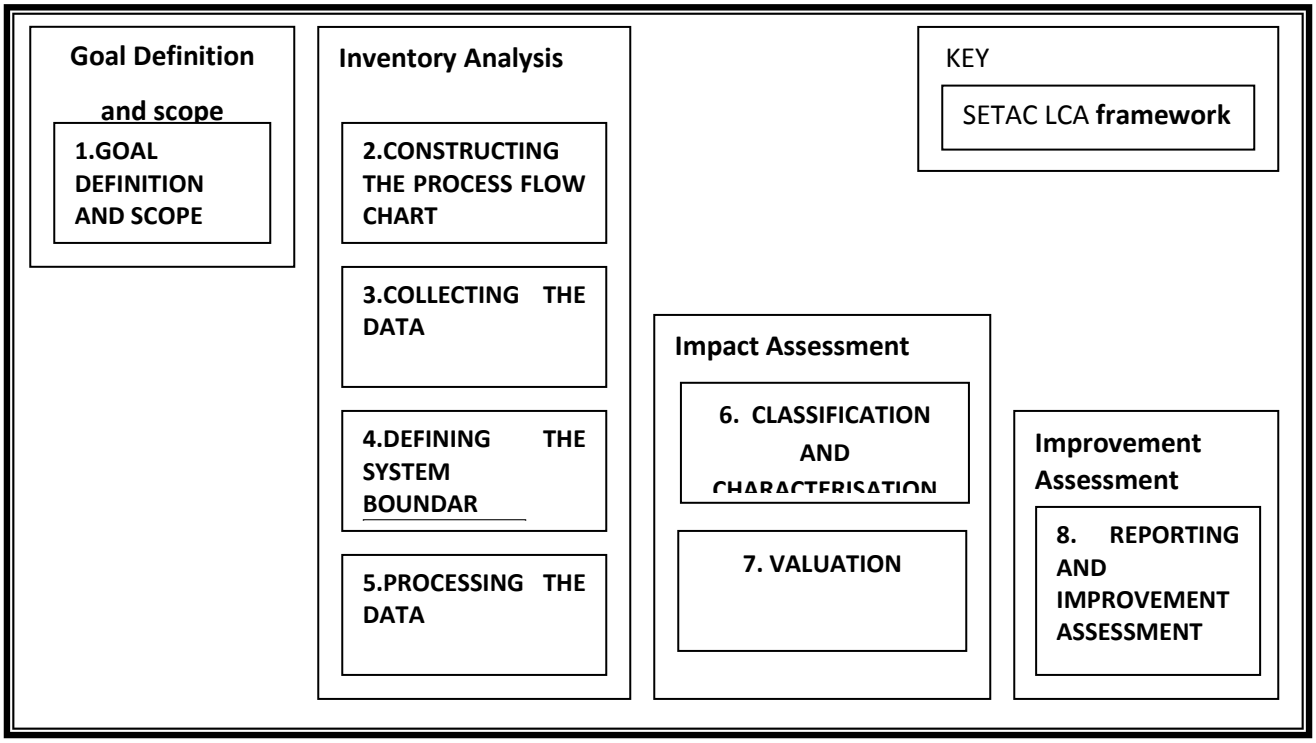

Figure 1: Framework for LCA

Life Cycle Assessment of Electricity Generating Systems

Using the life cycle perspective has been an efficient methodology to describe the environmental consequences of electricity generation systems. Aumonier (1998) described the LCA as an appropriate tool for comparing the costs and benefits of different electricity generation options.

Bergeson and Lave (2002) state that the first comprehensive analyses on the effects of power plants were performed in the 1970's by Lave and Freeburg (1972), and Sagan (1973). Both their studies showed that coal posed significant environmental risks, from mining, transport, and generation and that oil and natural gas have much smaller environmental and health costs. More recent papers have examined new technologies and newer data. Studies have been done to carry out LCAs for other nations (e.g. Bates (1995) Kivisto (1995) and Uchiyama (1996)). Two recent studies using a new life cycle analysis tool are Pacca (2002) and Meier (2002). Meier (2002) studied the energy and environmental performance of electricity generating systems using LCA. The results of his study were used to evaluate greenhouse gas emissions reduction strategies for the U.S.

