

**FINAL REPORT-COORDINATED THEMATIC RESEARCH  
PROGRAMME-2006**

**A Community Based Sustainable  
Waste Management System:  
Development of a Functional Model in  
the Faculty of Agriculture, University  
of Ruhuna**

**Contract No: RG/2006/EPSSD/02**

Funded by National  
Science Foundation  
of Sri Lanka

Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna,  
KAMBURUPITIYA

**FR 1686**

# **FINAL REPORT**



*of the Research Project Titled*

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**"A Community Based Sustainable Waste Management System: Development of a Functional Model in the Faculty of Agriculture, University of Ruhuna"**

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*funded by*

**National Science Foundation**

*Under*

**Coordinated Thematic Research Programme**

*conducted by*

**a research team of the Faculty of Agriculture, University of Ruhuna**

*to be submitted to*

**National Science Foundation of Sri Lanka**

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**Prepared by S WIJETUNGA – Principle Investigator of the Project**

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**2009**

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## **SECTION 1: Information regarding Project/Project Personal**

- I. Contract No:** RG/2006/EPSPD/02
- II. Title of the project:** "A Community Based Sustainable Waste Management System: Development of a Functional Model in the Faculty of Agriculture, University of Ruhuna"
- III. Principal investigator:** S Wijetunga
- IV. Co-Investigators:**
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- V. Collaborators:** No Collaborators-for this project
- VI. Institute(s) where research was being carried out:** Faculty of Agriculture, University of Ruhuna, KAMBURUPITIYA
- VII. Date of award:** 02.10.2006
- VIII. Date of completion of project:** 02.10.2008 (Extended up to 08.02.2009)
- IX. Total Allocation of Funds:** Rs 1,593,000.00 (Initially Budget) – (Request Additional funds for Research Student due to increasing of allowances – Total requested funds Rs 1,713,000.00)
- X. Total spend:** Rs 1,591,473.00
- XI. Number of Research Students employed:** 01
- XII. Postgraduate degree completed with dates:** One registered and still not completed
- XIII. Number of Technical Assistants and/or labourers employed and period of service:** No TAs were appointed, however, labourers worked in the project when required during the project period
- XIV. List of publications/communications arising from the project and/or presentations made at seminars, workshops etc. :** 14 (ANNEX I- Only Abstracts)

## **SECTION 2: Executive Summary of the Project**

The methods of waste management used in all most all municipalities in Sri Lanka such as open burning, land filling (not technical) and open dumping of wastes are not considered as environmental friendly methods since it creates other environmental problems. Waste management can be practiced in micro level (in homes, institutions such as schools, offices, etc) or macro level (Urban councils or municipal councils). In this study we tried to find the ways or methods for reducing or management the wastes (solid or liquid) in the places where wastes are generated.

The Faculty of Agriculture houses about 1500 people including undergraduates. The objective of this research was to develop and evaluate a sustainable waste management strategy for the institutions. To achieve the objectives, several studies were performed in the Faculty of Agriculture, University of Ruhuna. At the beginning of the study, the views of the people in the Faculty of Agriculture including undergraduates and workers were taken through a questionnaire survey. The most of the respondents agreed to support the project and they more concerned about waste management and other environmental related activities. The quantity of waste generation, the composition of wastes, and their variation were determined at different sections of the Faculty over one year period. It was found that over 85% of waste generated was food wastes (organic waste). The several studies on technological improvements were conducted on domestic wastewater treatment. It was found that aquatic plants can easily be used for the treatment of domestic wastewater. A simple design for waste water treatment was tested and it was found that the treatment system could reasonably be used for the treatment of domestic wastewater. The studies on biogas utilization for the control of pests in paddy rice were conducted and enthusiastic results were noticed. Further, the abandoned biogas digester was repaired and produced biogas was delivered to cafeteria for the preparation of foods. The cost for energy (LPG) can easily be reduced by using of biogas. The poultry processing waste were tested for the preparation of poultry feeds. The results were quite satisfactory. The digested materials were evaluated as an organic fertilizer for the cultivation of curry chilies. The results indicated that biogas slurry can easily be used for the production of vegetables. The different compost bins which are used in domestic compost production were evaluated in terms of compost quality. The cylindrical shape concrete compost bins were found to be effective for the domestic composting over other composting bins. And residents of the Faculty of Agriculture were encouraged to use the compost bins for the management of their kitchen wastes while producing valuable organic fertilizer. Further, they were encouraged for the home gardening also. Several awareness programs were conducted to make aware the people in the Faculty about environmental issues pertaining to improper disposal of wastes.

Some components of the research project could not be completed due to financial problems. However, the findings of the project are very valuable. During the course of the project, the waste management in Faculty was satisfactory, and waste separations were also properly practiced. Even after the research project, some activities introduced by the project were practiced well. However, later, the attention for the project activities was less and then some activities were failed. The suggestions for the improvement of waste management systems of the Faculty were also reported.

## **SECTION 3: Report in Detail**

### **General Introduction**

The generation of different types of waste in various places such as industries, institutions, residences, is common in the world. In considering Sri Lanka, waste collection and disposal is a serious problem in recent years. With the development, people are more likely to live in urban areas, so, every day waste generation is increasing. Therefore, more efforts have to be taken to tackle the waste disposal problem. The wastes found in urban areas (garbage) are composed of various matters such as degradable organics (plant and animal matters), non degradable organics (plastics, polythene, etc), various metals, glasses, rubber materials, textiles, papers, etc. According to the Visvanathan (2006) about 75 % of solid wastes in Sri Lanka are biodegradable. At same time these different wastes comes from various places such as institutions (government or private owned), factories, residences, etc.

Even though there are different methods that can be available for waste management, the universal waste management/disposal method that can be used in all locations in countries has not yet been developed. Therefore, it has to be developed well equipped sustainable waste management strategy for various locations in a particular country. In year 2001, it has been estimated that 6400 tons/day of solid waste were generated in Sri Lanka and day by day generation rates of wastes as well as the composition are being changed. Solid waste generation potential in Sri Lanka is in between 0.25-0.5 kg/day/person (Visvanathan, 2006).

The most common practiced in all most all municipalities in Sri Lanka are open burning, land filling (not technical) and open dumping of wastes. These methods are not considered as environmental friendly methods since it creates serious environmental problems. About 85 % of collected waste in Sri Lanka is subjected to open dumping (Visvanathan, 2006).

Wastes can generally be managed through reduction, reuse, recycling and final disposal by an environmentally friendly manner (Forbes et al, 2001). These methods can be used in micro level (in homes, institutions such as schools, offices, etc) or macro level (Urban councils or municipal councils). In this study we attempted to manage waste in the places where they are generated. It would have added advantage to reduce disposed waste to streets for collection and disposing by local authorities.

The Faculty of Agriculture, university of Ruhuna was selected as a model institution for this case study. Faculty comprises of different sections such as hostels of students, staff quarters, canteen, departments, administrations complex, and research farm with an area of 65 ha. The choice of Faculty of Agriculture as the site for waste management model was based on several reasons. Firstly, Faculty of Agriculture houses about 1500 people including undergraduate students (~600) and staffs (~200). In addition, approximately 500 people come to the faculty daily for various purposes such as buying farm goods. Fourteen families are living in staff quarters. The farm of the faculty is also located in this premise. By extensive study of waste generation, utilization and management in the faculty can provide the information that could be used for other different organizations/ institutions, factories, schools, farms, offices, etc. The information regarding the waste management in the farm can provide the guideline for waste management in the other farms in the country. Likewise, waste management of other sub sectors in the faculty such as student's hostels, staff residence houses, cafeteria, research laboratories can provide details information regarding how much waste generated, how to collect, what is the composition, what are the new methods that can be used for waste

utilization, etc. And this information will help to formulate the guideline for waste management for different institutions in the country.

### **Scientific scope of the project**

The primary objective of this research is to develop and evaluate a sustainable waste management strategy for the institutions.

The secondary objectives are

- To assess the amount of waste generated in different months in different sectors
- To evaluate the composition of waste in different periods of the year
- To identify and evaluate different waste management methods in terms of their applicability and adoptability
- To evaluate the merits and demerits of existing waste management's methods
- To assess physical and biochemical properties of wastes
- To develop and evaluate alternative methods of waste management that can be adopted to overcome the existing problems of waste management to tackle the waste problem in sustainable manner
- To evaluate the use of biogas (which comes anaerobic digestion of solid wastes) for alternative purposes.
- To develop a code of good waste handling practice in respect of waste management in institutional level

### **Relevance to the objectives and expected outputs of the Thematic Programme (CTRP)**

The following objectives given under "Waste Management" sub area of the theme of Environmental Protection and Sustainable Development (CTRP) are directly addressed by this research.

- To assess and estimate quality and quantity of solid waste generated in selected areas by households/tourist resorts
- To identify the existing solid waste management techniques in those particular areas and their deficiencies
- To develop/implement pilot projects to improve participation of communities, small industries and tourist resorts in waste management in selected areas
- To identify existing waste (solid, liquid and air) generation by selected small scale industries and recommend ways of reducing the quantities discharged by adopting Cleaner Production Technologies
- To study the legal/institutional implications on management of wastes to identify shortcomings and make suitable recommendations

The study was conducted under following four sub sections. Each subsection is explained in detail as follows.

**Part I:** Waste assessment, and the evaluation of composition and the present waste collection system in the faculty in different sections with emphasizing the merits, demerits and limitations.

**Part II:** Evaluation of wastewater disposal methods currently used and estimation of wastewater generation potential.

**Part III:** Improvement of technologies that can be used for efficient waste management (solid and liquid) for institution.

**Part IV:** Formulation of code of practice for good waste management for institutions and its instrumentation.

**Part I: Waste assessment, and the evaluation of composition and the present waste collection system in the faculty in different sections with emphasizing the merits, demerits and limitations.**

**Study 1: Assessment of the efficiency of the present waste collection system in different sections in the Faculty of Agriculture, University of Ruhuna**

## **Materials and Methods**

Questionnaire survey and informal discussions were carried out to gather information on waste management in the faculty. Identification of merits and demerits were also addressed with special reference to community attitudes towards waste management. Further, methodology of present waste collection system, frequency of collection, problems associated with collection system, fate of collected waste and the effectiveness of the waste collection system were focused in this survey. Randomly selected sample was taken, covering all possible parties such as academic staff, non academic staff, students and cleaning service personals comprising the sample size of 70 were interviewed. Informal discussions were also had with the individuals (randomly) in the faculty covering all parties in the faculty. Gathered data were analyzed through simple descriptive methods using Microsoft spread sheet software.

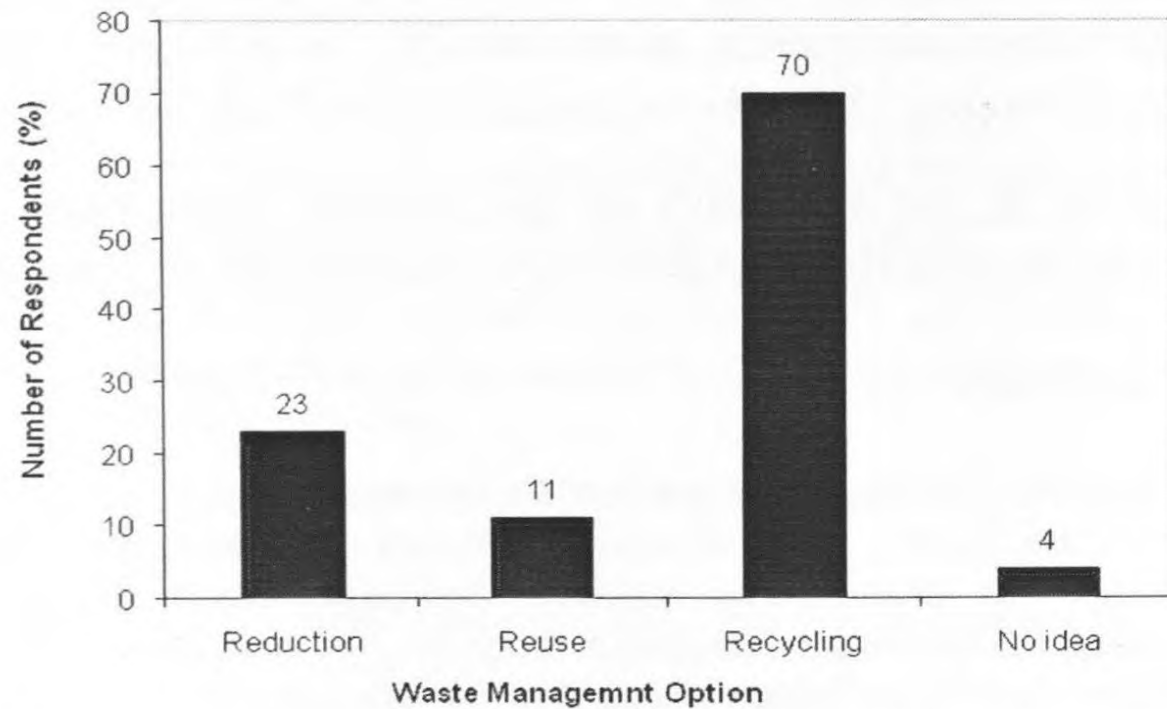
## **Results and Discussion**

### **Education**

According the survey and informal discussions, waste collection system, frequency of collection, problems associated with collection system, fate of collected waste and the effectiveness of the waste collection system were evaluated. Majority (51 %) of the sample were male, while 31 % of them were postgraduate qualified persons. The higher numbers of educated people in the respondents are basically due to the nature of institute. As far as others were concerned, 26 % and 30 % of them were graduates and undergraduates. There were only 3 % in the sample having only primary education. The implementation of well planned functional model of waste management to institute where higher numbers of educated people are working and residing would be easy. However, the practical limitation of implementing a functional model within such a community could be raised and those were identified and explained in the certain sections of this research.

## Waste Disposal Technologies

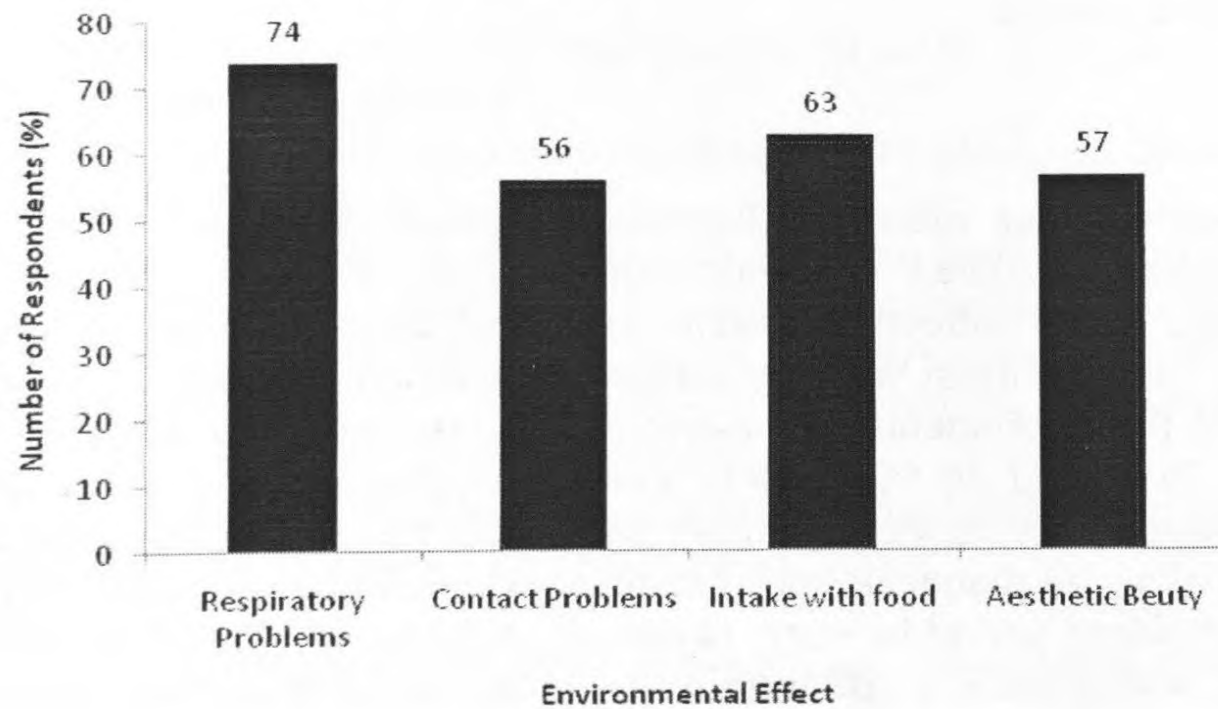
Almost all (96 %) of the community agreed that environment pollution due to the mismanagement of waste is a serious environment problem while 3 % said that, it's a problem but not serious and 1 % did not have idea about relationship between pollution and waste management. As far as the development and environment issues are concerned, 63 % of the community said that there should be balance on development and environment issues, while 17 % respondents argued that the development should consider over environment issues. Fourteen percent of respondents expressed their views on environmental issues should be considered over development. Over 91 % of the respondents were aware about, at least, the waste management in the faculty. When they were offered a multiple choices of management options regarding waste, majority (70 %) of them preferred to have recycling (Figure 1).



**Figure 1:** Responses on waste management option by residents

## Environmental Concern

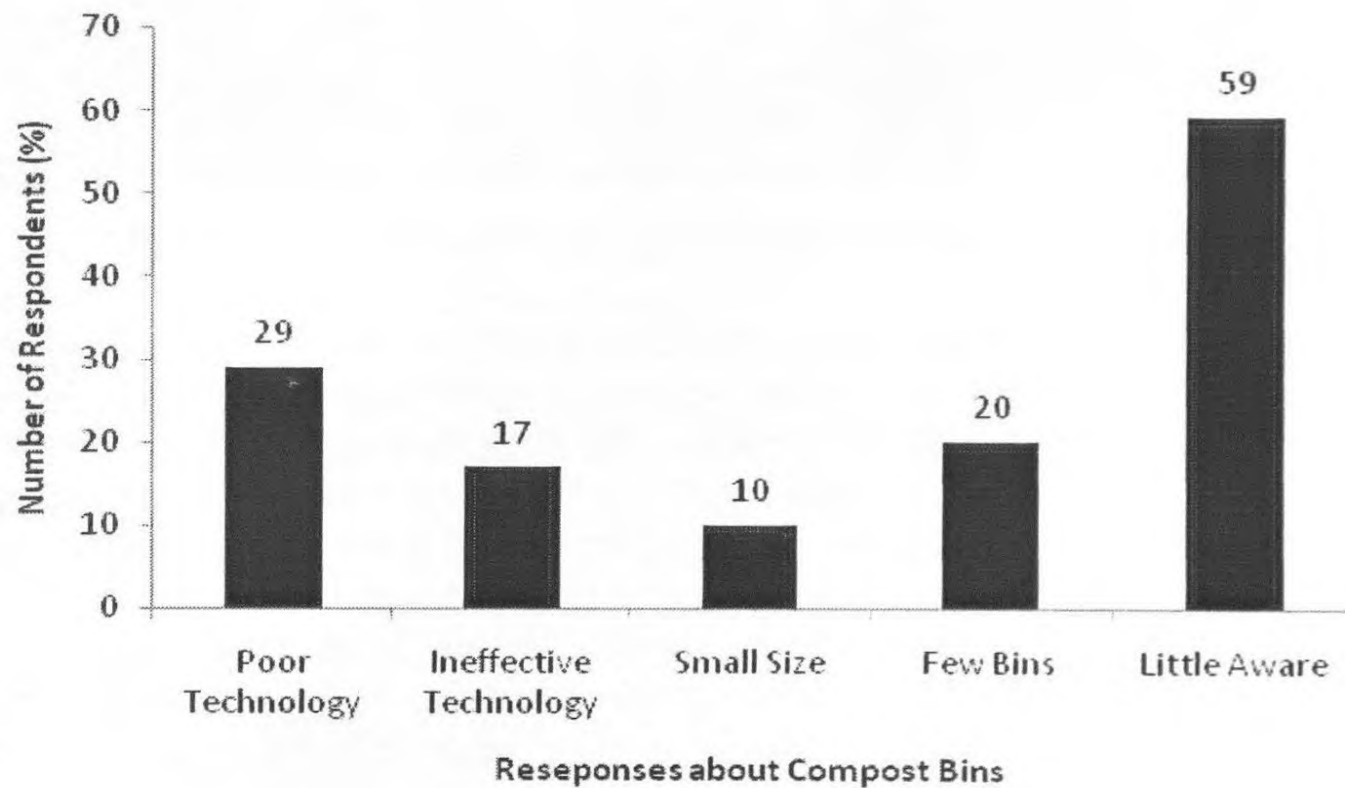
Community had mix ideas on the effect of waste on living beings and the environment. However, majority (74 %) of them said that respiratory problems could be occurred due to mismanagement of waste materials (Figure 2).



**Figure 2:** Effect of waste on living beings and the environment

### Present waste disposal technologies

Majority (66 %) of the faculty community has noticed the installed compost bins in the faculty; however, 59 % of them did not know the operation of the compost bins (Figure 3).

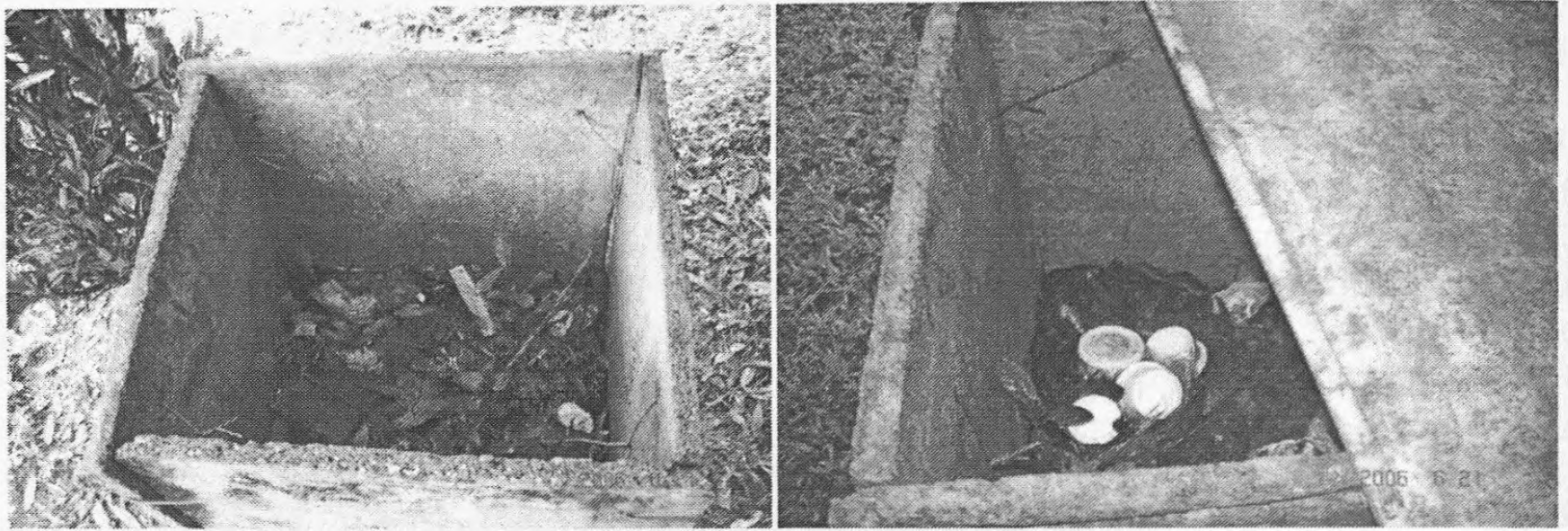


**Figure 3:** Community views on demerits of faculty compost bin

The current waste disposal system in the faculty is the open dumping and burning of collected wastes, the cheapest and the most common option practice in the most of the places in the country (Figure 4). The faculty administration have taken steps at various occasions to streamline the waste management in the faculty by introducing various technologies such as compost bins, separation of wastes, etc. However, the study showed that the most of the persons do not pay attention for the proper practicing of those technologies. The study team also observed that the most of the compost bins have been neglected or inappropriately used (Figure 5).



**Figure 4:** Waste disposal in the faculty

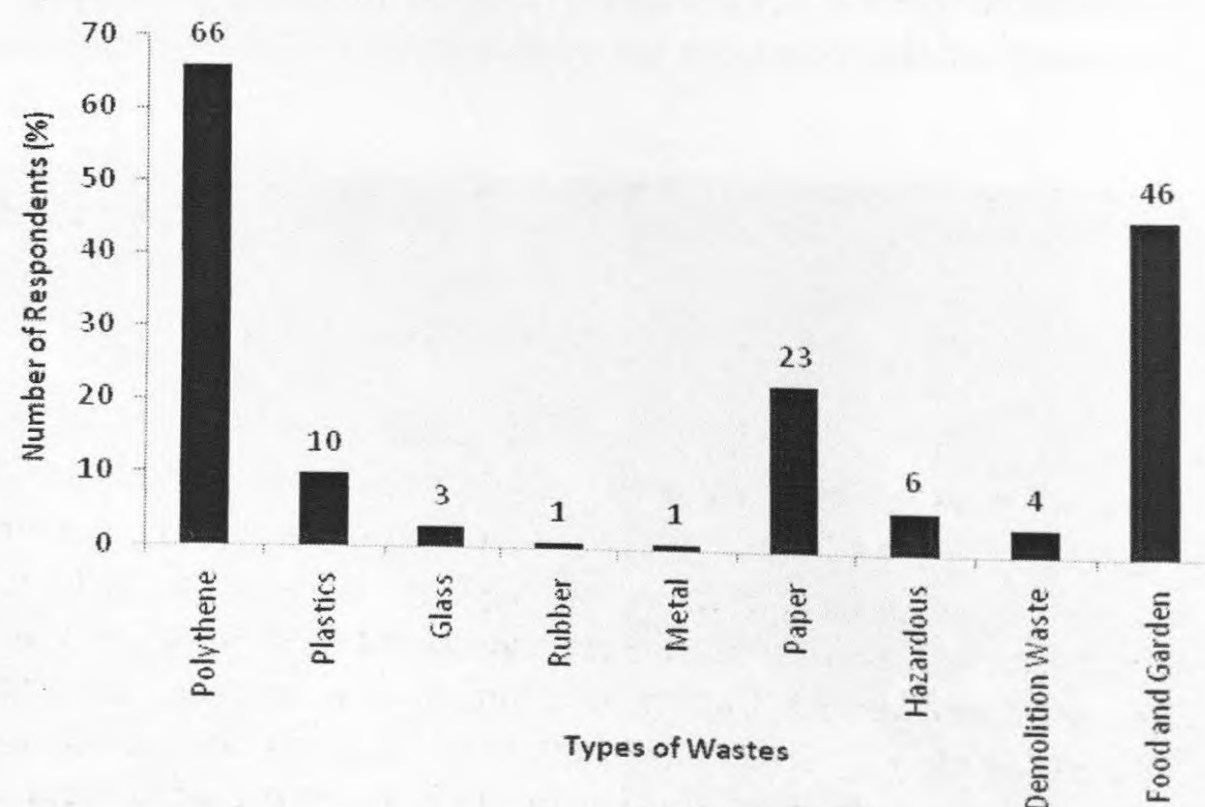


**Figure 5:** Inappropriately used compost bins in the faculty

The waste collection and disposal activities are totally practiced by a private company. Their main duty is to clean the buildings including students' hostels. Therefore, the attention for waste disposal is minimal and their duty ends when they disposed collected wastes to a place where people cannot see. There are ample areas in the faculty where waste can be dumped in the out of the vicinity of the people, making easy for their inappropriate function. The working efficiency and their education level are also poor and it further will affect for the waste disposal system. To overcome above ineffectiveness with respect to waste disposal, it is essential to make a mechanism to monitor the activities of the sanitary workers and the responsibility of proper waste disposal also should be included to the sanitary company work profile.

#### **Waste compositional views of the community**

The majority of respondents think that the highest portion of the waste could be polythene, even though it was not the highest as far as weight or volume basis is concerned. Polythene would be more harmful than other waste types if they were not properly managed. Due to current trend in polythene and plastic recycling program in national level, respondents strongly said that polythene is the most abundant waste in the faculty. The details of respondents' views on waste composition are displayed in Figure 6.



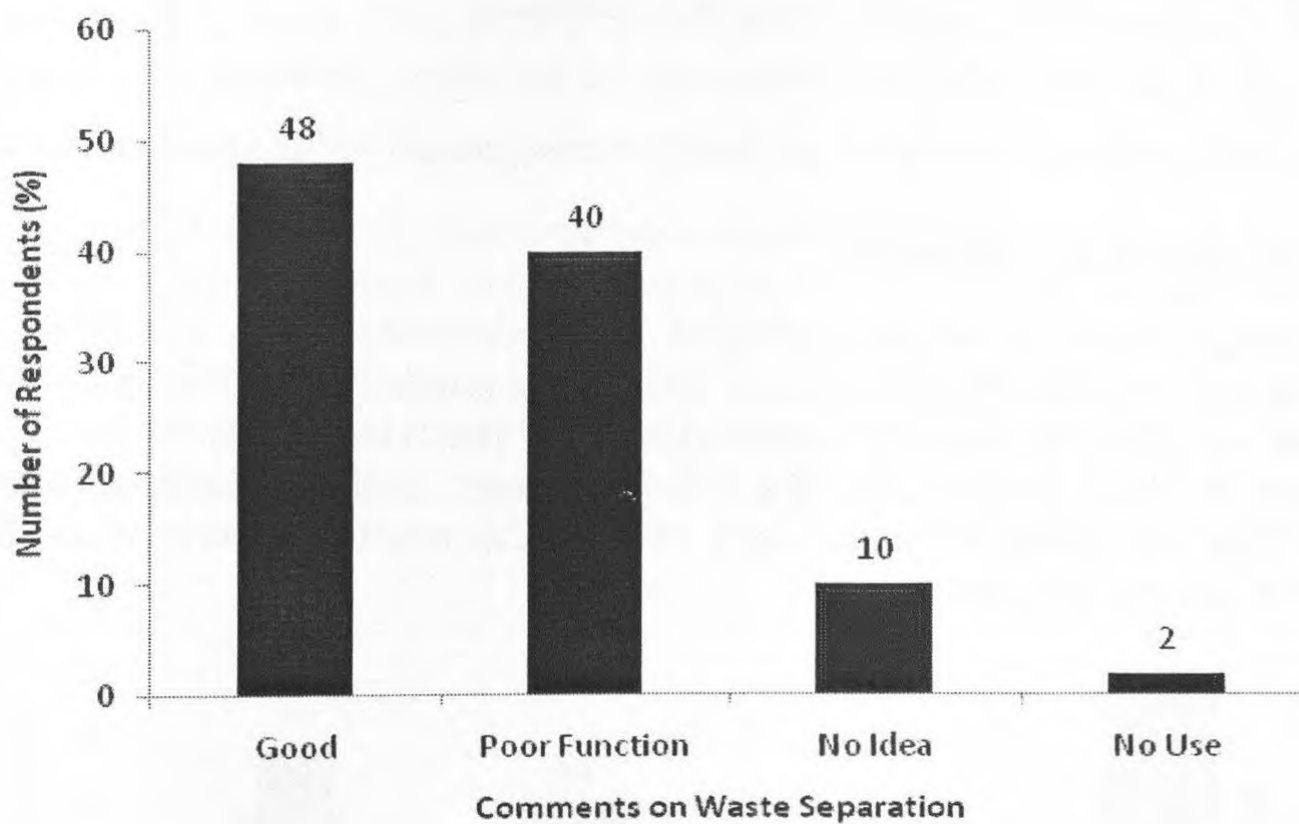
**Figure 6:** Proportion of different waste in the faculty according to the community views

## Waste separation in the faculty

The administration of the faculty has recently been introduced a waste separation system in few places, aiming to further enhancing the waste disposal in the faculty. However, it was also not properly practiced and monitored.

Majority (86 %) of the community were aware about recently introduced waste separation system in several sections of the faculty. Almost all parties in any institute should know about waste separation systems they practice if it is functioned properly. If 1 or 2% of persons in the institutes do not know or practice the waste separation process, it will badly affect the waste separation system leading to the waste management system get paralyzed.

Out of those who were not practicing waste separation within the faculty, 50 % did not know about the waste separation system of the faculty. Fourteen percent do not have time and some think that it is no use of waste separation in the faculty. Further 22 % said that they do not have interest on such a waste management system. These results revealed that the unawareness of present program among the persons in the faculty and inadequate of the present waste collection system.

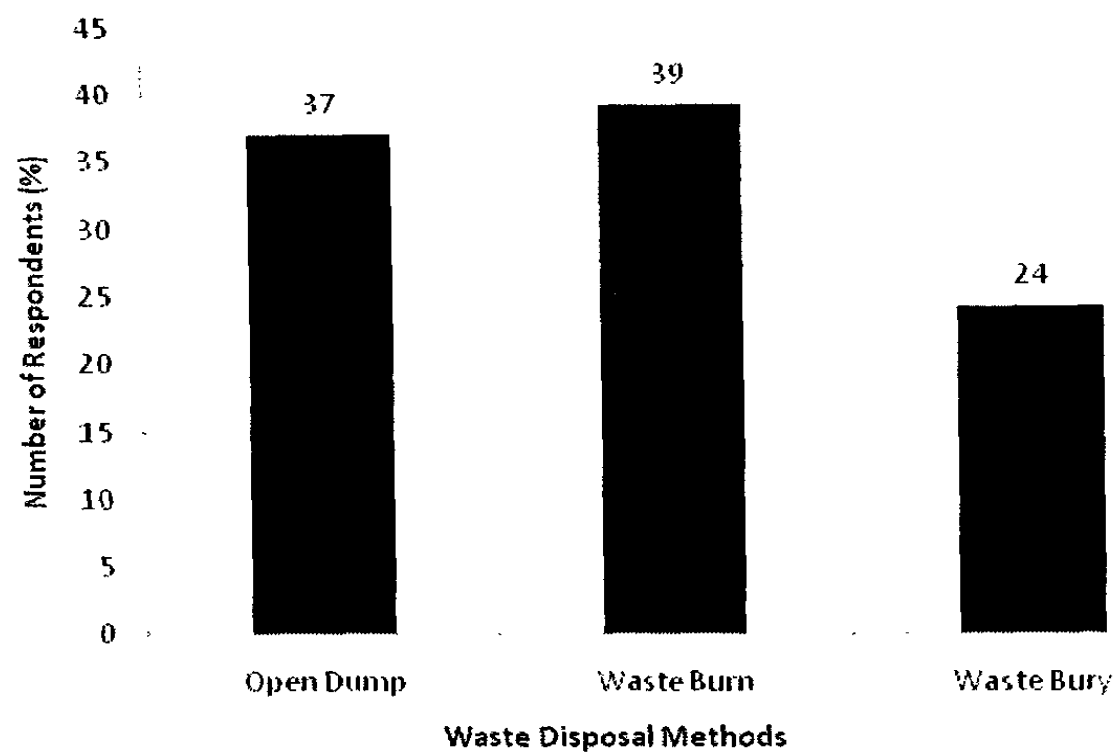


**Figure 7:** Attitudes towards present waste separation system in the faculty

## Community attitude over participation for waste management

According the survey conducted, 89 % of respondents had the positive attitudes for the participation of waste management in the faculty towards sustainability. The rest of respondents (11 %) had different ideas about waste management in the faculty. Among them, 50 % did not have clear idea about the waste management in the faculty while 37 % argued that even though faculty runs a proper waste management system they will not have enough time to engage with it. Further 13 % do not have any interest to participate in waste management. These results clearly indicated that even though the education level was high, still the community greatly requires some attitudinal changes on waste management. Without proper publicity and awareness about new waste management methodology, it will be also ended up as failure.

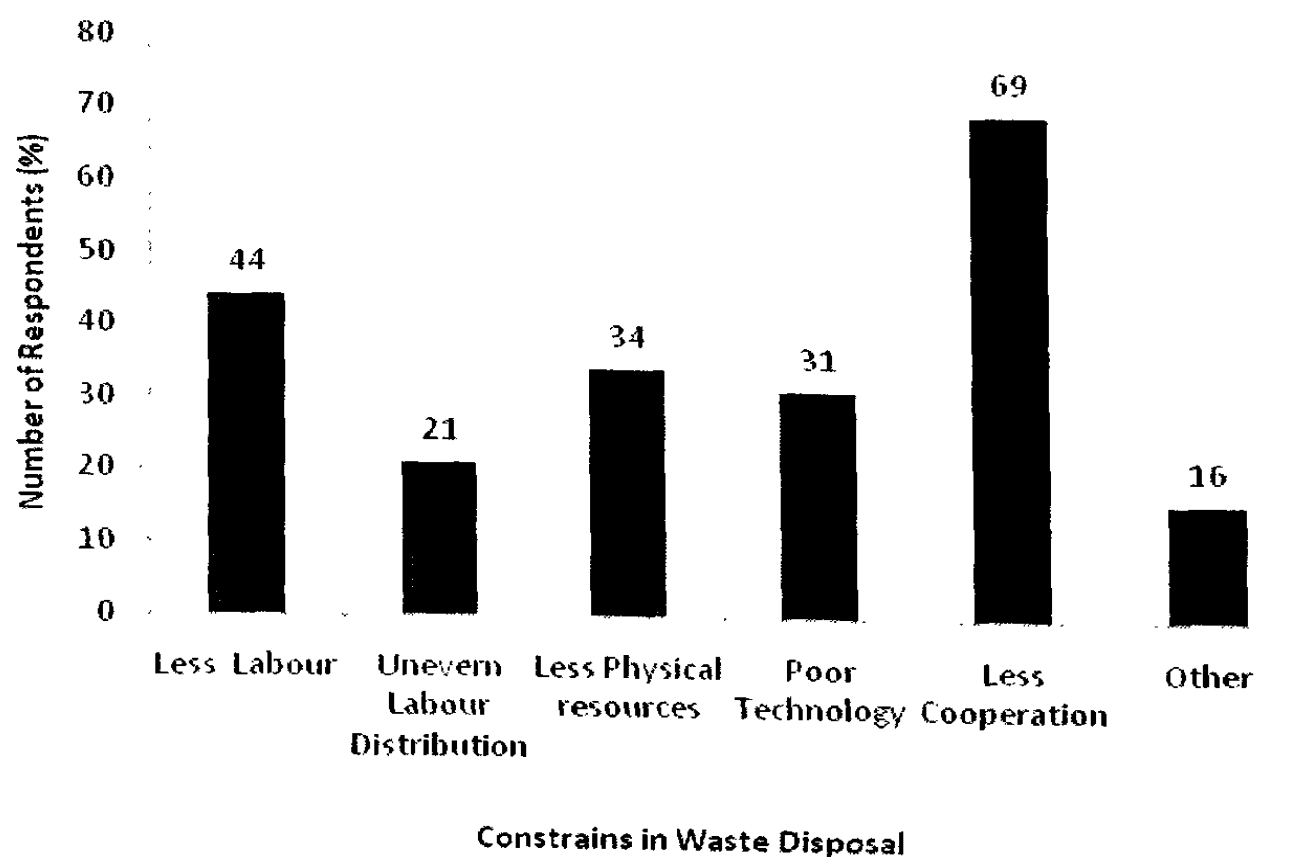
The greater part of respondents (66 %) did not know what happen to waste after disposal. This further indicated that their unsatisfactory awareness of the present system. Thirty seven percent of respondents who knew the fate of waste at final disposal said that the most of the time the waste is burnt at the final disposal site (Figure 8).



**Figure 8:** Respondents views on waste management techniques in the faculty

### Problems in current waste disposal

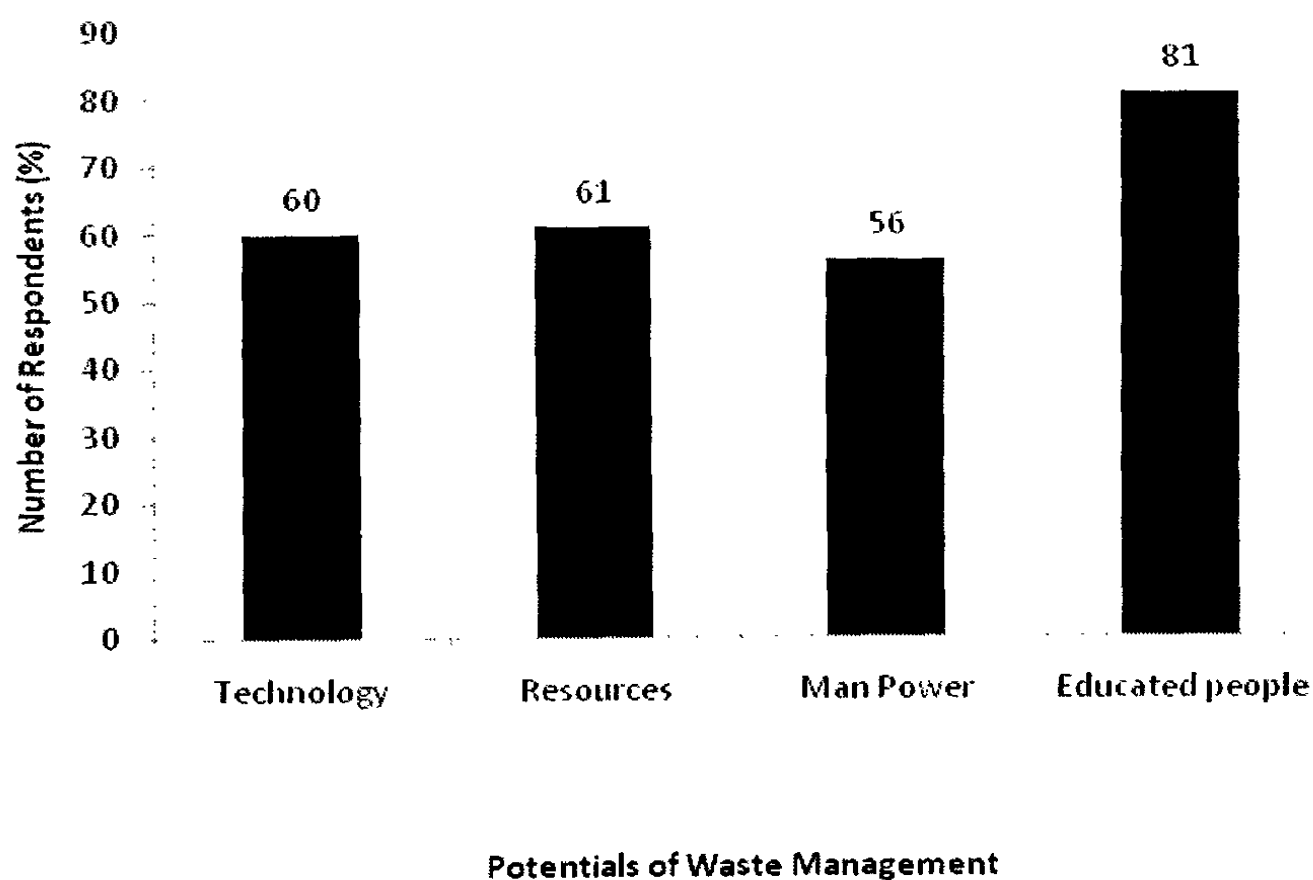
Faculty community were asked to highlight the major constrains identified regarding the waste management within the faculty. They responded with different ideas. However, majority agreed on that the lack of cooperation and participation were basic constrains (69 %). The second highest proportion (44 %) mentioned that the lack of labor as a major constrain. The lack of technology and lack of physical resources were also shown as major constrains in the faculty (Figure 9).



**Figure 9:** Major constrains identified by community on waste management in the faculty

Majority of the community in the faculty do not know about Sustainable Integrated Waste Management System (SIWMS) (51 %). Even though they identified the waste management concept they did not have any idea about SIWMS. Therefore, further enhancing of new concept about SIWMS was necessary for implementation of proper functional model for the faculty. Most importantly, at present, the people in the faculty are not in position to consider the management of their waste. It was evident that the large extent of land (108 acre) in the faculty still provides the ample opportunity of free dumping of garbage. But it was clearly stated by the community in the informal discussions, environmental deterioration had already begun in certain places in the faculty. Faculty is maintaining a man made Mahogany forest and small area of secondary natural forest. Even though this land area is small as far as natural forest ecosystems are concerned, it is a habitat for large number of wild animals and birds. According to the information sources of senior workers of the Faculty of Agriculture, particularly from faculty farm, they have observed that the certain severe environmental changes due to improper dumping of waste to the natural ecosystem. It is clearly stated that in the informal discussions, the open dumping of waste hugely increase the street dog population and it caused unsafe situation in the faculty, further it results the unsanitary conditions and the spreading of certain epidemic diseases such as tick fever. At previous occasions, some students' hostel have completely be vacated and students has been evacuated to avoid the spreading the ticks. This was a clear incident where inappropriate waste dumping could cause severe management problems of the faculty, which ultimately cost much money as well.

The most of the respondents (87 %) showed their dissatisfaction over waste disposal practices in the faculty. They further argued that administration do not pay enough attention for the waste management. However community greatly expressed that educated people in the faculty is huge potential for implementation of a Sustainable Integrated Waste Management System (81 %). They were also highlighted the other potentials such as technology and manpower within the faculty (Figure 10) as an advantages.



**Figure 10: Potentials for Waste Management**

Apart from solid waste, 71 % were seen wastewater sources within the faculty; however, only 49 % of them have seen proper wastewater treatment plants (TV, Newspaper, and Real). Eighty six percent can identify the wastewater. Majority of them (87 %) recognize wastewater by color and 32 % identify by color, odor and other physical properties. Around 70 % of them confirmed that wastewater could be identified by the chemical analysis. These information indicate that the most of the community in the faculty are well aware the water pollution and wastewater issues.

Resources utilization, especially energy utilization is directly related to environmental pollution. It is essential to pay attention on energy utilizations as well as energy conservation when the management of waste is performed. Environmental degradation by various human activities causes global warming which results climatic change. The burning of fossil fuels for generation of energy is a major cause of environmental degradation. Energy shortages and energy prices are burning issues in Sri Lanka. The efficient utilization of other resources such as water, paper, etc is also more important in reduction of waste generation. The attitudes of community towards energy conservation and other resource utilization are also more important as waste management issues. Therefore, the information on these issues is also gathered during the later part of the study.

Majority of the respondents agreed that there is a correlation between energy conservation and environmental pollution. Ninety three percent of respondents concerned about energy conservation. Out of those, 24 % respondents use sunlight as far as possible for light and drying of cloths while 28 % use energy efficient electrical instruments. Forty eight percent of respondents commented that they helped to conserve energy by switching off the bulbs and electrical instruments when they are not in use in the faculty and home. Most of the members (70 %) use energy saving bulbs at their homes.

Over ten places of water wastages had been observed by 21 % of respondents while 31 % revealed that they noticed 2 - 5 places. It indicated that there are places where water is wasting due to less priority of maintenance of water distribution systems.

Printing both sides of the papers helps to conserve resources, which indirectly conserve the energy and generation of waste, especially education institutes where a lots of printing papers are used. Sixty one percent of respondents used both the sides of papers for printing. Many believed that the current energy conservation practices in the Faculty are not effective to conserve energy wastages. The results of the current study showed that strong awareness program could play a leading role in the process of implementing the energy conservation strategies in the Faculty with the participation of all stakeholders.

## **Conclusions**

In this study, it was found that the faculty administration has been taken several steps to enhance the waste management in the faculty, however, further commitment of the administration are required for the proper waste disposal in the faculty. The majority of the people in the faculty fairly know the consequences arising from the uncontrolled disposal of waste. Their knowledge on waste management technologies and related issues are satisfactory, even though they do not like to spend a very little time on waste management activities such as waste separation, to enhance the waste management system in the faculty.

Further, it was found that even though the most of the people in the faculty are fairly educated, the strong attitudinal changes are required for the functioning of a proper sustainable integrated waste management system that could be accepted by the all stakeholders of the faculty. Further exploration of currently available resources is vital and commitment of the cleaning service workers (private company that responsible for faculty cleaning services) as well as the active participation of the students, academic and non-academic staffs are greatly important.

## **Study 2: Quantitative and qualitative assessment of wastes generated in different sections**

### **Materials and Methods**

The estimation of waste composition is a vital part for the implementation of sustainable waste management system for anywhere. Waste composition estimation for one year period was carried out in the faculty. All possible waste generation locations were categorized into four groups namely, Departments and Administration Buildings, Cafeteria, Quarters and Students' Hostels, based on the similarities of waste generation. Collected wastes in separate bins were further categorized by manually, when required. Different waste types were assessed by weight basis. In the first stage of the study, wastes were estimated according to their degradability. All types of waste such as paper, food waste, plastic, polythene, leather, wood, textile, rubber, animal waste, other organics, glass, metal, demolitions batteries, fluorescent, etc were measured. Further identification of seasonal (time) changes in waste generation and their types were recorded.

Waste estimation was performed once in two months for one year period in canteen, quarters, departments and administration complex and students hostels. Total waste generated from one week in different locations was collected, separated, categorized and estimated each estimation. Hostels further categorized into girls and boys hostel and further divided into separate buildings. Before the start of waste estimation, three color bin system was introduced to the faculty for the separation of waste into basic three categories namely degradable, non degradable and fragile matters (Figure 11). After the introduction of waste separation system, it was found that stray dogs and cats falls down the bins for seeking foods and it was paralyzed the waste separation system. To overcome the situation, the standards for waste bins were fabricated and installed.

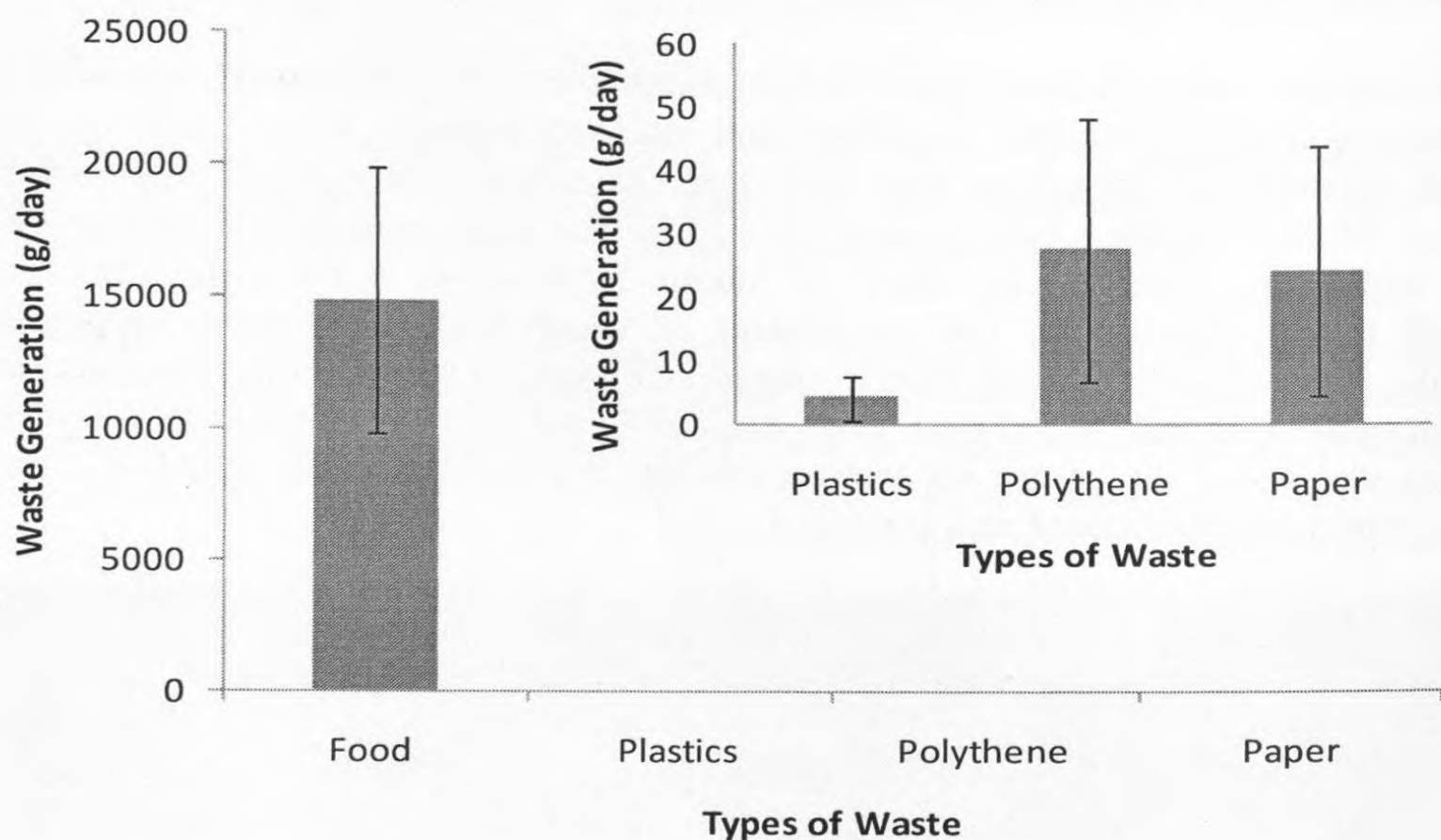


**Figure 11: Waste separation bins**

## Results and Discussion

### Waste generation in the canteen

Almost all the wastes (99.5 %) (Weight basis) collected from the canteen was food waste. It could be reasonable that due to its main function. The food waste should be the main waste of canteen. Nevertheless, there were three different bins for waste separation in the canteen for food waste, polythene and plastic and fragile matters (Degradable, Non degradable and fragile matter). Fragile matters were hardly found in the canteen during the research. One of the most important results found out from the research was polythene usage from the canteen. The use of polythene (lunch sheet) was completely ceased. The research team discussed with students and the personals of the cafeteria, and stressed the consequences due to use of lunch sheet in the faculty. All the stakeholders agreed to remove the lunch sheet usage from the canteen. The participation and cooperation is very important for the implementing a successful waste management system in the faculty. Lunch sheets are used in the most of small restaurants and hotels for their convenient of handling of food parcels and specially to avoid the washing time of the dishes. After removing of lunch sheets, those who used the dish had to wash their plate after their meal. At the beginning, it was difficult to convince the people but consumers soon realized the importance of such a program, which results the reduction over 300 lunch sheets per day. At present almost every cafeterias in higher education institutes use lunch sheet, however, according the success of our attempt, particularly with the active community participation, polythene usage could be reduced in other cafeterias also, at least some extent.



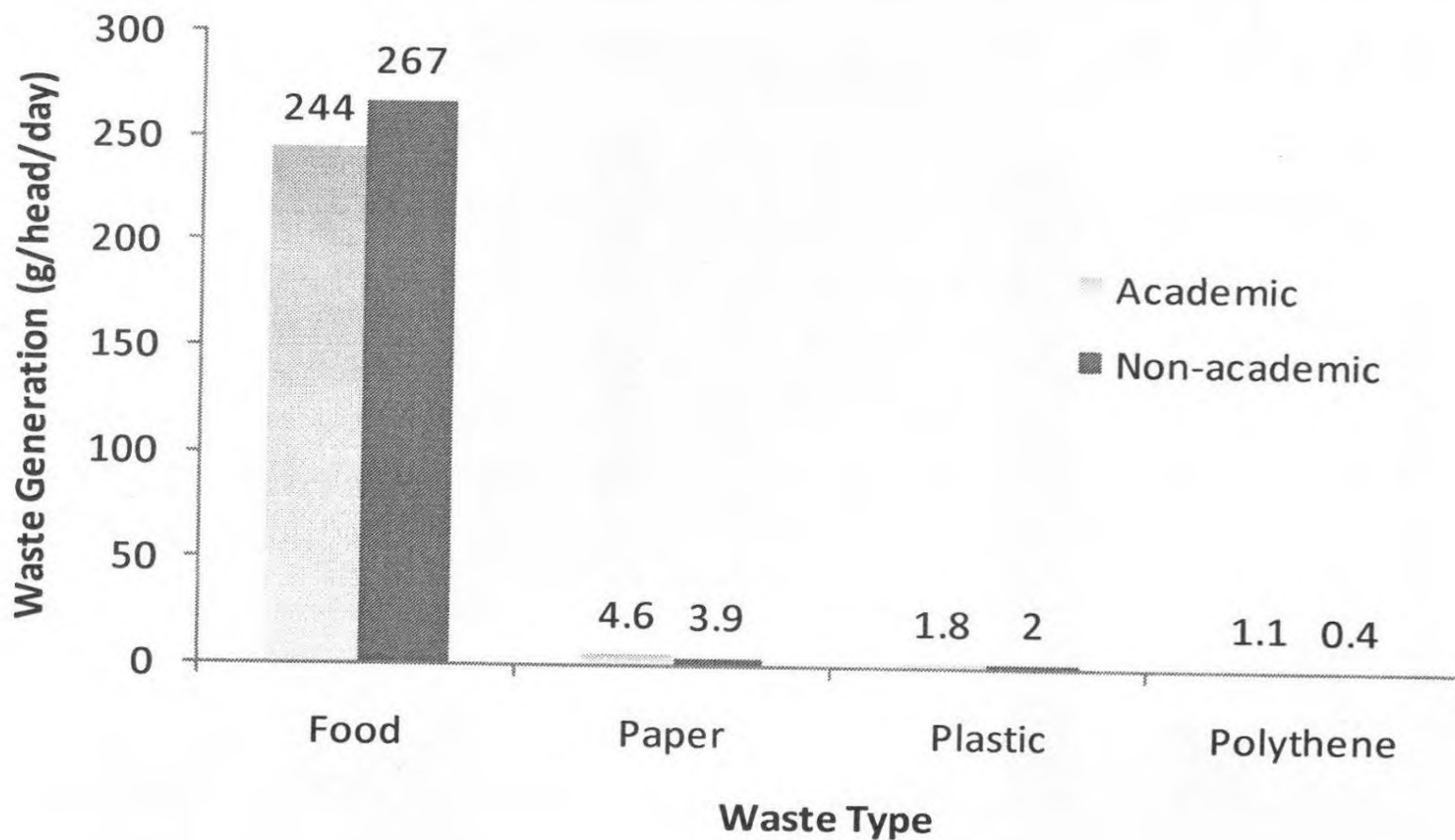
**Figure 12:** Waste generation rate in Cafeteria

The results obtained from waste estimation study for about one year (6 times) showed that the major component of the waste generated in the cafeteria is food waste. Polythene, plastics and paper can also be found in the cafeteria in very small amounts (Figure 12). Normally around 300 persons are served by cafeteria; however, it may vary during vacation and

examination periods. The average per capita food waste generation in the cafeteria is about 50 g/head/day.

### Waste generation in quarters

Over one year study period, the waste generation in staff quarters were estimated and analysis for characterization. The majority of waste found in the quarters was food waste (97.2 %) amounting 244 and 267 g/head/day for academic and non-academic staff quarters, respectively (Figure 13). In per capita waste calculation, children less than 15 years were considered as 0.5 of adults. Over 15 years was considered as an adult. Other than food waste, discarded paper was also found during the study; however, some of the quarter's community sells their old newspapers and magazines to paper collectors. Therefore, the amount of sold news papers could not be counted during this study. Based on the results obtained in this study, it was found that there was no considerable difference of waste generation and composition among academic and non academic staff members living in the quarters inside the Faculty of Agriculture, University of Ruhuna. Plastic containers and low gauge polythene (lunch sheet and similar bags) were also found in small quantities.



**Figure 13:** Waste generation/head/day in quarters

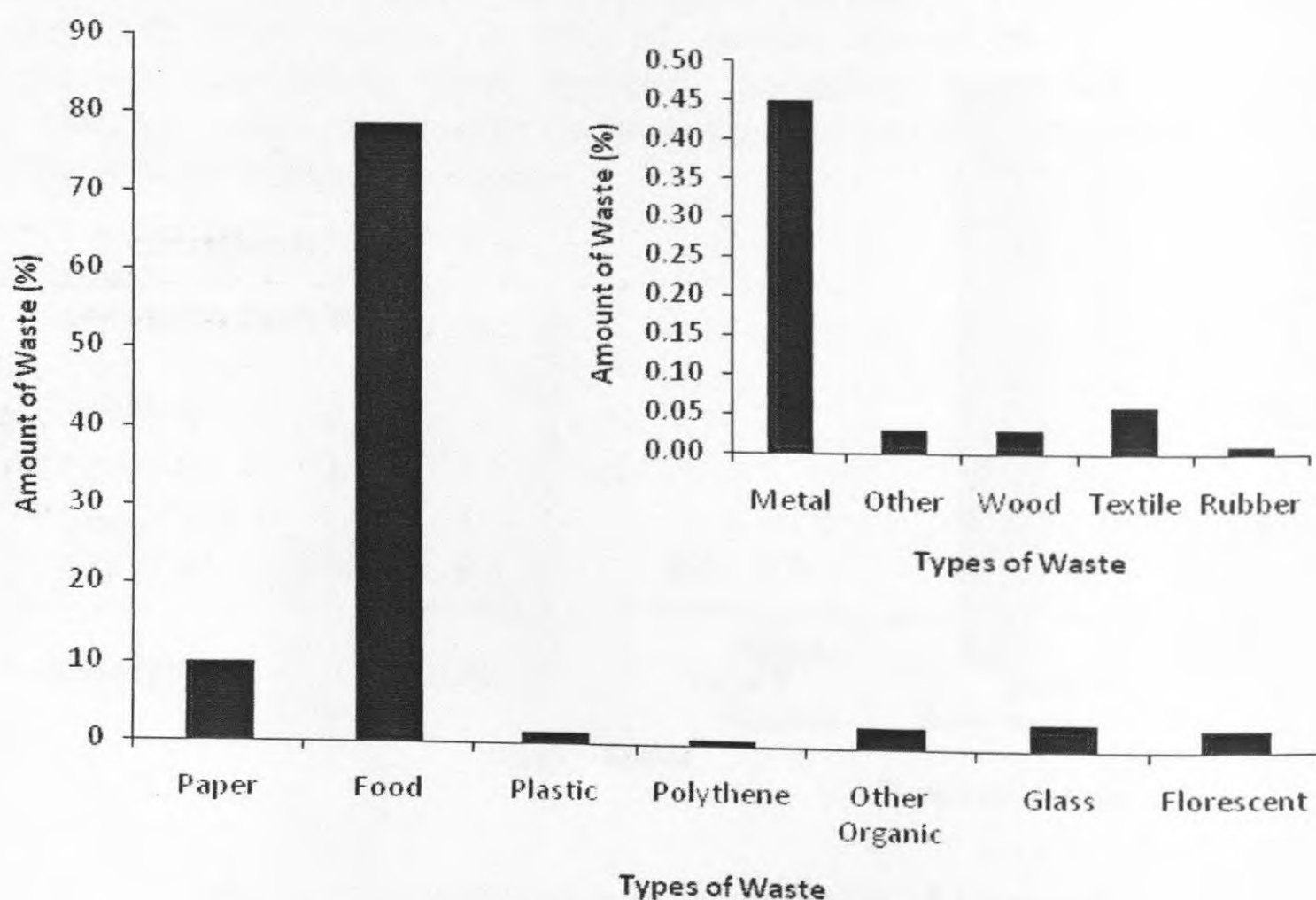
The government has decided to prohibit the use of low density polythene (<20 micron) in Sri Lanka from January 2007. Due to this law, the use of such types of polythene at community level was potentially reduced, initially.

In the initial survey conducted at the beginning of this research, people in faculty thought that polythene waste could be the most abundant waste in the faculty, however, the results of this study confirmed that food waste or degradable waste was significantly higher than that of other waste types. This reveals that even very small amount of polythene can make unpleasant environment giving wrong information to the general public.

The higher proportion of food wastes (degradable waste) would be expected in houses, basically, due to food preparation. Therefore, the quarters of the faculty are more or less similar to the outside residential area where general public are living. The higher proportion of degradable food waste reveals that there should be a methodology to safely dispose or utilize the degradable waste generating from houses and cafeteria to get the maximum benefit from them and to avoid the pollution causes by them. The proposed technology to address this situation is explained elsewhere.

### Waste generation in department and administration complex

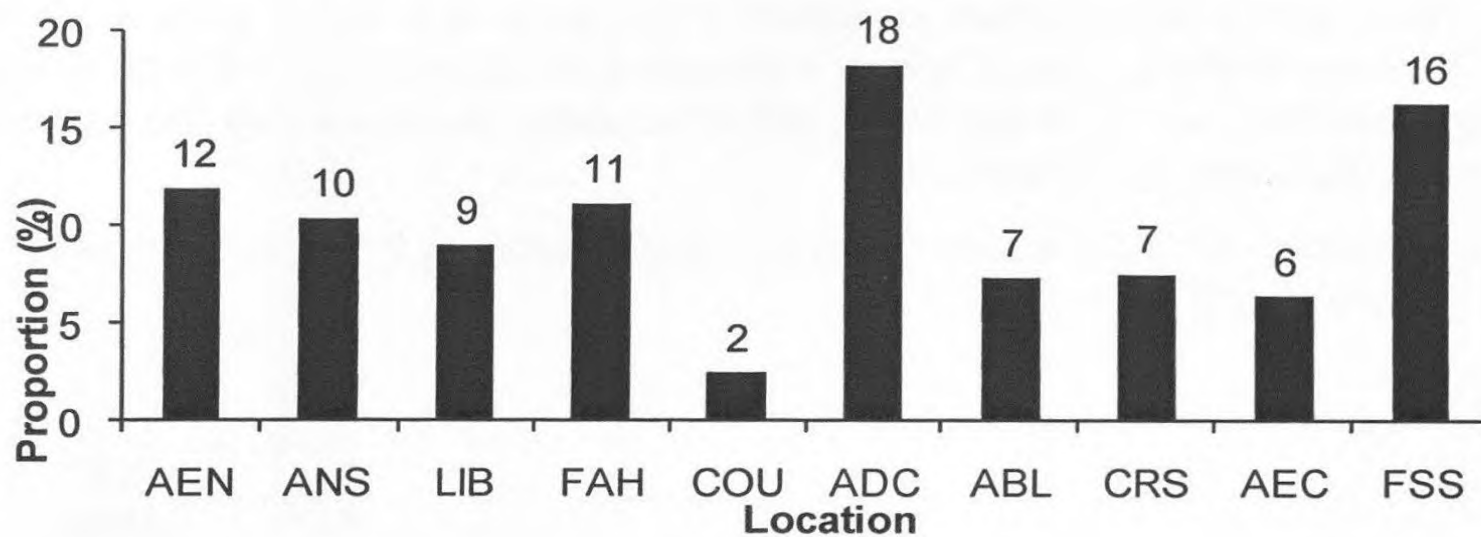
Around 10 % of discarded paper was reported from departments and administration complex due to documentation activities. In fact, food waste still generated as a higher portion of the total waste generated (78.5 %). Plastic, polythene, Glass, fluorescent and, other organics also contributed as other main sources of wastes (Figure 14). It was found that waste diversity in the departments and administration complex were higher than other places. As far as plastic waste is concerned, discarded print cartridges, cartridges of photocopiers were also present. Actually, some of the waste items could be categorized as electronic waste (E-waste). However, separate e-waste estimation was conducted apart from general waste estimation.



**Figure 14:** Different wastes in departments and administration complex

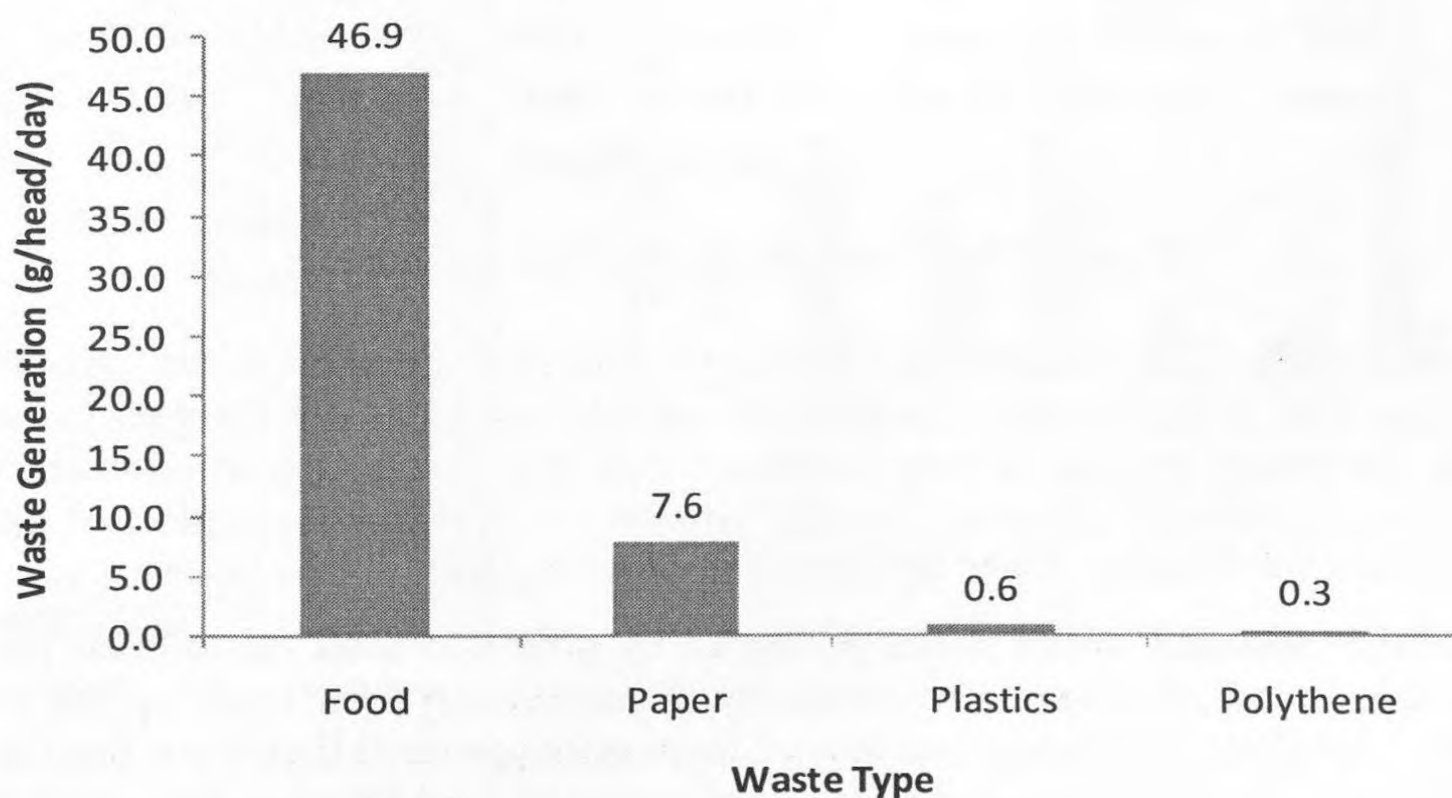
Waste generation potential in different departments (Agric Engineering-AEN; Animal Science-ANS; Library-LIB; Farm House-FAM; Computer Unit-COU; Administration Complex-ADC; Department of Agric Biology-ABL; Department of Crop Science-CRS; Department of Agric Economics-AEC; Department of Food Science and Department of Soil Science-FSS) and administration complex were different. The highest waste generation (18 %) in all types of waste was reported in administration complex (Figure 15).

Waste generation in the each department was also recorded during the estimation, and it could be helped to obtain comprehensive understanding about the amount of different waste generation and their sources of generation. Therefore, it is given an opportunity to manage their own waste for each department. The most common abundant waste types in the departments were food, paper, plastics and polythene. Food waste basically was generated due to having meals by workers in the departments. At the same time, lunch sheets and papers are also used for the wrapping of meals, and therefore, those waste types are also considerably high in the departments.



**Figure 15:** Waste generation proportions in different departments

The rate of waste generation by departments and other similar places are shown in Figure 16. It is clear that food waste generation was comparatively lower than the rates of food waste generation in staff quarters and hostels. This is obvious because workers in the departments and similar places do not prepare their meals like quarters and hostels. They only discard remaining of lunch. Other types of wastes such as plastics, bulbs, rubber, textiles, etc were also found in the departments. The amount of those types of waste generation do not basically influence by the workers in the department but other activities such as research, laboratory works, etc.

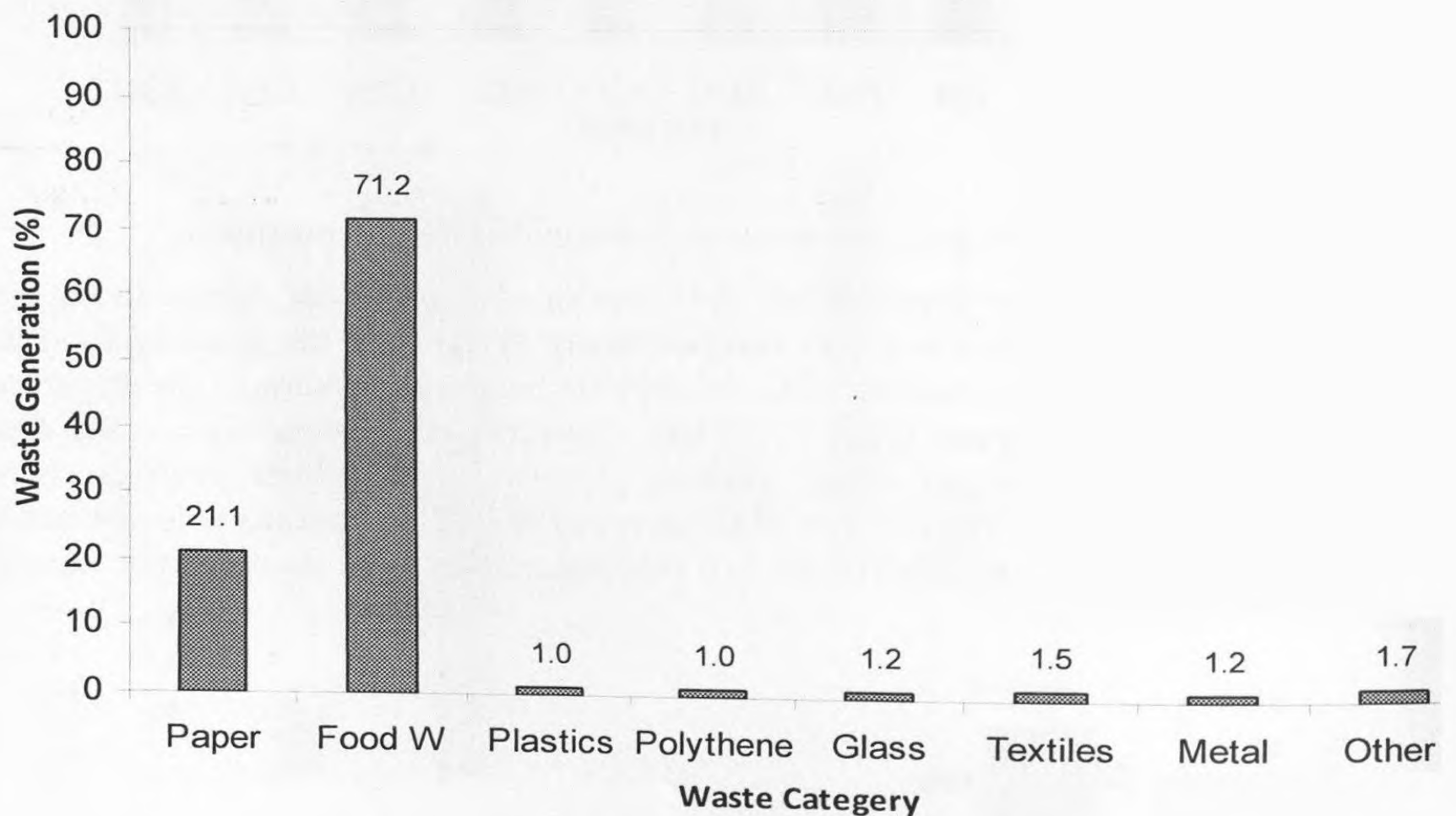


**Figure 16:** Waste generation rates in different departments and similar places

## Waste generation and composition in the hostels of students

Hostels are the main area of the faculty where a large number of undergraduates reside and generates more wastes. According to this study, it was found that amount of wastes generates and their compositions are varied in girls and boys hostels. The information with respect to waste generation and composition in residential university is rather new and provide opportunity to formulate waste management systems for other universities in Sri Lanka having quite similar environments. There are 15 hostels within the faculty comprising 340 students with similar proportion of boys and girls. There were two types of hostels called as Work Units (WU) and Blocks (BL) and the different names basically due to administrative purposes. There are 6 Work Units allocated 3 for boys and 3 for girls, each carries 30 students. There are 8 Blocks out of which 4 allocated for boys and rest for girls, each carries 20 students. Therefore, set up of the hostel are structurally similar giving the common ground for each hotel when they are compared.

In this waste estimation study, it was found that paper, food, polythene and plastics are major culprits in hostels also (Figure 17).



**Figure 17:** Waste generation in boys' hostels

The different types of waste were found in boys' hostels even though the amount of waste generation was low. It was hardly found leather, textile and metals in the girls hostels (Figure 18). During the study period, it was observed that boys have discarded their waste into introduced bins, separately according to the category while the cooperation of girls for this activity was quite ineffective. Their attention for waste separation was poor.

It was found that around 95% of waste generated by girls was food waste. This phenomenon is basically due to the preparation of meals by themselves in their hostels. The most of the boys gets their meals from outside and few of them only prepared their own food at hostel. In the observation it was found that the wastage of prepared food by girls was quite higher than boys. The higher proportion of paper wastes in boys hostels are basically due to the meal packets taken from outside. Further, boys are frequently read newspapers rather than girls and

it will also increase the paper components of the wastes in boys' hostels. The generation rates of different types of waste are shown in Figure 19. Food waste generation rate is high in girl's hostels (~200 g/head/day). Normally girls prepare their food in hostels and therefore food waste is also high compare to boys who normally bring the meal packets from the outside.

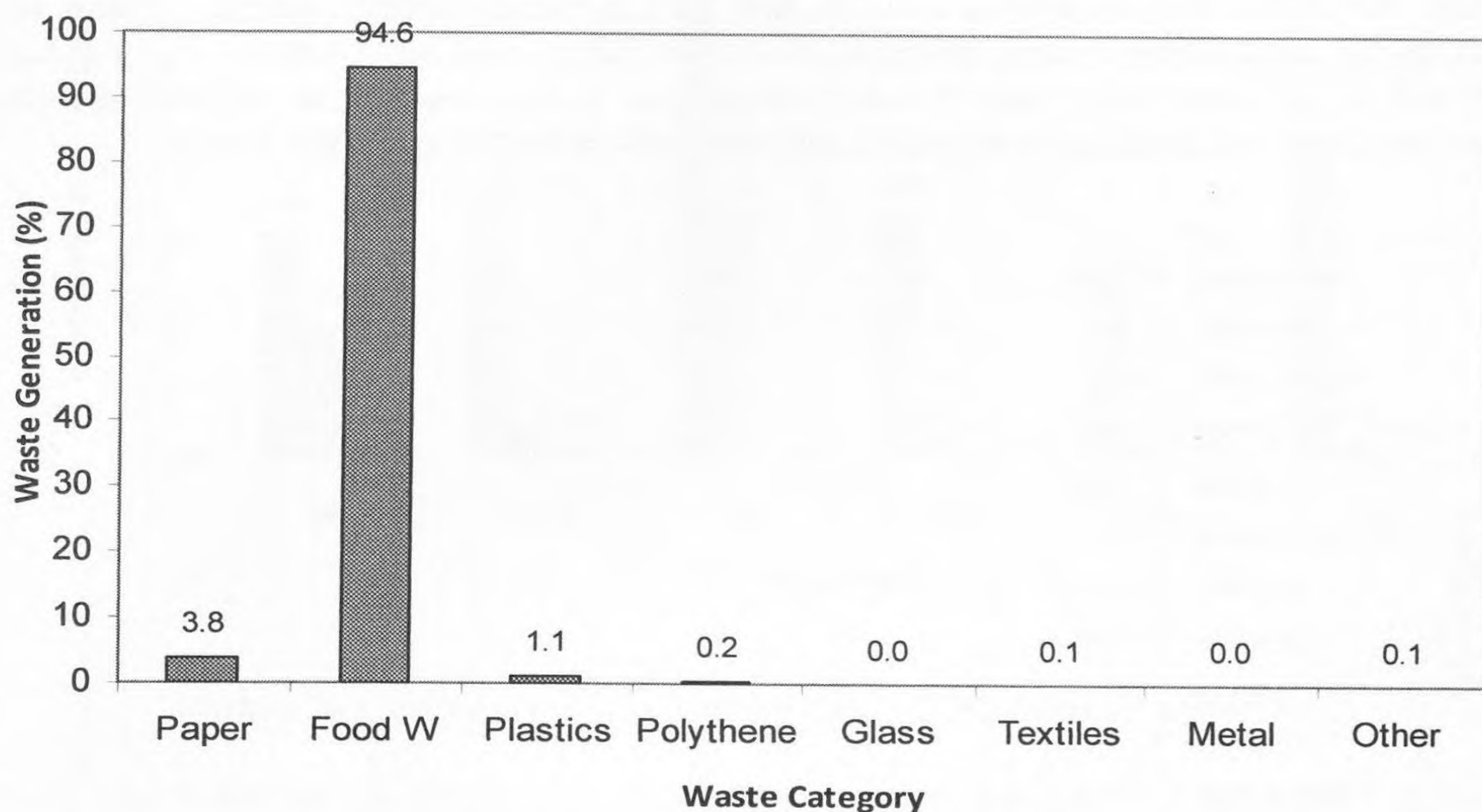


Figure 18: Waste generation in girls' hostel

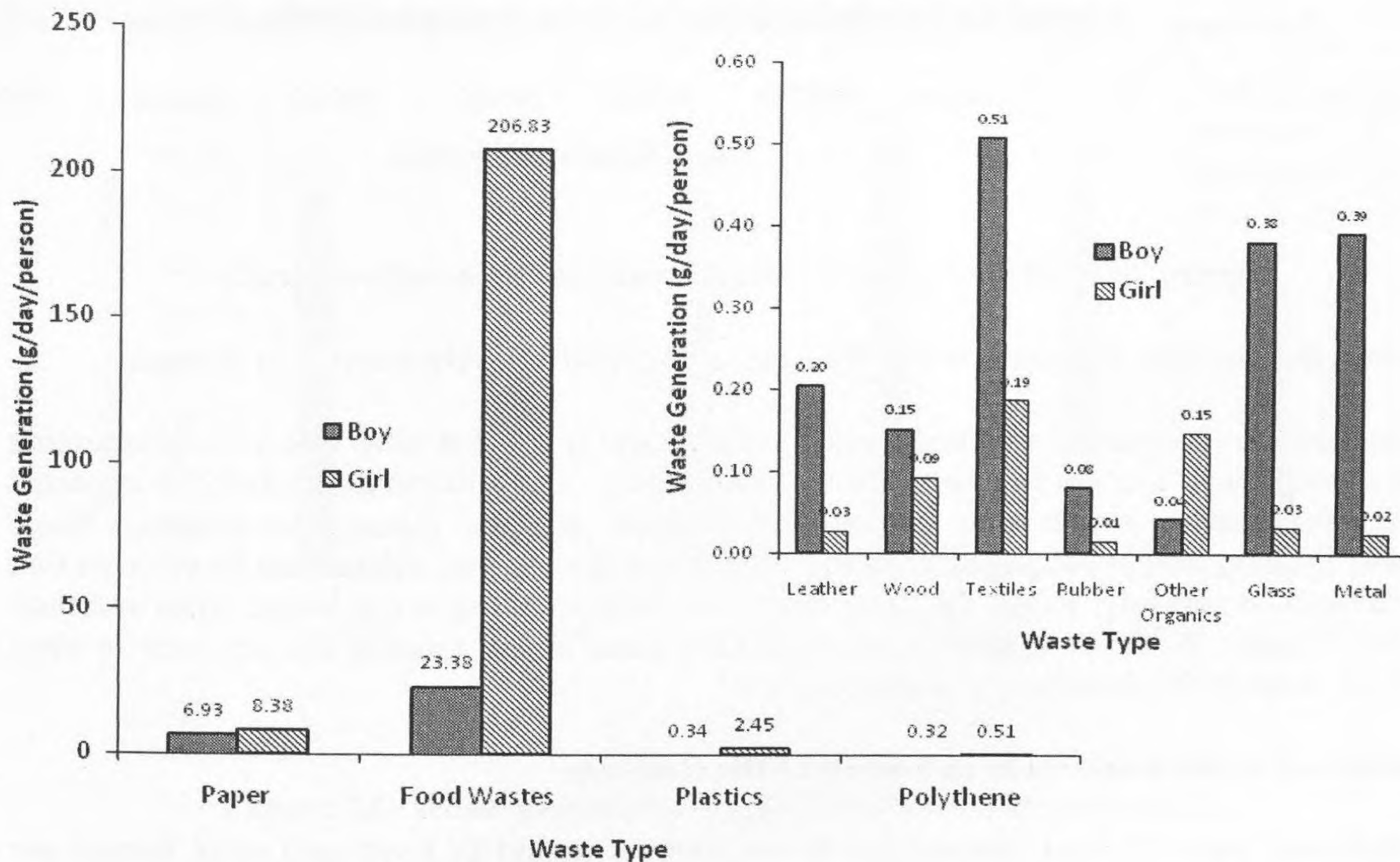


Figure 19: Different types of waste generation rates by the students

### Different types of waste generation in the faculty in a day

The different types of waste generation for a day are shown in Figure 20. The food waste, paper, plastic and polythene are the most common waste categories in the faculty. The generations of other types of wastes were very low compared with above four types of wastes. However, it is important to note that leather, wood, textile, rubber, animal waste, glass, metal, demolition wastes, batteries, florescent tubes, and incandescent bulbs could not be found in each and every time of waste estimation. In some occasions, they were found in large quantities and in other instances no any amounts of such waste were found.

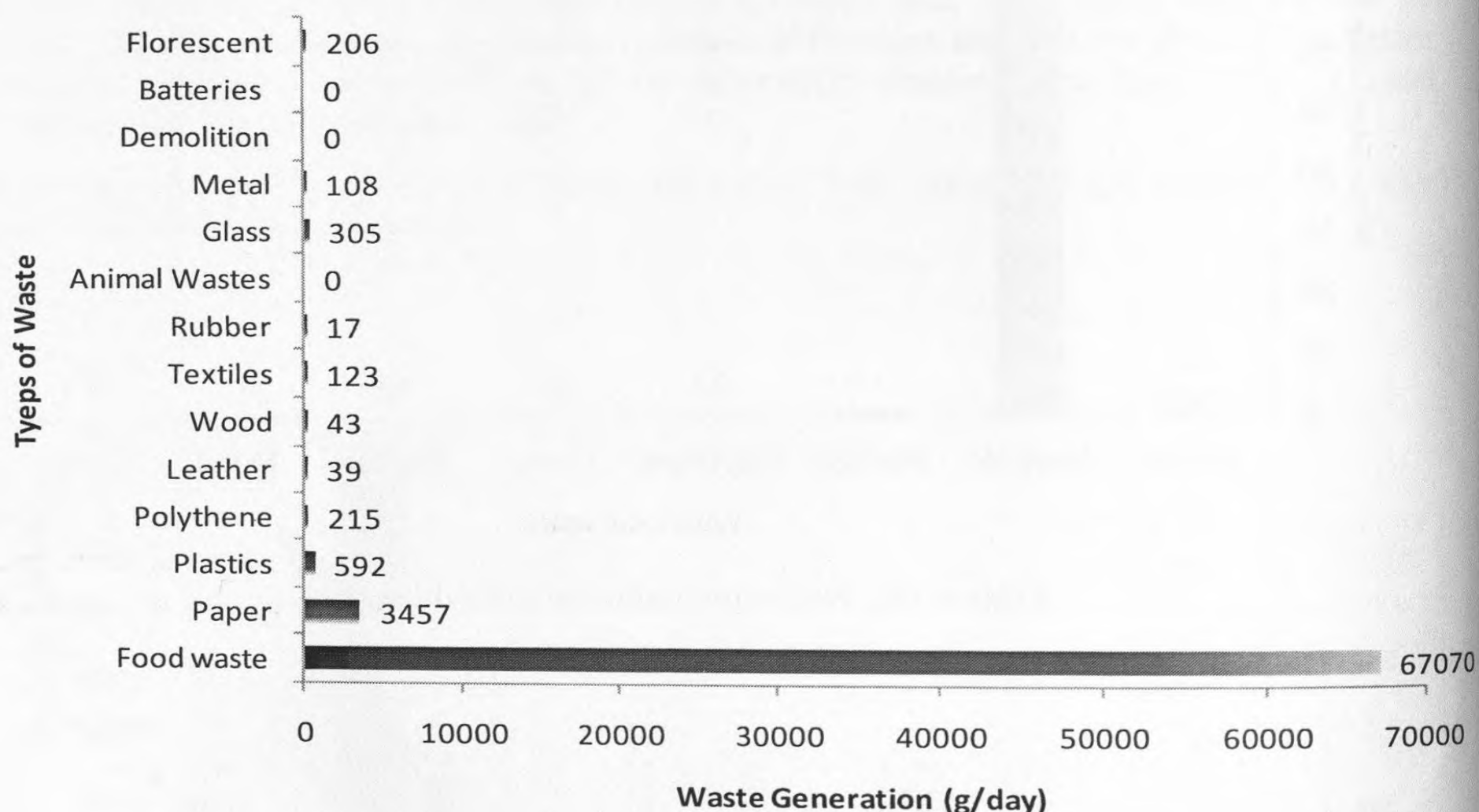


Figure 20: Different types of waste generation in the whole faculty

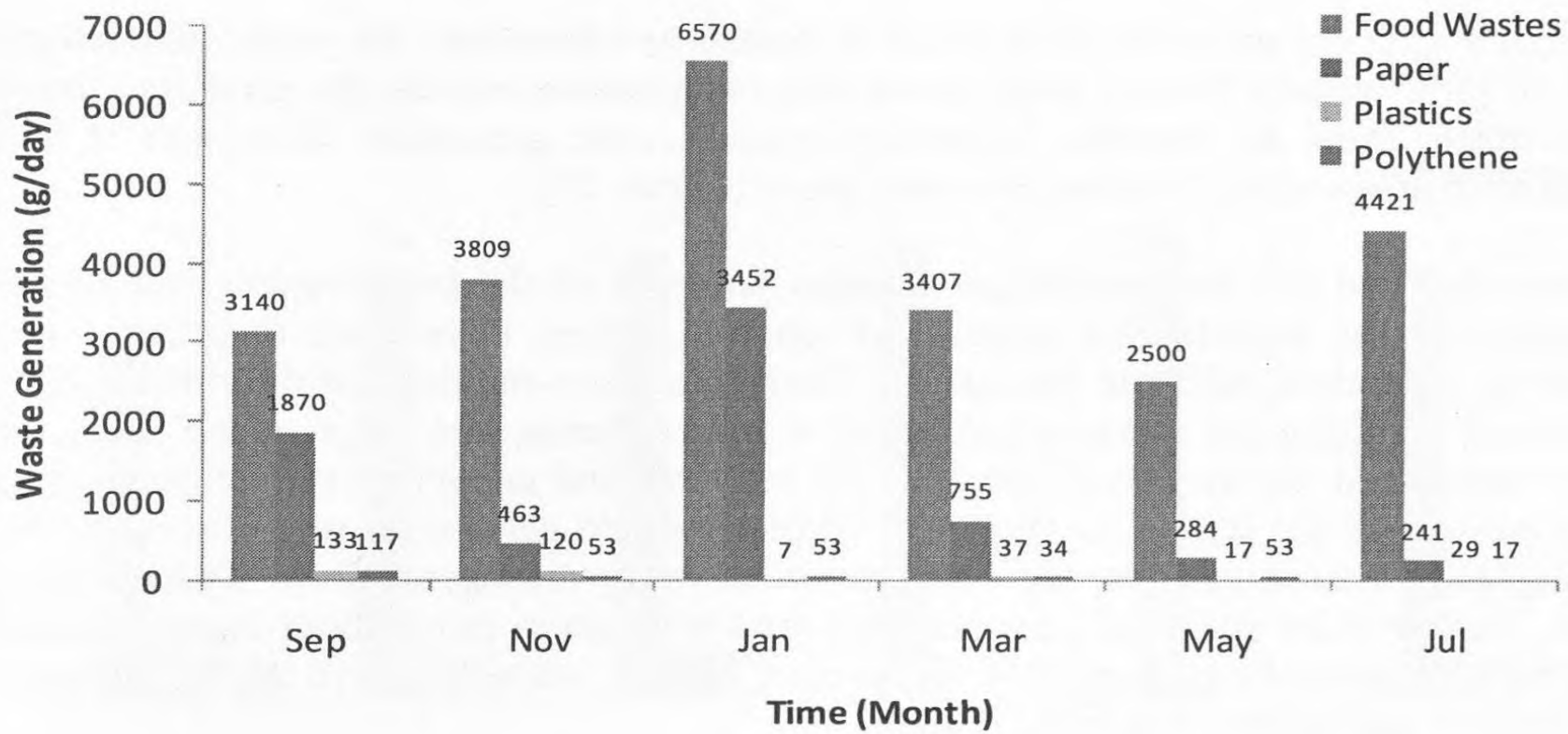
### Seasonal fluctuation of wastes in the Faculty of Agriculture, University of Ruhuna

Seasonal waste fluctuation was observed in this study. It plays a vital role in implementing waste management system in any place. Predominately, waste fluctuation could be expected in the education institutes due to vacation periods and the climate conditions. Waste composition can also be changed with the time. Therefore, waste estimation in each section was carried out carefully to get the comprehensive understanding about waste types and their generation rates. Waste estimation was carried out once in two months for one year in most of the sections of the faculty.

### Variation of waste generation in hostels of the students

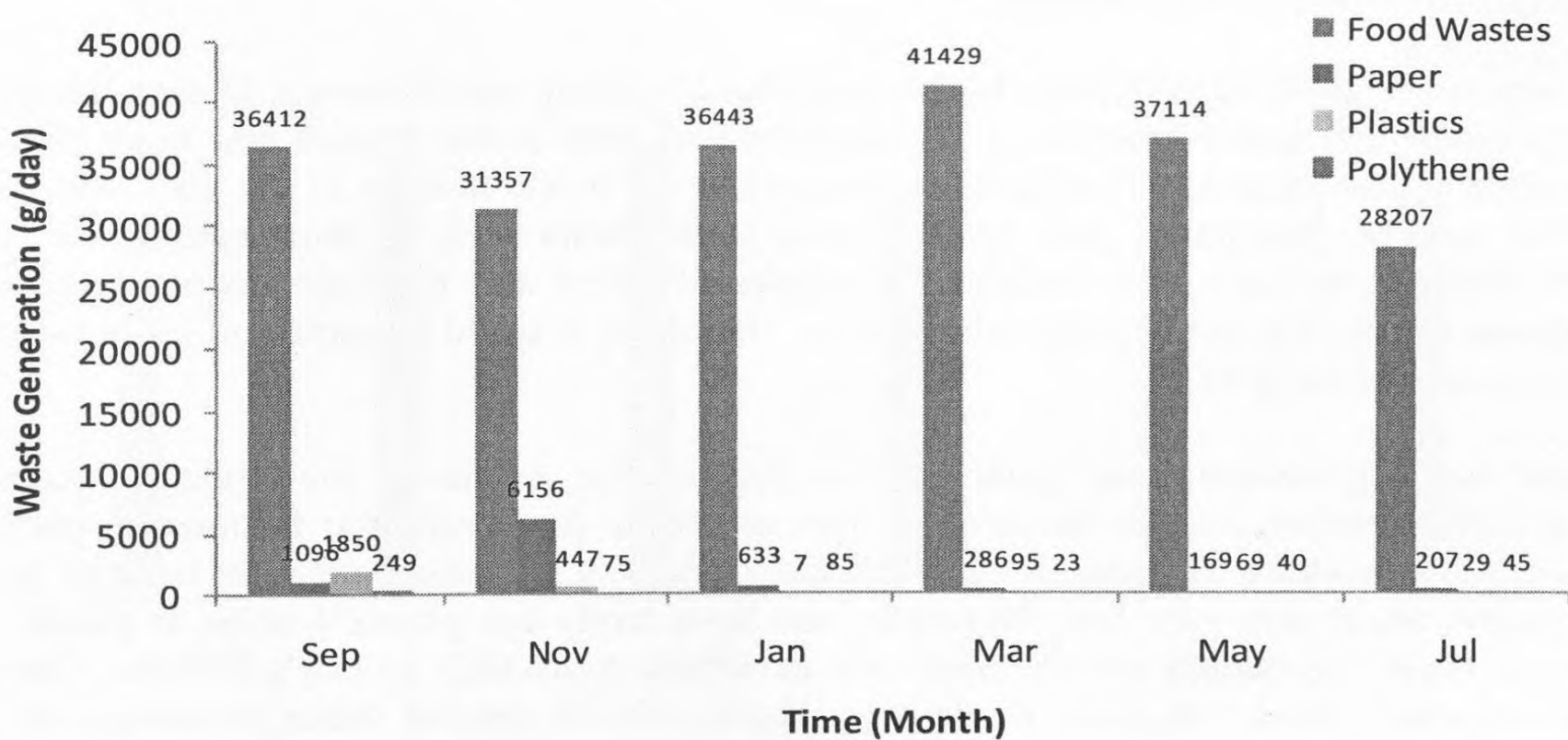
The different types of waste generation in six months period in boys' and girls' hostels are shown in Figure 21 and 22, respectively. In January and July, the generation of waste (food waste) was higher in boys' hostels compared other months and in contrary, the waste

generation is lower in girls' hostels in the same months (January and July). January and July were the study leave and examination period of the academic year 2008/2009.



**Figure 21:** Waste generation in boys' hostels in different months

Normally the boys do not prepare their meals at hostels, instead they take meal packets. Probably, the most of them take lunch and breakfast in cafeteria and some of them bring lunch packets from outside to the hostels. However, the most of the boy students like to have their dinner at hostels taking from outside restaurants and venders.



**Figure 22:** Waste generation in girls' hostels in different months

The less number of students like to have dinner at cafeteria during academic term. Therefore, the waste generation (food waste) in boys' hostels is normally less. However, during study leave and examination period, the most of the boys like to have their breakfast, lunch and

dinner at hostels taking from outside. As a result, the generation of waste is normally expected to be higher during these periods. The results of the study confirmed the above argument (Figure 20).

Normally girls are preparing their meals at hostels and therefore, the waste generation is also high in girls' hostels. During study leave and examination periods, the girls also like to have their meals from the outside. Therefore, overall waste generation in hostels is less. This phenomenon was clearly reflected in this study (Figure 22).

It was observed that the generation of paper waste in all the boys' hostels was increased in January. During examination periods, as reported earlier, boys tend to gather hostels and prefer to have their meals in the hostels. Therefore, the wrappings of the meal packets were discarded resulting the increased of paper wastes. During late stage of the study, research team introduced the awareness program for resource and energy conservation. Therefore, in later periods of the study, the reduction of paper waste generation was observed. However, during examination periods, the concern about waste management by students was rather poor. Further third and final year students tend to concern more about energy conservation and waste management. Paper was the second highest waste found in any boys' hostels and the amount was higher than girls' hostels.

Due to new polythene density policy implemented by the government since first of January 2007, the amount of polythene usage was reduced. But the low enforcement seems to be efficient after several months and the lack of publicity of anti-polythene campaigns results the higher polythene use. The polythene generation in hostels of boys was comparatively higher than that of girls'. The slight reduction of polythene waste generation could be observed in later months of the study in boys' hostels. The reduction may be due to the awareness program. The use of meal packets could be the main reason for the higher amount of polythene waste in boys' hostels.