Certain studies were more detailed and specific and carried out life cycle inventory of the production of electricity. In most cases, a functional unit of 1 unit of electricity, that is, 1 kWh, 1 MWh or 1GWh, was used, using the electricity mix of the country. The study entitled 'Life cycle inventory for electric energy system in Brazil' was carried out by Coltro et al in 2003 whereby an LCI for the interconnected electricity grid mix in Brazil in 2000 was developed, using a functional unit of 1,000 MG (1 GJ). The three main sources of electric energy, that is, hydropower, conventional thermal energy and nuclear power were considered, with 89% of the total electric energy being derived from hydropower stations.

Methodology

To carry out the Life Cycle Inventory for electricity generating systems in Mauritius, the standard LCA methodology as described by ISO 14040 - 14043 and the SETAC LCA framework were used.

Goal and Scope definition

This stage defines the purpose of the study, the functional unit, the boundary conditions and the assumptions for the context in which the assessment is being made. The scoping process links the goal of the analysis with the extent or scope of the study, i.e. what will or will not be included (UNIDO, 1994)

The functional unit

The functional unit was defined as 1 MWh of electricity at the consumer level. When carrying out the LCI for each fuel source, the functional unit considered was 1 MWh electricity from the specific fuel source.

System Boundary

The system boundary of this study begins with the extraction and production of the fuel source and extends up to the use of the electricity. Each fuel source was considered separately; however the system boundary was similar and in each case it comprised of the following main stages:

- Production of the fuel
- Transportation
- Power Generation
- Transmission and Distribution
- Electricity Use

The diagram below shows the system boundary for the production of electricity from coal.