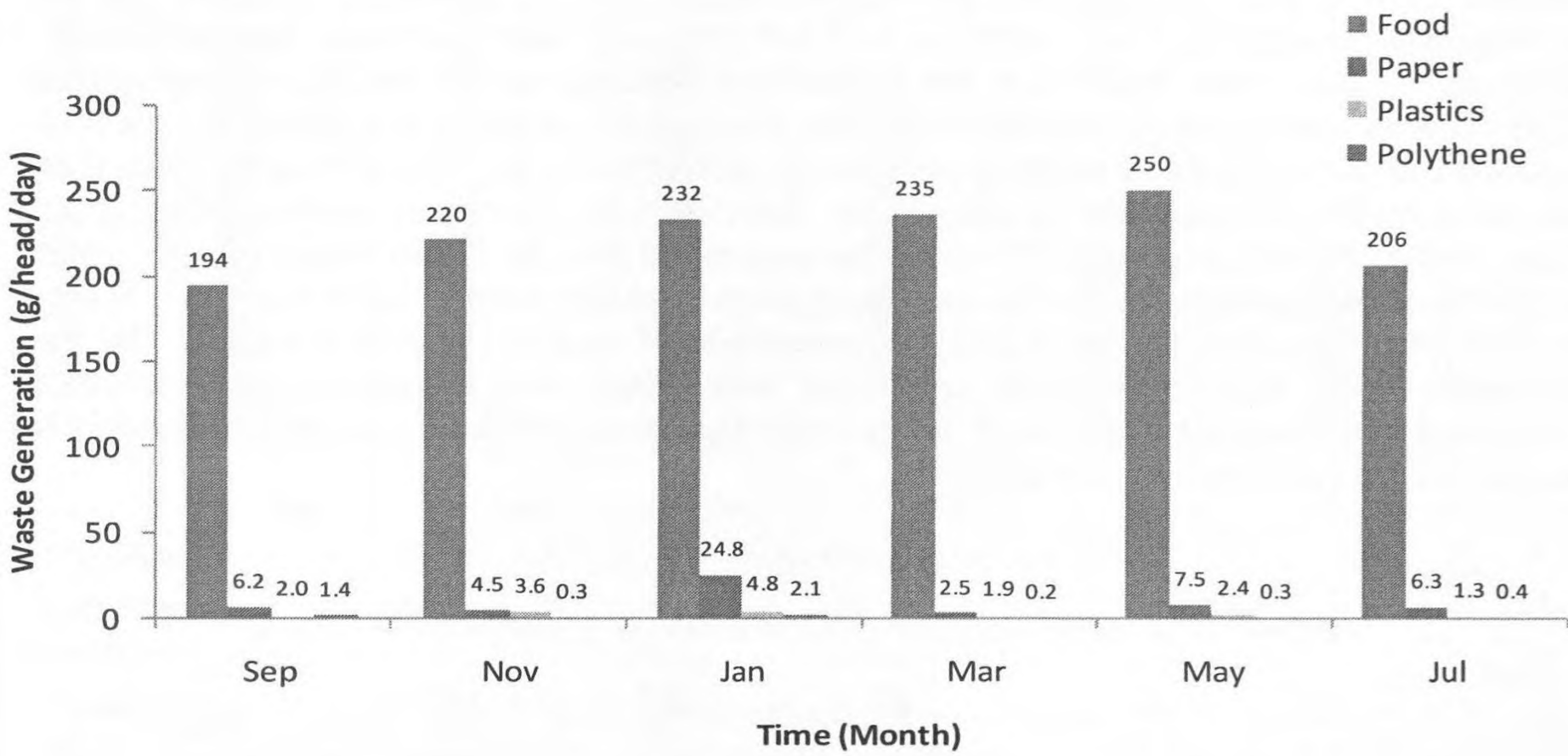
In September 2007, significantly higher polythene amount was observed. During this period, it was noted that some function of the students was held in the hostels and more polythene was used for decorations. Polythene waste generation in the hostels of the girls was high in several months. Normally, girls like to bring some foods such as short eats to the hostels rather than eating them in the canteen or restaurants. And also girls are frequently going for shopping for buying clothes and other items. Therefore, it could be expected more polythene from hostels of the girls.

Plastic waste generation was quite little in the faculty. As far as the students hostels are concerned, situation also is the same. It was unable to find particular fluctuation pattern of plastic waste because the generation of plastic waste was a random incident. In boys' hostels, the plastic waste was very low. Normally, the boys rarely use plastic bottles or plastic bags. In girl's hostels generally plastic waste are generated more than in boy's hostels. Therefore, much attention should be given for hostels where girls are resided when planning a program for plastic waste management. The probable reason for the increase of plastic waste in the girls' hostels could be the higher usage of plastic items in kitchen and bathrooms.

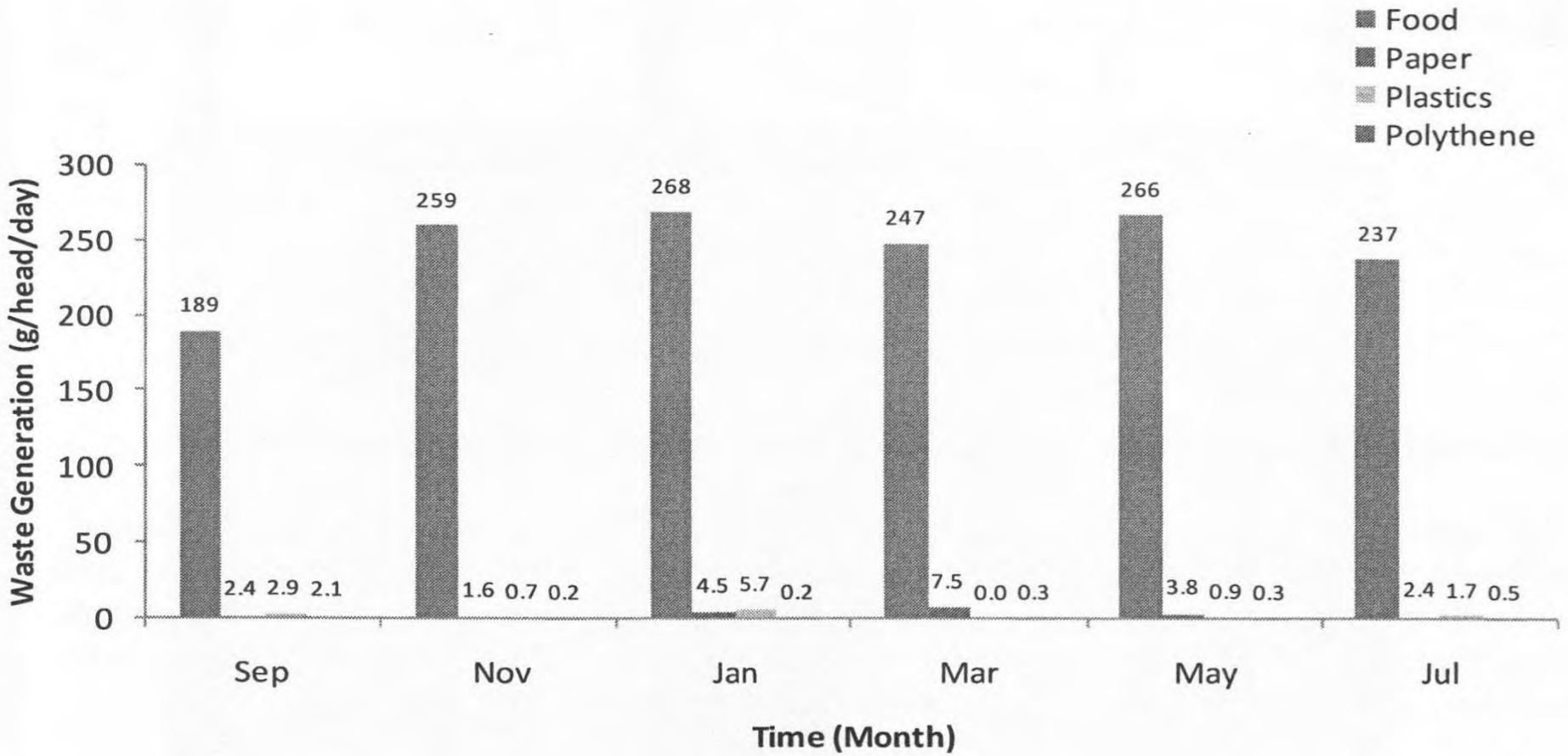
### **Changes in waste generation in quarters**

The generation of major four types of wastes in academic and non-academic staff quarters is shown in Figures 23 and 24, respectively. No considerable changes in waste generation were

observed in both academic and non-academic quarters during study period. However, waste generation in the month of September was found to be low in both quarters.



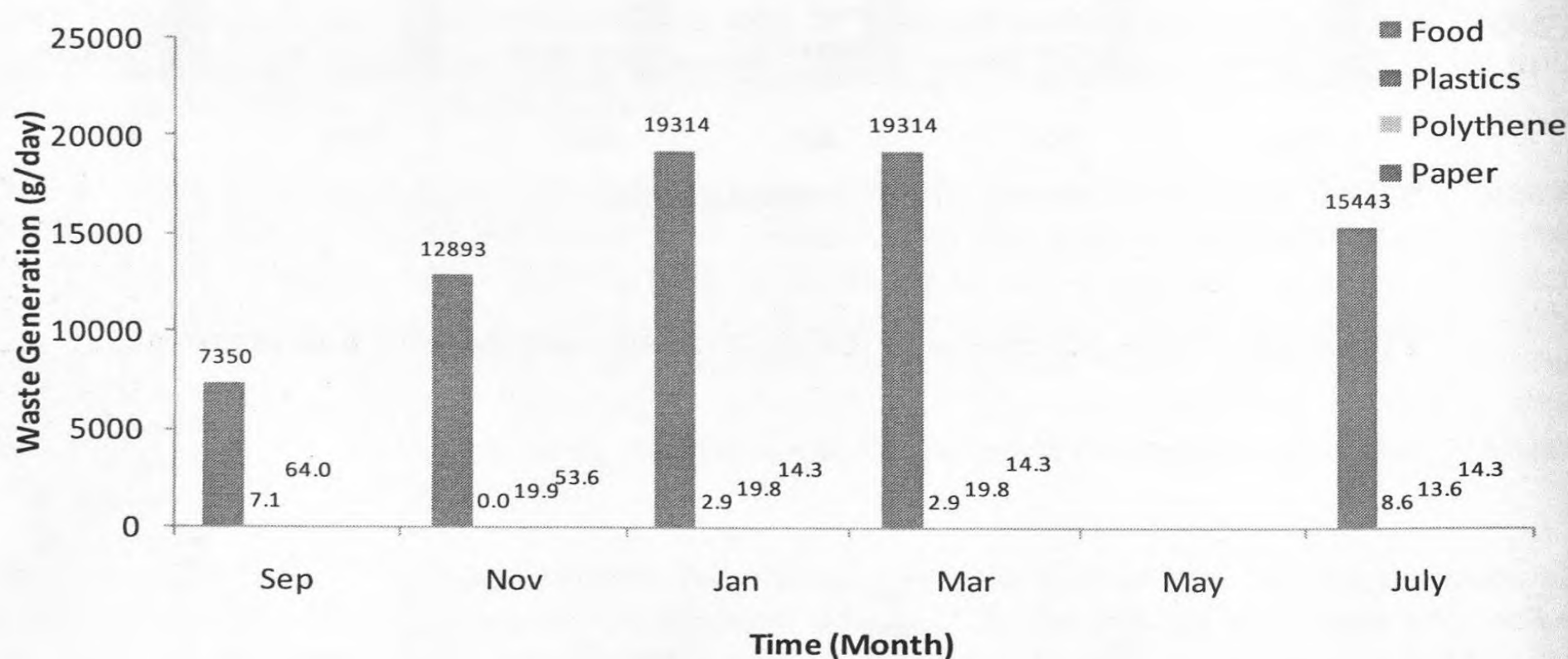
**Figure 23:** Waste generation in different months in academic staff quarters



**Figure 24:** Waste generation in different months in non-academic quarters

## The waste generation in cafeteria

Faculty cafeteria is operated by outside persons. Normally the cafeteria was rented out for 6 months or one year or two year periods depending on the operators' requests. In some months, for example in May, cafeteria was not operated, then, no waste was generated. In addition, students take meal from the cafeteria depending on the quality of meal packets. Therefore, the numbers of students who take meals from cafeteria are changing. As such it could not be concluded that waste generation in cafeteria was varying with time. Even though the most of the students like to take meals from outside, instead of cooking, during study leave and examination periods; it cannot be concluded that the entire student go for meal to cafeteria. If the quality of foods in cafeteria is poor, students would like to buy foods from the outside of the faculty. During which the generation of waste is low in cafeteria. The waste generation was high in January compared with other months where study leave and examination periods were (Figure 25). However, the waste generation was comparatively low in July where examination was also held.

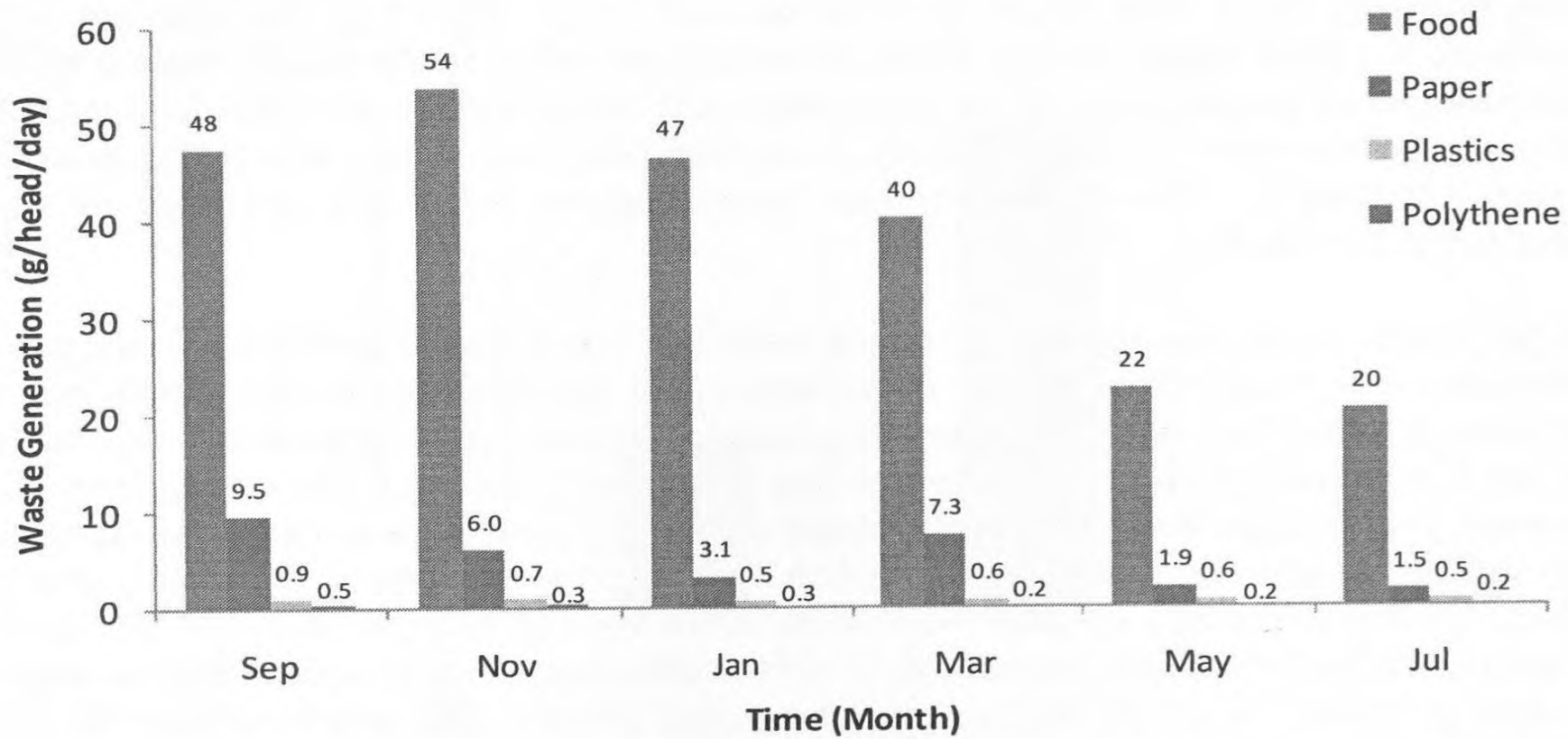


**Figure 25:** Waste generation in cafeteria in different months

## Variation of waste generation in departments and administration complex

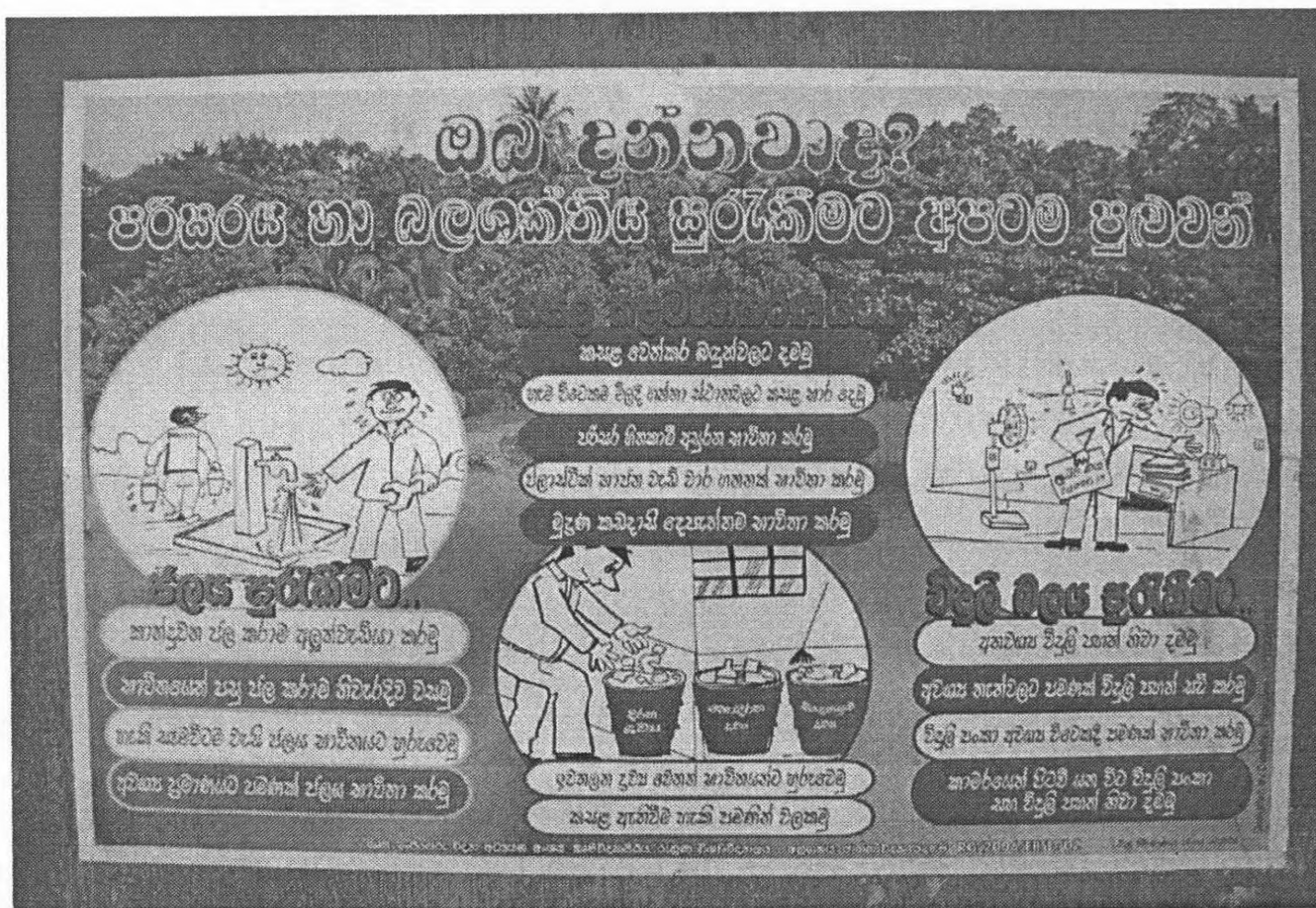
The activities in academic department and administration complex are comparatively different from the activities of other places. The waste generation pattern could be changed basically due to office activities. It is expected to have more paper wastes in department and administration complex than other places. In fact as an education institute, the paper activities may increase the generation of paper wastes in every place except quarters.

The most of paper wastes found in the departments and similar places was newspapers which were used as the wrappings of meals. Even though, it was expected to have more discarded computer printouts, photocopies of documents and other similar documents such as handouts, tutorials, etc; no such items were commonly found. It was found that in the study, the above items do not discard every day from the departments and they were discarded as the bulks in some months.



**Figure 26:** Generation of waste in different months in departments

The generation of four different common waste types namely food, paper, plastics and polythene in academic departments, administration complex and library in different months are shown in Figure 26. The rate of waste generation is decreasing from the month of November 2007 until July 2008. Beginning of the year 2008, an awareness program was launch by the project team to make aware the workers in the university about the environmental burdens associated with the waste generation (Figure 27). The program was quite effective and the impact of the program could be seen by the reduction of waste generation.

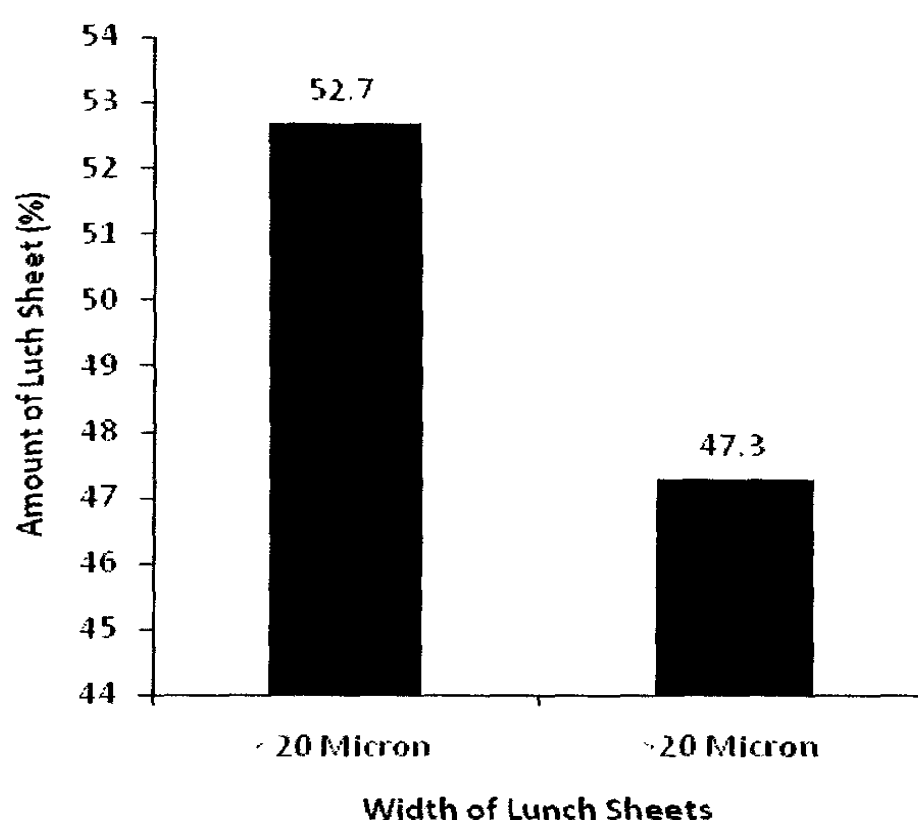


**Figure 27:** Poster to make people aware on environment

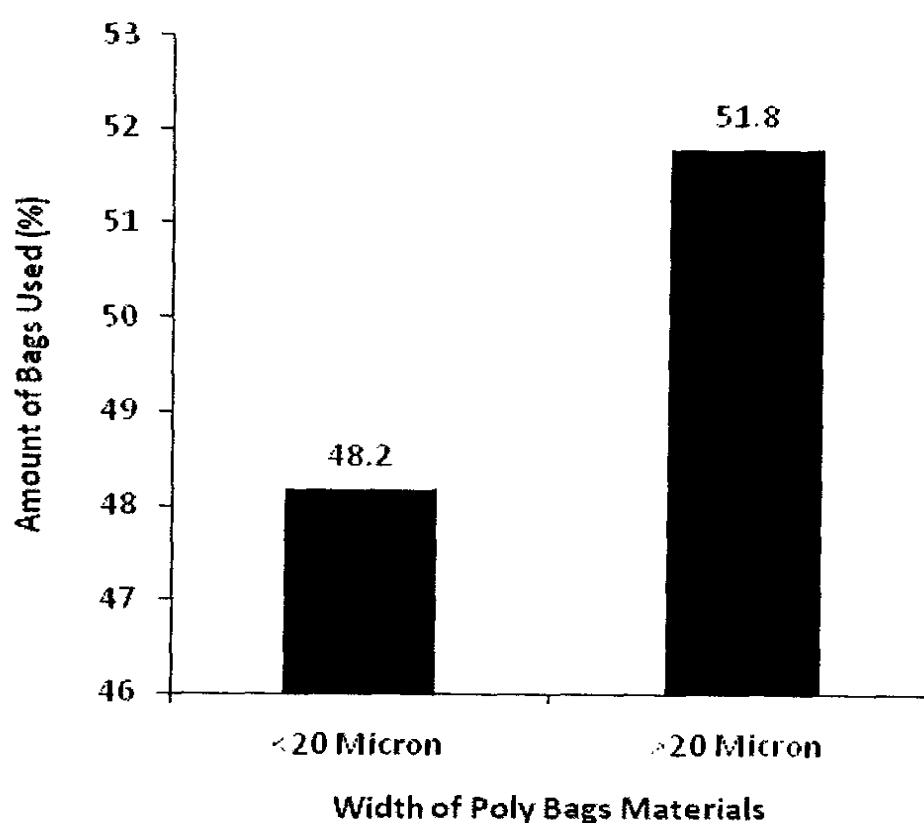
Food waste was the main waste category found in any place at the faculty. The workers in the faculty normally bring their meals for breakfast and lunch. Therefore, the leftovers of the meals were the main source of food waste. However, according to the weight basis it was the major category of wastes found in the department and administration complex. The reduction of food waste was noted during the study. This phenomenon basically due to the awareness program conducted. The community now more concern about the reduction of waste generation in the faculty.

The polythene waste was mainly generated from the lunch sheets and from wrappings of instruments and items taken to the departments and laboratories. It was noted that the generation of polythene waste was also being reduced. Plastic waste generation was also very low and it was difficult to get right figures due to uneven/uncommon discarding time. The discarded yogurt cups were commonly found in some places. It was observed during the study that the food waste can be considered as main sources of waste in the faculty in every section. However, the rate of food waste generation was different in different places. The highest per capita food waste was found in girls student hostels. The second highest amount of waste generated in the faculty was the paper and plastics and polythene take the other places in order. The higher polythene waste generation was noted in girls, hostels.

Even though polythene generation was low in weight basis, their environmental effect could be higher than that of other waste types. There was no proper discarding mechanism for polythene waste in the faculty. Three methods were practiced namely open dumping, burying and burning. All these methods are not environmental friendly it results various adverse environmental problems. The recycling option can be recommended as a good method. However, no proper mechanism is still developed for polythene recycling in the faculty as well as in the Southern Province. It was found that new polythene density policy implemented by the government did not influence of the reduction of polythene. During the study conducted in student hostels it was found that 50 % of polythene generated was low density polythene (<20 micron).



**Figure 28:** The proportion of lunch sheets according to density



**Figure 29:** The use of polythene bags with their width (of polythene sheet)

As far as plastic waste generation was concerned, the higher amount was generated by girls in hostels. It was initially assumed that plastic waste could be higher in the department and administration complex but it was lower than student hostels.

## Conclusions

The waste estimation of the different section of the Faculty of Agriculture, University of Ruhuna was practiced for one year in two months interval. The most common waste type in the faculty in all sections was food wastes. In addition, paper, plastics and polythene were also found in reasonable quantities. During study period, there were no significant changes in the rate of different waste generation. However, it was found that during study leave and examination periods, food waste generation in hostels of boys were increased while girls generated less waste in same period. After implementation of awareness program, the community in the faculty paid more attention for waste management and resources utilization. The little reduction of waste generation in later period of the study is basically due to the awareness program implemented by the project team. However, it was felt that more and more awareness programs with active participation of all stake holders, especially administrators, are required for the long term sustainability of the waste management in the faculty.

## Study 3: Evaluation of physical and biochemical properties of waste

### Materials and Methods

Physical parameters are important for the determination of rate and extent of degradation of wastes. Therefore, some physical and biochemical properties of different types of wastes were determined in the study. Four samples from each waste category were used for the determination of physical and biochemical properties. The physical and biochemical parameters such as dry weight (moisture content), volatile solids, Ash content, bulk density,

particle size, temperature, pH, etc were measured for common waste types using standard analytical methods.

## Results and Discussion

The different types of solid wastes such as food waste, paper, plastics, polythene, leather, wood, textiles, rubber, animal/human wastes, glasses, metals, demolition wastes, batteries, incandescent bulbs, florescent tubes, sanitary wastes, ceramics, etc can be found in municipal or domestic wastes. However, in the process of waste estimation, it was found that the most common waste types in the faculty are food wastes, paper, polythene and plastics. Other types of waste were found in minor quantities. Therefore, physical and chemical properties food wastes, paper and polythene (lunch sheets) were determined in the study (Table 01).

**Table 01:** The Physical and chemical properties of selected wastes

Type of Waste	Moisture Content (%)	Volatile Matter (%)	Ash (%)	Bulk Density (g/cm <sup>3</sup> )
Food Waste	84.65	93.96	6.04	2.05
Paper	9.55	90.31	9.69	0.32
Lunch Sheet	49.16	96.65	3.35	0.29

The highest amount of waste generated in the faculty are food waste, however, the dry matter content of the foods are comparatively low. Around 85 % of its weight is water. Therefore, any management or treatment methodology for food wastes should be practiced in very close proximity to the generation point. Otherwise, it will increase the transportation cost as well as the generation of exhaust gases to the atmosphere. At the same time, food waste contains the higher amount of volatile matter, which can easily be degraded by microorganisms. Therefore, the compost and biogas production can easily be adopted for the management of food waste.

The paper waste contains less amount of moisture. Relatively higher amount of volatile matter can also found. Even though composting and biogas production can be applied for paper waste also, the best option for the management of paper waste is recycling. Still in Sri Lanka, especially in the southern province, it is hardly found the paper recycling facilities. However, paper collectors are engaged in the process of collection of news papers, but they do not collect dirty used papers. Therefore, the proper paper collection chain and recycling units to be implemented in near future for the recycling of waste paper. It will help to conserve the environment as well as foreign exchange.

Third highest waste found in the Faculty of Agriculture is low density polythene used for the wrapping of foods (lunch sheets). Since they are used for wrapping of foods, it contains higher amount of moisture (~50%). Even though volatile matters are very high, it could not be used for the composting or biogas production. Polythene is very resistant to natural degradation. Therefore, the best option which could be adopted for the management of polythene waste is to recycling. The amount of polythene generation in the faculty in weight basis was comparatively law, however, the volume was comparatively high (0.29 g/cm<sup>3</sup>). This will badly affect to the collection of polyether for recycling.

When polythene is in outside environment, it is a really menace. The blocking of the drainage systems, the reduction of the aesthetic beauty of the environment, accumulation long period of time in the environment without degrading, providing breeding grounds for flies and mosquitoes, and polluting the water sources are some of the bad impact due to the discarding of polythene into natural environment. During the study, it was found that polythene is a threat for animals, especially, goats and cattle in the faculty. These animals eat the foods in the lunch sheets and unintentionally they swallow the lunch sheets also. Polythene is accumulated in the digestive system and finally animals died. Therefore, a proper mechanism is needed for the collection and disposal of polythene wastes.

The other waste types namely, plastics, leather, wood, textiles, rubber, animal/human wastes, glasses, metals, demolition wastes, batteries, incandescent bulbs, florescent tubes, sanitary wastes, ceramics, etc were found in very small quantities and therefore, the properties of such wastes was not evaluated in this study.

## **Conclusions**

According to the properties of the most common waste types generated in the Faculty of Agriculture, the composting and anaerobic digestion (biogas production) could be recommended as suitable methods. However, the recycling would be the best option for the management of waste papers and polythene. Still no proper mechanism has been developed for the collection and recycling of papers and polythene in the southern province of Sri Lanka. Therefore, the setting up a proper mechanism with participation of people and local authorities is the most important and effective way for the management of such types of waste.

## **Part II: The evaluation of wastewater disposal methods currently used and the estimation of wastewater generation potential**

### **Study 1 and II: Evaluation of wastewater disposal methods currently used and the estimation of wastewater generation potential**

#### **Materials and Methods**

The discussions and field visits were made to identify the wastewater disposal sites of the faculty. There are several laboratories in Academic Departments. The wastewater with different chemicals is normally discharged from the laboratories. In addition, wastewater is discharged from the cafeteria as well as from the farm of the faculty also, where milk related foods are processed. In addition, students' hostels also generate a reasonable amount of wastewater from kitchens and bath rooms. The generation of wastewater from cafeteria was estimated. Water wastage by different places of the water distribution system of the faculty was also determined. Primary data were collected from the documents, journals and informal discussion with the officers of the different sections in the faculty. Water leakages were measured by randomly selected sample of taps within the faculty premises during 9 am to 10 am in week days. This information is very important for the faculty to reduce the cost for water.

The physical and biochemical properties of the wastewater were determined. The standard analytical methods (APHA, 1985) were used for the determination of physical and chemical properties.

#### **Results and Discussion**

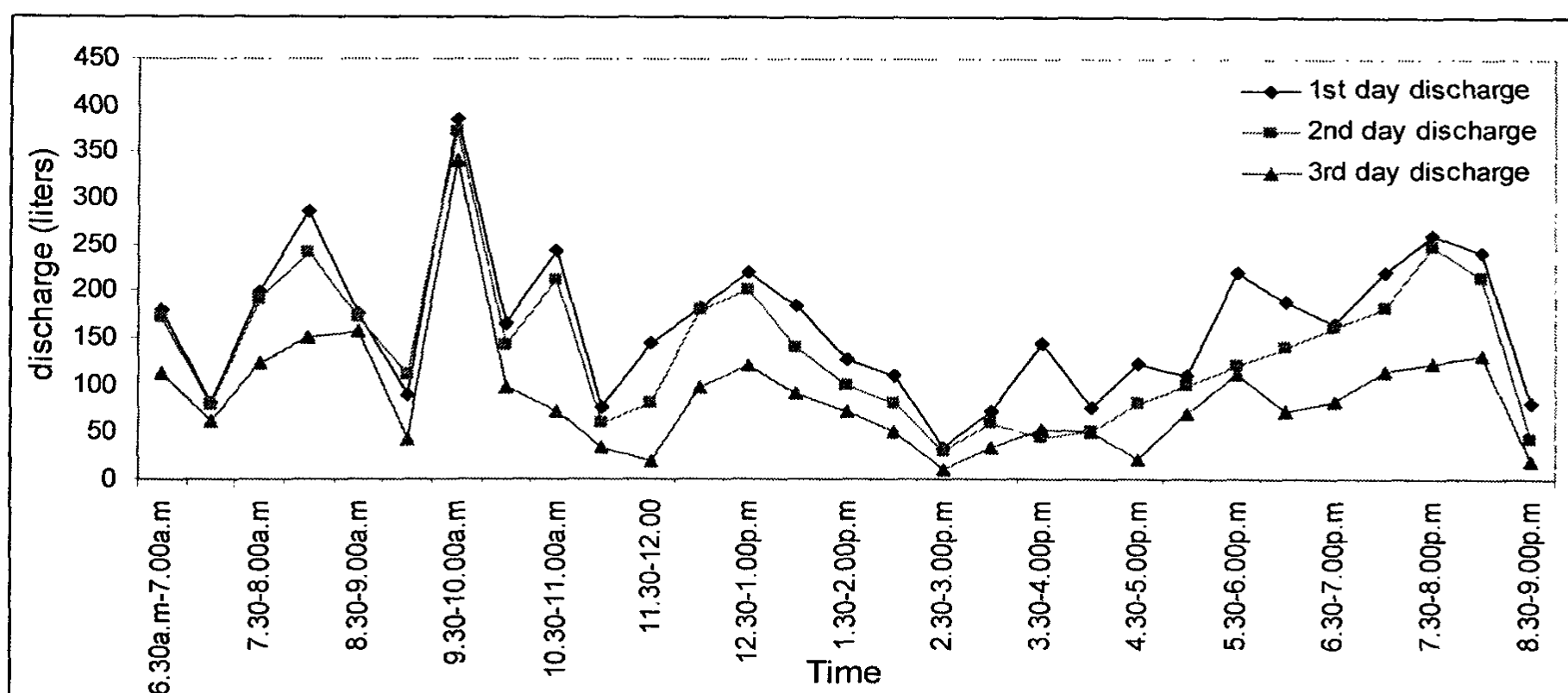
##### **Wastewater generation**

The amount of wastewater generated from the students' hostels could not be estimated because the wastewater directly transfers to the underground storage pits. However, the total water usage in the faculty was estimated using water meters. Faculty has 6 water tanks, each with a well and a pump. Volume of total storage tanks was about 30 m<sup>3</sup> except one tank (6 m<sup>3</sup>). Daily water pumped from the wells was 190 m<sup>3</sup>. About 40 m<sup>3</sup> of water obtained from the national Water Supply and Drainage Board (NWSDB) which was equal to the 16 % of the additional water requirement of the Faculty. Students consumed about 100 m<sup>3</sup> of water while the departments consumed 110 m<sup>3</sup> and farm consumed 15 m<sup>3</sup> daily. The water usage for toilets of the faculty was about 36.75 m<sup>3</sup>/day.

The water usage in the Departments of the faculty is comparatively higher than students, hostels. The higher water use could be expected in laboratories where practicals are conducted by the students. The discharged water from the laboratories contains more chemical pollutants because the different types of chemicals are used in the laboratories. However, the amount of wastewater generated from the laboratories could not be estimated due to several reasons. No individual water meters are installed in the different departments and buildings of the faculty. Therefore, water consumption by each building or department could not be obtained. The wastewater generated from the laboratories are directly discharged to underground pits, however, no one in the faculty knows where the underground pits are located. The research team of the faculty tried to find the master plan of the faculty from which the location of wastewater pits can be identified. It was not successful.

The discussions were made with senior workers in the faculty to get the information about wastewater discharge pits where wastewater from the laboratories are treated and stored. Some of them located the places; however, it could not be able to verify the places. They emphasized that proper treatment procedures were adopted to treat the wastewater generating from laboratories. The systems and the places they emphasized where treatment systems are located could not be verified. Therefore, the total wastewater generation from the laboratories could not be estimated.

The wastewater generated from research farm was quite small, and all the wastewater generated from the cattle shed was diverted to the nearby biogas digester. The considerable amount of wastewater is generated from the cafeteria. The daily discharge rates of the effluents in the canteen are given in the Figure 30. At 6.30a.m-7.00a.m water was used for cooking. So, more water was used for wash raw foods, pots etc. Therefore, during this period high effluent discharge from the canteen could be seen.



**Figure 30:** Average effluent discharge variations with time of the day in the cafeteria

During 7.30a.m-8.30a.m majority of students have their breakfast and much more water is used for washing hands, plates etc. Thus during this time effluent discharge was high. At 9.30a.m-10.00a.m the drains of the canteen are washed and effluent discharge is high. Students take their lunch at 12.00-1.30p.m and more water is used for the washing hands and plates etc. 5.30p.m-6.30p.m is time for the preparation of dinner preparation. During this period, more effluent discharge is occurred. The average canteen effluent discharge was observed as 3768 L/day.

### Water losses in the faculty

Monthly average cost for additional water obtained from NWSDB was Rs ~44311.00 per month. Daily per capita water consumption was 0.447 m<sup>3</sup> per day which was quite higher than the Sri Lankan daily water consumption. (0.115 m<sup>3</sup>/person/day). Total water leakage for a day at faculty was 11.01 m<sup>3</sup> which was 4.91 % of total water consumption which cost Rs ~13877.00 per month. The cost of water in leakages was 31.31 % of cost bared for additional water supplied from NWSDB. It was estimated that 20000 m<sup>3</sup> of rain water can be harvested annually within the faculty premises, which can particularly be used for toilets and farm

activities covering 25 % of annual faculty water demand. It was estimated that currently 69.36 % of water over used by the faculty community. However due to laboratory work and farm activities water consumption in the faculty is high compared with other places. The lack of attitudes and less attention for water conservation caused over luxury consumption ( $> 0.300 \text{ m}^3/\text{person}/\text{day}$ ) of water in the faculty. It is suggested that further attention should be given to water conservation by community awareness programs and frequent repairing of water leakage conditions. Rain water harvesting can be introduced to farm activities to minimize the cost for the water. It is suggested that well planned integrated water conservation strategy is needed to minimize the water wastage of the campus.

### Physical and chemical properties of wastewater

The physical and chemical properties of wastewater generated from cafeteria were determined. The determined parameters are total solid (TS), Total suspended solids (TSS), Total dissolved solids (TDS), Orthophosphate, Total Kjeldhal nitrogen (TKN %) and pH. The parameters determined are shown in Table 02.

**Table 02:** Physical chemical properties of wastewater generated from the cafeteria

Time	TS (mg/L)		TSS (mg/L)		TDS(mg/L)		N (mg/L)	pH	P (mg/L)
	AVG	STD	AVG	STD	AVG	STD			
6.30-8.00	2287	417	1234	180	783	67		5.75	0.380
8.00-9.30	636	126	279	39	173	19	0.645	6.03	0.344
9.30-11.00	1531	276	483	47	550	119		5.56	0.405
11.00-12.30	1598	51	441	42	733	22	0.681	5.78	0.405
12.30-2.00	2441	374	1529	211	801	59		5.50	0.430
2.00-3.30	1170	106	663	155	271	55	0.65	6.14	0.307
3.30-5.00	896	186	416	30	288	36		6.23	0.356
5.00-6.30	983	54	653	35	301	16	0.588	6.14	0.319
<b>AVG</b>	<b>1443</b>	<b>199</b>	<b>712</b>	<b>92</b>	<b>487</b>	<b>49</b>	<b>0.641</b>	<b>5.9</b>	<b>0.37</b>
<b>Permissible Value*</b>			<b>50</b>				<b>25</b>	<b>5-8.5</b>	

\*Source: Environmental Protection Act, Ministry of Environment and National Development Unit

The amount of wastewater generation and the quality of wastewater are varied during day time with the food preparation and food consumption. Early morning and lunch time, the properties of wastewater such as TS, TSS and TDS are changed. The average TS, TSS and TDS values of wastewater were about 1443 mg/L, 712 mg/L and 487 mg/L, respectively. The considerable changes in Nitrogen (TKN) and Phosphorus (Ortho) have not been detected. The average Nitrogen and Phosphorus content of cafeteria wastewater were 6.41 mg/L and 3.7 mg/L, respectively. The pH of wastewater is quite acidic and it was about 5.9. Chemical Oxygen Demand of wastewater was about 398 mg/L. It is higher than the permissible value (250 mg/L) to discharge to natural water sources.

### Conclusions

The total wastewater generation in the faculty could not be determined; however, the wastewater generation from cafeteria was estimated. According to the investigations made, it

was revealed that the proper wastewater disposal units have been installed at laboratories. However, it was not clear whether the wastewater was properly treated or not before divert to the underground tanks. The water wastage is apparent in the faculty. It was about 5% of the total water consumption in the faculty. The broken joints and tubes in water distribution system, wore or broken tapes were the major water leakage points. The time taken for repairs and maintenance of the water distribution systems takes long time in the faculty due to administration shortcomings and financial difficulties. To reduce the water wastage, it is essential to have proper awareness program for the staff of the faculty. Moreover, simple, low cost water purification system is required for the treatment of wastewater generated from the cafeteria of the faculty. According to the wastewater quality determined, these properties are changed during day time with food preparations and consumption in the cafeteria. The nutrients values are quite high and therefore, it is necessary to have a treatment system before divert cafeteria wastewater to natural water bodies.

### **Study III: Development of a Small Scale Sustainable Wastewater Treatment System for Cafeteria**

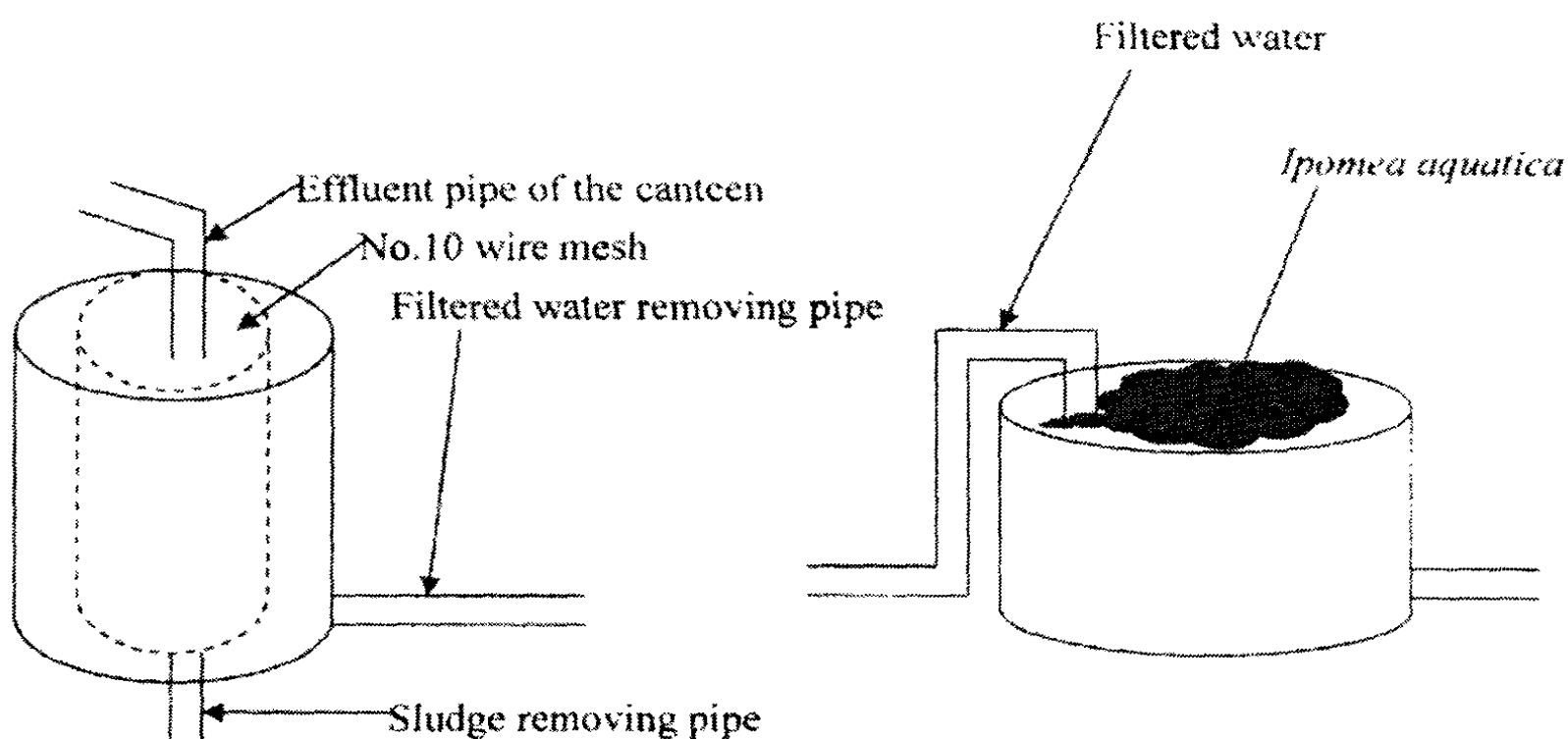
#### **Materials and Methods**

The amount of wastewater generated from the cafeteria was 4 m<sup>3</sup>/day. The results of the study conducted showed that phytoremediation technology, where plants are used for the removing of pollutants from the wastewater, can easily be used for the treatment of pollutant from the wastewater generated from the cafeteria. In this study, we attempted to design and development of a simple wastewater system combining a filtration unit and a phytoremediation unit for the use of restaurants.

Experiment was conducted at the site of the Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka during December (2006) to June ( 2007).

#### **Design and layout of the wastewater treatment system**

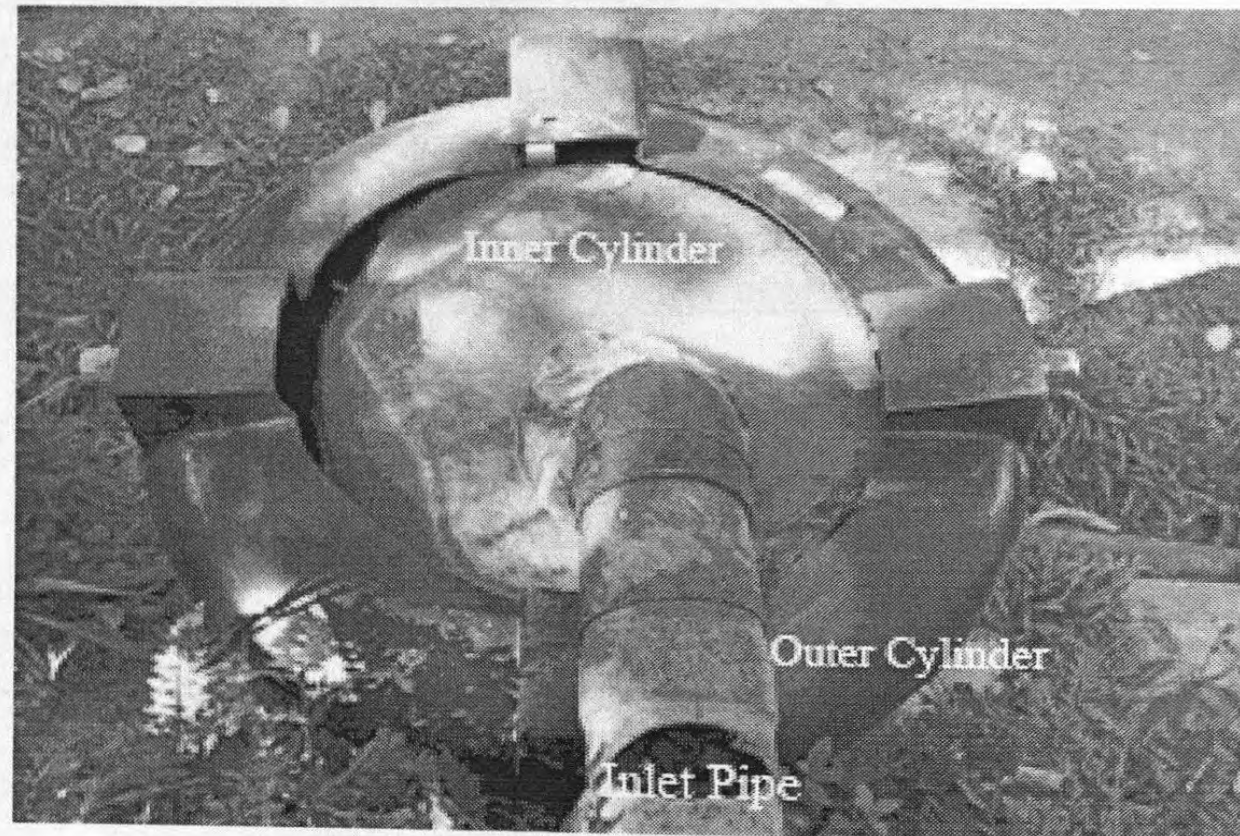
There are major two parts in the treatment system namely, a filtering unit and a bio purification unit. The sketch of the treatment system is shown in Figure 31.



**Figure 31:** Sketch of the filtering unit (left) and biopurification unit (right)

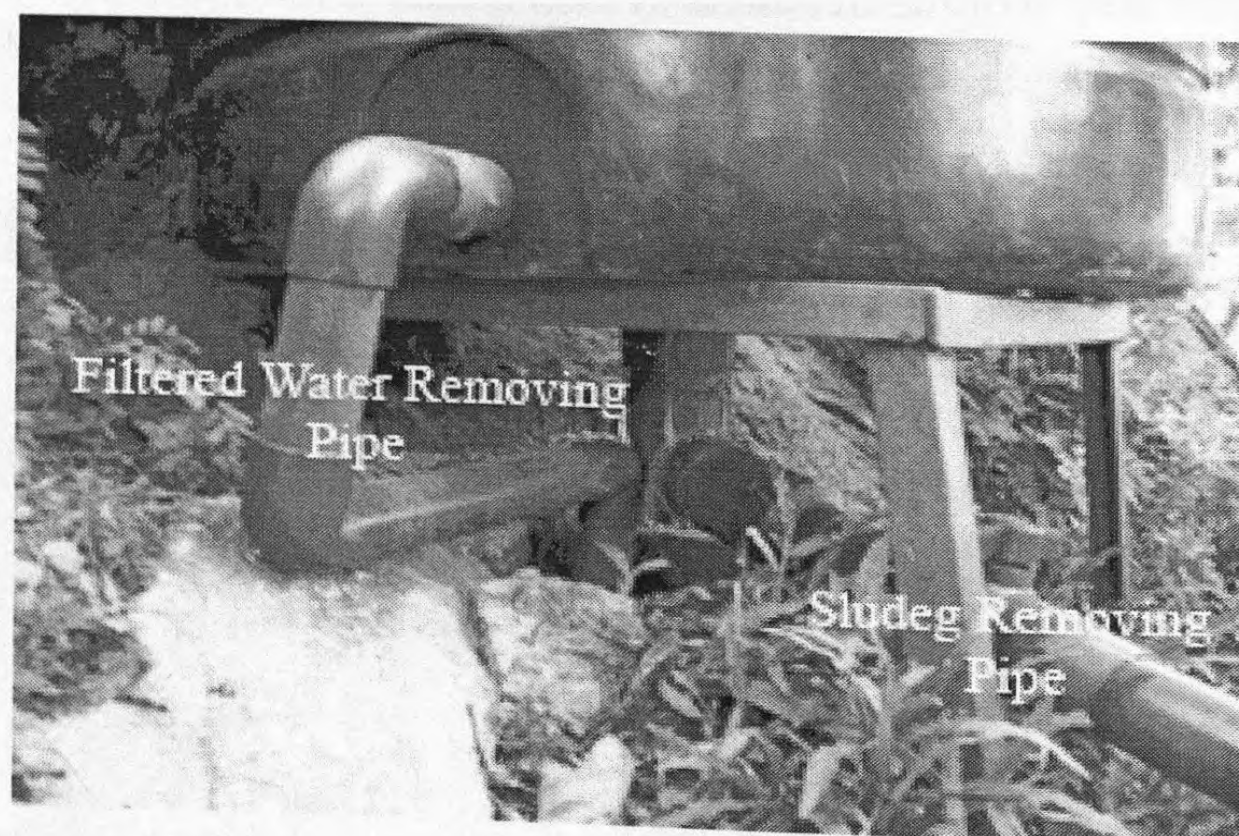
## Design of the Filter

The filtering unit was designed to separate large and heavy particles of the canteen effluent. It was comprised of inner and outer two cylinders. The top of the inner cylinder was covered with no.10 wire mesh. The canteen effluent was diverted to the inner cylinder through the wire mesh, on its top by a 5 cm diameter PVC pipe. After the inner cylinder was filled to its full capacity, the filtered water discharged to the outer cylinder filtering through the wire mesh (Figure 32).



**Figure 32:** Top view of the filtering unit

The collected sludge in the inner cylinder could be removed manually with the help of 2" diameter PVC pipe and a valve fixed in the bottom of inner cylinder. The filtered water is diverted to the biopurification unit (Figure 33). The completed and installed water filtering system is shown in Figure 34.



**Figure 33:** Sludge removing and filtered water removing pipes



**Figure 34:** The completed water filtering unit installed behind the Cafeteria

#### **Installation of the biopurification unit**

Biopurification unit was installed close to the faculty canteen. *Ipomea aquatica* (Kang-kung) was used as macrophyte for the removal of pollutants in filtered water (Figure 35). This unit can store 400 L of filtered water at a time. *Ipomea aquatica* were put using root dipping technique. Initial weight of plants used was 2 kg (fresh weight)



**Figure 35:** Planting of *Ipomea aquatica* in the biopurification unit

Before testing *Ipomea aquatica* as the wastewater purification macrophyte, the unit with macrophyte and wastewater was kept for some time to stabilize the root system. The filtered water was then diverted to biopurification unit. After 23 days of planting *ipomea aquatica* in the biopurification unit are shown in Figure 36.



**Figure 36:** Biopurification unit after 23 days of establishment

### **Evaluation of the filtering unit**

The average effluent discharge of wastewater from the canteen was determined by measuring the volume of wastewater generated from the canteen for 3 days in half an hour intervals. After diverting the wastewater generated from the canteen to the filtering unit of the wastewater treatment systems designed, samples were taken from both canteen wastewater and the filtered wastewater by the filtering unit in one and half hour intervals. The samples were analyzed for the total solid (TS), Total suspended solids (TSS), Total dissolved solids (TDS), Orthophosphate, Total Kjeldhal nitrogen (TKN %), pH. Then removed efficiencies were determined. For the consistency of the results, filtering unit was evaluated for three days. Then the removal efficiencies in different pollutants were determined. The sludge accumulated in the filtering unit was measured for 3 days to determine the average sludge discharge per day.

### **Evaluation of the biopurification unit**

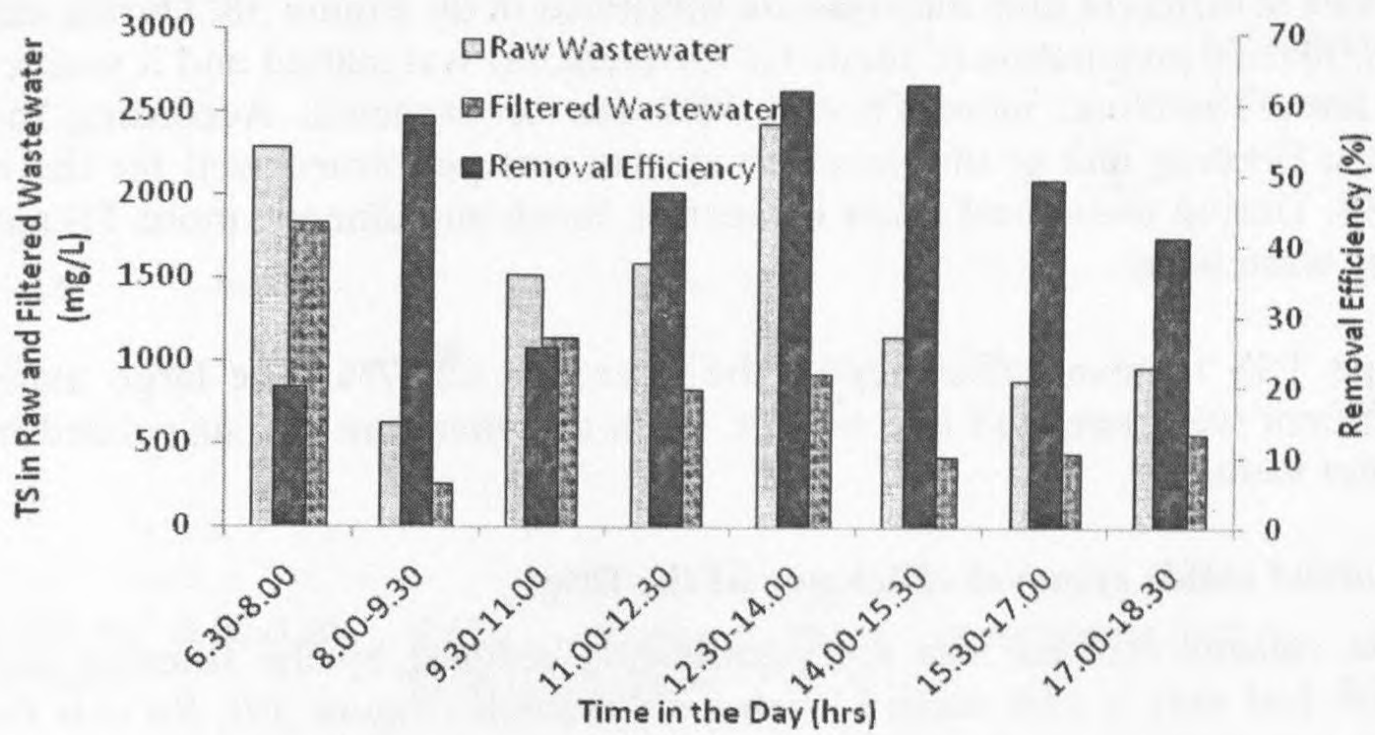
After filtering from the filtering unit, filtered wastewater diverted to the biopurification unit. Biopurification unit was evaluated for the possible removal of pollutants in wastewater. Wastewater sample was taken from about 30" depth of the biopurification unit and analyzed for TS, TSS, TDS, pH, Orthophosphate, TKN%, COD. The number of leaves of randomly selected 50 water hyacinth plants at different grown stages was counted to monitor the plant growth. Initial and final dry weights of the plants were also determined.

### **Results and Discussion**

The treatment system was evaluated for the removal of pollutants in the canteen wastewater. At the first step filtering unit was evaluated for physical pollutants.

#### **Total solid removal efficiency of the filtering unit**

To determine the solid removal efficiency of the filtering unit samples from canteen effluent and filtered water were taken in one and half hour intervals. This procedure was repeated for three days (Monday, Tuesday, and Thursday). The results are shown in Figure 37.

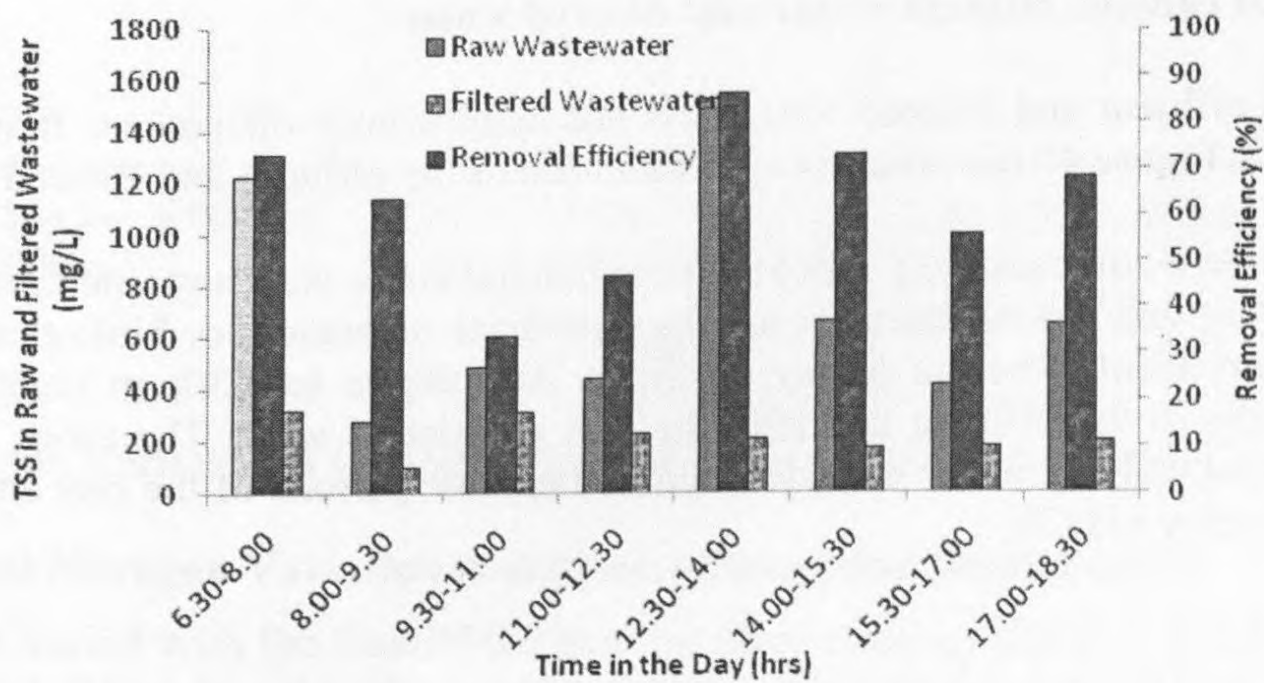


**Figure 37:** Average total solids in effluents, filtered water and removal efficiency

During 6.30a.m-8.00a.m time period TS was high in effluent. During this time period, water normally was used for cooking. As such grain particles, raw vegetable debris etc could be seen in the samples. During this time period, effluent water was white in color due to color gain from rice and dhal washing. At 7.30a.m to 8.00a.m most students were got their breakfast and more swills were contained in the effluent. Therefore, TS in that time periods were high. During 8.00a.m -9.30a.m there were few people at the canteen. So, TS in the effluent was low. During 9.30a.m-11.00a.m the drains of the canteen were washed using more amount of water, and at the same time lunch was prepared. Therefore, effluent water contained more sand and carbon of washed pots. Total solid in water was also high during 12.30-2.00p.m. Because it was the lunch time and more swill was contained in the effluent water.

Average TS removal efficiency of the filtering unit was 45.63%. Swills, vegetable debris, etc (large particles) were removed by the No.10 wire mesh. This efficiency can be reduced with the time since solid particles can block the pores of the wire mesh. Therefore, it is essential to back wash the filtering unit after some time.

**Total suspended solids removal efficiency of the filtering unit**



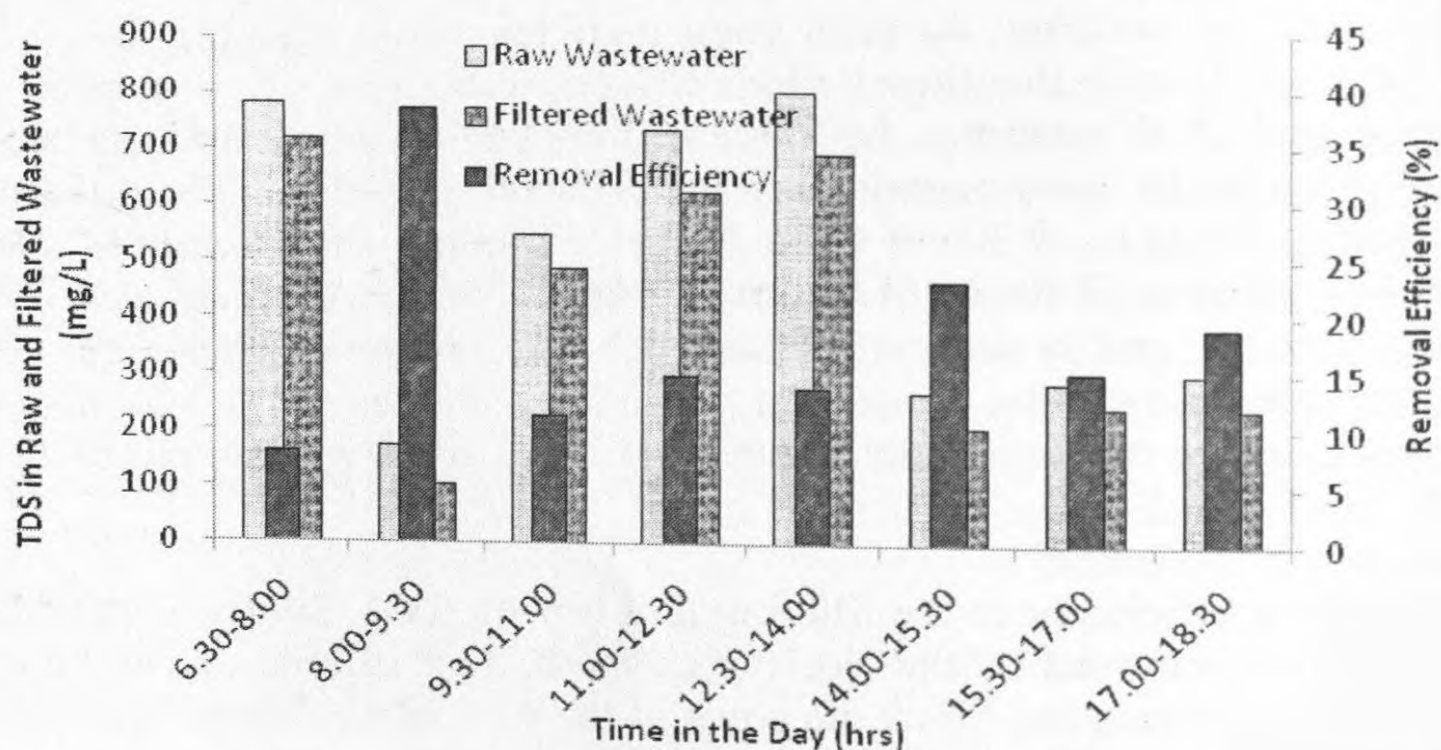
**Figure 38:** Average total suspended solids in effluent, filtered water and removal efficiency

TSS removals at different time intervals are illustrated in the Figure 38. During early morning (6.30a.m-8.00a.m), preparation of foods for the breakfast was started and it was served during this time also. Therefore, more TS and TSS can be expected. According to the results obtained, the filtering unit of the treatment system was performed well for the removing of TS and TSS. During main meal times (breakfast, lunch and dinner), more TS and TSS were noted in the wastewater.

The average TSS removal efficiency of the filter was 62.77%. The large materials in the canteen effluent were removed due to wire mesh and therefore the suspended solids in the filtered water were low.

### Total dissolved solids removal efficiency of the filter

TDS in the canteen effluent was not significantly reduced by the filtering unit since the filtering unit had only a wire mesh to remove the solids (Figure 39). So that the dissolved solids were not retained on the mesh and they entered the filtered water directly and also there was a microbial degradation of organic materials in the effluent water. Due to this microbial degradation the TDS content of the effluent water was not significantly changed.

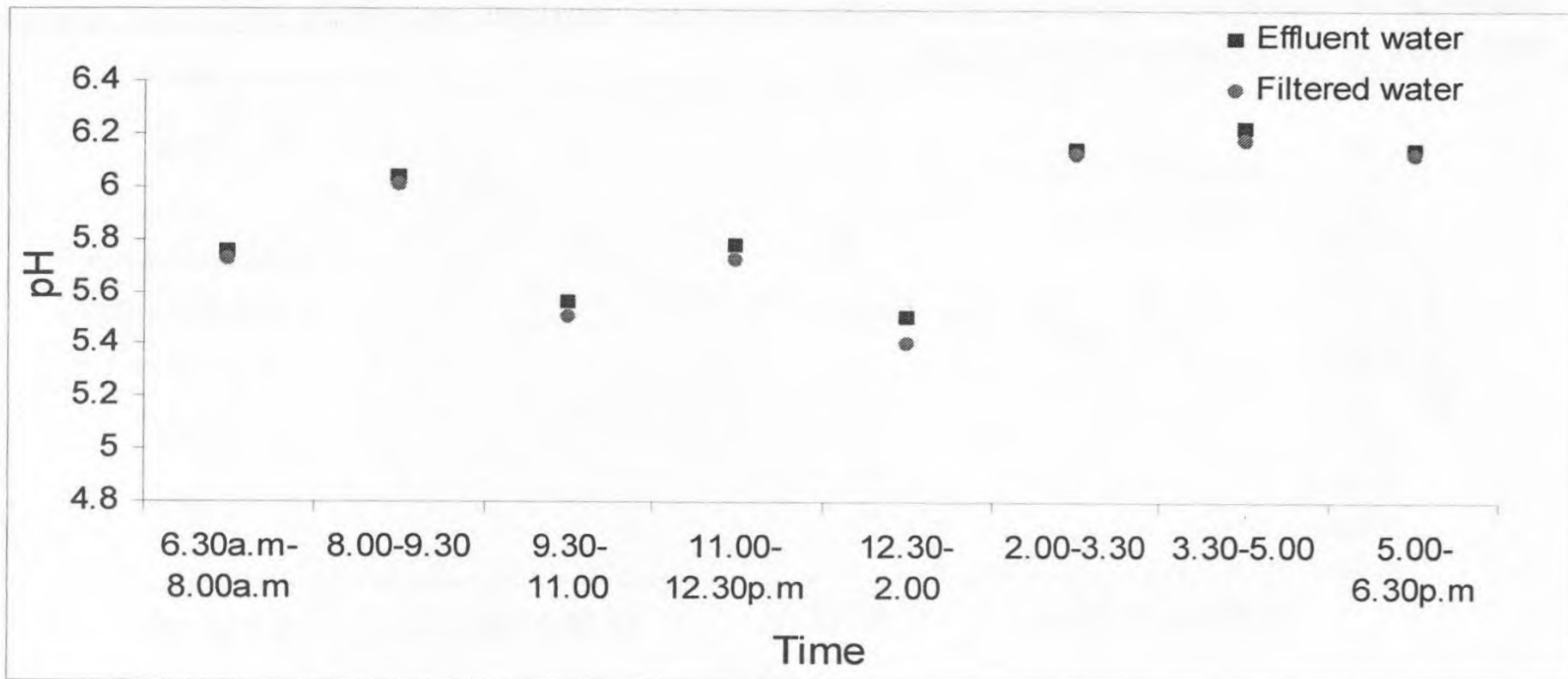


**Figure 39:** Average total dissolved solids in effluent, filtered water and removal efficiency

### pH variation of canteen effluent water and filtered water

The pH of the effluent and filtered water was not significantly difference. It was varied in between 5.4-6.3. Figure 40 illustrates the pH variation of the effluent and filtered water.

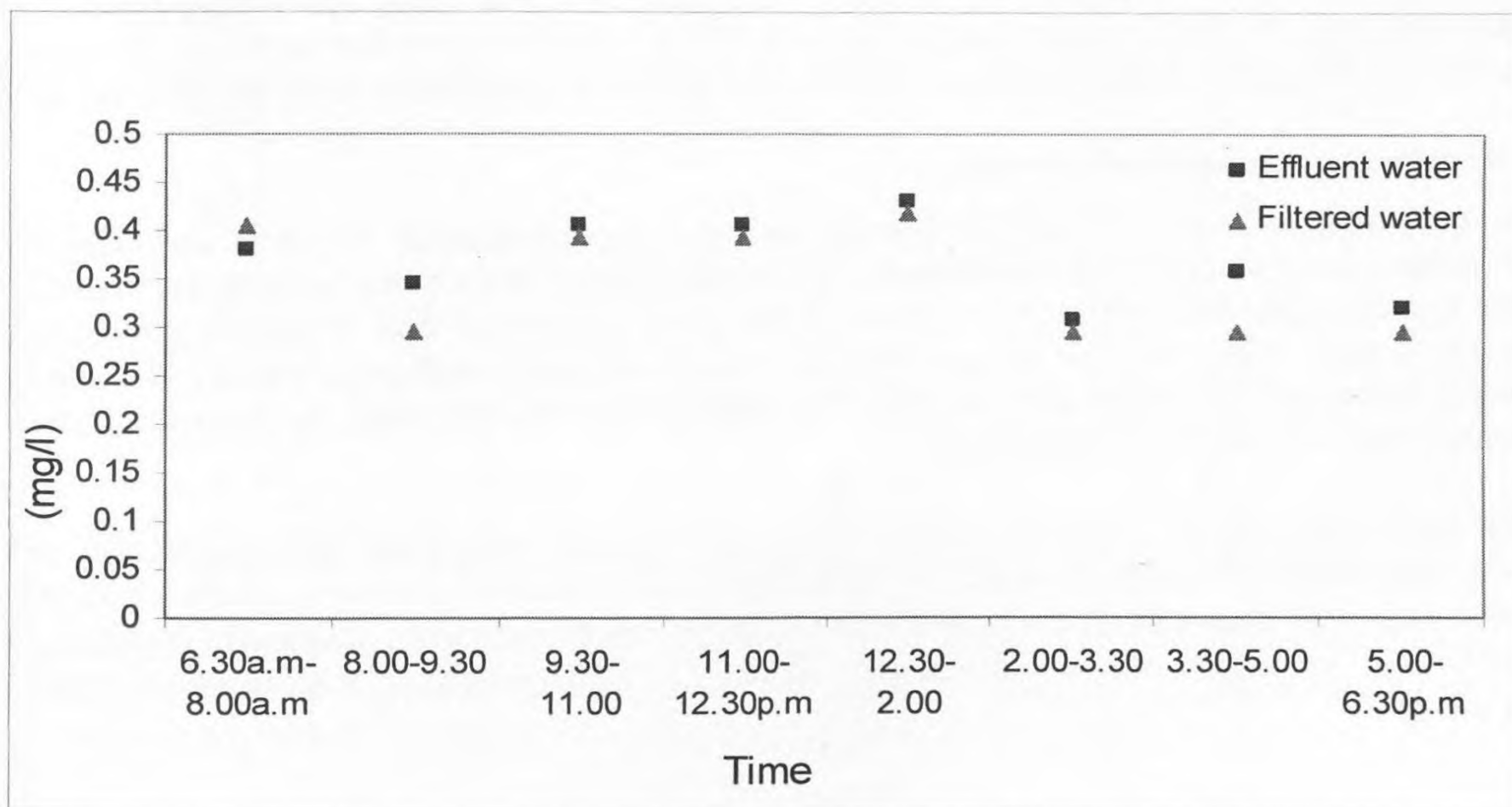
The pH values were comparatively more acidic when the water was contained more swill and sand. The filtering unit did not have pH altering chemical substances or biological agents and therefore no significant effect on pH by the filter. At 2.00p.m to 6.30p.m there were fewer amounts of swills in the effluent and also the less amount of sand. Therefore, in that time period the canteen effluent water was clear than other time periods of the day and reached to the neutralized water pH (7).



**Figure 40:** pH variation of effluent and filtered water (Tuesday)

### Orthophosphate variation in canteen effluent water and filtered water

The Orthophosphate in effluent and filtered water was varied between 0.29 -0.41 mg/l. The degradation of organic matter by the microorganisms that present in the effluent water may be the reason to increase the orthophosphate content in the water (Figure 41). The orthophosphate in the effluent was fluctuated with the time of the day.

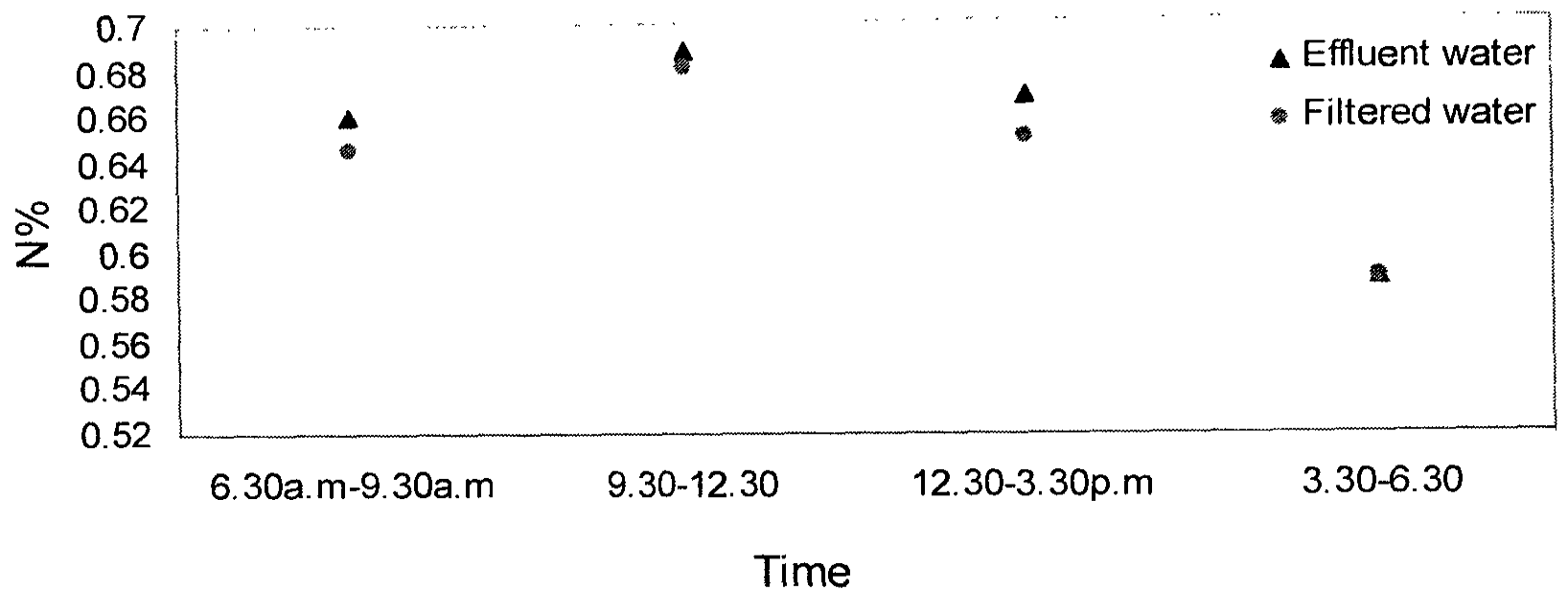


**Figure 41:** Variation of Orthophosphate in effluent and filtered water (Thursday)

### Total Kjeldhal Nitrogen Variation in canteen effluent and filtered water

The TKN was varied with the time of the day but there were no significant different of TKN in effluent and filtered water (Figure42). Because the filtering unit was not consisted

chemical or biological agent to remove the dissolved nitrogen and those dissolved nitrogen was came to the filtered water directly.



**Figure 42:** Variation of TKN% in effluent and filtered water

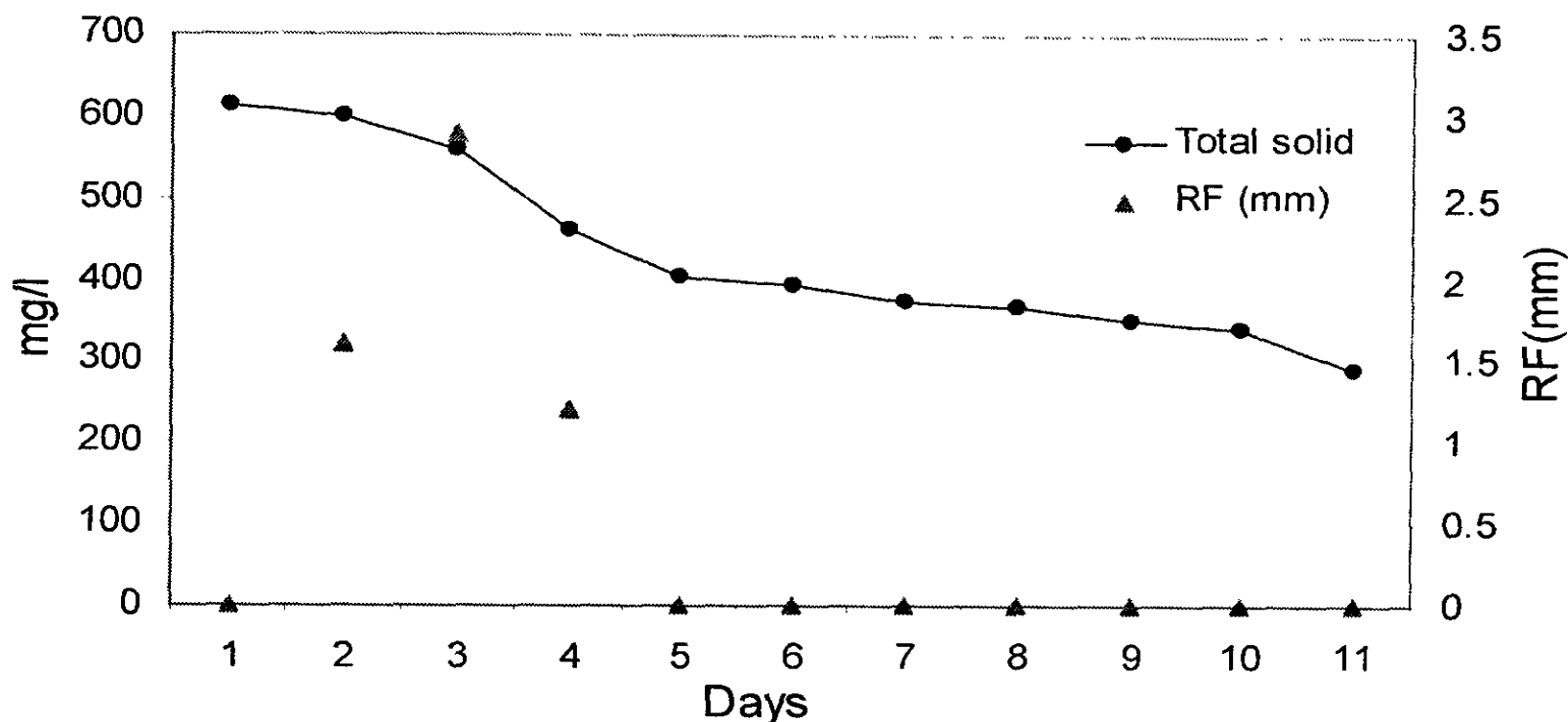
#### **Amount of sludge variation with the amount of raw food**

The amount of raw food, which used in the canteen, was varied with the different days. The average raw food amount was 137.7 kg per day. The sludge amount was varied with the amount of raw food used. For an example if the raw food was high, the sludge production was also high. The average sludge per day was 543 g and which is a low amount. To control the odor problem it is better to remove the sludge daily and completely from the filtering unit.

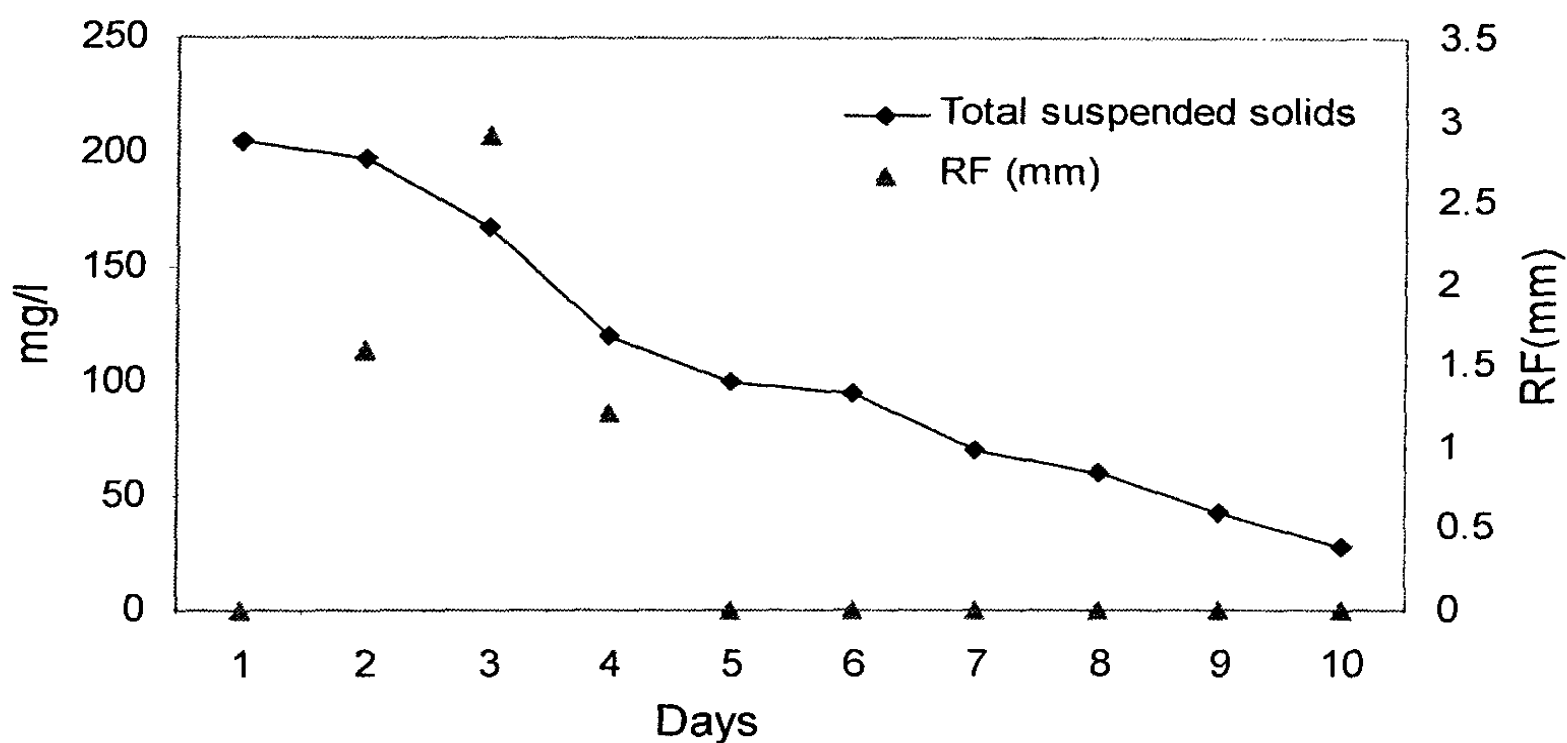
#### **Evaluation of biopurification unit**

The treatment efficiency of biopurification unit was also evaluated. Physical and chemical parameters were used for the evaluation. The aquatic plants absorb nutrients in the water for their growth. The effluent water contained the both suspended and dissolved substances, known as total solids. So, the plants absorbed those substances and grow rapidly. Therefore, the TS in the effluent were reduced with the days. Total solid removals by aquatic plants in different days are shown in Figure 43.

Total suspended solids of the wastewater were also reduced with time. This is basically due to the degradation of organic matter by microorganisms attached to root systems of aquatic plants. After the degradation of organic matter, dissolved components of organic matter were used by the aquatic plants. It will cause to reduce the TSS content of wastewater with time (Figure 44).



**Figure 43:** Total solid removals by *Ipomea aquatica*



**Figure 44:** Total suspended solid removal by *Ipomea aquatica* with time

Total dissolved solids were also reduced with the days (Figure 45). But the TDS reduction was not significantly higher as TSS. Because of the degradation of suspended particles by microorganisms added the dissolved solids to the water, continuously.

The pH changes in the wastewater in the biopurification unit with time are shown in Figure 46. At the beginning, the pH of the water was 5.81. The dropped of pH may be due to the rainfall, and when there was no rain pH value gradually increase. Aquatic plants absorb the dissolved acid forming anions in the water such as nitrate ( $\text{NO}_3^-$ ), carbonate ( $\text{CO}_3^{2-}$ ), nitrite ( $\text{NO}_2^-$ ) etc. Therefore, pH of the water may increased.

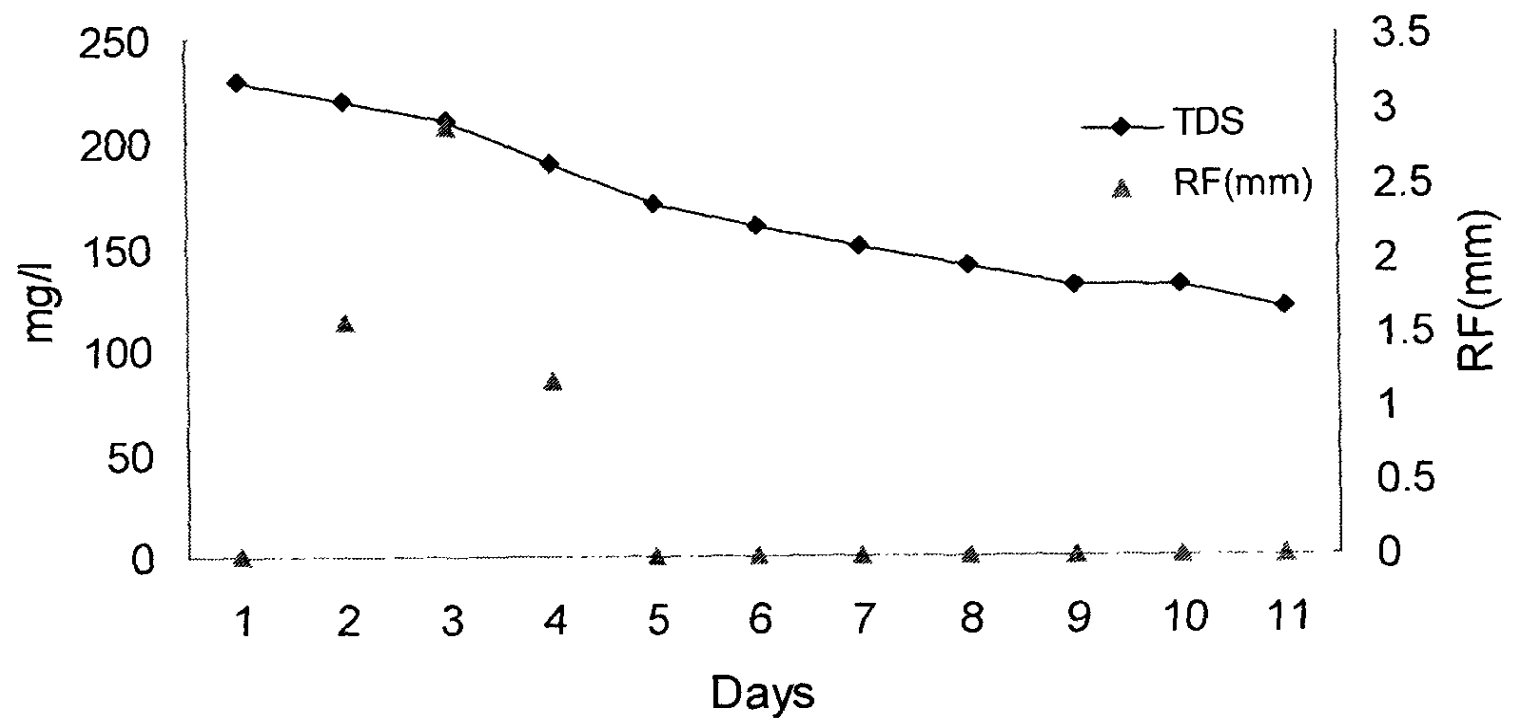


Figure 45: Total dissolved solids removal by *Ipomea aquatica*

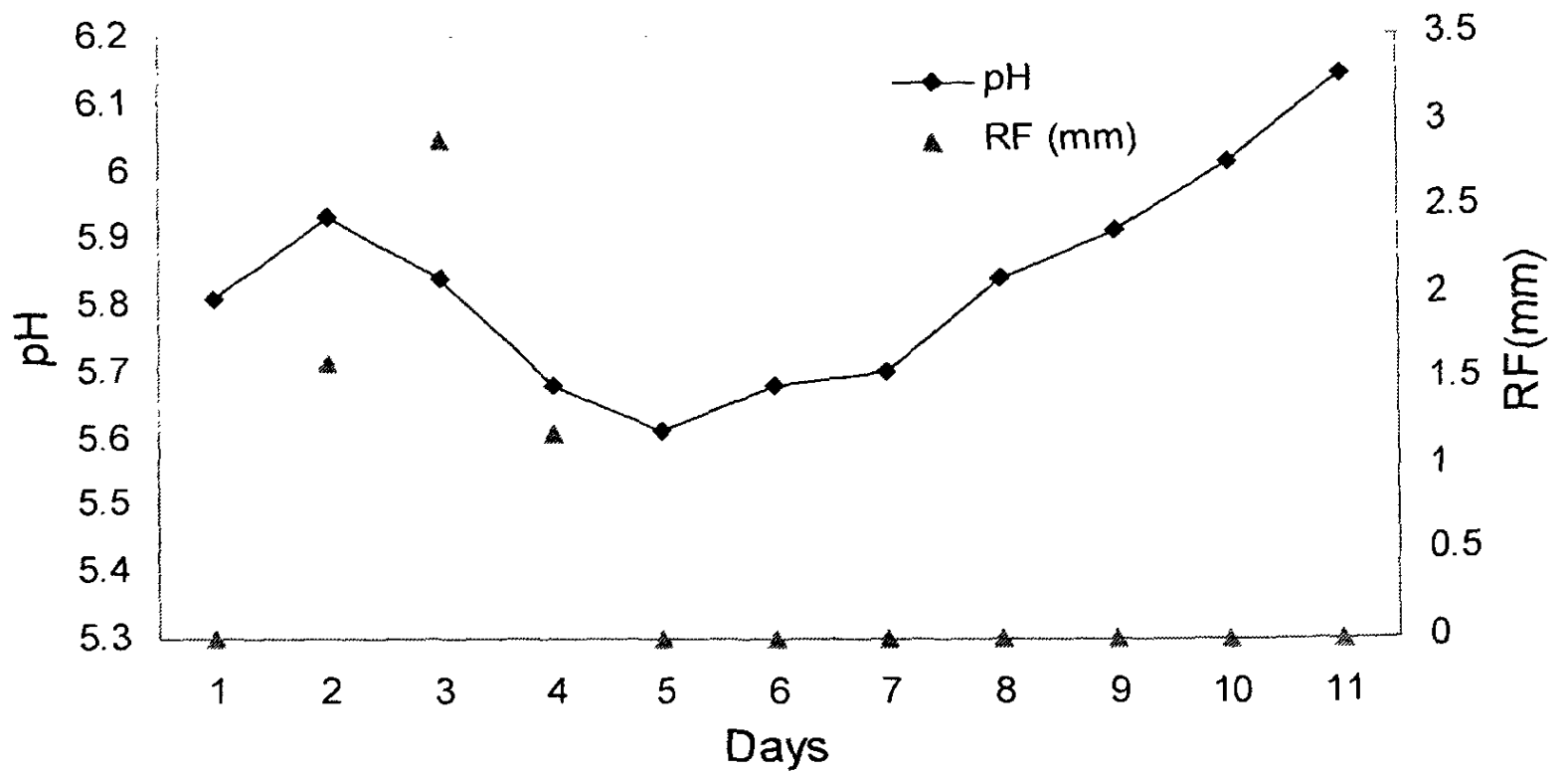
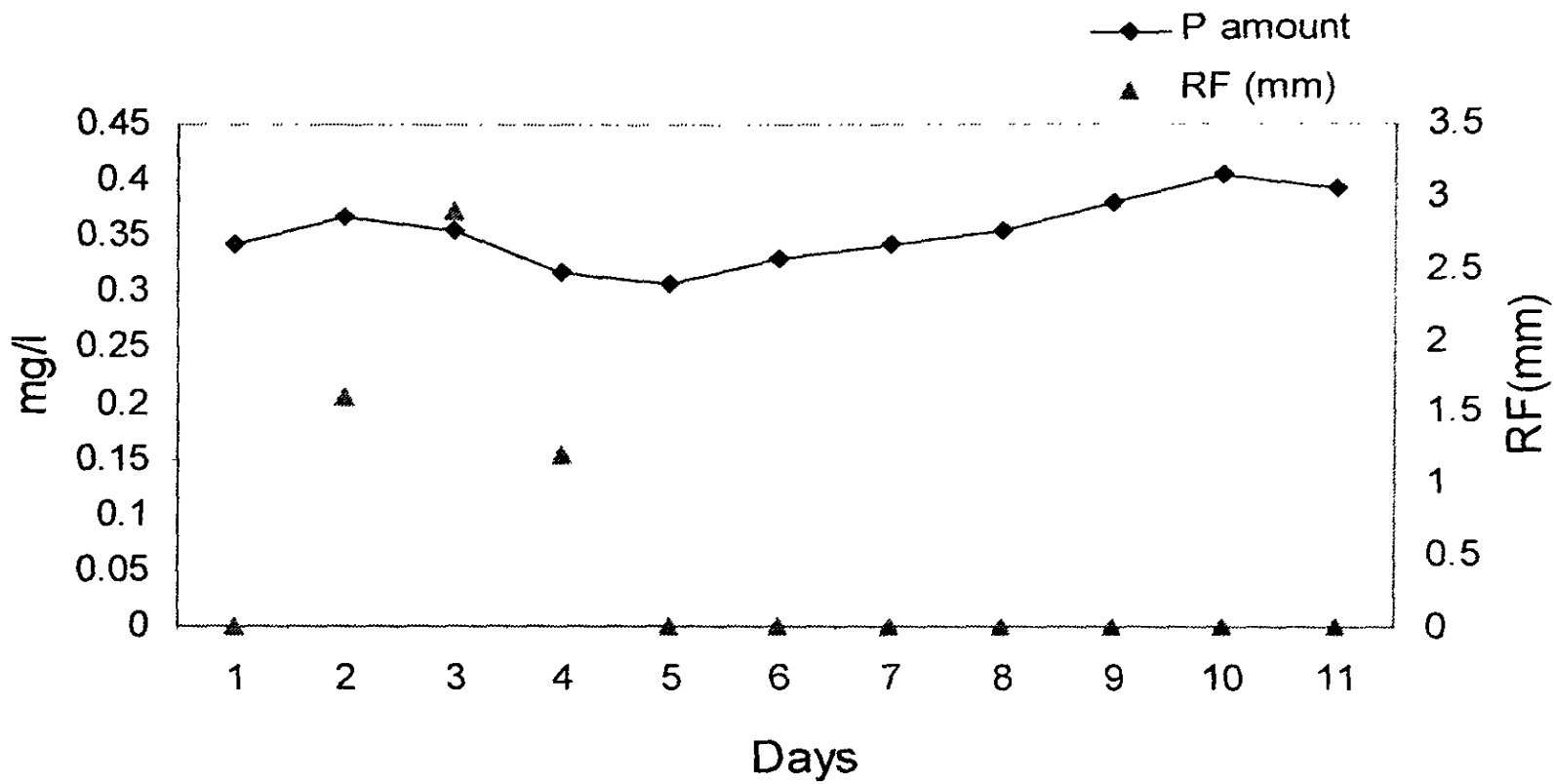


Figure 46: pH variation in biopurification unit with time

**Removal of chemical pollutants by the biopurification unit**

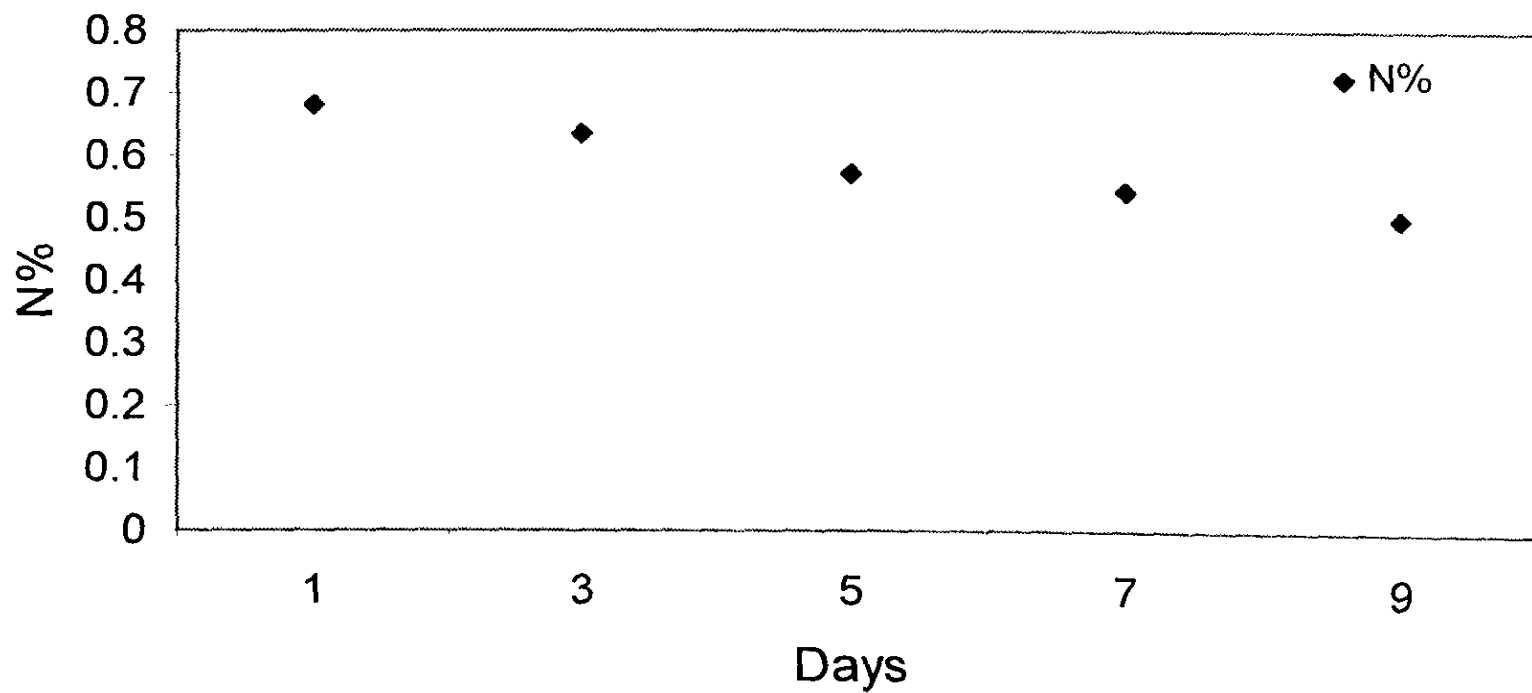
Phosphorus is present in wastewater as  $\text{HPO}_4^{2-}$ ,  $\text{H}_2\text{PO}_4^-$  and  $\text{PO}_4^{3-}$ . Orthophosphate is the form of phosphate that readily absorbed by plants. The Orthophosphate amount was fluctuated with the days (Figure 47).