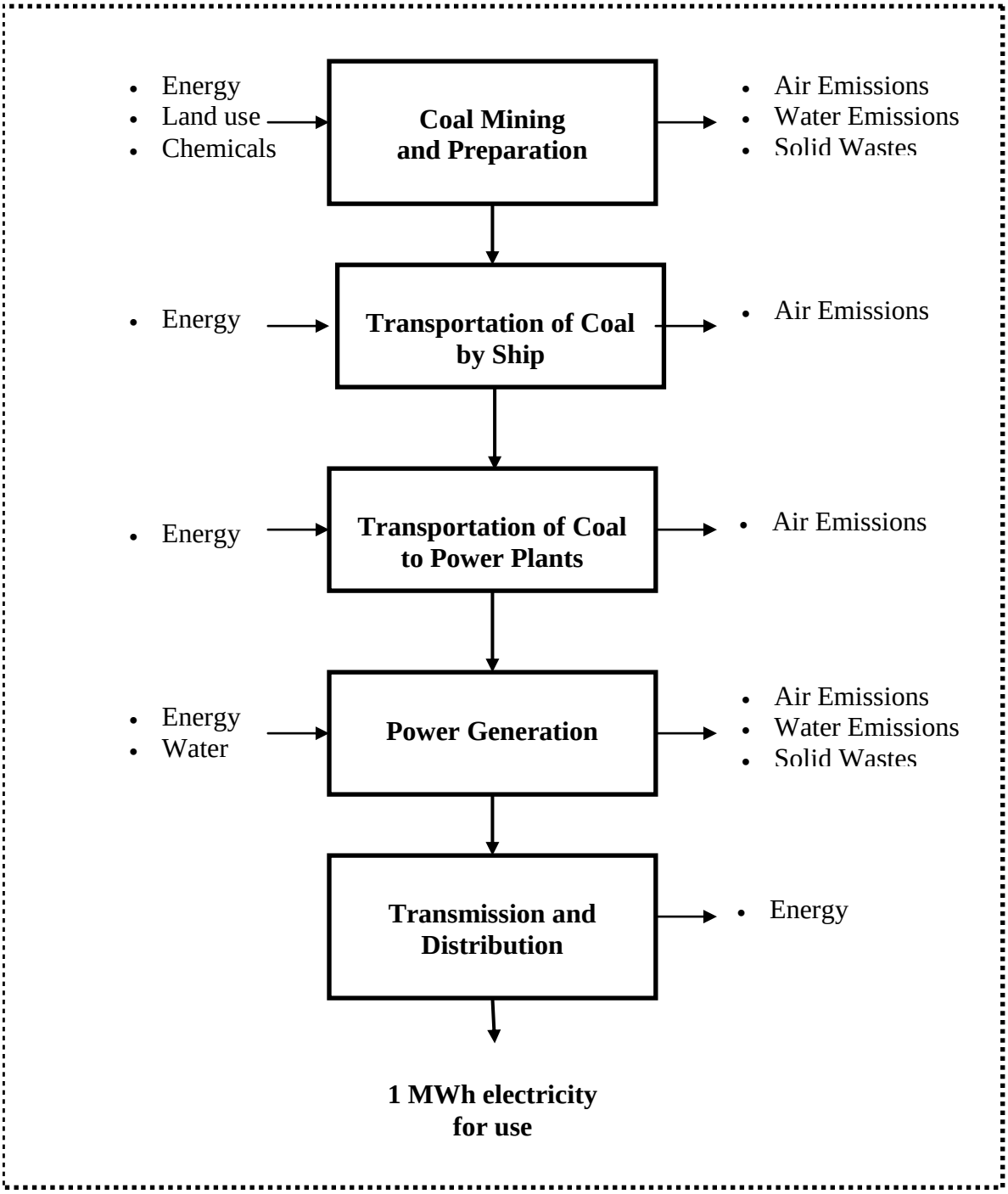

Figure 2: Stages involved in the production of electricity using coal

In the case of electricity from bagasse, the system boundary includes the whole sugar cane processing, starting from the sugar cane cultivation, then the sugarcane processing to product bagasse, which is the fuel source, till the production of electricity to be consumed.
The following diagram shows for example the system boundary considered in the case of electricity generation from bagasse.

System Boundary

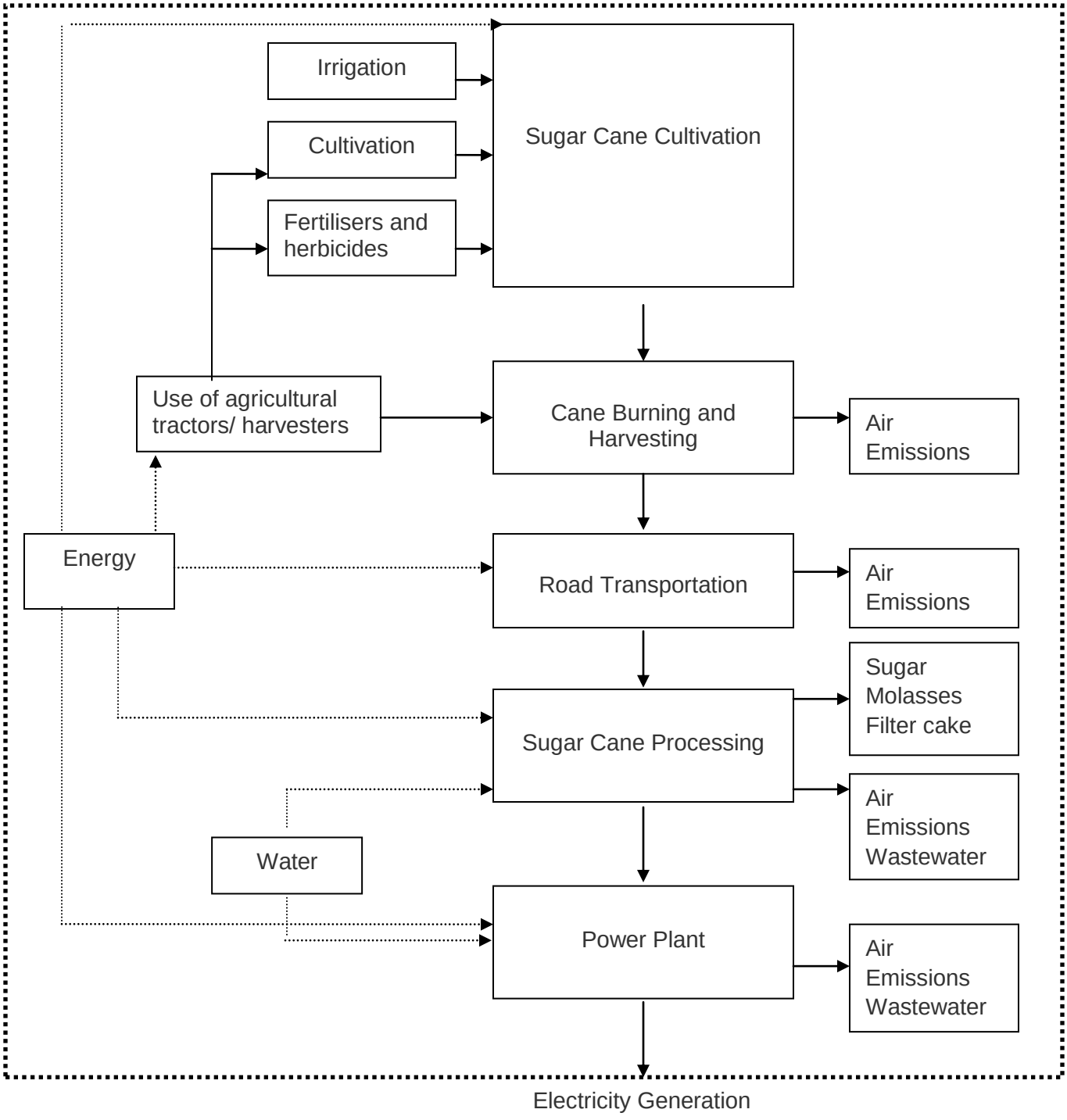

Figure 3: System boundary showing stages involved during production of electricity from sugarcane bagasse

Modeling Approach

The study was based on the attributional modeling approach with data and figures for the year 2007 (CSO, 2008) and using the electricity mix of fuel source with 19.0 % from bagasse, 40.3 % from coal, 37.2 % from fuel oil and 3.5 % from hydropower illustrated in the figure below:

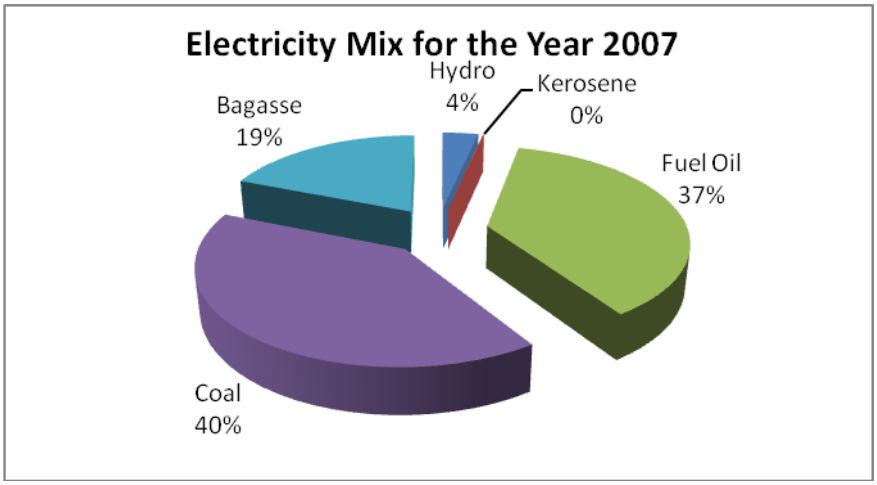

Figure 4: Electricity Generation Mix for 2007

(Source: CEB, 2008)

Life cycle inventory

The inventory analysis specifies the processes required in the manufacture, use and eventual disposal of a product. Each process requires an input and produces an output. These inputs and outputs are defined here as resource use and emissions.