**Figure 47:** Variation of Orthophosphate in biopurification unit

In the end of the experiment, the concentration of orthophosphate in water is increased. The activity of the microorganisms was high and rapid in that time period. Therefore, more and more orthophosphate was released to the water. During rainy days Orthophosphate was low.

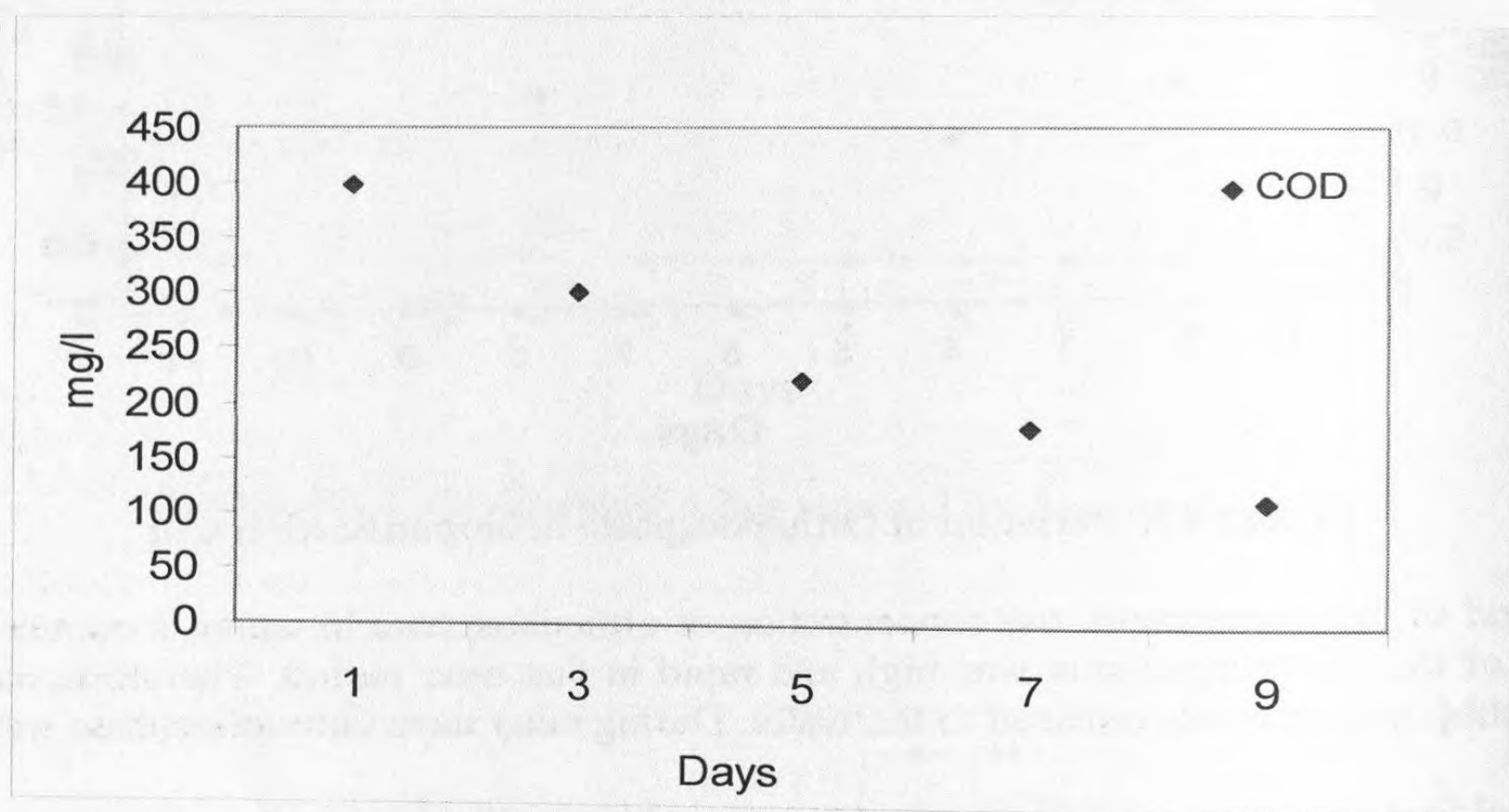
Total kjeldhal nitrogen variation in wastewater of biopurification unit is illustrated in the Figure 48. TKN % was reduced with the days. Initially, the TKN% was 0.68 and finally it was 0.50. Nitrogen is one of the major constituents for plant growth and also need for growth of the aquatic plants.



**Figure 48:** variation of TKN% in biopurification unit

The dissolved nitrogen was taken by the *Ipomea aquatica* for their growth. This is the reason for reduction of nitrogen in the effluent water. The microbial decomposition of organic matter is also added further nitrogen to the water.

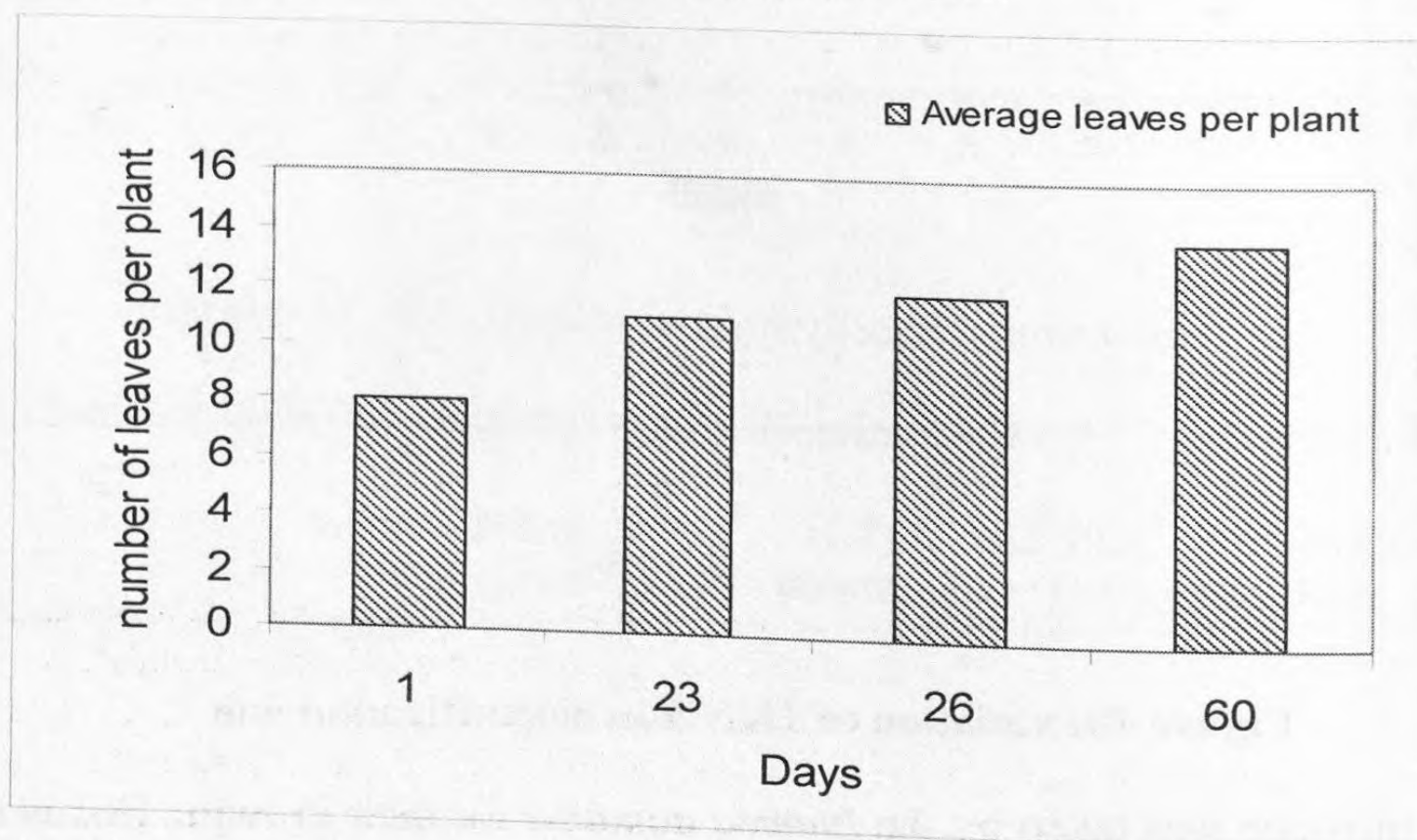
Chemical oxygen demand is a measurement of oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. Initially, COD of the effluent water was 398mg/l. After 9 days, it became 111mg/l. According to the environmental protection act, the maximum permissible limit of COD to release effluent water is 120mg/l. So, after 9 days the effluent water was purified and could be able to release to the environment (Figure 49).



**Figure 49:** Variation of COD in biopurification unit during study

#### Biomass production of aquatic plants during the study

Figure 50 shows the variation of average number of leaves per plant. Initially, the average number of leaves per plant was 8 and after 2 months it was 14 leaves per plant. So, there was a significant growth of *Ipomea aquatica* in the effluent water.



**Figure 50:** Average number of leaves per plant in aquatic plants in biopurification unit

Total dried weight of the *Ipomea aquatica* which used for the biopurification unit was 226 g and after two month period it was increased to 1119.3 g. It seems that plants absorbed the nutrients from the biopurification unit. Because of the high nutrient absorbance of the *Ipomeas*, the plants grew rapidly and vigorously in the effluent water. Therefore, it could be concluded that *Ipomea aquatica* as a good domestic wastewater purification macrophyte.

## **Conclusions**

The filtering unit, made up of mesh no.10 with a capacity of 200L is an appropriate filter to remove 45% of total solids (TS), 63% of total suspended solids (TSS) of the canteen effluent. However dissolved solid cannot be removed by the proposed filter. The total load of sludge enter to the canteen disposal system was ~ 543g per day and the proposed filtering unit is an efficient unit to remove the total sludge enters to the waste disposal system of the canteen.

The aquatic plant, *Ipomea aquatica* is an efficient macrophyte to remove TS, TSS, TDS, TKN, COD of the wastewater after 9 days. The filtering unit combined with the proposed biopurification unit is an efficient system to purify the canteen effluent of the Mapalana canteen by removing 93%, 98%, 23%, 72% of TS, TSS, TKN and COD, respectively. The proposed treatment system composed of filtering unit and biopurification unit can be used in small restaurants to purify wastewater to achieve a safe level for disposal to the natural environment. However, frequent maintenance of the filtering unit should be practiced to avoid the possible breakdown of the filtering unit and further studies are suggested to evaluate the treatment system for long term operations.

## **Study IV: Construction of a small scale sustainable wastewater treatment system for cafeteria using constructed wetland technology**

### **Introduction**

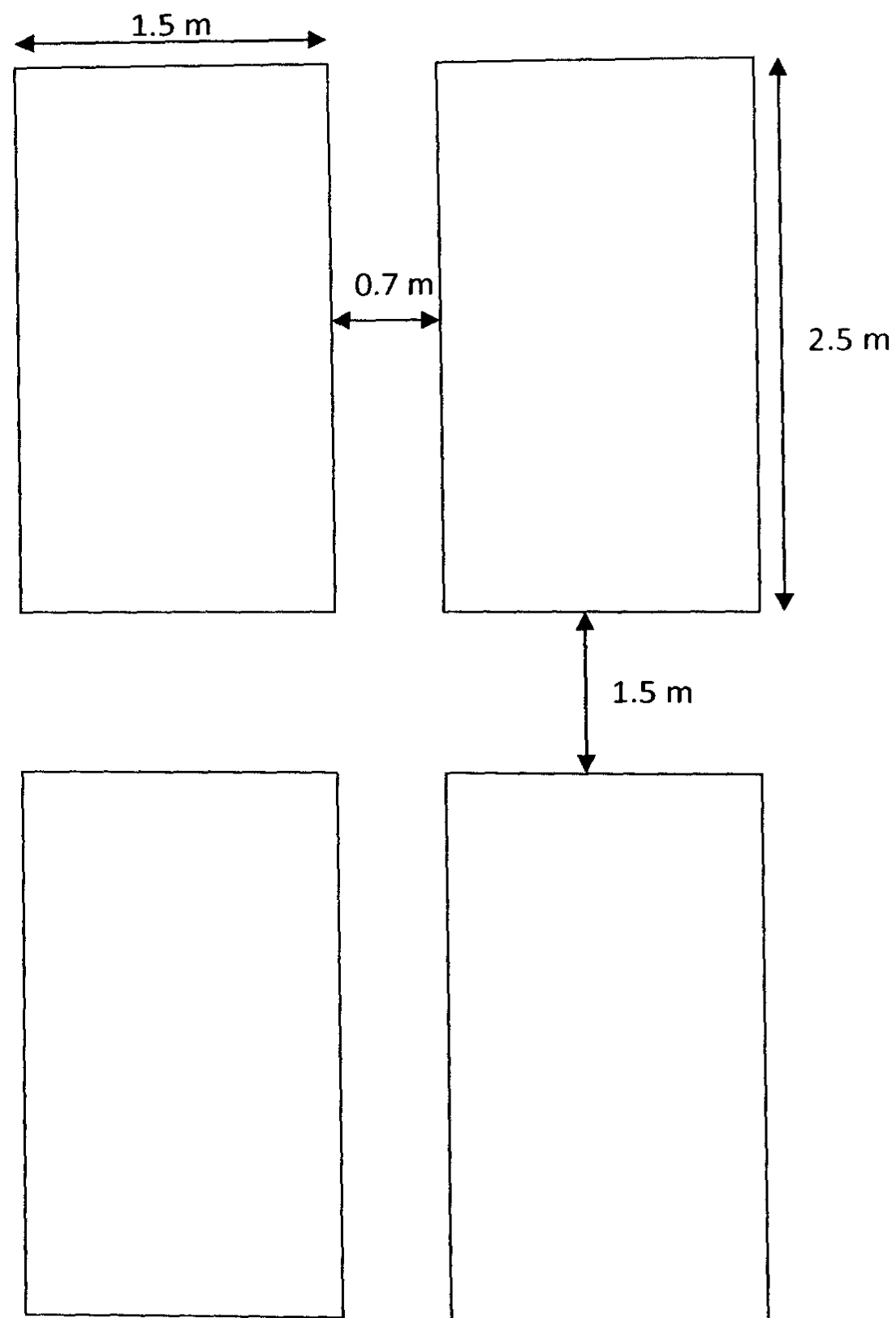
According to the results of the studies conducted to treat wastewater generated from cafeteria, it was found that aquatic plants, basically, water spinach, can easily be used for the treatment of cafeteria wastewater. However, only aquatic plants may not perform well for the removing of wastewater. Therefore, it is necessary to have a filtering unit where large particles can be removed from the wastewater.

### **Materials and methods**

The operation and maintenance of a separate filtering unit is somewhat difficult due to labor problems. Therefore, aggregate (Sand or gravel in different diameters) filtering system can easily be used for this purpose. The tank system, filled with sand in different diameters, can be used for the growing of aquatic plants.

The tank system should have a capacity to store reasonable amount of wastewater for quite some time for the biopurification. The tank system having the configurations shown in Figure 51 were constructed for the treatment of wastewater from the cafeteria. The depth of each tank is about 0.75 m. And the tanks were constructed using bricks and cements. The floors of the tanks were made using concrete. The provisions were made with regulation valves at the lower end of the first tanks to transfer the treated water to second tanks.

The tanks should have been filled with gravels and sand. It was planned to grow aquatic plants (water spinach) at the top of each tank.



**Figure 51:** Configuration of the designed and constructed treatment system

## Results and Discussion

The treatment tanks were partially constructed. However, it was unable to finish the tank system with gravels and sands due to unavailability of funds from the funding agency. At the same time, this study was abandoned and could not be completed.

## Conclusions

The study could not be completed.

### **Part III: Improvement of Technologies that can be used for Efficient Waste Management (Solid and Liquid) for Institutions**

The different types of waste materials are produced in the Faculty of Agriculture in various places such as farm, students' hostels, academic departments, etc. According to the results of the waste estimation study, food wastes are comparatively higher than other types of wastes. Therefore, it is necessary to have a proper disposal or treatment method for food wastes. The considerable amounts of wastes (animal excreta) are generated from the cattle and poultry sheds. During the processing of the broiler chickens in the farm, chicken offal is also generated. When addressing the solid waste problem in the faculty, it is necessary to give more attention those wastes also.

In considering the wastewater generation, the cafeteria of the faculty produced considerable amount of wastewater. The wastewater generated from other places of the faculty could be avoided due to less generation volume and the adoption of proper disposal methodologies.

For the purpose of improving the waste disposal technologies, several studies have been conducted to find the suitable technologies.

#### **Study I: Evaluation of different composting bins available in southern region for their performance for the production of quality composts**

##### **Introduction**

Composting of source-separated domestic organic solid waste is a method currently being used for the management of organic domestic waste and the production of organic manure by the Sri Lankans. It is suggested that compost bins could be used as decentralize degradable solid waste management technique for semi urban and urban communities where they have less space for their organic wastes disposal. Decentralization of compost production (at the site where waste generated) will result in less labor and lesser cost. It has been practiced as method for domestic organic solid waste management (Balasubramaniyan, 2004). Particularly, it is a solution for environmental sanitary problems and health hazards caused by open dumping of domestic garbage along road sides and dumping places. Different shapes of compost bins made of different materials are available in the market. Their performance evaluation with regard to composting process parameters has not been adequately reported. The objectives of this experiment were to evaluate the different parameters in the composing process in different compost bins currently available in Southern Province of Sri Lanka, and to find the comparatively most effective compost bin for kitchen waste composting.

##### **Methodology**

Four types of commercially available compost bins namely Concrete Box (CB), Plastic Cylindrical (PC), Plastic Conical (PCO), and Concrete Cylindrical (CC) were used for the experiment. Their physical characters were shown in (Table 3) and layout of the experiment is shown in Figure 52.

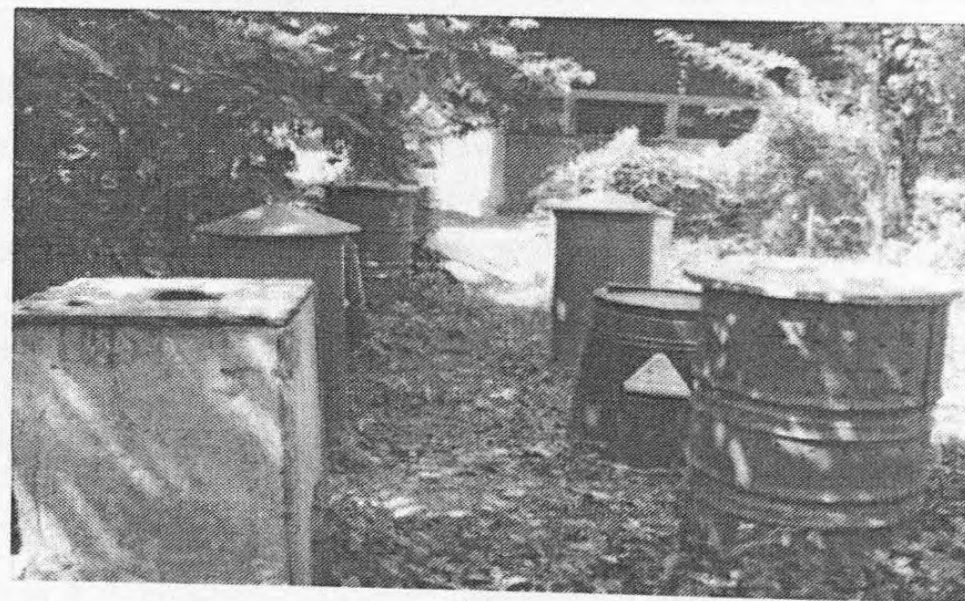
Research design (treatments) was completely randomized. Kitchen waste was used as main source of material and garden waste was also used as a supplement. The parameters shown in Table 4 were recorded during two month study period.

**Table 3:** Physical characters of compost bins

Type of Bin	Height/Diameter (Width) (mm)	Ventilation Holes (No)	Diameter of Ventilation hole (mm)	Area of Ventilation mm <sup>2</sup>
CB	925:600	-	-	-
PC	1020: 460	230	10	3.614x10 <sup>6</sup>
PCO	700:450 (Top) 700:690 (Bottom)	190	9	2.679 x10 <sup>6</sup>
CC	1850:520	174	13	3.549 x10 <sup>6</sup>

**Table 4:** Data recoding procedure

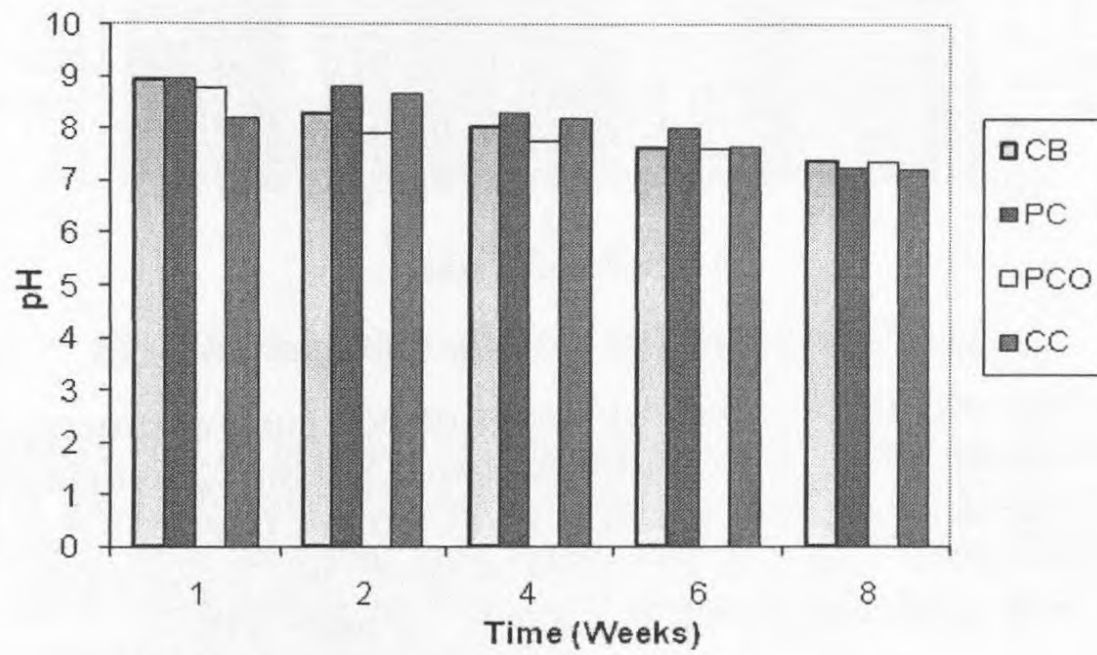
Parameter	Frequency	Method	Remark
Temperature	Daily	Thermocouple	Top, bottom & middle
pH	Weekly	Meter	Compost/water+CaCl <sub>2</sub> extract
EC	Weekly	Meter	1: 2 compost water extract
MC	Weekly	Oven Dry	
BD	Weekly	Oven Dry	
OM	Monthly	Muffle Furnace	
Ash content	Monthly	Muffle Furnace	
Nitrogen	Weekly	Kjeldhal Method	
Total Carbon	Monthly	Walkley and Black	

**Figure 52:** Different compost bins used for the study

## Results and Discussion

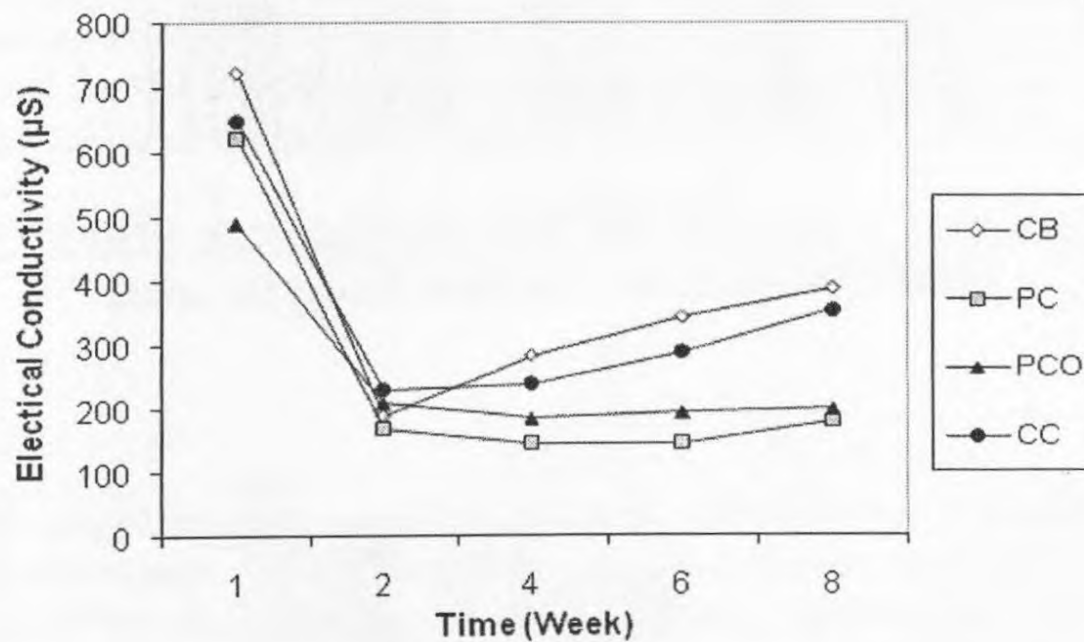
The composting process in the bin can be considered as a passive method in which raw materials are fed to top and decomposed materials are taken out from the bottom. In all composting bins temperature was relatively high particularly during the first week. Highest average temperature was reported in CB bin (34.64 °C) followed by CC bin (33.85 °C)

during the first week, when ambient temperature was 31 °C. Comparatively high temperature in CB bins may associate with lack of ventilation holes. Matured compost was dark brown in color, moderately sticky and no abnormal odor in CC shape bin and its particle size higher than 2 mm; while in PCO bins product was much sticky with bad odor. Compost of PCO was light brown in color with large particles with less stickiness. CB produced small particles, without odor and moderately sticky compost. The pH levels of four treatments were high.

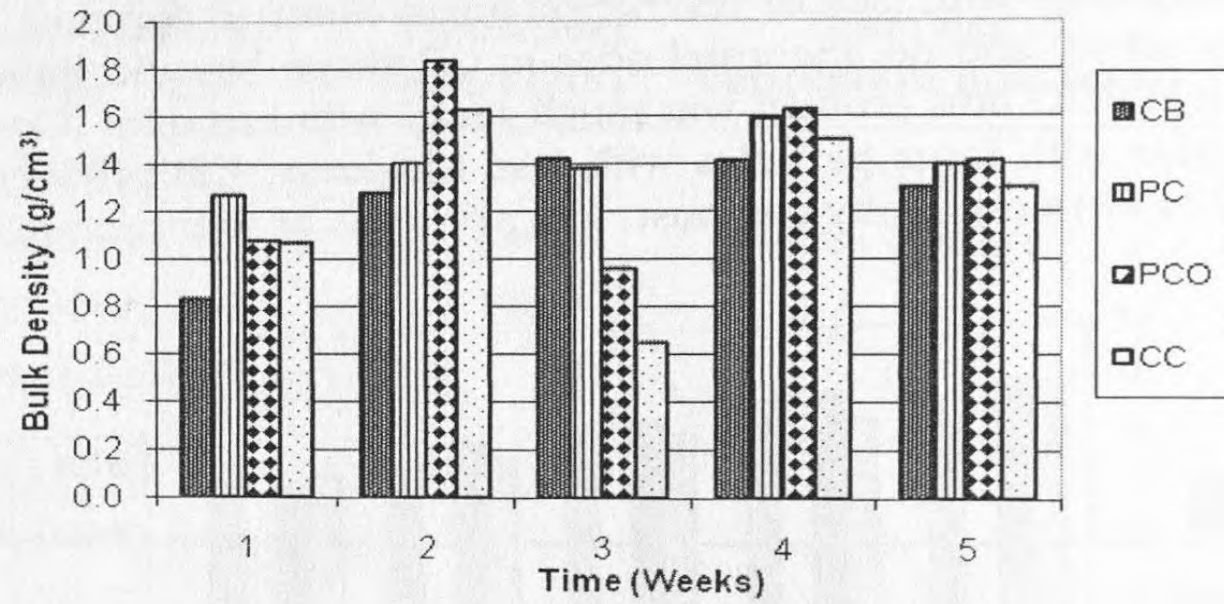


**Figure 53:** pH variation during the study

pH was reduced during the composting process, and it was close to pH 7 at the mature stage. pH of CB, PC, PCO and CC were 7.4, 7.25, 7.35 and 7.2, respectively, at the mature stage (Figure 53). Preferred pH range of compost is 6 to 7.5 (Gupta, 1999). pH of all four bins was within the acceptable range.

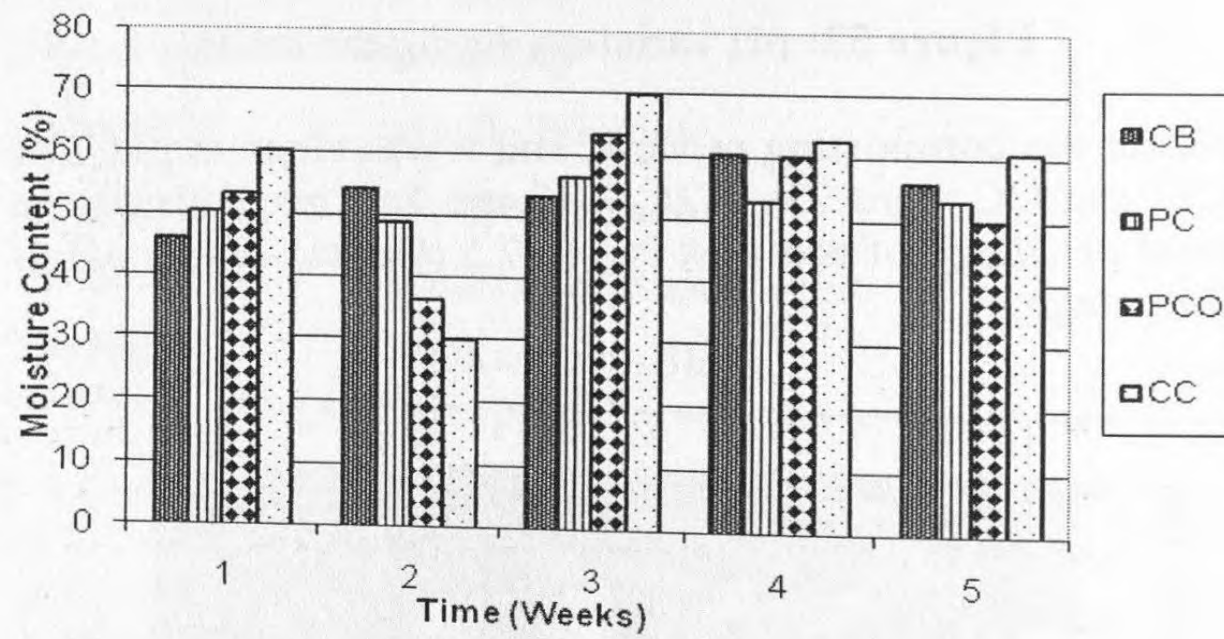


**Figure 54:** Variation of electrical conductivity

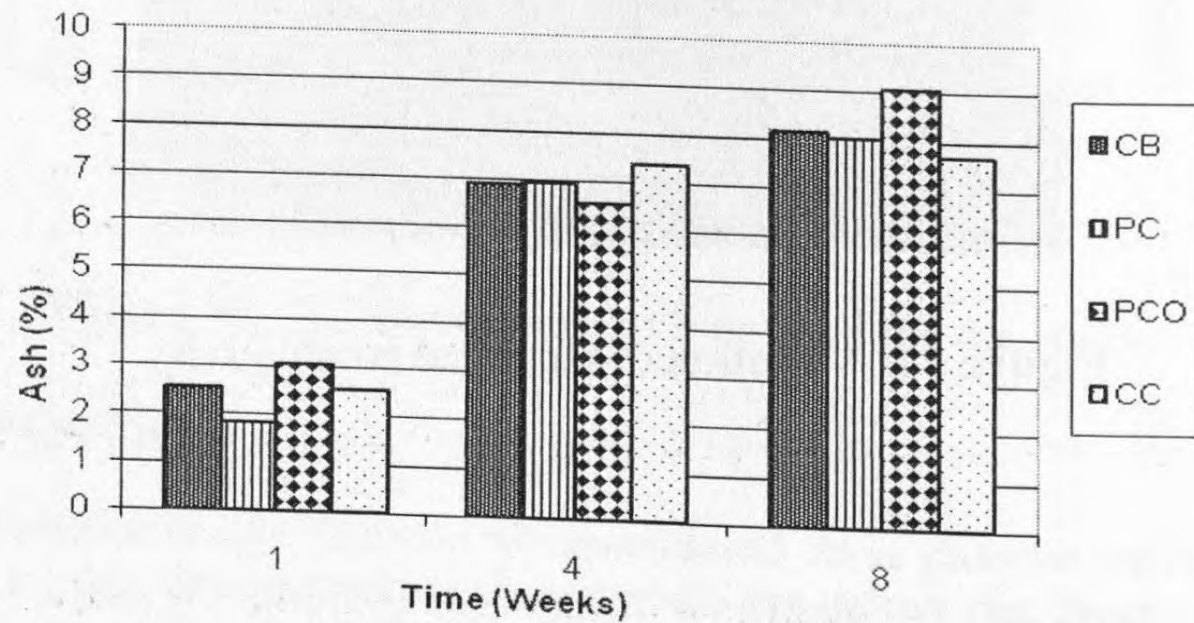


**Figure 55:** Bulk density during study

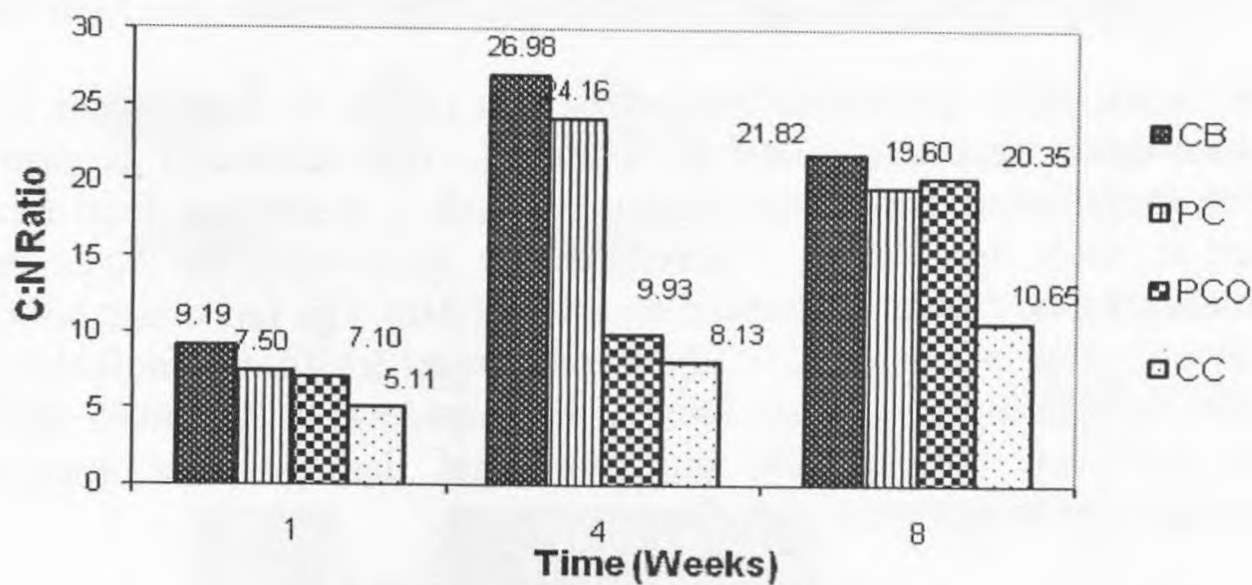
Electrical conductivity was high at the beginning of composting process, which was being reduced gradually over the time. If EC is lower than  $0.8 \text{ dSm}^{-1}$ , no deleterious effects could be found to crops (Gupta, 2004). EC of CB, CC, PC and PCO were  $3.9 \times 10^{-5} \text{ dSm}^{-1}$ ,  $3.55 \times 10^{-5} \text{ dSm}^{-1}$ ,  $1.8 \times 10^{-5} \text{ dSm}^{-1}$  and  $2 \times 10^{-5} \text{ dSm}^{-1}$  (Figure 54), respectively. At the end of 8<sup>th</sup> week, Bulk density was in the range of 1.2 -1.4  $\text{gcm}^{-3}$  (Figure 55).



**Figure 56:** Moisture variation during the study



**Figure 57:** Ash content of samples during study



**Fig. 58:** Variation of C/N ratio during composting

Organic matter content in CC bin and PC bin were 92.31 % and 91.94 %. Most vital in the compost making is the C: N ratio. CC bin showed the lowest C: N ratio in the end product (Figure 58). All other bins also had less than 1:30 of C: N ratio. During the composting process some of the N compounds are releasing to air as ammonia. It is a disadvantage and retention of N is important in compost making.

## Conclusions

According to the results, the concrete cylindrical bins has comparative advantages in composting of kitchen waste over other compost bins such as concrete box type bin, plastic cylindrical bin and plastic conical bin. With respect to the maintenance of an optimum C: N ratio, concrete cylindrical bins can be recommended for the use for composting kitchen wastes. In addition to those advantages, cylindrical concrete compost bins cannot be over turned animals such as stray dogs, monkeys, iguana, etc. Therefore, cylindrical concrete bin can be recommended for the production of compost using food wastes in home gardens (even rural home gardens) while managing the organic waste generated in the home.

## Study II: Use of aquatic macrophytes for the treatment of wastewater generated from cafeteria

### Introduction

The generation of wastewater in various human activities is a major problem for the degradation of environment which imposes serious threats to living beings. With the identifying the threat by wastewaters to living beings especially humans, the different technologies involving chemical, physical and biological principles, have been developed for the tackling the problem (Metcalf and Eddy, 2003). All the processes used for the treatment of wastewater have their own advantages, disadvantages and limitations in terms of costs, treatability and secondary environmental impacts in the application for the different types of wastewater.

Chemical, physical and biological treatment technologies together or individually can be used for the treatment of wastewater originated from various places. However, biological

treatment methods are more popular for the treatment of municipal waste waters while chemical and physical methods are used in industrial wastewaters.

In urban areas, wastewater generated from different places is diverted to a central location where the wastewater treatment plant is installed. The advanced technology and cost involved in the installation and maintenance of such a treatment facilities are the major negative forces to their application. Therefore, the application of large central treatment systems in developing countries is limited to urban cities. On the other hand, in rural areas, especially in developing countries, the advanced central treatment facilities are not feasible since wastewater generating points are located in considerable distances with the lower rate of generation; however, considerable environmental damages are apparent due to the releasing of wastewater to environment, directly.

The phytoremediation is an emerging technology which uses the direct living green plants for in-situ risk reduction for contaminated soil, sludges, sediments, and ground water, through removal, degradation, or containment of the contaminant (EPA, 2001). Since the phytoremediation is a natural process it does not pose the secondary environmental impacts and does not need to have higher installation and maintenance cost. The applications of this technology for various types of wastewaters have been reported (Margaret , 1997; Zhu and Zhu , 1998; Judith and Peddrick, 2004; Jones et al., 2006). However, the application of phytoremediation techniques, especially comparative evaluation, for the treatment of domestic wastewater was inadequately reported. Therefore the objective of this study was to evaluate the locally available wetland plants in Sri Lanka for the possible application of the treatment of domestic wastewater.

## **Material and Methods**

### **Aquatic macrophytes used for the study**

Four different aquatic plants namely, *Ipomoea aquatica* (IA), *Limnocharis flava* (LF), *Monochoria vaginalis* (MV) and *Colocasia spp* (CS) were used in this study. These plants are commonly found in water logged places in Sri Lanka. However, *Ipomoea aquatica* can be grown in uplands as well and it is used as a green vegetable.

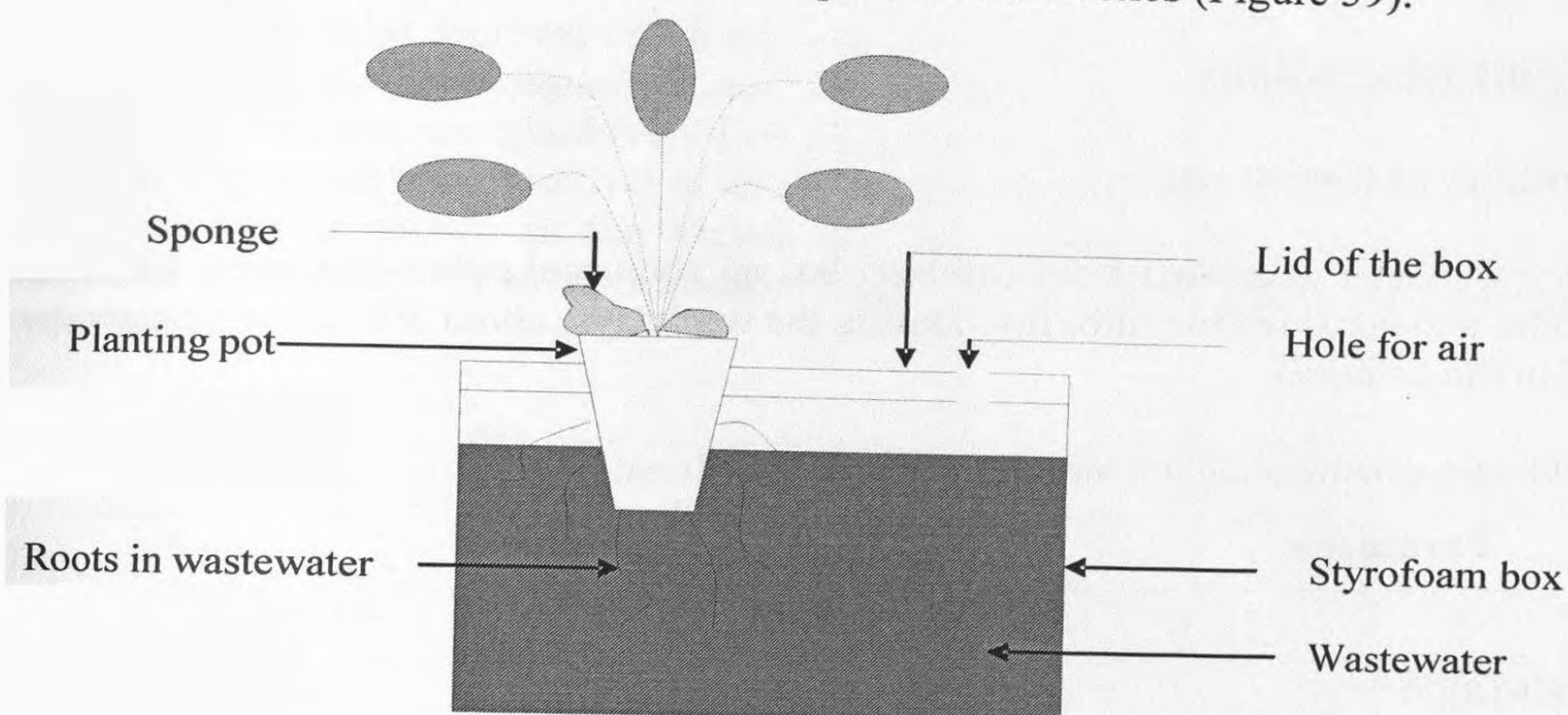
### **Preparation of experimental units**

Experiments were conducted according to root dipping technique used for the hydroponically grown crops. Styrofoam boxes having dimensions of 65 cm x 35 cm x 33 cm (75 L) were used as experimental units (Figure 59). Thick black polythene sheet was used to cover the inside of the box to avoid possible water leakages. A circular portion in the top of the cover of the box was removed to insert the plants and provide sufficient air movement into the boxes. The boxes were functioned as independent systems.

### **Preparation of macrophytes**

*Ipomoea aquatica* (IA), *Limnocharis flava* (LF), *Monochoria vaginalis* (MV) and *Colocasia spp* (CS) were collected from a wetland. Root systems of the selected small plants were washed to remove the soil particles and organic materials. Plants were weighted to 0.1 kg for each box and put them in the punched cups with the help of sponges. Cups were inserted into the boxes which were filled with fresh water in order to clean the roots of plants further. After

several days, boxes were filled with cafeteria wastewater filtered by a 3 mm x 3 mm pore sized mesh, and the cups with plants were placed in the boxes (Figure 59).



**Figure 59:** Schematic diagram of an experimental unit

### Layout of the experiment

The design of the experiment was a complete randomized design with five treatments (four with different macrophytes and one control unit without plants) and three replicates. Three boxes were kept as control without any macrophytes to find out the possible physicochemical removals of pollutants.

### Wastewater collection and experimental procedure

Wastewater was collected in the main drainage outlet from the cafeteria and removed the solid particle by filtering through a mesh having the pore sizes of 3 x 3 mm. After the analysis of chemical and physical properties of the wastewater, they were transferred to experimental units. Then, the wastewater samples from the each box were obtained after the thoroughly mixing for the analysis in two or three days intervals. Two runs of the experiment were practiced and the duration of the first and second run of the experiment was 14 and 10 days, respectively. At the first instance, plants were transferred to wastewater containing box and plants were kept in the boxes about one month to acclimatize the plants to cafeteria wastewater. Then, after removing of wastewater used for acclimatization, new wastewater was introduced to the boxes and first run of the experiment was conducted. Three weeks after first run, second run of the experiment was conducted for about 10 days. The treatment efficiency of the each experimental unit having plants was evaluated by the change of pollutants (chemical or physical parameters of the wastewater) in wastewater with the time.

### Wastewater analysis

The dissolved chemical oxygen demand (DCOD) was determined spectrometrically by digesting the sample in HATCH-DBR 200 (Hatch Company, Loveland, Colorado, USA) digester. Total solids (TS), total dissolved solids (TSS), Orthophosphate (OP) were determined according to the procedure outlined in the standard methods (APHA, 1985). Total Kjeldahl nitrogen (Organic Nitrogen and total Ammonia nitrogen) was determined by

Kjeldahl methods. Total dissolved solids (TDS), pH and electrical conductivity (EC) were measured using a portable meter (HI 9810, HANNA Instruments)

## Results and Discussions

### Characteristics of wastewater

The fresh wastewater generated from cafeteria has no abnormal color; however, wastewater had foul odor and considerable turbidity. During the weekdays, about 5-8 m<sup>3</sup> of wastewater is generated in the cafeteria.

**Table 5:** Physicochemical characteristics of canteen effluent

Parameter	Value	
	Min	Max
Total Solids (mg/L)	606.67±12	657.13±27
Total Suspended Solids (mg/L)	196.67±6	215.66±7
Total Dissolved Solids (mg/L)	192±23	296.67±17
pH	5.51±0.14	5.87±0.12
Orthophosphorous (mg/L)	0.38±0.07	0.41
Chemical Oxygen Demand (mg/L)	397.81±15	397.81±15
Total Kjeldhal Nitrogen (%)	0.648±0.03	0.648±0.03

Water used for the washing of food materials (vegetable, rice, meat, fish, etc) prior to cooking, the washing of cooking utensils, washing of hands and plates and cups are normally constituted the wastewater in the cafeteria. The physicochemical characteristics of the wastewater generated from cafeteria are given in the table 5.

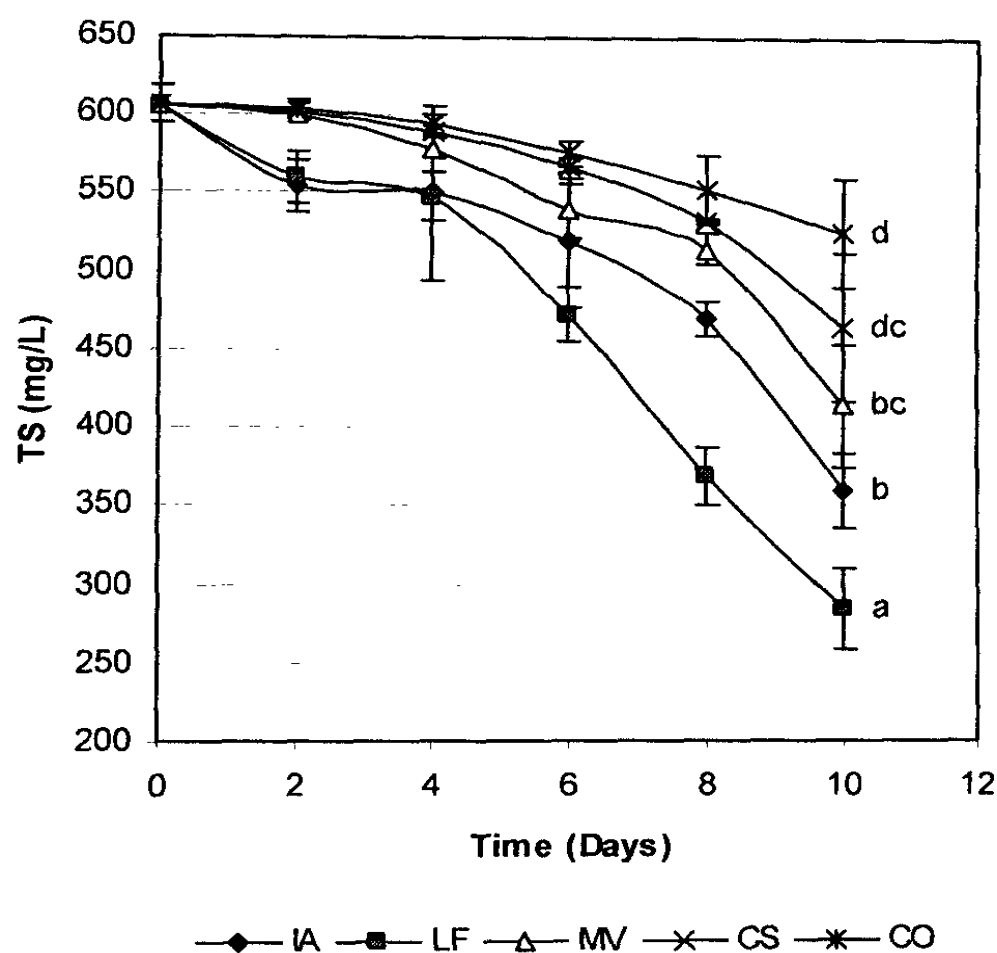
### Reduction of organic constituents in aquatic macrophytes systems

Organic constituents (pollutants) in wastewater can be found in two forms as aggregate organic compounds and individual organic compounds. Aggregate organic compounds in wastewater can be determined by the evaluation of TS, COD, BOD and TOC. The individual compound can be determined by using the Chromatographic methods such as GC, HPLC, GC-MS, etc.

In this study, organic compounds were determined in terms of TS, TSS, TDS and COD. The average TS removal observed in the first run of the experiment (14 days) were 47.58%, 41.39%, 33.15%, 28.93%, and 13.31% in *Limnocharis flava*, *Ipomoea aquatica*, *Monochoria vaginalis*, *Colocasia sp*, and control unit respectively. The highest TS removal (47.58 %) was observed in the *Limnocharis flava* system. However, final TS in wastewater kept under *Limnocharis flava* unit was still quite high and it was reported as ~344 mg/L while TS in control unit without any macrophytes was 570 mg/L. The reduction of TS in the second run of the experiment is shown in Figure 60. It was apparent that the highest TS removal was occurred in *Limnocharis flava* unit (53.16%) and it was significantly different at 5% probability level (Figure 2). Duncan's Multiple Range Test was used for the analysis of

variance in TS, TSS and TDS. The results are shown in the respective Figures (Figure 60, 61 and 62).

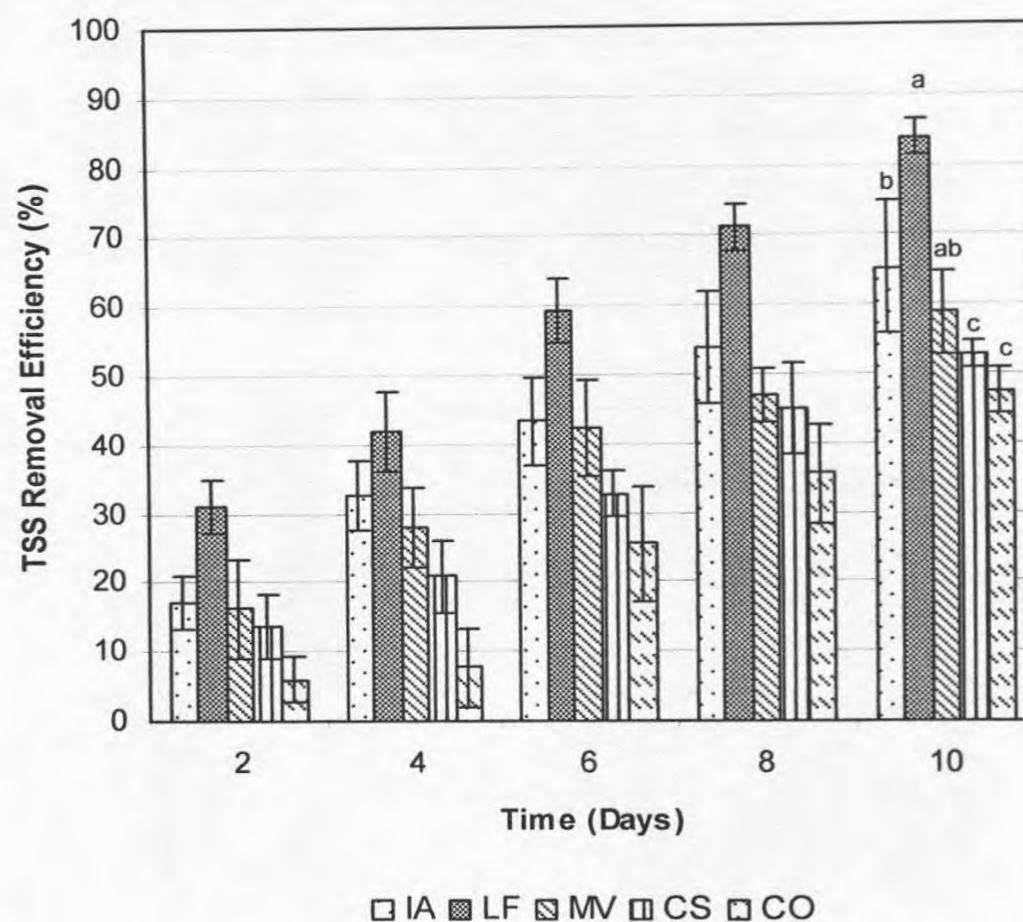
Total suspended solid removal efficiency was also highest in the *Limnocharis flava* unit and slightly less in *Ipomoea aquatica* unit. In the first run of the experiment the removal efficiency (73%) was comparatively low compare to the second run of the experiment (84 %). Total suspended solid removal of all the aquatic macrophytes system in the second run of the experiment is shown in the Figure 61. It confirmed that the removal of TSS in *Limnocharis flava* unit was significantly higher (at 5% probability) compare to the other systems.



**Figure 60:** Reduction in TS in the second run of the experiment

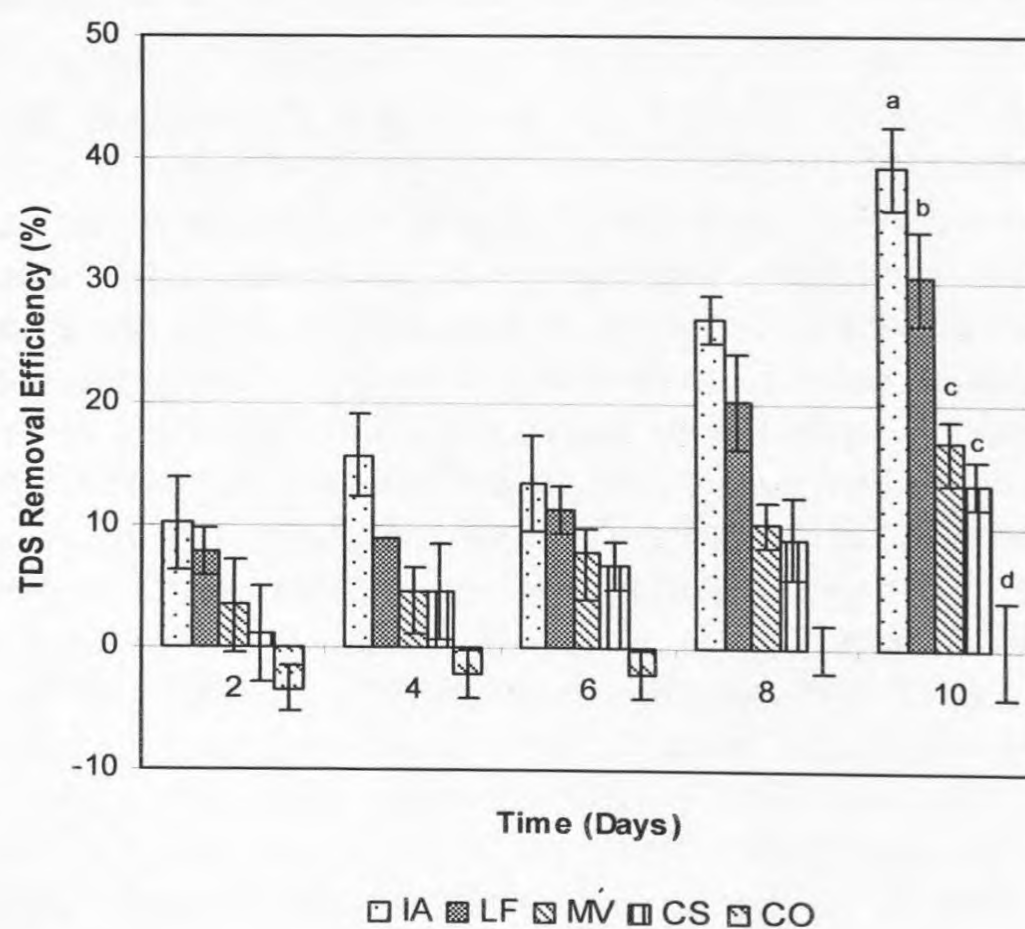
Even though higher TS and TSS removals were observed in aquatic macrophytes system having *Limnocharis flava*, the TDS removal was high in the system with *Ipomoea aquatica* in both runs of the experiments. In the control without macrophytes showed negative or zero TDS removals (Figure 62). This is probably due to the dissolving of solids by the microbial activities which results to increase the TDS in experimental units. The significantly higher removal of TDS can be seen in the system with *Limnocharis flava* and *Ipomoea aquatica* macrophytes. With respect to DCOD removal efficiency, the aquatic plant systems exhibited higher removal efficiency compared to the control. The dissolved chemical oxygen demand removal efficiency was highest in the system *Limnocharis flava* (68.39%). According to the statistical analysis, DCOD removal by *Limnocharis flava* and *Ipomoea aquatica* were no significant difference (Figure 63). Aggregate organic compounds represented by TS, TSS, TDS and DCOD could be removed by the physicochemical and biological processes occurred in the wastewater systems having aquatic macrophytes. The most of the macrophytes cannot directly assimilate and utilize the most of the organic compounds, especially large molecular organic compounds (Zhu and Zhu, 1998). However, microbes attached to well-developed root system of aquatic macrophytes can utilize the organic compounds in wastewater; eventually, plants are able to utilize the dissolved compounds easily as the nutrients. At same time, roots offer the expanded adhesive base for microorganisms and results in the formation

of a mutual beneficial sub-system based on the coordinated and additive effects between them (Zhu and Zhu, 1998).



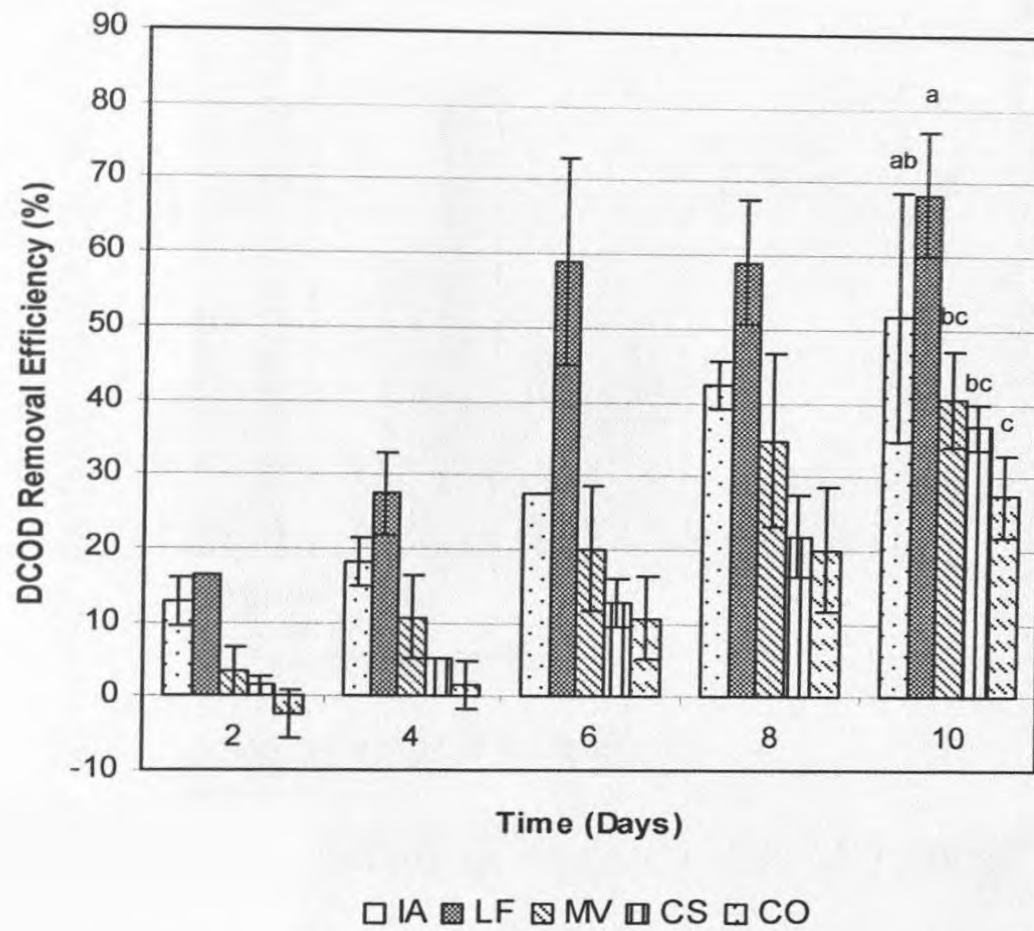
**Figure 61:** TSS removal efficiency during the second run of the experiment

It is apparent that by the reduction of TSS, TS, TDS and COD in control units, the microbes in wastewater perform a major role in reduction of organic compounds. Köner et al. (1998) reported that their study with duckweeds (*Lemna gibba* L) for the removal of COD in domestic wastewater reduced significantly after destroying the bacteria with antibiotics or sterilization (Köner, 1998). Therefore, it is clear that well-developed root system can play a vital role for the removing of organic compounds in wastewater.



**Figure 62:** TDS reduction during the second run of the experiment

Solid trapping by plant roots and sedimentation are the major physical solid removal processes. Anaerobic or facultative microbes living in the bottom of the system in low oxygen condition degrade the sedimented organic compounds by utilizing them as an energy sources, consequently, releasing nutrient assimilates by the macrophytes.

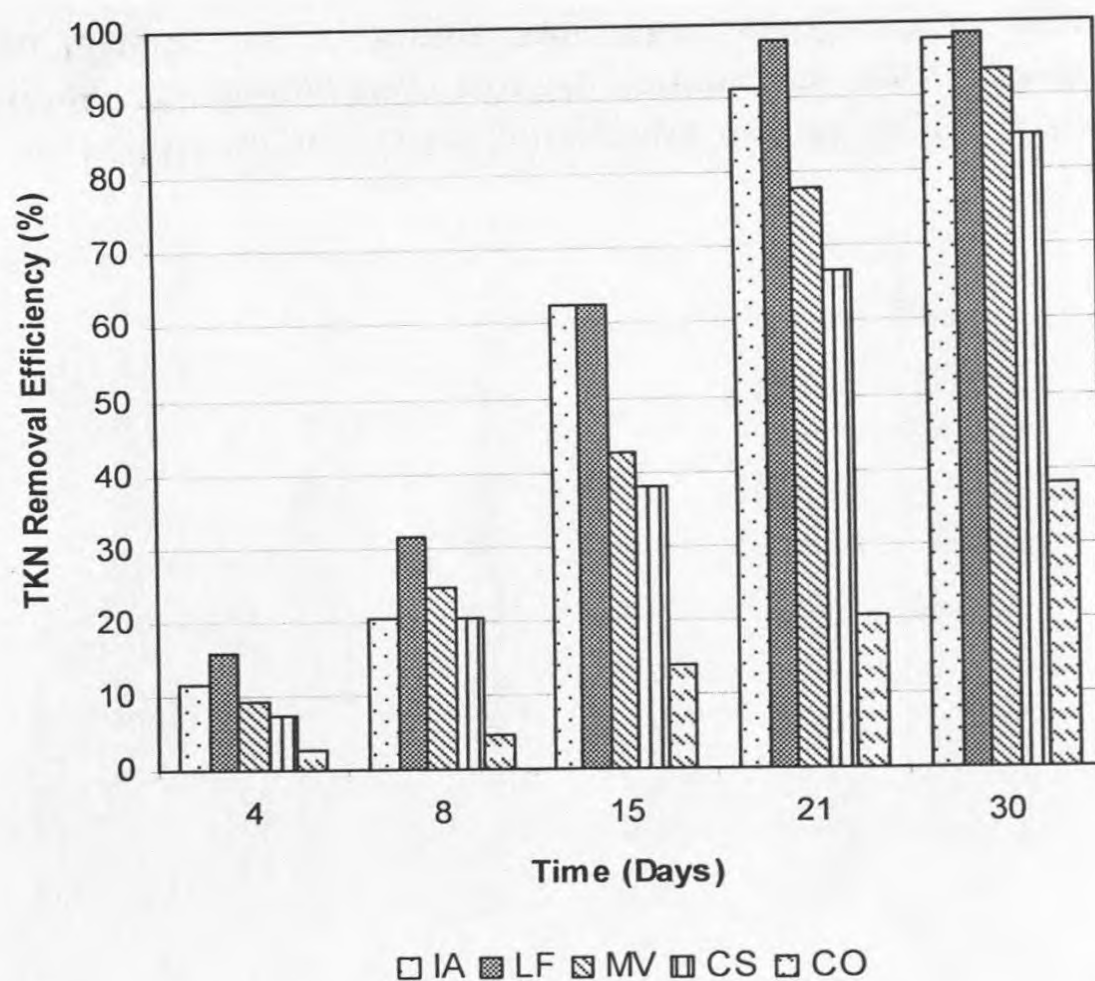


**Figure 63:** DCOD removal efficiency during the second run of the experiment

### Reduction of total Kjeldahl nitrogen

The different forms of Nitrogen namely organic, ammonium, ammonia, nitrate and nitrite are found in wastewater. With the activity of microbes, the organic nitrogenous organic compounds are converted to final stable compound, nitrate (Metcalf and Eddy, 2003). It is assumed that the fresh domestic wastewater does not contain inorganic forms of nitrogen. Total Kjeldahl nitrogen represents all nitrogen form except nitrite and nitrate. Total Kjeldahl nitrogen removal during 30 days of study period is shown in Figure 64.

Within 30 days of the experiment almost all the TKN had been removed by the macrophytes. Total Kjeldahl nitrogen removal efficiency in the control unit was 38.12%. Total Kjeldahl nitrogen removal was quite a low process with compared to removal of organic compounds. This is basically due to the slow growth of microbes that assimilate the nitrogenous organic compounds. With the increase of bacteria population, the TKN nitrogen removal was increased and almost all TKN was removed after 30 days. The system with *Limnocharis flava* and *Ipomoea aquatica* removed more than 60 % of TKN within 15 days and more than 90 % was removed within 20 days (Figure 64). It is apparent that *Limnocharis flava* and *Ipomoea aquatica* perform well with regards to the removal of nitrogen. The higher nitrogen removal obtained in this study is agreed with the results by Miao et al., (2007) with *Ipomoea aquatic* (Miao et al, 2007).



**Figure 64:** TKN removals in different aquatic systems

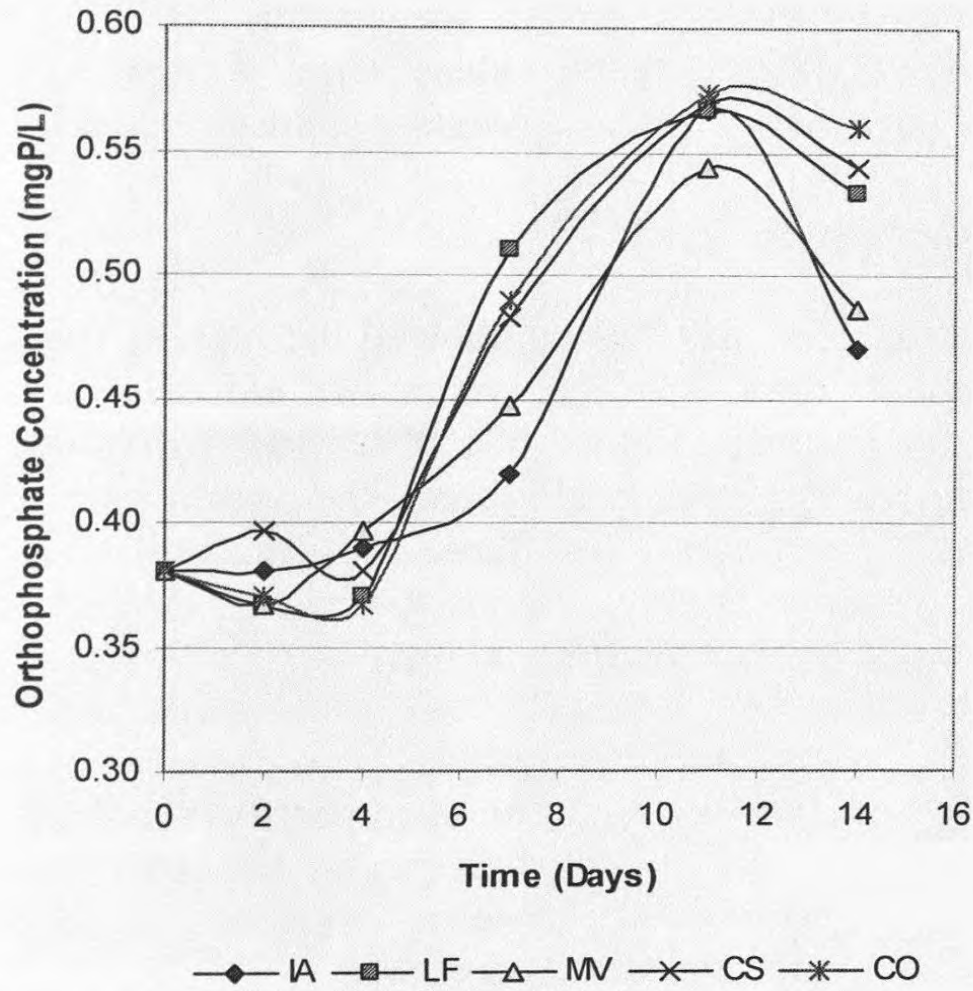
### Phosphate removal in wastewater

Phosphorus can be found in wastewater as orthophosphate and polyphosphate. Orthophosphate is the form of phosphate that readily absorbed by plants. Orthophosphate in wastewater can be found as  $\text{HPO}_4^{2-}$ ,  $\text{H}_2\text{PO}_4^-$  and  $\text{PO}_4^{3-}$ . Orthophosphate in cafeteria wastewater used for the study was comparatively lower than the reported values (Köner et al, 1998; Stephen, 2004). The types of detergent used in washing and types of foods may influence the concentration of phosphorus in wastewater. Orthophosphate concentration in the first run of the experiment is shown in Figure 65. It seems that the polyphosphate present in wastewater had been converted to OP by microbial activities during the course of the experiment resulting the increased of OP in all experimental units even in the control unit which do not have any macrophytes. In the second run of the experiment, it was found that OP concentration was not considerably changed. This phenomenon could be occurred due to the utilization of OP, which was converted from polyphosphate by microorganisms, by macrophytes. However, orthophosphate removals by aquatic macrophytes were comparatively very low. Quite similar study conducted by Seni and Jara (1995) reported that *Ipomoea aquatica* grown in a tank removed the DCOD and TSS considerably over facultative ponds (Seni and Jara 1995). However, they further reported that total phosphorous removal by *Ipomoea aquatica* was quite low and considered to be insignificant.

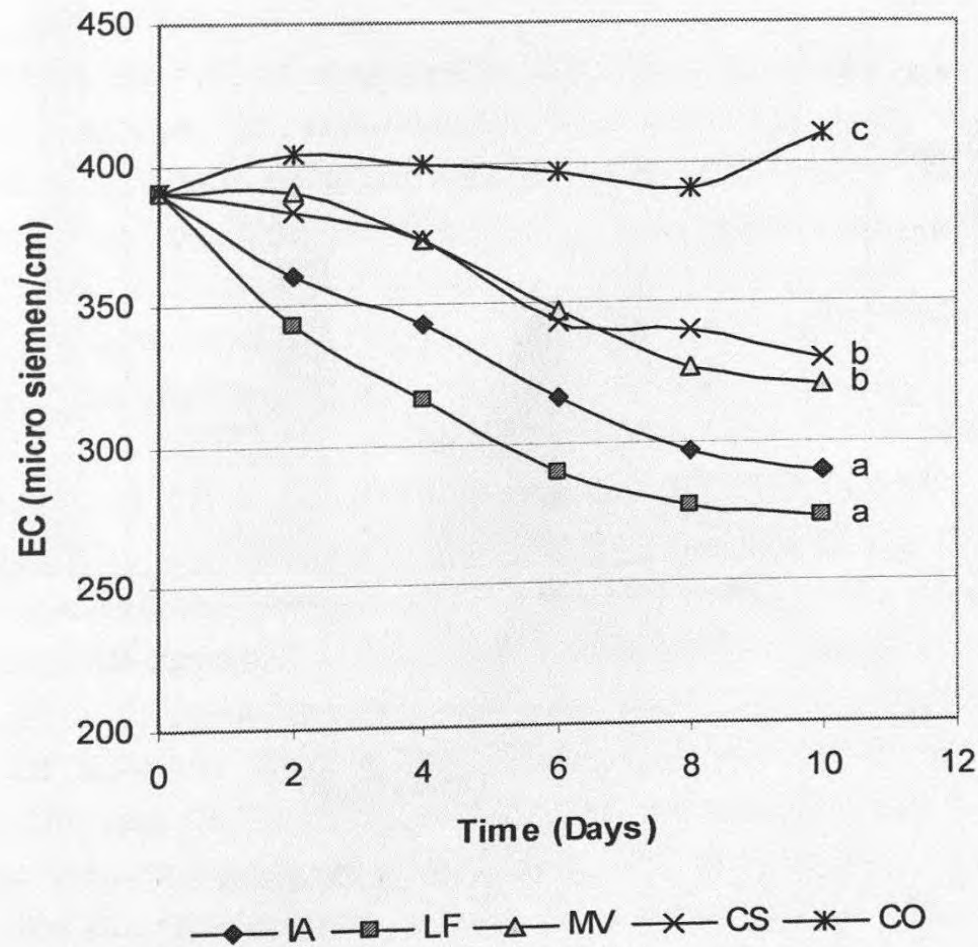
### Electrical conductivity variation in different aquatic systems

The reduction of EC in cafeteria wastewater used for the study with macrophytes was observed in all the experimental systems. The electrical conductivity of cafeteria wastewater used in the first run was  $416\mu\text{s}/\text{cm}$  and it was reduced considerably (during 14 days) in all treatment units having macrophytes, while EC of control without macrophytes was observed to be increased. In the treatment units with macrophytes, the EC may reduce due to utilization of soluble degraded product by the macrophytes. In the second run of the experiment, the

reduction of EC in macrophytes systems was comparatively higher than the first run. However, highest reduction of EC was observed in the system with *Limnocharis flava* followed by *Ipomoea aquatica* system. No significant difference (at 5% probability) in reduction of EC in macrophytes systems with *Limnocharis flava* and *Ipomoea aquatica* were observed (Figure 66).



**Figure 65:** Orthophosphate concentration in the first run of the experiment



**Figure 66:** EC variation during the second run of the experiment

### pH variation during study

The average pH during the both runs of the experiment was slightly increased in all aquatic plant systems and the control. The pH was initially increased from 5.5-6.5. The rise of pH is basically attributed to the biochemical processes (Cooper et al, 1996). Plants can absorb anions such as  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ,  $\text{PO}_4^{3-}$ , etc., for their growth and, eventually, the reduction of acid forming anions result to increase the pH in wastewater. The pH in treatment units during study varied in between 5.4 and 6.6, no values below 4 or above 9.5, which the most of bacteria cannot be tolerated, was observed (Metcalf and Eddy, 2003).

### Weight gain of aquatic macrophytes

The treatment unit with *Limnocharis flava* showed the highest final fresh weight (716.67g) than others at end of the 47 days. The final weight of *Colocasia sp.* was comparatively lower than other macrophytes systems (Figure 67). After stabilizing the plants to the cafeteria wastewater and developing the good root system, the weight gain was higher in the second run of the experiment. The well developed dense and elongated roots system was observed in wastewater treatment system with *Limnocharis flava* and *Ipomoea aquatica* while very poor root system was developed in *Colocasia sp.* (Figure 68).

The nutrient deficiency symptoms of macrophytes were observed at the end of the first run of the experiment. Nitrogen deficiency could be observed mainly because all most all nitrogen was absorbed by plants at the end of the first run of the experiment. During the period of second run of the experiment above symptoms were evaded, however, at the end of the second run the deficiency symptoms were reappeared.

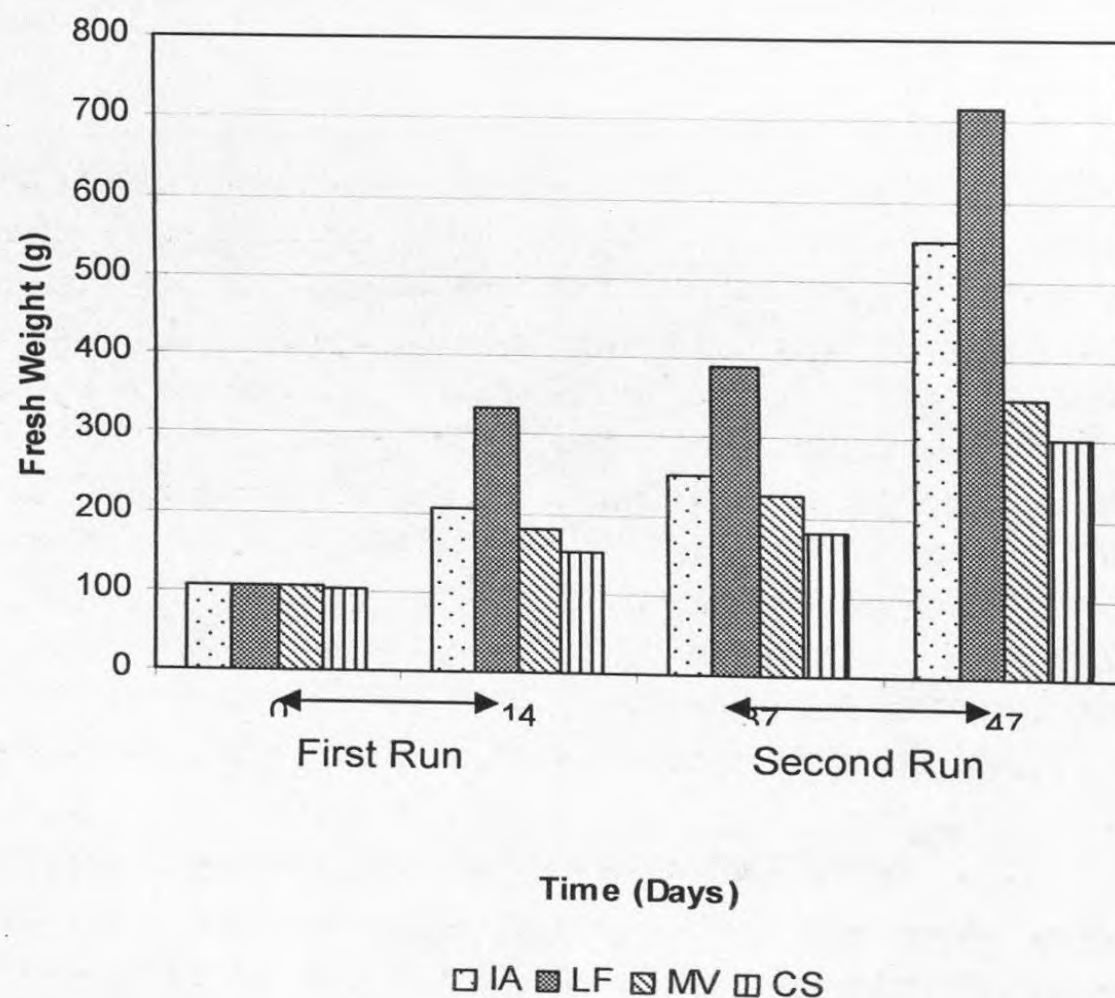
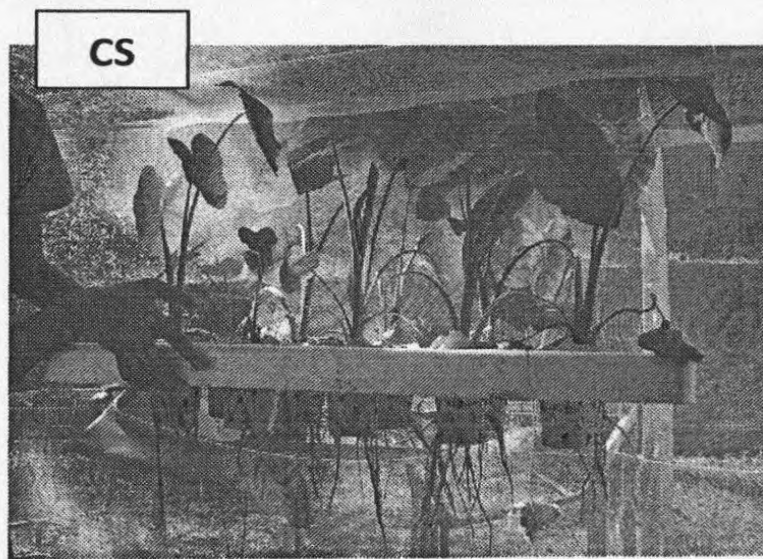
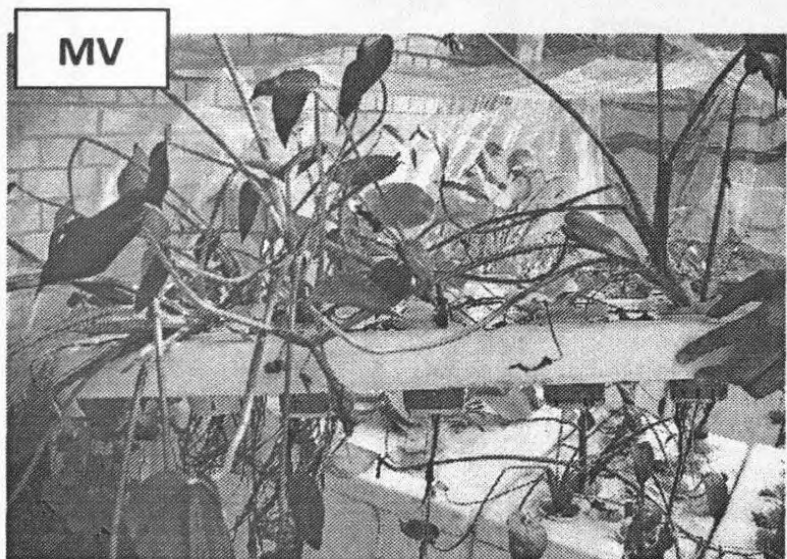
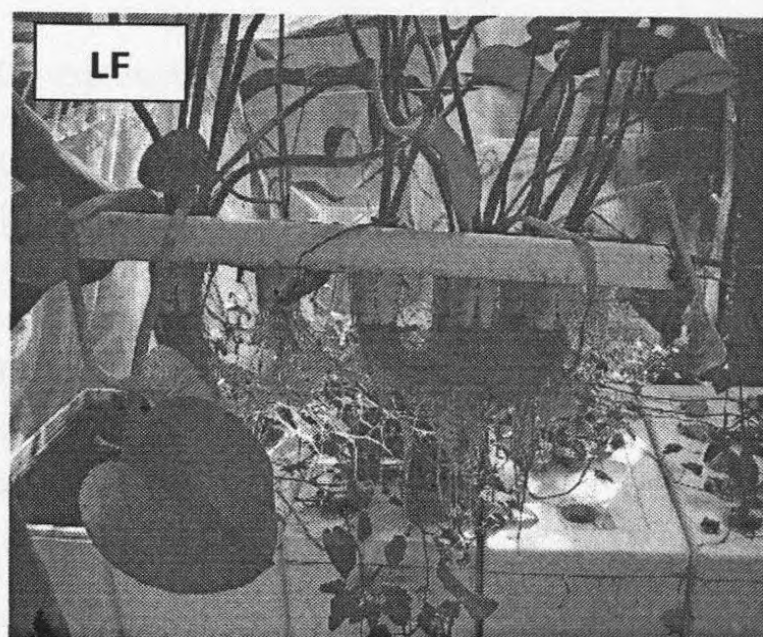


Figure 67: Weight gain by the different aquatic macrophytes



**Figure 68:** Root system of *Ipomoea aquatica* (IA), *Limnocharis flava* (LF), *Monochoria vaginalis* (MV) and *Colocasia sp* (CS)

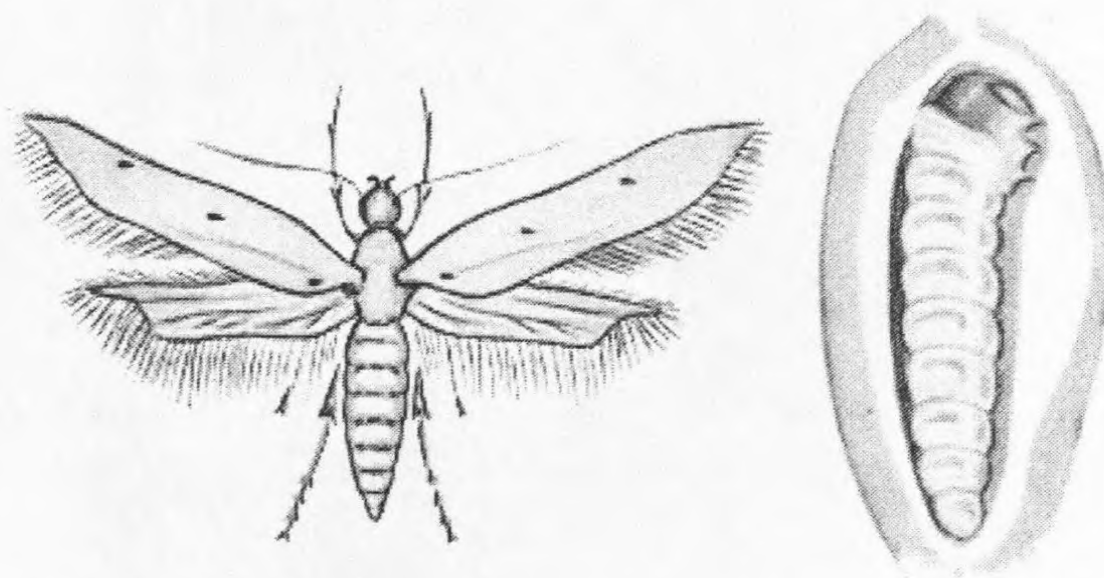
## Conclusions

The aquatic macrophytes can reduce aggregate organic compounds such as COD, TS, TSS and TDS, in different degrees, in wastewater. The systems with *Limnocharis flava* can successfully reduce the aggregate organic compounds over other macrophytes used in the study. Based on the results obtained in this study, it appears that microbes in wastewater perform a vital role for the releasing of nutrient to the wastewater by utilizing the organic compounds for their growth and development. The macrophytes, which showed good performances with regard to pollutant removal, had a well developed, elongated, dense root system, which facilitate the microbes to colonize well to form satisfactory habitat for their growth and development. Eventually, the benefits of degradation product of organic compounds can be used by the aquatic macrophytes to their growth and development. Therefore, it can be concluded that microbes as well as macrophytes, together, performs great role to purify the polluted wastewater. The phytoremediation systems with *Limnocharis flava* and *Ipomoea aquatica* after developing a good root system have a high potential to reduce the pollutants in cafeteria or kitchen wastewater. Since the low cost, environmentally friendly and simple technology, the use of macrophytes for the remediation of domestic wastewater is a promising technology which could be adopted by the developing countries where limited resources are available for the installation of high tech treatment plants.

## Study III: The use of biogas for pest control in cereals and pulses

### Introduction

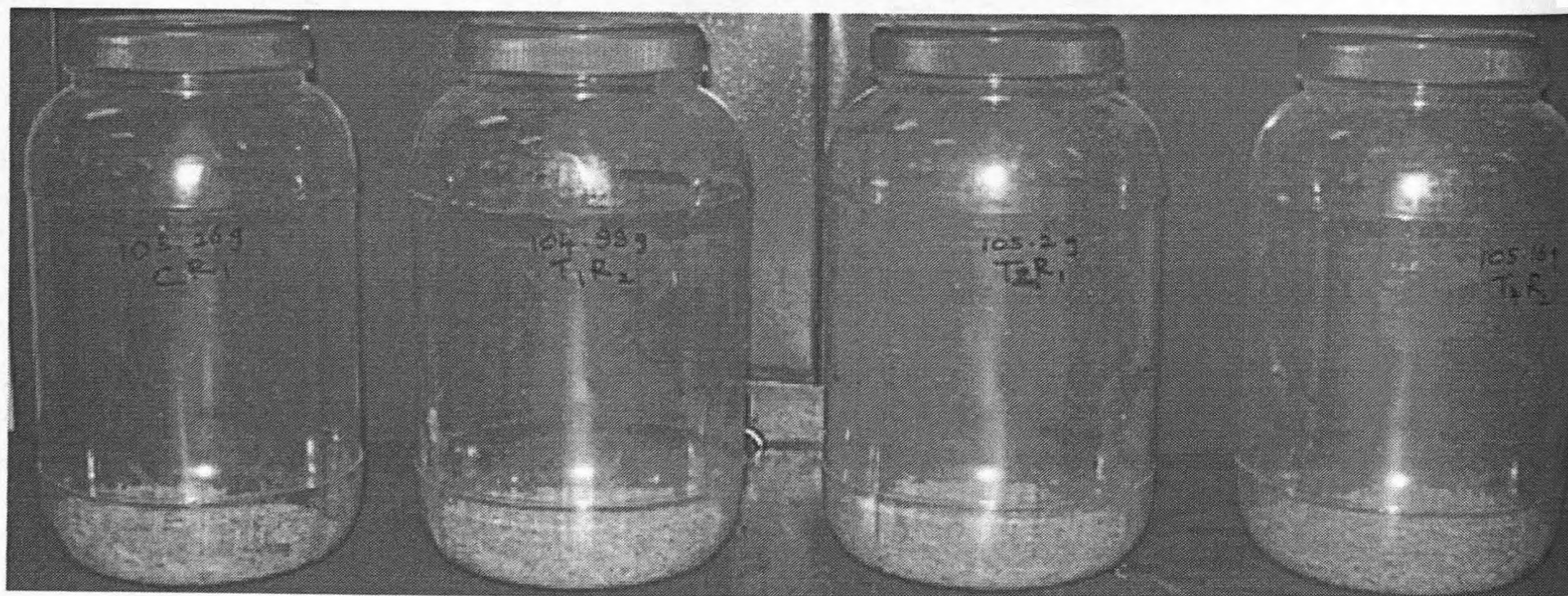
In Sri Lanka 4 to 6 % of harvested paddy is lost during storage due to pest attack. Angoumois grain moth, *Sitotroga cerealella* (Oliv), (Lepidoptera: Gelechiidae) (Figure 69) is considered as the major culprit for storage losses in paddy in many parts of Sri Lanka. Both adult and larvae damage the grain paddy in storage condition as well as in the field. This experiment was performed to evaluate the biogas as a pest controlling agent in grain paddy for Angoumois grain moth in storage conditions. The basic objective of the research was to find the capability of biogas to control the Angoumois grain moth in stored paddy as a fumigant.