Process flow chart construction

All the processes involved in the product life cycle are specified in the form of a process flow chart and includes all the inputs and outputs. The process flow charts for the different sources of fuel were derived.

Data Collection and Processing

Data were collected from different sources, such Environmental Impact Assessment Reports, the Central Electricity Board, the Independent Power Producers, Eco-Invent databases etc. The data collected were then processed using dedicated software. The educational version of SimaPro 7.1 was used to process and analyze the data. SimaPro is a

dedicated LCA software that provides a professional tool to collect, analyze and monitor the environmental performance of products and services (more information on www.pre.nl). The final LCI for each fuel source and ultimately the LCI for the electricity mix in Mauritius comprised a list of inputs (resources) and outputs for airborne emissions, water borne emissions and emissions to soil. The environmental flows selected was in line with the 'minimum' list of environmental flows for energy supply systems developed during the international workshop on electricity data for life cycle inventories organized in Cincinnati in 2002 (Curran et al, 2002).

Process Stages

Acquisition of fuel

This stage comprises the raw material acquisition and the process involved in obtaining the fuel. For example, for coal, coal mining and preparation stages are considered. For fuel oil, extraction and refining stages are considered and for bagasse, the processes involved in obtaining the product bagasse are looked into.

Transportation

The transportation of fuel is an important process during the life cycle inventory of production of electricity. Inventory data for transport systems normally should be based upon a life-cycle perspective. This means that emissions and resources depletion from both the fuel production and the final use in transportation should be included. However, the final use of fuels in transportation is much more significant than oil extraction and fuel production (De Beaufort-Langeveld, 2003). Therefore when considering transportation in this case, the type of vehicle used, the fuel used and means of transportation is more important.

Power generation

When carrying out the whole life cycle assessment for production of electricity, the stage of power generation is the most important and significant. In the local context, during the inventory stage, only the inputs and outputs during the process of generation of electricity were considered. Data for the inputs were obtained from different sources and were

computed in the SimaPro software. Air emissions were calculated using the IPCC guidelines and the methodology described by Matsuno et al (2000). Water-borne emissions and emissions to soil were obtained from literature or from the CEB where available.

Transmission and Distribution

From information gathered at the CEB, it is estimated that a transmission and distribution loss of 9.2 % of the electricity generated occurs.

Case of hydropower plants

Although the production of electricity from hydropower does not produce direct air emissions, but when taking a life cycle approach, hydropower is not free from environmental burdens. A relatively significant amount of energy and materials, associated with environmental burdens, are required during the construction. All the hydropower stations in Mauritius are situated in remote areas and no habitation is present in nearby regions. However the construction of the power plants involved a large amount of land use, with significant impacts to the flora and fauna and usage of materials. From data gathered, hydropower plants are seen to have been constructed many years ago, the first being in 1899 and the most recent commissioning was carried out was in 1987.

For the purpose of this inventory, since local data on environmental impacts were not readily available, data from Eco-Invent database was used. These data represent the basis for hydropower plants in Europe, however, due to lack of local data and assuming that the construction is basically the same, the data is considered appropriate. Only data for the amount of water used in hydropower plants in Mauritius was used; data obtained from CEB.

The model described in the database describes the production of electricity from run-of-river power plants and this was considered to be relevant to use in the Mauritian context.