**Figure 69:** Adult insect and Larvae *Sitotroga cerealella* (Oliv)

### Materials and Methods

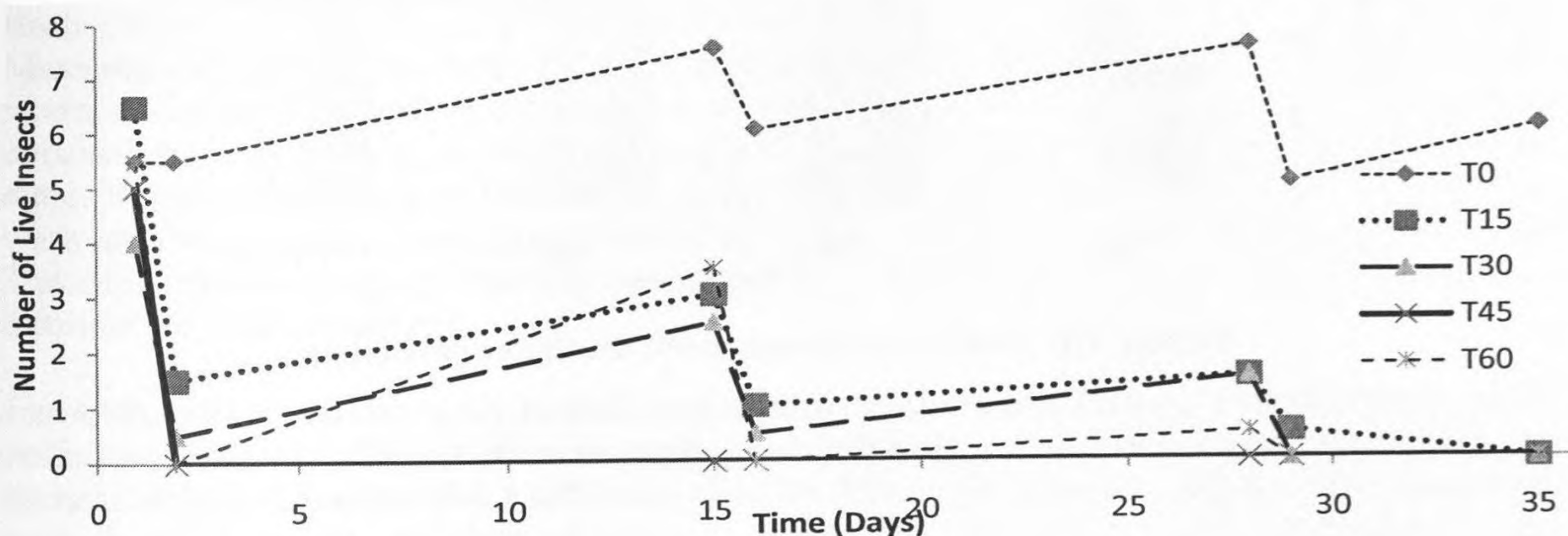
Infested stored paddy samples by Angoumois grain moth were taken into air tight plastic containers (Figure 70) and treated with biogas using syringe in different time intervals of 15 minutes, 30 minutes, 45 minutes and 60 minutes with three replicates and treatments were repeated 3 times within 4 weeks. Each replicate contain 1 kg of stored paddy. The number of adult moths was counted before application of biogas. The number of dead insects was counted after 24 hours of application. The application rates of biogas for each treatment were also measured. The methane % of biogas was also determined using portable methane meter.



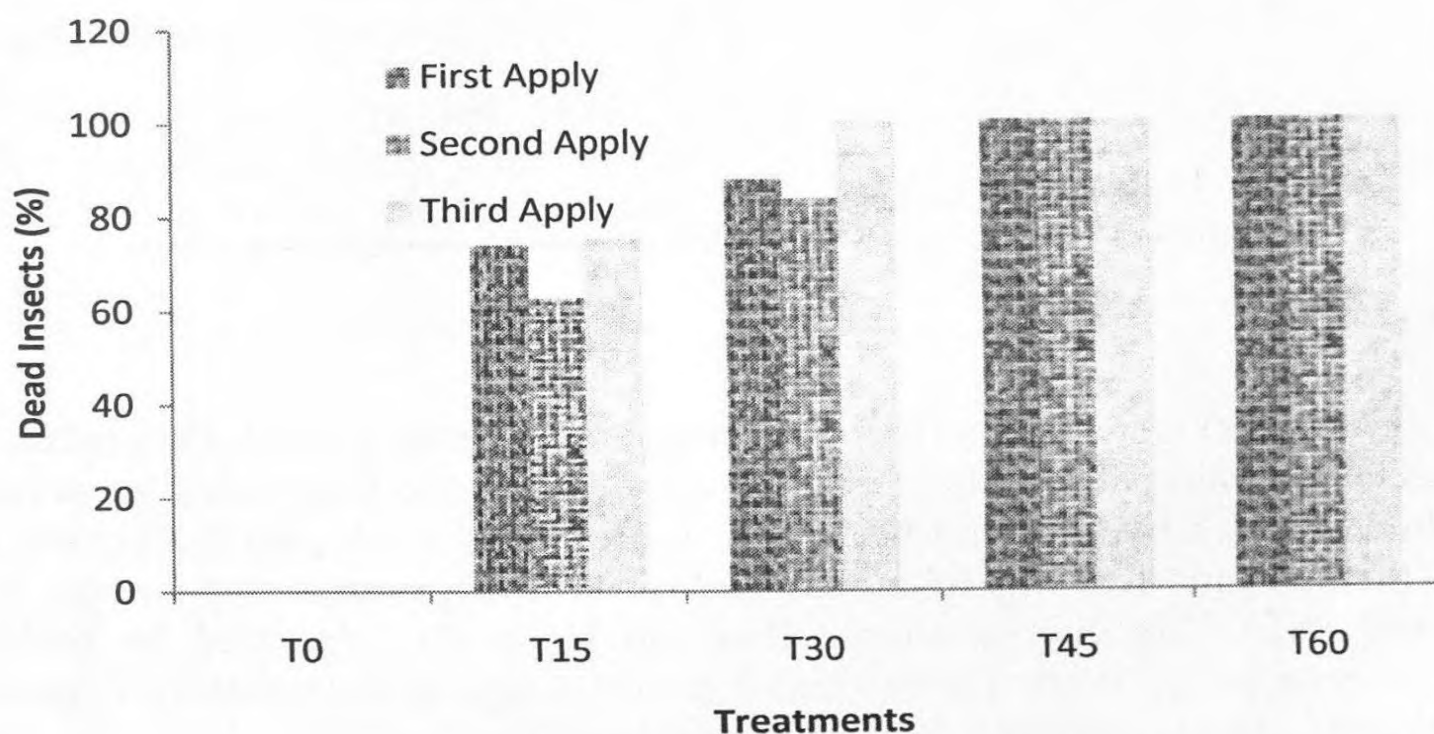
**Figure 70:** Experimental Units

## Results and Discussion

The average number of live insects after the first application (15 minutes) was 6.5 and it was decreased into 3 and 0.5 in second and third applications respectively (Figure 71). The percentage of dead insects were 100 % in third (45 minutes) and fourth treatments (60 minutes) in one application. It was 75 % in first treatment (15 minutes). The percentage of dead insects was varied from 87.5 % to 100 % in second treatment (30 minutes) in second and third applications (Figure 52).

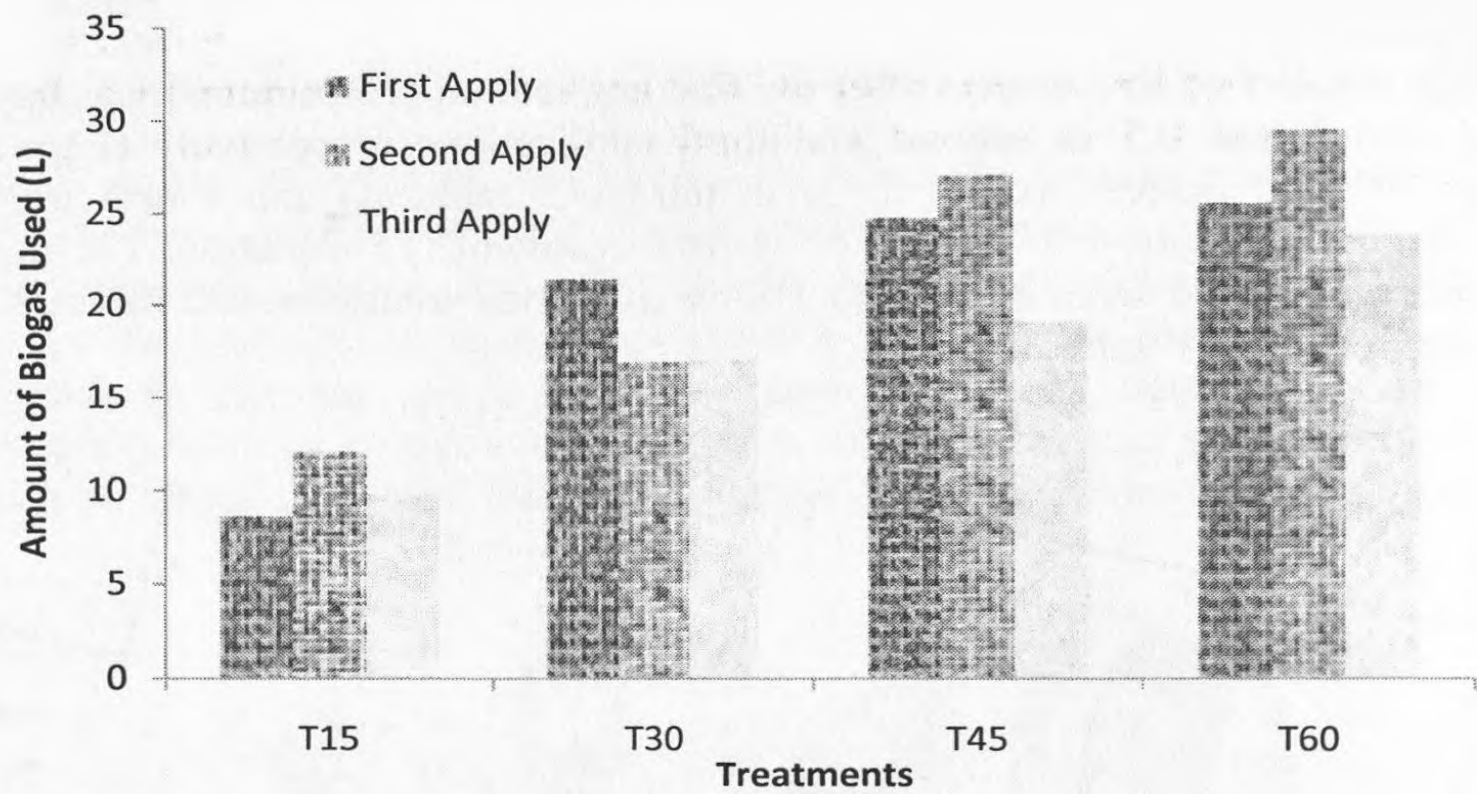


**Figure 71:** Reduction of insects in different treatments with time



**Figure 72:** Efficiency of killing the insects at different treatments

The applied average volume of biogas were  $0.01015 \pm 0.001759 \text{ m}^3$  for 15 minutes treatment and it was  $0.01835 \pm 0.002556$ ,  $0.0234 \pm 0.004056$ ,  $0.0259 \pm 0.002914 \text{ m}^3$  for 30, 45 and 60 minutes treatments respectively (Figure 53). The general composition of biogas was given in table 6.



**Figure 73:** Amount of biogas used for the experiments

When comparing the control there was a significant effect in Angoumois grain moth control by using biogas. According to the mortality rates there was no significant difference among the treatments two (30 minutes), three (45 minutes), and four (60 minutes) except treatment one (15 minutes).

**Table 6:** General composition of biogas

Type of gas	Percentage
CH <sub>4</sub>	50-70
CO <sub>2</sub>	25-40
H <sub>2</sub> S, NH <sub>3</sub> , H <sub>2</sub> O(l)	0-5

## Conclusion

Treatment T45 and T60 were most effective treatments because in first application had killed almost all insects in grain paddy. Therefore, it can be concluded that paddy grain moths could be effectively controlled by applying biogas for more than 15 minutes having the volume of  $(0.01015 \pm 0.001759) \text{ m}^3$  for 1kg of stored paddy. It is suggested that biogas is low cost sustainable and renewable energy source that can be easily produced by paddy farmers themselves by using paddy waste (straw) and it also has a good potential for control of paddy grain moth at paddy storage under modified atmospheric condition.

## Study IV: Evaluation of biogas slurry as liquid fertilizer for vegetable cultivation

### Introduction

Capsicum (*Capsicum annuum*) referred to as bell pepper or sweet pepper or paprika belong to family *solanaceae*. Sweet peppers are very rich in vitamin A. It is grown in soils rich in organic matter and with adequate drainage. Foliar application of micro nutrients such as Cu, Zn, Mn, B and Fe increases the yield and improves the quality of capsicum fruits. It is said to respond well to fertilizer application. The efficiencies of cattle manure, chicken manure,

sludge, farm compost, etc in improving growth of plants and increasing the yield have been well documented. In this study several types of liquid fertilizers were used to evaluate the biogas slurry as an organic liquid fertilizer for curry chilies. The objective of this study was to evaluate the biogas slurry as a liquid fertilizer comparing with other organic and inorganic liquid fertilizers.

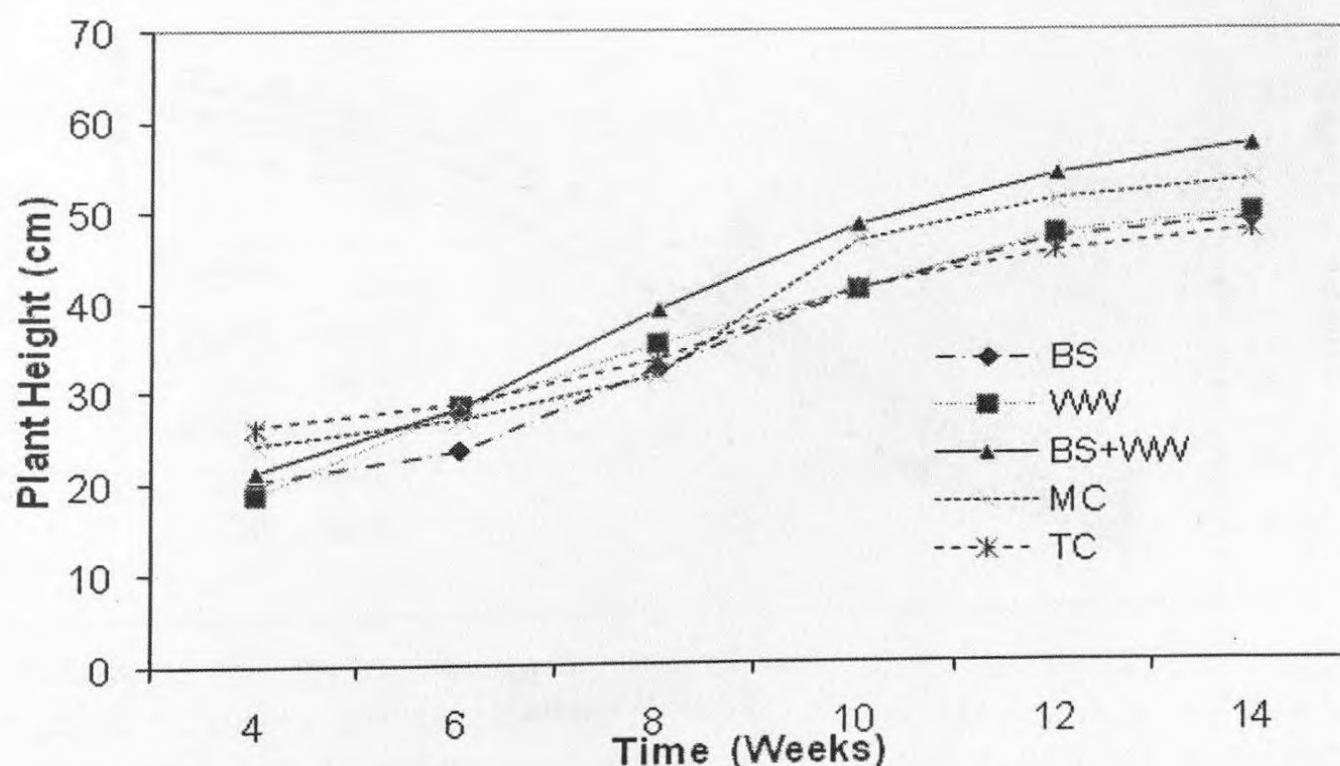
## Materials and Methods

The study was conducted using five different liquid fertilizers as treatments namely worm wash (WW), biogas slurry (BS), mixture of biogas slurry and worm wash (BS+WW), Maxicrop (MC) (Commercial liquid fertilizer) and composted tea waste (TC). The liquid of worm wash was prepared by diluting 1 L of worm wash with 5 L of water. Biogas slurry was obtained from the outlet of the continuous flow fixed dome biogas digester fed with cow dung. Before application to the plants, solid materials were removed. The mixture of worm wash and biogas slurry was prepared by mixing of worm wash and biogas slurry 1:1 ratio. Three kilo grams of composted tea waste were mixed with 10 L of water and make the liquid fertilizer for final treatment.

The soil was prepared and beds for curry chilies were also prepared. Four week aged curry chilies seedling were planted in the prepared beds by 45 x 45 cm intervals. Randomized completed block design was used with four replicates for the study. The yield parameters such as plant height, number of leaves, number of branches and number of pods were recorded in two weeks interval where necessary. The soil samples were taken and analyzed for Nitrogen and Potassium before and after the study.

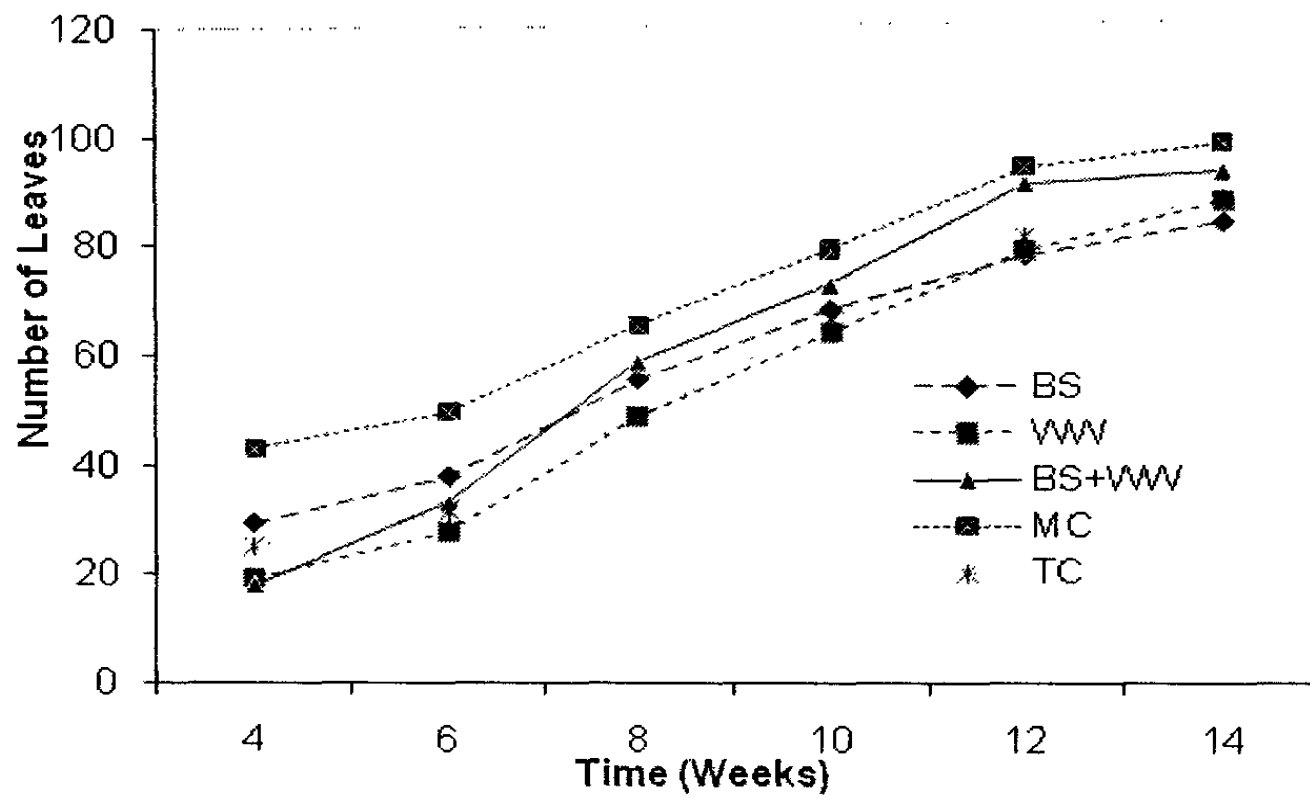
## Results and Discussion

The plant height of the curry chili plants treated with different liquid fertilizers is shown in Figure 74. Curry chili treated with mixture of worm wash and biogas slurry showed the highest plant height (~58 cm) after 14 weeks of planting.



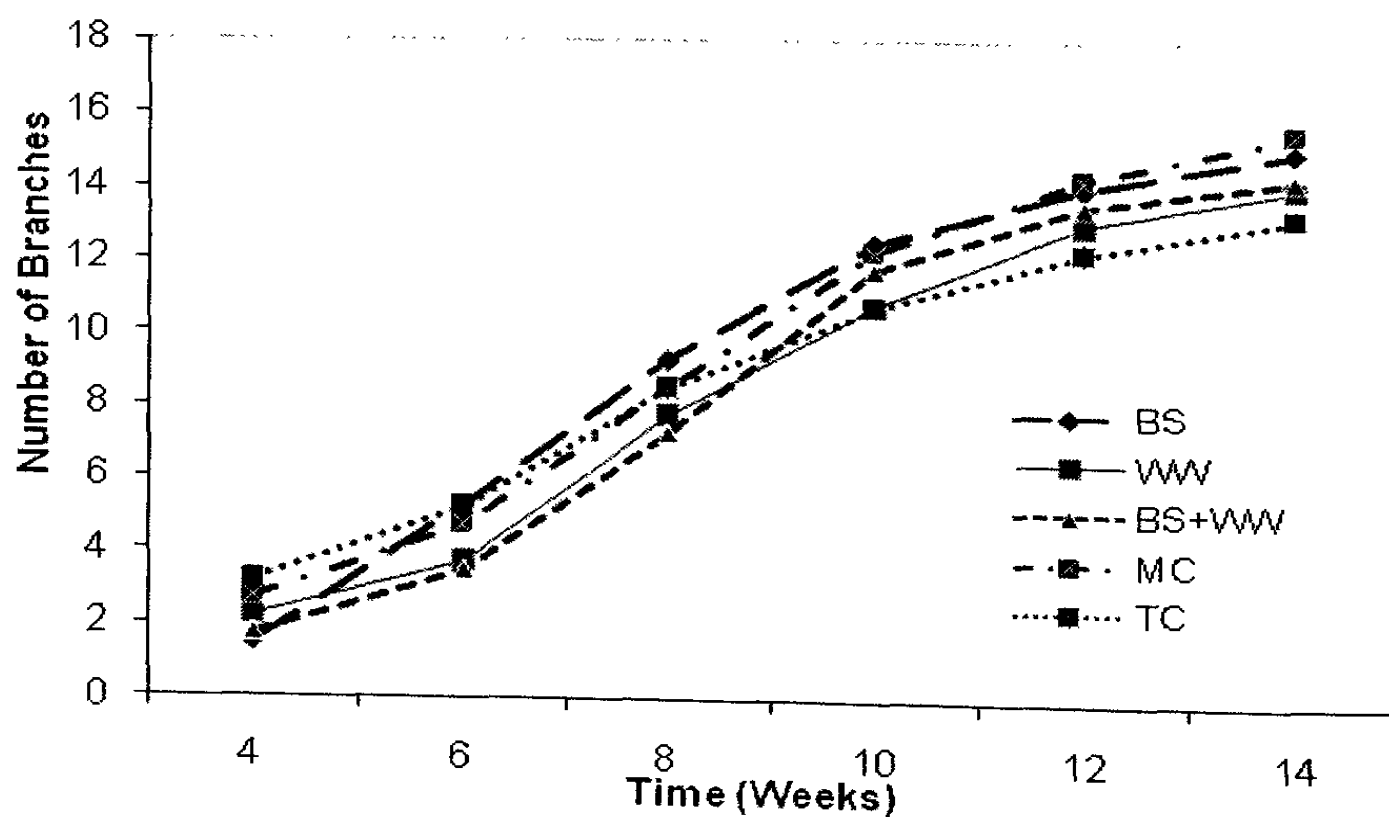
**Figure 74:** Plant height under different liquid fertilizers

The higher numbers of leaves were observed in the chili plants treatment with Maxicrop, commercial liquid fertilizer where second highest numbers of leaves were noted in chili plants treated with biogas slurry and worm wash liquid fertilizers (Figure 75).



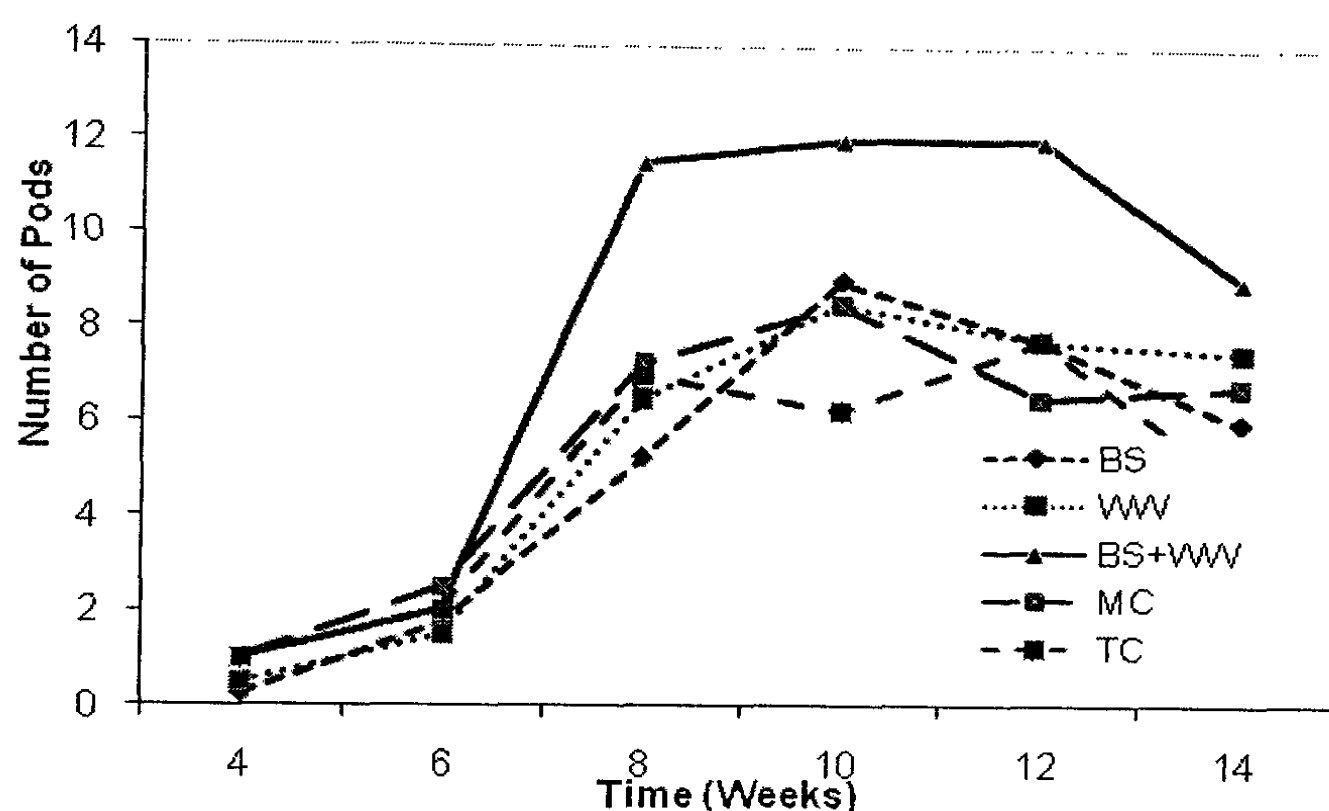
**Figure 75:** Number of leaves under different liquid fertilizers

The numbers of branches of chili plants were high in the Maxicrop treated plans. It revealed that Maxicrop, commercial fertilizer perform well as a liquid fertilizer. However, other treatments with organic liquid fertilizers produced almost similar number of branches (Figure 76).



**Figure 76:** Numbers of branches under different liquid fertilizers

Curry chilies treated with mixture of worm wash and biogas slurry showed significantly higher ( $p=0.05$ ) number of pods (12) than other treatments in 12 weeks (Figure 77). Even though, higher numbers of leaves and branches were observed in chili plants treated with Maxicrop, the higher numbers of pods were produced by the plants treated with biogas slurry and worm wash.



**Figure 77:** Number of pods during experimental study with different liquid fertilizers

Nitrogen and Potassium content of the soil before and after of the study were also conducted to find out the effect of liquid fertilizer on nutrient content of the soil. It was observed that three months after application of worm wash and biogas slurry, Nitrogen and Potassium content of the soil were increased up to 0.17% and 83.33 mg/kg, respectively (Table 7). Nitrogen and Potassium content of the soil treated with worm wash alone were 0.1% and 66.67mg/kg.

**Table 7:** Changes of soil N and K contents before and after study

Treatment	Nitrogen (%)		Potassium (mg/kg)	
	Before	After	Before	After
BS +WW	0.09	0.17	58.33	83.33
WW	0.09	0.1	58.33	66.67

## Conclusions

The mixture of biogas slurry and worm wash appeared to be the most promising treatment to obtain higher yield of curry chilies. At the same time, nutrient content of the soil were also considerably increased due to mixture of biogas slurry and worm wash liquid fertilizers. It can be concluded that the biogas slurry with worm wash could be used as a liquid fertilizer for curry chilies.

## **Study V: Development of broiler offal silage –rice bran mixture as an animal feed ingredient: In-Vitro nutritive**

### **Introduction**

Processing of 100 kilo grams of broiler live weight give rise to approximately 20-25 Kg of offal that include heads, inedible internal organs, feathers and legs. If not properly discarded, broiler offal (BO), causes severe environmental and health problems. Environmental problems associated with indiscriminate deposal of BO have become one of the major reasons for the closure of many boiler operations. On the other hand, Disposal of BO has become one of the burdens on broiler farmers. One of the best mean of encouraging proper disposal of waste is to increase the usability of waste and thereby adding some value to it. It has been found that BO can be ensiled with citric acid (XA) and preserved without any adverse environmental problems. If mixed with a suitable material and then dried, broiler offal silage (BOS) may be caused as an animal feed. Objective of this study was to evaluate the in vitro nutritive value of broiler offal silage (BOS) rice bran mixture.

### **Materials and Methods**

BO (without feathers) was ground and ensiled with 10% CA. The initial pH of the mixture was 4.2. The pH of the BOS maintained more or less constant level (<4.4) for 10 weeks. Resulting BOS was mixed with rice bran at 1:2 ratio and dried until the dry matter content of the mixture was 85%.

### **Results and Discussion**

The analysis of resulting broiler offal silage rice bran mixture (BOSRB) contained  $20\pm 0.7\%$  crude protein,  $5.1\pm 1.2\%$  ash,  $30\pm 0.8\%$  crude fat, and  $1.88\pm 0.04$  total phosphorus. The pH of the BOSRB was  $5.2\pm 0.04$ .

### **Conclusions**

It was concluded that in-vitro nutritive value of BOSRB was higher than that of the normal rice bran and they could be a good feed ingredient in non-ruminants and fish diets.

## **Study VI: Use of broiler offal silage-rice bran pellets in a qualitative feed restriction strategy for mature broilers**

### **Introduction**

Processing of 100 kg live weight of broilers produces around 20-25 kg of offal. Since offal has no direct financial value to the farmer, the disposal of offal is an additional burden on them. It has been shown that broiler offal can be ensiled and stored for several months (Atapattu and Amarasekara, 2007). However, offal silage as it is cannot be used as a feed ingredient for poultry due to its liquid nature. Offal silage has to be mixed with a suitable carrier which has good absorbent properties and dried before being incorporated into a poultry diet. Liyanaarachchi et al. (2008) found that mixing of broiler offal silage with rice

bran and subsequent drying reduced the liquid nature of broiler offal silage to a level that is satisfactory to be included in practical poultry diets.

Early growth retardation in broiler chicks induces an accelerated growth known as compensatory growth, which results in final body weights equal or even exceeding that of the birds fed *ad libitum* (Plavnik and Hurwitz, 1991). A number of recent studies have shown that restricted feeding strategies could be helpful to reduce the metabolic disorders such as ascites (Acar et al., 1995) and leg weaknesses (Su et al., 1999). The method, severity and the timing of feed restriction and the length of the subsequent *ad libitum* feeding periods reported in restricted feed studies vary widely. In many of the studies reported in literature, birds have been subjected to feed restriction during early ages. Restriction feeding studies done with mature broiler chicken are limited. Balog et al. (2000) did not find compensatory growth capacity in mature broilers who subjected to a severe quantitative feed restriction. However, recently, Atapattu and Chandrasiri (2008) have found that mature broiler chicken also possess compensatory growth capacity following a qualitative feed restriction. They have used a mixture of soybean and maize in alternate days to induce growth retardation.

Rice bran is a much cheaper feed ingredient than soybean and maize and thus may be a suitable candidate for qualitative feeding strategies. It was assumed that mixing of rice bran with broiler offal silage would improve the nutritive value and the palatability of the same. The objective of this study was to evaluate the production and economic performance of broilers subjected to a qualitative feed restriction program which utilizes broiler offal silage rice bran pellets (BOSRBP).

## Materials and Methods

Twenty seven days old broiler chicks (n=54) were allocated in 18 pens so that between cage live weight variation was minimum. The pens were randomly assigned into three dietary regimens. Dietary regimens are shown in Table 8. BOSRBP and commercial broiler diets were given *ad libitum*. Broiler offal silage (BOS) was prepared as described by Atapattu and Amarasekara (2007). Ten weeks old BOS had pH <4.5. Rice bran and BOS were mixed at 2:1 ratio (w/w) and oven dried at 80 °C until a constant dry matter content of 85% was achieved. Dried BOSRB mixture was mixed with water 1:1 ratio and pelleted using a small scale pelleting machine. Pellets were also oven dried at 80 °C for three hours. The size of the BOSRB pellets (BOSRBP) was more or less similar to that of commercial pellets though the former was slightly harder than commercial pellets. The time periods from 0600h to 1800h was and from 1800 to 0600h were considered as day time and night time, respectively. Session wise-feed and water intakes were recorded during the feed restriction period. During the subsequent *ad libitum* feeding period, the feed and water intakes were recorded. Birds were weighed at the end of the restricted feeding period and at the end of the experiment on day 41. The price of the commercial feed was 70 Rs and the estimated cost of a 1 kg of BOSRBP was considered as 18 Rs. Data was analyzed using the GLM procedure of SAS.

## Results and Discussion

Intakes of BOSRBP in both sessions (day time and night time) were significantly lower than the intake of commercial feed during the respective sessions. When included at higher levels, rice bran has found to reduce the feed intake of poultry. Though the length and the diameter of the BOSRB pellets were more or less similar to those of commercial pellets, the former were harder than commercial pellets. Birds in dietary regimen 3 continued to ingest the same

commercial finisher pellets which they had been given from day 21, whereas birds in other two dietary regimens faced a change in feed in a one session of a day. Those factors may be the reasons for lower BOSRBP intakes.

**Table 8:** The feeding regimens used in the experiment

Phase	Dietary regimens					
	1 (BOSRBP <sub>d</sub> )		2 (BOSRBP <sub>n</sub> )		3 (control; Con)	
	Day time	Night time	Day time	Night time	Day time	Night time
Restricted feeding period (RF)(from day 27-34)	BOSRB	Commercial Feed	Commercial Feed	BOSRB	Commercial Feed	Commercial Feed
<i>Ad libitum</i> feeding period  From day 35-41)	Commercial broiler finisher <i>ad libitum</i>					

It can be fairly assumed that the nutritive value of BOSRBP was inferior to that of commercial feed. Intestinally, when birds were offered the commercial feed in night or day time following a session of BOSRBP feeding, their commercial feed intakes were significantly higher than the commercial feed intakes of the respective sessions of the birds of control group. Even though the withdrawal of commercial feed for 12 hours a day reduces the time available for commercial feed intake by 50%, the actually commercial feed intake reductions of the birds in BOSRBP<sub>n</sub> and BOSRBP<sub>d</sub> dietary regimens were only 38% and 22.5%, respectively. It seems that birds have tried to recover the loss of nutrient intake by ingesting more commercial feed when offered. Atapattu and Chandrasiri, (2008) have also reported similar compensatory feed intake in broilers following an offer of a mixture of soybean and maize.

Though birds showed some compensatory feeding capacity, the commercial feed intakes of the birds in restricted feeding regimens during RF period were significantly lower than the birds fed commercial feed uninterruptedly. The total feed intake of the birds in BOSRBP<sub>d</sub> feeding regimen during the RF period was also significantly lower than that of the birds in commercial feeding regimen. Interestingly, the former group ate significantly more commercial feed during subsequent *ad libitum* feeding period. In all dietary regimens, the intake of both commercial feed and BOSRBP were higher during night than during day time. This suggests the importance of providing suitable source of light during the night.

Both during day time and night time, water:feed ratio was significantly higher when BOSRBP were given.

As expected feeding of BOSRBP either during day or night time from day 27-34 significantly reduced the live weight on day 34 and weight gain from day 27-34. Feeding of BOSRBP during night time was more detrimental than during day time. It was expected that birds subjected to feed restriction would gain more weight during the subsequent *ad libitum* feeding period. However that was not the case in this experiment. Even though birds fed BOSRBP during night gained numerically higher weight, compared to control groups, that was not sufficient enough to equate the final live weight of the birds of control group. These findings are in line with those of other studies such as (Proudfoot et al. 1983; Summer et al. 1990; Su et al. 1999; Boa-Amponsen et al. 1991) but contrary to the results of Atapattu and Chandrasiri (2008). As to whether the compensatory growth capacity is sufficient enough to equate the final body weight depends on many factors such as the type, severity of feed restriction, length and the, timing of the feed restriction and subsequent *ad libitum* feeding. Inability of the birds to show compensatory growth following growth retardation may be due to one or any combination of the above factors.

## **Conclusions**

Based on the results of the study, it is concluded that restricted feeding strategy tested using BOSRBP does not produce positive effects on growth performance of mature broiler chicken. Feed conversion ratio was not significantly altered by the dietary regimens. Even though the total feed cost of the birds fed commercial feed throughout significantly reduced from 181 Rs to 166 Rs under BOSRBP<sub>n</sub> feeding regimen and to 161 Rs under BOSRBP<sub>d</sub> feeding regimen, respectively, the feed cost per unit live weight gain showed no benefits. It was concluded that restricted feeding strategy which used BOSRBP has no beneficial effects on growth or financial performance of mature broiler chicken.

## **Study VII: Properties of bricks produced by discarded glasses**

### **Introduction**

The discarded fragile matters (glass) are normally generated considerably in the Faculty of Agriculture. There were no proper collection procedures for the recycling of fragile (glass) materials. The disposal of fragile matters needs great concern. In this study, we attempted to produce bricks using glass particles as aggregates and cement as the binding agents. Further, the properties of produced bricks were evaluated.

### **Materials and Methods**

The discarded glass bottles were collected for the premises of the Faculty and they were ground, manually using motor and pestle to produce aggregates. The suitable aggregates were selected based on the aggregate size and distribution in river sands. The bricks were made by mixing the glass sand and cement in different ratios (Figure 78). A brick made using river sand and cement was used as a control.



**Figure78:** Bricks produced by glass sand and cement

### **Results and discussion**

There were no analytical instruments available in the Faculty of Agriculture, University of Ruhuna for the testing of the bricks. The assistance from an external institute is required for the testing. However, due to lack of funds in the research project, analysis of properties of the bricks could not be performed.

## **Part IV: Formulation of a code of practice for good waste management for institutions and its instrumentation**

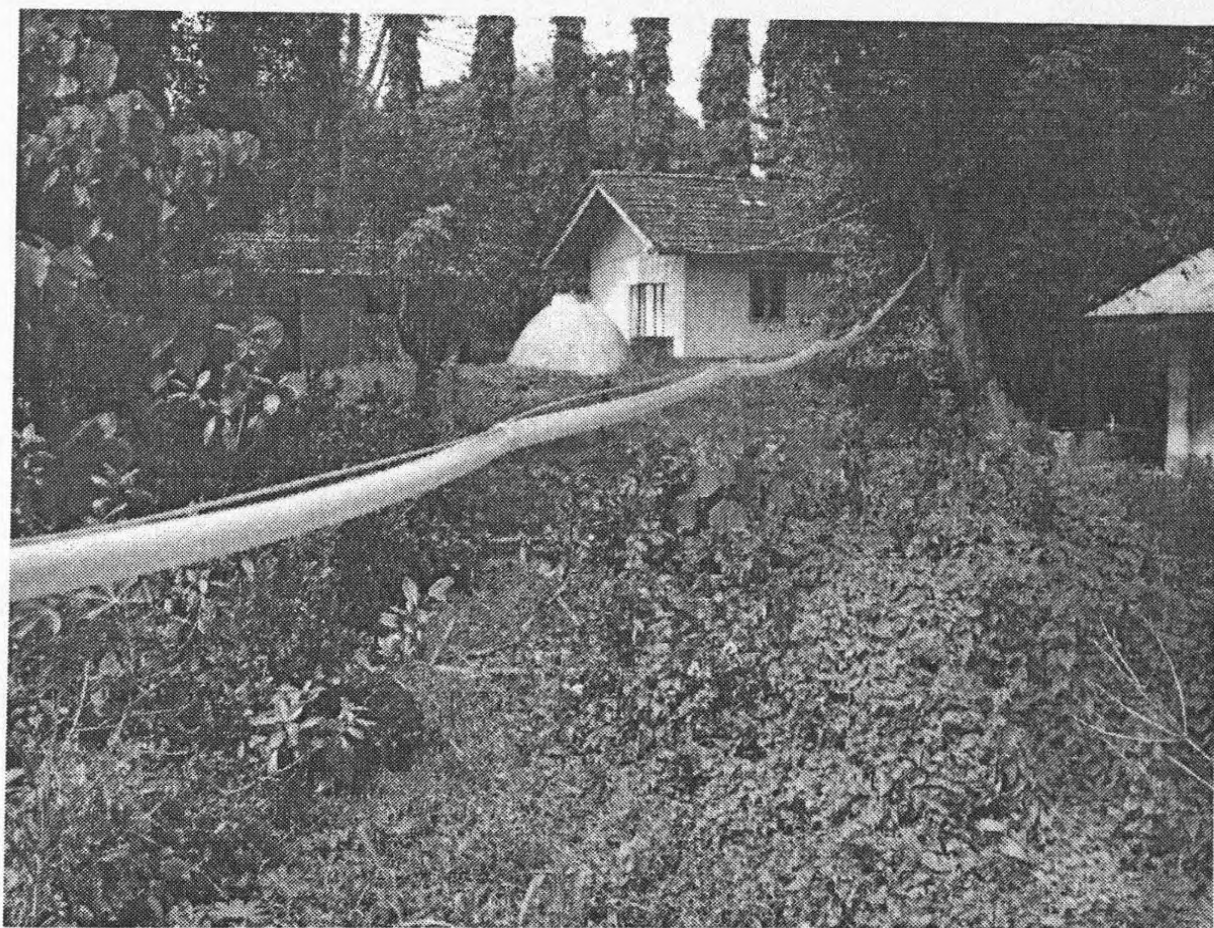
### **Activity 01: Use of available energy sources**

#### **Introduction**

During the initial stage of the study, a questionnaire survey and field visits were done and. The abandoned biogas digester was located near the cattle shed of the University Farm. According to the discussions we had with the workers in the faculty, it was found that the biogas digester was constructed ~1970's. Due to malfunction of the system it was abandoned.

#### **Materials and Methods**

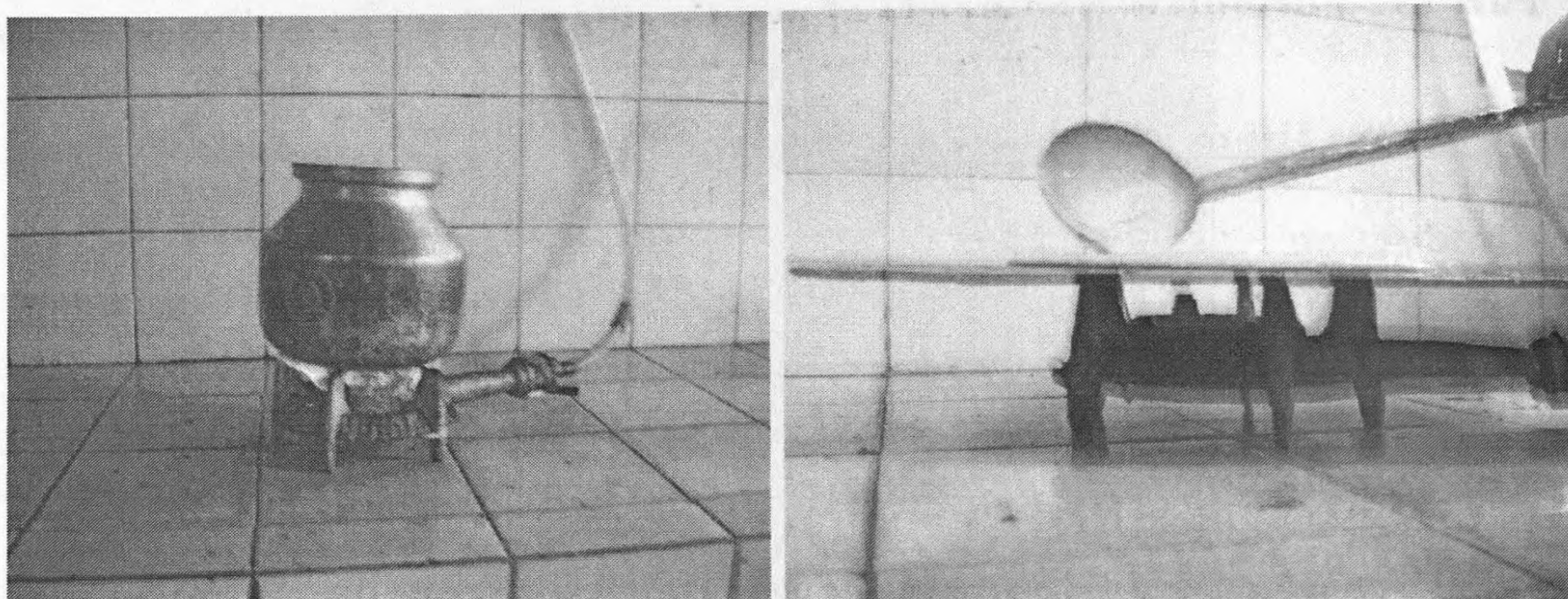
After the initial investigation by the research team, it was found the biogas reactor would be recovered. Then, the site was cleared and materials inside the digester were removed. The reactors was repaired and checked for biogas leakages. The feeding channels of the biogas reactor were reconstructed. Then, the feeding with cow dung was started. The biogas distribution line was also arranged to cafeteria of the Faculty and the workers hut nearby the biogas digester (Figure 79).



**Figure 79:** Biogas delivery from digester to cafeteria

#### **Results and Discussion**

Biogas production was started just 4-5 days after the filling of the digester. The distance to the cafeteria from the biogas digester was quite high. The volume and pressure of the biogas should be enough high to transfer the gas to cafeteria. The biogas was used for the preparation of hoppers, rotti and boiling of water in the cafeteria using the normal burner shown in the Figure 80.



**Figure 80:** Burner used for biogas

The biogas consumption by the cafeteria for one month period was recorded. The amount of biogas received from the biogas reactor was sufficient for the preparation of foods for about 1.5 hours. It is just equal to cooking time of 1.32 hours by LPG. Based on the calculations it was found that by using the biogas, the saving of cost for LPG is about Rs 1457.00 per month (Table 9).

**Table 9:** Cost reduction due to biogas

<b>Activity</b>	<b>Unit</b>
Time Cooked by Biogas (h/month)	<b>42.53</b>
<b>Reduction LPG cooking h/day</b>	<b>1.32</b>
LPG consumption (Cylinders/month)	3.50
Cooking Time by LPG (h/day)	6.50
Cost for LPG (Rs/Cylinder)	1909.00
Total Cost for LPG/month Rs	6681.50
Total Cooking Time by LPG (h/month)	195.00
Cost for LPG (Rs/h)	34.26
<b>Cost Reduction Due to Biogas (Rs)</b>	<b>1457.30</b>

The maintaining of the biogas unit, gas distribution line and the burner was handed over to the keeper of the cafeteria after about one months of operation of the biogas reactor by the project team. The feeding of the biogas reactor was done by the workers of the cattle shed. However, their commitment for the feeding of the reactor was very poor. To uplift their enthusiasm for the feeding of biogas digester and its maintenance, a biogas line was diverted to their hut for the preparation of tea for them also. However, the member of the project team

monitored the feeding of the reactor every day. The major reasons for their less attention for the biogas digester were basically, (1) no direct benefits for them, (2) it is an extra work, (3) administration do not advice then to do it and (4) they are not willing to give free gas for the cafeteria keeper.

First couple of months, the biogas reactor was sufficiently maintained by the keeper of the cafeteria. The keeper was encouraged by the project team and he was keener on biogas because he has the direct benefit from it. Normally the subsidy for LPG was given by the University for the keeper of the cafeteria. However, during the period where biogas digester was operated, no subsidy was given. Therefore, the keeper of the cafeteria maintained the biogas digester system properly. After successful operation of about six months, the university administration decided to provide subsidy for LPG again. Then, later on, the maintenance of the biogas digester was abandoned by the keeper.

## **Conclusions**

The following conclusion can be drawn from the results and experience of this study. (1) The biogas can easily be utilized for the energy needs of the cafeteria sufficiently. (2) The commitment of the keeper of the cafeteria is very important for the maintaining of the biogas digester. (3) The proper feeding of the reactor with cow dung is required for the successful operation of the reactor. (4) The administrative supports for such activities are very important. (5) The subsidies for energy may results the reduction use of alternative energy sources.

## **Activity 02: Introduction of composting bins for staff quarters**

### **Introduction**

The results of the survey conducted by the begining of the study indicated that the most of people in the Faculty is willing to contribute the waste management programs introduced by the Faculty. At the same time, in the waste estimation, it was found that more food wastes are available in the quarters of the staff. Therefore, the project team introduced the compost bins for the staff quarters.

### **Material and Methods**

The comparison study of different composting bins for their performance, it was found that the cylindrical concrete compost bins (Figure 81) are more suitable for the making of compost in home gardens. Therefore, the project team provided the compost bins to staff quarters at half price to use for the kitchen and garden waste for making compost.