Findings and Discussion

The LCI for fuel source was carried out and the data was computed in the SimaPro software. The results obtained for each fuel source was modeled using the electricity mix to determine the LCI of 1 MWh of electricity generated at consumer level each source was carried out

The generation and distribution of 1 MWh of electricity required approximately 302.2 MJ of total energy, 5,044 m3 of water and a land occupation of 51.9 m2a. Emissions to air are 835.9 kg of carbon dioxide, 0.57 kg carbon monoxide, 423.6 kg of sulphur dioxide, 2.9 kg nitrogen oxides, 0.98 kg methane, 0.2 kg of NMVOCs and 0.36 kg particulates, amongst others. The main waterborne emissions were 1.8 kg BOD5, 7.7 kg chloride, 2.4 kg COD and 23.6 kg phosphate. The soil emissions consisted mainly of fly ash, bottom ash and slags and ashes which were respectively 20.8 ton, 10.4 ton and 3.5 kg. The table below shows the summary of inputs and outputs obtained.

Table 1: Summary of inputs and outputs for 1 MWh of the electricity mix in Mauritius

INPUTS	Unit/MWh	Amount
Energy, total	MJ	23.2
Energy, electricity use	MJ	279.0
Coal, in ground	kg	297.5
Oil, in ground	kg	96.2
Land Occupation	m2a	51.9
Water use	m3	5043.9
OUTPUTS	Unit/MWh	Amount
Airborne Emissions		
Carbon dioxide	kg	835.9
Carbon monoxide	g	574.9
Sulfur dioxide	kg	423.6
Dinitrogen monoxide	g	3.0

Methane	g	981.0
Nitrogen oxides	kg	2.9
NMVOC, non-methane volatile organic compounds, unspecified origin	g	203.7
Ozone	mg	89.3
Particulates	g	359.9
Radioactive Species	kBq	26.9
Cadmium	mg	4.0
Lead	mg	30.7
Mercury	mg	2.1
Zinc	mg	166.0
Chromium	mg	18.2
Arsenic	mg	5.1
Vanadium	mg	131.4
Ammonia	g	30.8
PAH, polycyclic aromatic hydrocarbons	mg	10.4
Waterborne Emissions		
BOD5, Biological Oxygen Demand	kg	1.8
Chloride	kg	7.7
COD, Chemical Oxygen Demand	kg	2.4
DOC, Dissolved Organic Carbon	g	479.3
Hydrocarbons, all	g	4.6
Nitrate	kg	9.5
Oils, unspecified	g	505.9
Phosphate	kg	23.6
Sulfate	g	811.7
Suspended solids, unspecified	g	695.1
TOC, Total Organic Carbon	g	495.5
Radioactive wastes	Bq	149.8

Cadmium, ion	mg	12.6
Lead	mg	71.1
Mercury	mg	2.1
Zinc, ion	g	1.7
Chromium, ion	µg	185.4
Arsenic, ion	mg	23.7
Vanadium, ion	mg	81.3
PAH, polycyclic aromatic hydrocarbons	mg	36.6
Nitrogen	mg	503.6
Emissions to Soil		
Bottom Ash	ton	20.8
Fly Ash	ton	10.4
Slags and Ashes	kg	3.5

From the inventory table, it is seen that the energy requirement was 192.7 MJ and 279 MJ for electricity use. A land occupation amounting to 51.9 m2a and water usage of 5044 m3 was required. The emissions to air for the electricity mix were 835.9 kg carbon dioxide, 574.9 g of carbon monoxide, 423.6 kg of sulphur dioxide, and 2.9 kg nitrogen oxides. The main waterborne emissions were 1.8 kg BOD5, 7.7 kg chloride, 2.4 kg COD and 23.6 kg phosphate.

This inventory could be used for other LCIs and LCAs when considering electricity as a requirement. However this set of data represents the life cycle inventory for a particular year and taking into consideration the related electricity mix; unless there are significant changes in mix and scenarios, this set of data is valid.

Future work will include a comprehensive life cycle impact assessment with the most suitable impact assessment method as well as modeling the response of the electricity supply system to demand (marginal versus average data). Different scenarios of electricity mix can be considered and the environmental implications can be modeled.

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