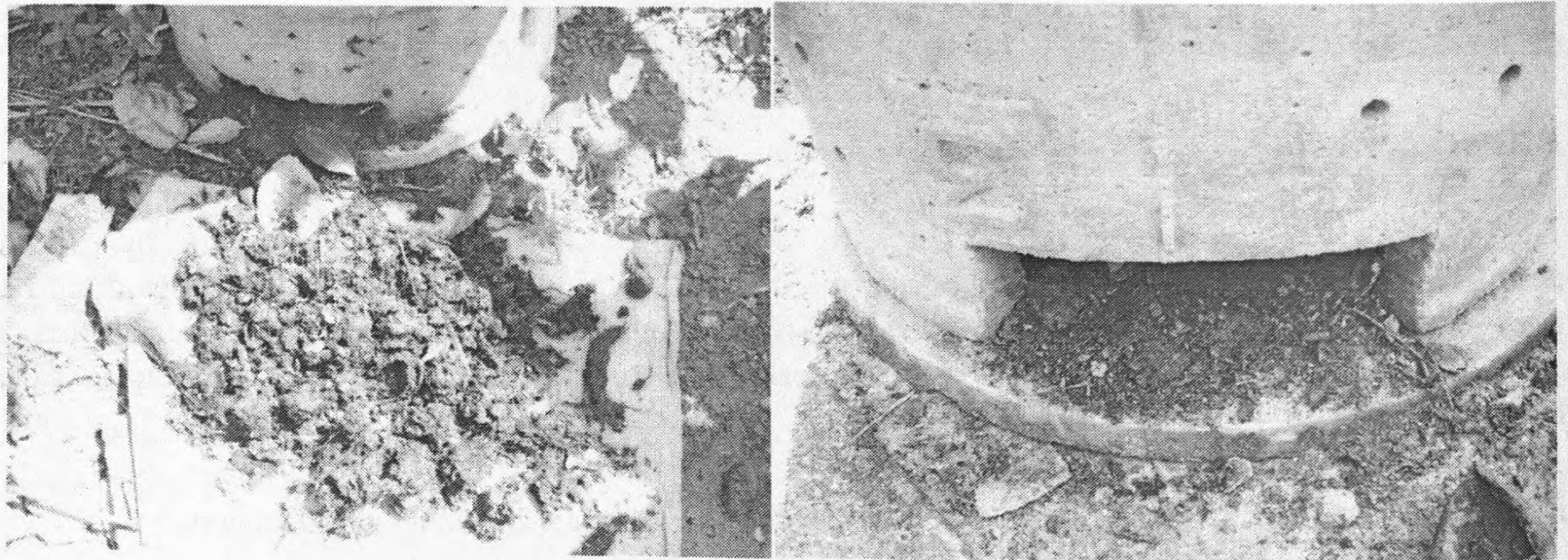
The installation was done by the project team and operation procedure such as feeding method, suitable raw materials and the removing of mature compost from the bin were properly demonstrated for the family members of each quarters.



**Figure 81:** Cylindrical concrete compost bins

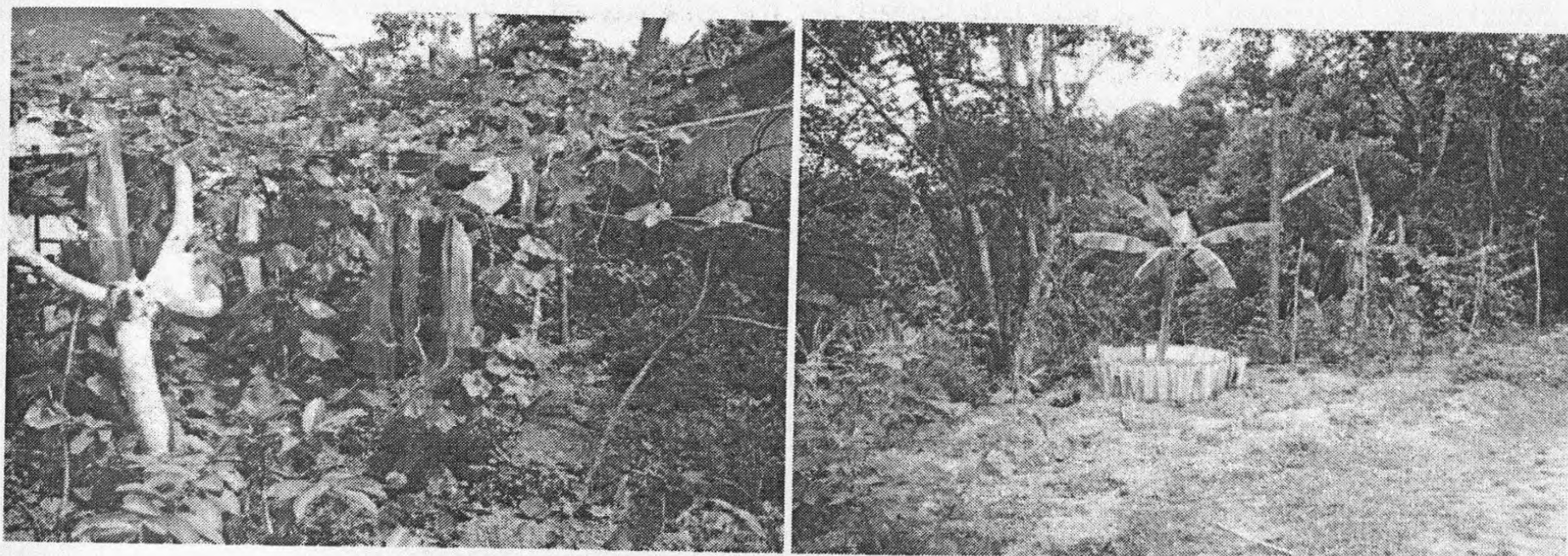
## Results and Discussion

There was a problem of disposal of food wastes in quarters before the introduction of compost bins. Basically, dogs, cats and other animals drag the wastes from the bins and it was made uneasy environment around the quarters. And some residents has prepared the pits for food wastes, however, they were also damage by the wild boar. Therefore, the residents properly maintained the compost bins according to the instruction given by the project team. The compost production from these bins was successful (Figure 82).



**Figure 82:** Produced compost from compost bins

The project team requested the residents to cultivate crops using produced compost. The residents enthusiastically started home gardening and it helped them reduce the cost for vegetables (Figure 83). The activities performed with respect to composting and home gardening were monitored during project period.



**Figure 83:** Home gardening using compost

## **Conclusions**

The composting and home gardening program was successful. The food and garden wastes in residential quarters were properly managed by the residents themselves and they could be able to reduce the cost for vegetables due to home gardening. Still the home gardening activities are going on.

## **Activity 03: Separation of wastes and disposal**

### **Introduction**

The management of waste is prime important in any institution. The Faculty of Agriculture, University of Ruhuna located in a rural area where no waste collection system was practiced by the local authority. Therefore, the wastes generated in the Faculty should be collected and disposed by the Faculty. At the time of the research project started, the collection and disposal of wastes were practiced by a hired company. They collect the wastes and disposed of them in to prepared pits at several location of the Faculty. No separation of waste was practiced and all wastes dropped in to the pits and after some time the pits were closed by a soil layer. This practice is not an environmental friendly method. Therefore, waste separation was introduced and the attempts were made to recover the resources from the wastes.

### **Materials and Methods**

As first step, the waste disposal places were visited and identify the advantages and disadvantage of the procedures. The collected wastes were put in to the soils pits at several locations as sole method for waste disposal at the Faculty (Figure 84).

Since all the waste including degradable organics, plastics, polythene, glasses, etc are dumped into same pit; it is not an environmentally sound method. Therefore, the project team initiated a program of waste separation. The three colour bucket system was introduced for the separation of wastes at waste generation. Three buckets were used for degradable waste, fragile matter and plastics and polythene. In the student's hostels, no fragile matters were commonly found, so, two bucket system for degradable waste and plastics and polythene were introduced (Figure 85). The buckets were placed at different places where wastes are

generated. The iron frame was fabricated for the placing of buckets so that felling of bucket and dragging of wastes in the bins cannot be done by the cats and dogs.



**Figure 84:** Waste disposal in to the soil pits

The waste separation at initial stage of the project was poor; however, later waste separation was further improved due to awareness program conducted by the project team. The poster was prepared to highlight the importance of the waste separation and it was displayed in notice boards and other suitable places in the faculty (Figure 86).

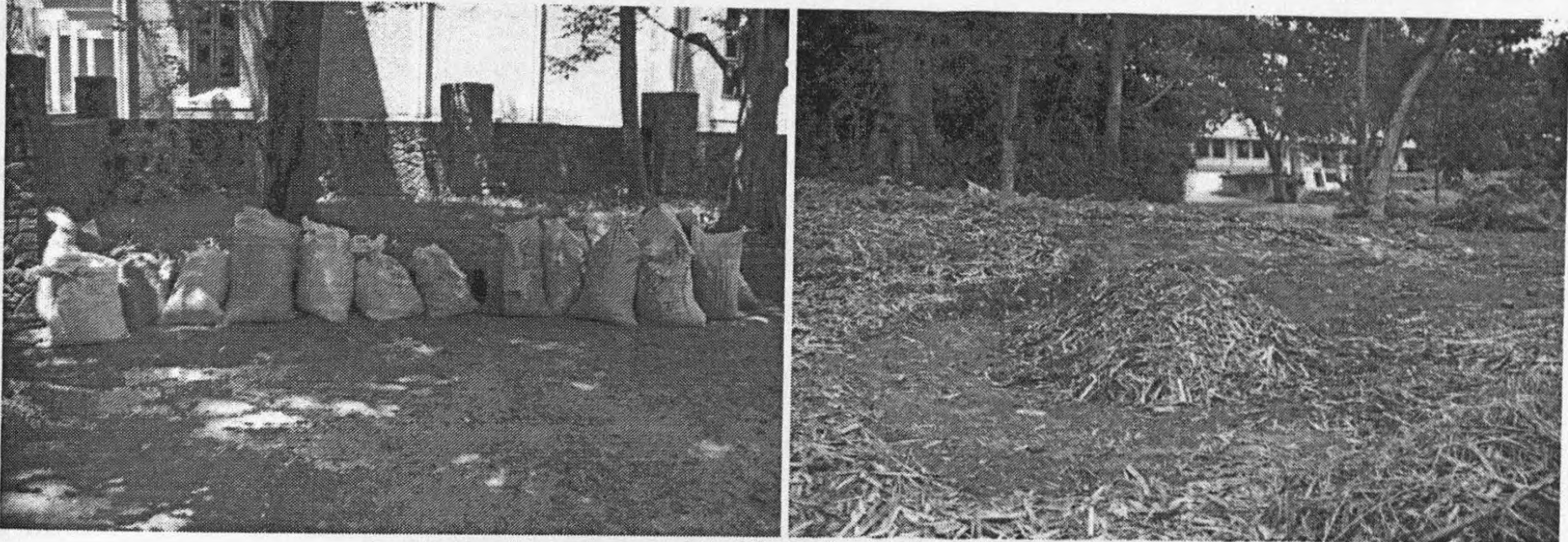


**Figure 85:** Waste separation bin system



**Figure 86:** Awareness program-poster

The awareness program was successful and residents and workers in the faculty practiced the waste separation. The separated organic wastes were dumped into the soil pits where they were kept for some time to be composted. The produced compost was used for cultivations in the faculty farm. The garden wastes such as leaves, grass cuttings, etc were used for making compost by using heap method. The workers in the farm collected the garden wastes separately for making compost (Figure 87). All the required information and advices were given for them by project team.



**Figure 87:** Garden waste collection for compost

There was no place for the collection of plastics and polythene, and fragile matters. Therefore, the boxes were constructed using iron pipes and wires and they were kept in several places for the collection of fragile matters, and plastics and polythene until they were properly disposed (Figure 88).



**Figure 88:** Boxes for fragile matter, polythene and plastics

The amount of plastics and polythene, and fragile matter were quite low. Therefore, the boxes provided by the project are sufficient to collect those wastes about 3-5 years. During the

project period, project team attempted to find the companies or people who collect waste polythene and plastics, and fragile matters. There were some companies who collect such wastes for recycling; however, they require in large quantities. Therefore, it was unable to dispose the collected plastics and polythene, and fragile matters during project period.

The discarded bottles and metal parts can easily be sold to third party vendors. However, the administration regulations in the government institutions did not allow such procedures. There were lots of discarded metal items such as tables, beds, refrigerators, fans, etc in the faculty premises making unpleasant environment. In addition, they need lots of space for store them and due to lack of storing facilities, the most of them dump in the open environment. It is a resource waste because still those items can be recycled. The project team attempted to sell out those items through administrative regulations. However, even after 4 years, the process could not be succeeded.

## **Conclusions**

The waste separation program was successful during project period. After the project period, no project team members are totally involved in the project activities. Then, attentions for waste disposal by sanitary workers (who collect and dispose of waste) were minimal. Sometimes, separated waste they put into same basket disposed to the same put instead of putting different wastes in different pits and boxes. These types of activities were negatively affected for the waste separation by people in the faculty. The most of the sanitary workers were uneducated rural women. They normally did not consider about the environment or the advices given by project members. They just tried to collect the waste the disposed them into the places where others cannot notice. Some of sanitary workers were mentally handicapped. Therefore, it is difficult to convince them about waste management. They do not care about it. The project team formulated the monitoring teams among the students. Initially they participated well for the waste management activities, however, later on their involvement were minimal.

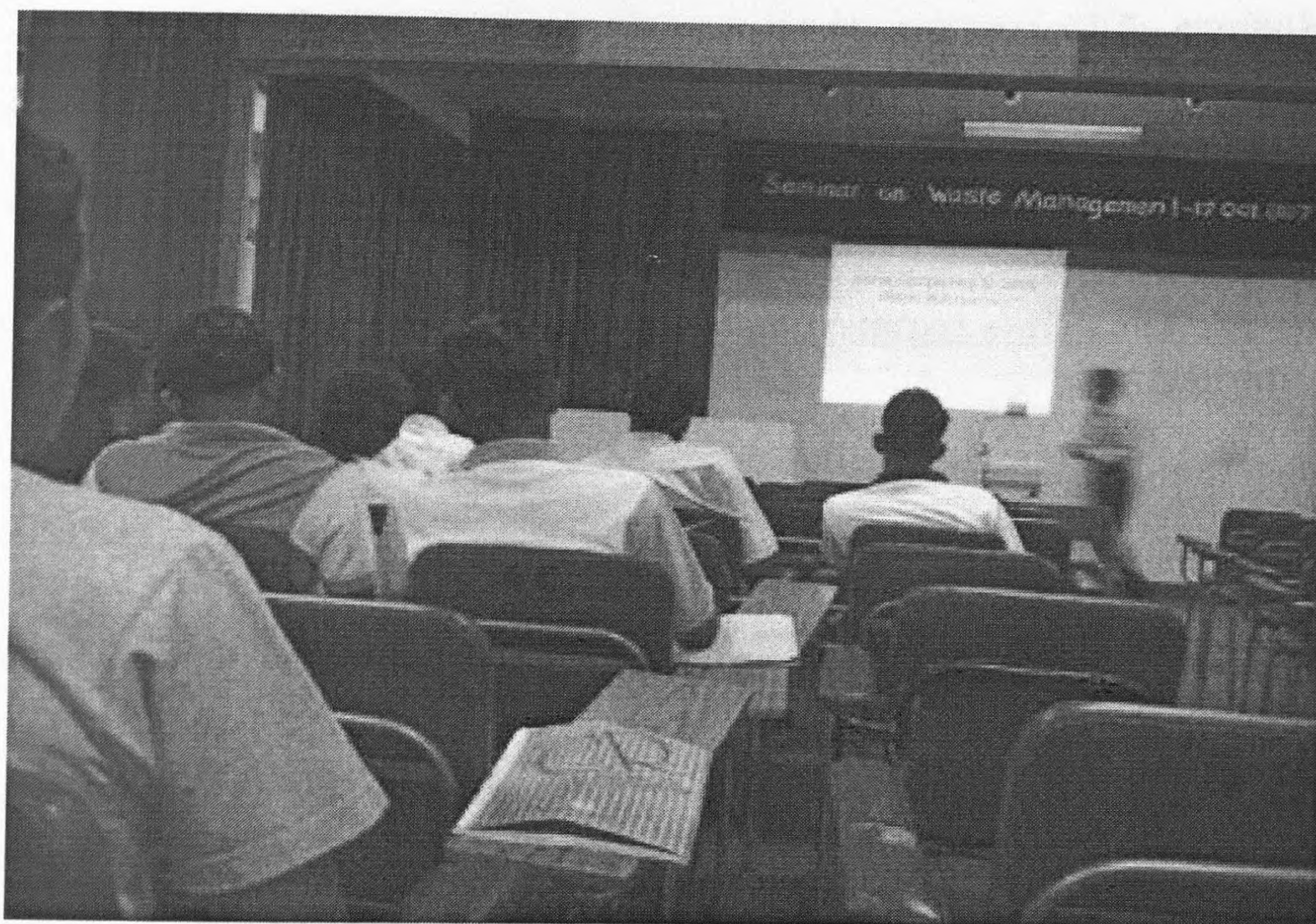
### **Activity 04: Awareness program about home gardening composting**

#### **Introduction**

Several awareness programs were conducted in the faculty for the students and the workers to make aware them about the waste disposal problem in the faculty and its impact on the environment. One which was more interested and important was the home gardening composting program. It was conducted by getting the external expertise.

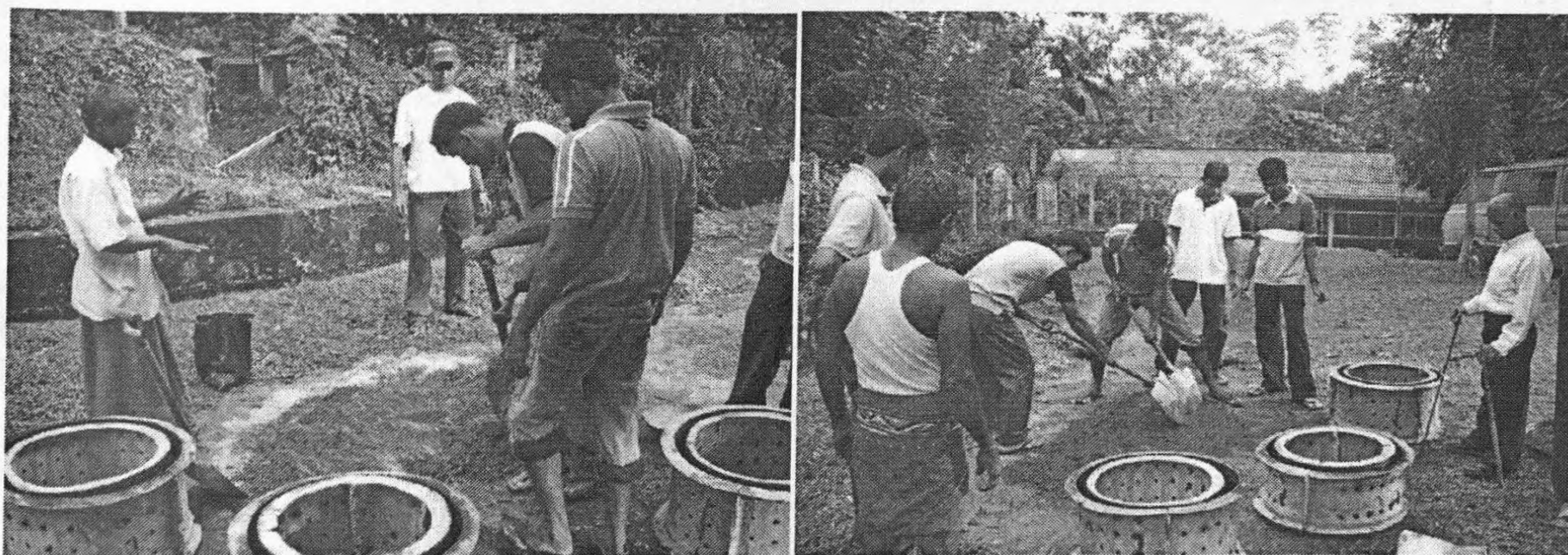
#### **Material and Methods**

The compost bin system which can be used for the composting of gardening waste was explained with theoretical background (Figure 89). Then, participants were exposed to the operation and the maintenance of compost system.



**Figure 89:** Home garden composting awareness program

The practical program was conducted two weeks after the first awareness program (Figure 90). In this program students were trained to making concrete composting bins. And the program was conducted by collaboration with Practical Action (NGO). The program was successful and participation was quite good.



**Figure 90:** Concrete compost bin preparation training program

The selected undergraduates actively participated for the training program. A required mould for the making of domestic compost bin was donated by the Practical Action (NGO) for the Faculty of Agriculture, University of Ruhuna.

## Conclusions

The training program was successful and undergraduates were able to acquire the technology and practical experience on the making of domestic compost bins. At the same time the people in the Faculty were influenced on environmental awareness and the waste management by this program.

### **Activity 05: The points required more attention for proper waste management in an institution**

According to the results and experiences gathered through the study, the following points should be properly addressed when a waste management system is planned for the institutions similar to Faculty of Agriculture, University of Ruhuna.

- The proper awareness program should be implemented for the residents or employers in the institution about the consequences of human activities on environment and waste management.
- Administrative supports for waste management activities are compulsory. Otherwise, the any waste management program may fail.
- The items to be discarded should be auctioned in regular intervals. It helps to remove the unnecessary items from the premises of the institute as well as generate extra income by selling those items.
- Employers should be advised to utilize natural lights and ventilation to reduce the energy consumption.
- Waste separation program should be implemented.
- Separated waste should be properly disposed of using approved technologies.
- The organic wastes such as food waste, garden waste can easily be composed using simple compost bins. Then, home gardening in the premises of the institute can be popularized. The highest portion of wastes in the most of the educational institutions and offices are organic wastes including food wastes. As such proper attention should be paid for the management of organic wastes
- There are paper recycling companies. However, the most of the companies are located in the Western Province. Therefore, they do not like come to collect small quantity of waste paper in remote areas like Kamburupitiya. And they require large quantity of waste papers. It was a problem for paper waste disposal during project period also. The paper waste collected during the project period was disposed to soil pits for making compost.
- Plastic waste including polythene can also be recycled. The plastic recycled companies do not like to come for the collection of small amount plastic wastes. Therefore, it is necessary to have a place for the storing those waste for quite some time.
- Fragile wastes should also be recycled. However, there are some glass bottle collectors and they collect certain types of glass bottles. It cannot be practiced in government organizations due to administrative regulations. Glass recyclers could not be found during project period.
- Metal items such as iron components should also be recycled. It is necessary to store those items also quite some time until reasonable amount to be collected.

- The simple wastewater treatment systems can be implemented for the treatment of domestic wastewaters generating from cafeterias. Some aquatic plants can also be used for the removal of pollutants in wastewater.

## References

- Acar, N., Sizemore, F.G., Leach, G.R, Wideman, R.F., jr., Owen, R.L. and Barbato, G.F. (1995). Growth of broiler chickens in response to feed restriction regimens to reduce ascites. *Poultry Science*, 74: 833 – 843.
- Anon R.A. (1991). Environmental management and fishery –based industries, Working papers of Industrial planning UNIDO, Vienna pp 3.
- APHA AWWA WPCF (1985). Standards methods for the water and wastewater. Washington American Public Health Association.
- APHA, AWWA, WPCF, (1985). Standard Methods for the Examination of Water and Wastewater, 16th ed. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington, DC.
- Atapattu N.S.B.M and Chandrasiri, W.C.J (2009). Effects of a qualitative feed restriction strategy on the growth performance and feed cost of mature broiler chicken Proceedings of sixth the fifth academic sessions of University of Ruhuna.
- Atapattu, N.S.B.M and Amarasekara, R.P (2007). Proximate composition of broiler offal ensiled with citric acid. Proceedings of the twelfth Forestry and Environmental Symposium. 30th Nov-1st Dec 2007, at Tangerine Beach Hotel, Kalutara, Sri Lanka. Pp 42
- Balasubramaniyan, P and Palaniappan, S. P. (2004). Principles and Practices of Agronomy. Agrobios (India). Jodhpur, 194-195.
- Boa – Amponsem, K., Dunnington, E.A., and Siegel, P.B. (1991). Genotype, Feeding Regimen, and diet interactions in meat chickens. 1. Growth, Organ size, and feed utilization. *Poultry Science*, 70: 680 – 688.
- Cooper P.F., Job G.D., Green M.B. and Shutes R.B.E. (1996). Reed bed and constructed wetlands for wastewater treatment, WRc Swindon, Wiltshire, UK,.
- Environmental Protection Act, (2011). Central Environmental Authority, Ministry of Environment.
- EPA, (2001). Brownfield technology primer: selecting and using phytoremediation for site cleanup, US Environmental protection agency, Office of solid waste and emergency response, Technology innovation office, Washinton, DC 20460.
- Forbes McDougall, Peter White, Marina Franke and Peter Hindle (2001). Integrated Solid Waste Management: a Life Cycle Inventory, Blackwell Science Ltd, Malden, USA.

- Gupta, P. K. (1999). Hand Book of Soil, Fertilizer and Manure. Agrobios. Bikaner. India, 273-281.
- Gupta, P. K. (2004). Soil, Plant, Water and Fertilizer Analysis. Agrobios (India). Jodhpur, 123-129, 375-385.
- Jones D.L., Williamson K.L. and Owen A.G. (2006). Phytoremediation of landfill leachate, Waste Management, 26, 825-837.
- Judith S.W. and Peddrick W. (2004). Metal uptake, transport and release by wetland plants: implications for phytoremediation and restoration, Environment International, 30, 685-700.
- Köner S., Lyatuu G.B. and Vermaat J.E. (1998). The influence of *Lemna gibba* L. on the degradation of organic material in duckweed-covered domestic wastewater, Water Research 32(10), 3092-3098.
- Liyanaarachchi, N., N.S.B.M. Atapattu and S. Wijetunga (2008). Development of broiler offal-rice bran mixture as an animal feed: In vitro nutritive value Proceedings of the thirteenth Forestry and environmental symposium, University of Sri Jayawadanapura. Pp 75
- Margaret G. (1997). Nutrient content of wetland plants in constructed wetlands receiving municipal effluent in tropical Australia, Water Science and Technology, 5(35), 135-142.
- Metcalf and Eddy, (2003). Wastewater Engineering: Treatment and Reuse, fourth edition, Tata McGraw-Hill, New York.
- Miao L., Yue-Jin W., Zeng-Liang Y., Guo-Ping S. and Han-Qing Y. (2007). Nitrogen removal from eutrophic water by floating-bed-grown water spinach (*Ipomoea aquatica* Forsk.) with iron implantation, Water research, 41, 3152-3158.
- Plavnik, I. and Hurwitz, S. (1991). Response of broiler chickens and turkey poults to food restriction of varied severity during early life. British Poultry Science, 32: 343 – 352.
- Proudfoot, F.G., Hulan, H.W. and Mcrae, K.B. (1983). The effect of feed denial in starter diets on the performance of broiler chickens. Poultry Science, 62: 1915 – 1917.
- Seni K. and Jara S. (1995). Comparative study of domestic wastewater treatment efficiencies between facultative ponds and water spinach pond, Water Science and Technology, 32(3), 263-270.
- Stephen E. Mbuligwe (2004). Comparative effectiveness of engineered wetland system in the treatment of anaerobically pre-treated domestic wastewater, Ecological Engineering, 23, 269-284,
- Su, G., Sorensen, P. and Kestin, S.C. (1999). Meal Feeding is more effective than early feed restriction at reducing the prevalence of leg weakness in broiler chickens, Poultry Science, 78: 949 – 955.

Su, G., Sorensen, P. and Kestin, S.C. (1999). Meal Feeding is more effective than early feed restriction at reducing the prevalence of leg weakness in broiler chickens, *Poultry Science*, 78: 949 – 955.

Summers, J.D., Spratt, D. and Atkinson, J.L. (1990). Restricted feeding and compensatory growth for broilers. *Poultry Science*, 69: 1855 – 1861.

Visvanathan, C. (2006). Domestic Solid Waste Management in South Asia, 3 R South Asia Expert Workshop, Kathmandu, Nepal.

Zhu J. and Zhu X. (1998). Treatment and utilization of wastewater in the Beijing Zoo by an aquatic macrophytes system, *Ecological Engineering*, 11, 101-110.

## **SECTION 4: Impact of Research Results**

### **i) Immediately applicable research results and the intended beneficiaries.**

- Biogas can be used as a method for pest control in storage paddy.
- Designed wastewater treatment systems can be used for the treatment of domestic wastewater in restaurants.
- Concrete cylindrical type compost bins can be used for the management of food waste and garden wastes.
- Waste separation program can be practiced for the efficient management of different wastes.
- Phytoremediation can easily be used for the treatment of domestic wastewater treatment.
- Concrete composting bins can be introduced among households and they can produce compost using kitchen and garden waste and it will help to manage waste and generate extra income by home gardening.

### **ii) Relevance of results achieved to scientific advancement in relation to the Thematic Programme.**

Waste Management is one of major four areas under thematic area of "Environmental Protection and Sustainable Development". The results obtained in this study are directly related to the scientific advancement of the thematic program. Some of them are as follows,

- Waste assessment in the Faculty of Agriculture in various places including students' hostels, academic departments, and administrations buildings.
- Waste composition determination of different waste generation points.
- The problems of practiced waste management system were identified.
- The suggestions were made for the improvement of waste management in institutions.
- Simple waste treatment technologies were developed and evaluated.
- Home gardening using compost produced from kitchen and garden waste were suggested, evaluated and implemented for the quarters.

### **iii) Relevance of results achieved to national/socio-economic development.**

- Sanitation and hygienic condition of the peoples of the Faculty were improved.
- Waste estimation and composition data can be used for the preparation of waste management plans for other similar institutions.
- Technologies investigated (Wastewater treatment, Phytoremediation, application of biogas for pest control, domestic compost bins, etc) can be used for other similar places.
- Knowledge and interest on waste management and environmental issues of the people were enhanced by this study.

- iv) Methods adopted and/or proposed for the dissemination/application of research outputs.

Methods Adopted

- Findings of the study were published in scientific communications
  - International conferences in outside the country
  - International conferences in the home country
  - National conferences
  - International Journals
- Publicity were given for a certain finding through news papers (such as Vidusara)
- Research findings were shared with undergraduate students

Methods Proposed

- Discussion on Radio to make aware the general public about the necessity of waste management and the findings of the study.

**SECTION 5: Miscellaneous** (List of major equipment acquired during the project period and their functionality.)

Following major equipments were purchased through the funding of the research project.


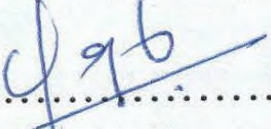
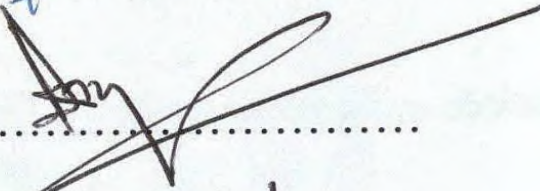
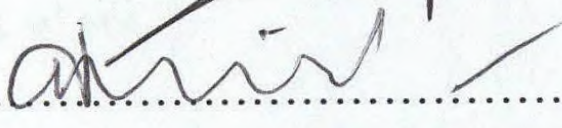

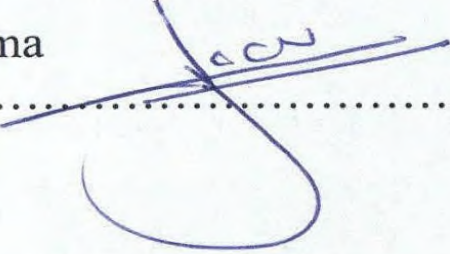
1. Peristaltic Pump (1) - Still working properly and used for the practical and researches of the undergraduates
2. COD Digester (1) - Still working properly and used for the practical and researches of the undergraduates.
3. Desktop Computer (1) - They are in still proper working condition and used in the Department of Agricultural Engineering.

**SECTION 6: Summary Statement of Expenditure** (indicate under Personnel, Equipment, Consumables, Travel and Subsistence and Miscellaneous)

Personal	<i>650129.34</i>
Equipments	<i>594429.49</i>
Consumables	<i>281462.21</i>
Travel and Subsistence	<i>25012.50</i>
Miscellaneous	<i>40439.46</i>

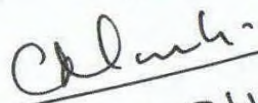
**SECTION 7: Signature page**

i) Signatures of the Investigators

- Mr. S Wijetunga 
- Ms. CP Rupasinghe 
- Prof. KDN Weerasinghe 
- Mr. NSBM Attapattu 
- Prof. S Subasinghe 
- Dr. LM Abeywickrama 


ii) Comments of the Head of the Department of the Principal Investigator/ Signature

The principal Investigator conducted the research at the Department of Ag. Engineering, Faculty of Agriculture, University of Ruhuna.

  
25/10/2011

**Prof. (Mrs.) Champa M. Navaratne**  
Head  
Dept. of Agricultural Engineering  
Faculty of Agriculture  
University of Ruhuna  
Mapalana - Kamburupitiya

iii) Signature of the Head of the Institution of the Principal Investigator

  
04/11/2011

**Acting Vice Chancellor**  
**University of Ruhuna**  
**Matara**

## **ANNEX I: Publications/Communications made from the Results of the Project**

1. Communal attitude towards waste management practices: A case study in Faculty of Agriculture, University of Ruhuna. Sri Lanka Association for the Advancement of Science, 63rd Scientific Sessions, 5th – 8th December, 2007.

**Communal attitude towards waste management practices: A case study in faculty of Agriculture, university of Ruhuna.**

N. Liyanaarachchi<sup>1</sup>, S. Wijetunga<sup>1\*</sup>, N.S.B.M. Attapattu<sup>2</sup>

*Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Kamburupitiya.<sup>1</sup>*

*Department of Animal Science, Faculty of Agriculture, University of Ruhuna, Kamburupitiya<sup>2</sup>.*

### **Abstract**

The reduction, reuse and recycling (3R) of institutional waste have been identified as the key components of waste management strategies throughout world. This paper explores the attitudes of a community of tertiary education institute. All possible parties such as academic staff, non academic staff, students and cleaning service personals were interviewed. Questionnaire survey and informal discussions were carried out to gather information regarding their attitude toward and the present status of the waste management practices of the faculty of Agriculture, University of Ruhuna. Majority of the faculty community agreed that there should be a balance between development and environmental pollution. Ninety six percent of respondents expressed that environmental pollution as a serious threat. Even after introduction of 20 microns polythene policy by the government, 31 % of the community used lunch sheets daily, and 29 % used in five days a week. If recyclables are available 77 % of the faculty community was ready to pay extra money for them and 68 % of them liked to pay up to 5 Rs per sheet. Most of the faculty members (66 %) were unaware of the fate of waste produced by them in the faculty. Majority (89 %) of them were ready to cooperate or participate in future waste management plans of the faculty, indicating the potentials to implement a community based sustainable waste management system. (CBSWMS) Many believed that the current waste management system is not an effective enough. Strong awareness program is needed to develop and strengthen CBSWMS. Eighty one percent of respondents identified that the higher education lead by the community is most important strengthen for implementation of CBSWMS. It was concluded that CBSWMS could be successfully incorporated in to the community of a Tertiary education system.

Financial support by NSF (RG/2006/EPSP/02) is acknowledged.

2. Solid waste generation potential and composition in a higher education institute. 12th International forestry and environment symposium, University of Sri Jayewardenepura. Sri Lanka. 30th November- 1st December. 2007. ISBN 978-955-9054-63-4

## **Solid Wastes Generation Potential and Composition in a Higher Educational Institute**

N.Liyanaarachchi and S.Wijetunga

*Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, Sri Lanka.*

### **Abstract**

The estimation of waste composition is a vital part for the implementation of sustainable waste management system for anyplace. Waste composition estimation for six month period was carried out in Faculty of Agriculture, University of Ruhuna, as an initial step for formulating a community based sustainable waste management system. All possible waste generation locations were categorized into four groups namely, Departments and Administration Buildings, Cafeteria, Quarters and Students' Hostels, based on the similarities of waste generation. Collected wastes in separate bins were further categorized by manually, when required. In the first stage of the study, wastes were estimated according to their degradability. Degradable and non degradable wastes in Departments and Administration Building per day per head were  $64.4 \pm 7.6$  and  $7.4 \pm 1.5$  g, respectively. Degradable wastes collected in cafeteria were about  $60.7 \pm 1.7$  g while non degradable wastes were quite low ( $0.19 \pm 0.08$  g). Relatively higher amount of waste were collected in quarters. It was  $132.31 \pm 57.13$  g of degradable and  $1.28 \pm 1.15$  g of non degradable waste per head per day. Degradable and non degradable wastes in Boys' Hostels were  $60.38 \pm 3.14$  g and  $4.53 \pm 1.58$  g respectively, while it was relatively higher in Girls' Hostels,  $168.06 \pm 11.52$  g and  $16.71 \pm 2.92$  g, respectively. Further categorizing of wastes such as paper, polythene, plastics, food wastes, glasses, metal, wood, textiles, rubber, animal wastes, hazardous wastes and fluorescents were carried out in one occasion (one week). Food waste was the highest in every section; in fact, it was relatively higher in quarters (152.27g) and hostels (114.22g) per head. Quite similar amount of discard polythene (about 0.30g) was collected in canteen and quarters. The reduction of use of lunch sheets in cafeteria, considerably, reduced the generation of waste polythene. Paper wastes generation was relatively higher in Department and Administration buildings (7.46g per head/day) rather than other places. The results of this research reflect the types of wastes generated and composition in the higher educational institute and it could be used to formulate the common strategy for the proper waste management in such, similar, institution in Sri Lanka.

**Key Words:** Solid wastes, Waste Composition, Educational Institutes, Degradable Wastes

**Acknowledgement:** The financial support offered by NSF (RG/2006/EPSPD/02) for the study is highly appreciated.

3. Attitudes towards energy conservation: A case study Faculty of Agriculture, University of Ruhuna, 5th Academic Sessions, University of Ruhuna, 5th March, 2008.

**Attitudes towards energy conservation: A case study Faculty of Agriculture, University of Ruhuna.**

N. Liyanaarachchi, S. Wijetunga\*

*Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka*

**Abstract**

Environmental degradation due to various human activities causes global warming resulting climatic change. Burning of fossil fuels for generation of energy is a major cause of environmental degradation. Energy shortages and energy prices are burning issues in Sri Lanka. Therefore, it was attempted to explore the attitudes of community in a higher education institutes towards the energy conservation, which help to reduce environmental burden associated with energy utilization. All members of the Faculty of Agriculture, University of Ruhuna were interviewed. A questionnaire survey and informal discussions were conducted to gather the information regarding their attitudes towards the present status of the energy conservation practices of the Faculty. Majority of the Faculty community agreed that there is a correlation between energy conservation and environmental pollution. Ninety three percent of respondents concerned about energy conservation. Out of those, 24 % respondents use sunlight as far as possible for light and drying of cloths while 28 % use energy efficient electrical instruments. Forty eight percent of respondents commented that they helped to conserve energy by switching off the bulbs and electrical instruments when they are not in use in the Faculty and home. Most of the members (70 %) use energy saving bulbs at their homes. Over ten places of water wastages had been observed by 21 % of respondents while 31 % reveled that they noticed 2 - 5 places. Printing both sides of the papers helps to conserve resources which indirectly conserve the energy. Sixty one percent used both sides of papers for printing. Many believed that the current energy conservation practices in the Faculty are not effective to conserve energy wastages. The results of the current study showed that strong awareness program can play a leading role in the process of implementing the energy conservation strategies in the Faculty with the participation of all stake holders. It can be concluded that energy conservation strategies can successfully introduced to higher education institutes in Sri Lanka.

**Key words:** Communal attitudes, Energy conservation, Environmental degradation, Educational institutions.

**Acknowledgement:** The financial support offered by NSF (RG/2006/EPSP/02) for the study is highly appreciated.

4. Evaluation of Efficacy in the Treatment of Domestic Wastewater by Different Aquatic Macrophytes. International Congress of Environmental Research-2008, Birla Institute of Technology and Science, Pilani, (GOA CAMPUS), ZUARINAGAR, GOA - 403726, INDIA, 18th to 20th December 2008.

## Evaluation of Efficacy in the Treatment of Domestic Wastewater by Different Aquatic Macrophytes

S Wijetunga, DHU Sandamali and KDN Weerasinghe

Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, Sri Lanka.

### Abstract

The use of phytoremediation is an emerging technology as an environmentally friendly and a low cost technology for the treatment of different kind of wastewaters. Application of phytoremediation techniques for the treatment of domestic wastewater was inadequately reported. Therefore the objective of this study was to evaluate the locally available wetland plants for the possible application of the treatment of domestic wastewater. Four different aquatic macrophytes, *Ipomoea aquatica*, *Limnocharis flava*, *Monochoria vaginalis* and *Colocasia spp* were evaluated for the treatment of domestic wastewater generated from student's cafeteria in the University. The root dipping technique was practiced for the study. Seventy five liter Styrofoam boxes were used and experiment was arranged according to the Randomized Complete Block Design (RCBD). The water quality parameters such as Chemical Oxygen Demand(COD), Total Solids(TS), Total Suspended Solids(TSS), Total Kjeldahl Nitrogen(TKN), Orthophosphate, Electrical Conductivity(EC) and pH were monitored to evaluate the treatment efficiency of different plants and the fresh weight gain of the plants were also determined at the end. The average COD removal efficiency, 68.39% was the highest in the system of *Limnocharis flava*, while lowest 36.77% was observed in the *Colocasia sp.* system. TS, TSS, TKN, removal efficiencies were highest in the treatment system of *Limnocharis flava*, while TDS is removed efficiently by *Ipomoea aquatica*. During the study period pH was initially increased from 5.5 to 6.5 at the 6<sup>th</sup> day and it was constant until the end of the study in all aquatic plant systems and control units. The highest weight gain was observed in the *Limnocharis flava* and *Ipomoea aquatica*. According to the results *Limnocharis flava* is the most suitable plant for the treatment of domestic wastewater. Nevertheless, *Ipomoea aquatica* was also considerably removed different pollutants present in the domestic wastewater. *Colocasia sp.* did not show any progress in the treatment of pollutants in the study wastewater. Therefore, the treatment system with *Limnocharis flava* and *Ipomoea aquatica* could be recommended for the removal of pollutants present in the domestic wastewater as an effective, environmentally friendly and low cost treatment system.

**Key Words:** Phytoremediation, Aquatic Macrophytes, Wastewater Treatment, Domestic Wastewater

5. Evaluation of Different Types of Commercially Available Domestic Compost Bins as an Option for Kitchen and Garden Waste Management. Sri Lanka Association for the Advancement of Science, 63rd Scientific Sessions, 1st – 6th December, 2008.

## **Evaluation of Different Types of Commercially Available Domestic Compost Bins as an Option for Kitchen and Garden Waste Management**

N Liyanaarachchi, S Wijetunga\* and K D N Weerasinghe

*Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka*

### **Abstract**

Composting is one way in which some of the problems associated with the utilization of various organic wastes can be resolved. Particularly in the urban area compost bins are being used for home composting, however, no any performance evaluation has been done with regard to different compost bins in Sri Lanka. The objectives of this research were to evaluate the different parameters in the composing process in different compost bins currently available in Sri Lanka, and to find the comparatively most effective compost bin for kitchen waste. Four types of compost bins, namely, concrete box type (CB), plastic cylindrical shape (PC), plastic conical shape (PCO), and concrete cylindrical shape (CC) bins were used. Kitchen waste was used as main source of materials and garden waste was also used as a supplement. Parameters such as temperature, pH, electrical conductivity (EC), moisture content (MC), bulk density (BD), dry matter (DM), ash, Carbon: Nitrogen ratio, (C:N) ratio and volume reduction were measured for about 2 months. Highest average temperature was reported from CB (34.64 ° C) followed by CC (33.85 ° C) during first week. Mature compost, dark brown in colour, moderately sticky, and no odor, were observed after 8 weeks of operation in CC. Moisture in all types of bins were observed in the range of 50- 60 %. pH was reduced during the composting process, and it was close to pH 7 at maturity stage. Ash percentages at the maturity stage of compost were 8.15 %, 8.05 %, 9.10 % and 7.65 % in CB, PCO, PC and CC, respectively. The highest organic matter (92.31 %) and Nitrogen content (1.06 %) with compared to other bins were observed in CC and PCO, respectively. Lowest C: N ratio (1:10.65) was observed in CC. Due to passive composting (no mixing of bulk) within the compost bin, the rate of decomposition was relatively low. According to the results, other parameters except C:N ratio, were shown relatively similar observations. However, since C: N ratio is vital factor in composting, CC can be recommended, compared with other types, for home composting of kitchen waste.

### **Acknowledgement**

Financial assistant offered by NSF (RG/2006/EPSP/02) is highly appreciated.

6. Development of Broiler Offal Silage-Rice Bran Mixture as an Animal Feed Ingredient: In Vitro Nutritive. 13th International forestry and environment symposium, University of Sri Jayewardenepura. Sri Lanka, 27<sup>th</sup> – 28<sup>th</sup> December, 2008. ISBN 978-955-9054-70-2.

**Development of broiler offal silage-rice bran mixture as an animal feed ingredient: *In vitro* nutritive value**

N.Liyanaarachchi,<sup>1</sup> N.S.B.M.Atapattu<sup>2</sup> and S.Wijetunga<sup>1</sup>

<sup>1</sup>Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya

<sup>2</sup>Department of Animal Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya

**Abstract**

Processing of 100 kilo grams of broiler live weight gives rise to approximately 20-25 Kg of offal that include heads, inedible internal organs, feathers and legs. If not properly discarded, broiler offal (BO) causes severe environmental and health problems. Environmental problems associated with indiscriminate disposal of BO have become one of the major reasons for the closure of many broiler operations. On the other hand, disposal of BO has become an additional burden on broiler farmers. One of the best means of encouraging proper disposal of waste is to increase the usability of waste and thereby adding some value to it. It has been found that BO can be ensiled with citric acid (XA) and preserved without any adverse environmental problems. If mixed with a suitable material and then dried, broiler offal silage (BOS) may be used as an animal feed. Objective of this study was to evaluate the *in vitro* nutritive value of broiler offal silage (BOS) rice bran mixture. BO (without feathers) was ground and ensiled with 10 % CA. The initial pH of the mixture was 4.2. The pH of the BOS maintained more or less constant level (<4.4) for 10 weeks. Resulting BOS was mixed with rice bran at 1:2 ratio and dried until the dry matter content of the mixture was 85%. The analysis of resulting broiler offal silage rice bran mixture (BOSRB) contained 20±0.7% crude protein, 5.1±1.2 % ash, 30±0.8 crude fat, 14.2±5.2 % crude fibre and 1.88±0.04 total phosphorus. The pH of the BOSRB was 5.2±0.04. It was concluded that *in vitro* nutritive value of BOSRB was higher than that of the normal rice bran and thus could be a good feed ingredient in non-ruminants and fish diets.

**Keywords:** broiler offal, silage, feed, nutritive value

7. Effect of Application of Organic Liquid Fertilizer on Growth and Yield Performance of Curry Chili (*Capsicum annuum*). 13th International forestry and environment symposium, University of Sri Jayewardenepura. Sri Lanka, 27th – 28<sup>th</sup> December, 2008. ISBN 978-955-9054-70-2.

**Effect of Application of Organic Liquid Fertilizer on Growth and Yield Performances of Curry Chili (*Capsicum annuum*)**

M.K.T. Amarasinghe<sup>1</sup>, N.D.N. Priyadarshani<sup>1</sup>, H.K.M.S. Kumarasinghe<sup>1</sup> and S. Wijetunga<sup>2</sup>

<sup>1</sup>Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Sri Lanka.

<sup>2</sup>Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Sri Lanka

**Abstract**

Capsicum which belongs to family Solanaceae is referred to as bell pepper or sweet pepper or paprika and is mostly of European origin with large mild fruits. It can be grown in soils rich in organic matter with adequate drainage. Foliar application of micro nutrients such as Cu, Zn, Mn, B and Fe is reported to increase the yield and improve the quality of fruits of capsicum. Capsicum plant is reported to respond well to fertilizer application. Sweet peppers are very rich in vitamin A the efficacies of cattle manure, chicken manure, sludge, farm compost etc. in improving the growth yield of Capsicum plants are well documented. Experiments were carried out to determine the effect of different organic liquid fertilizers on growth and yield of curry chill. Worm wash (1L of warm wash diluted in 5L of water), biogas slurry, mixture of warm wash and biogas slurry (1:1), Maxicrop and compost tea (3kg of compost dissolved in 10L of water), were used in different treatments. Four week old Capsicum seedlings of variety CA 8 were used for this experiment. Seedlings were planted at 45cm apart in a Randomized Complete Block Design with four replicates. Data on plant height, number of leaves, Number of branches and number of pods were collected at two weeks interval. Data were analyzed using Anova in the computer statistical package, Statistical Analysis System (SAS). Capsicum plants treated with mixture of warm wash and biogas slurry (1:1) showed higher number of leaves (91) and a higher plant height (58.4cm) at 14 week after planting. A significant higher ( $P < 0.05$ ) number of pods (12) were also observed in the same treatment. In contrast, a higher number of branches (15.5) were observed in curry chili treated with Maxicrop solution. Addition of mixture of warm wash and biogas slurry (1:1) increased the soil nitrogen and potassium contents. Before the treatments, average soil N and K contents were 0.09% and 58.33 mg/kg. It is observed that three months after application of warm wash and biogas slurry (1:1), N and K contents of soil increased up to 0.17% and 83.33 mg/kg, respectively and K contents were 0.1% and 66.7 mg/kg of soil treated with warm wash alone.

Addition of a mixture of warm wash and biogas slurry (1:1) appeared to be the most promising treatment to obtain a higher growth and yield in capsicum.

**Key words:** biogas slurry, Curry chili, growth and yield performances, worm wash

8. Ability to Control Angoumois Grain Moth (*Sitotoga cerealella*) in Paddy Storage Condition Using Biogas. 13th International forestry and environment symposium, University of Sri Jayewardenepura. Sri Lanka, 27<sup>th</sup> – 28<sup>th</sup> December, 2008. ISBN 978-955-9054-70-2.

**Ability to control Angoumois grain moth (*Sitotoga cerealella*) in paddy storage condition using biogas**

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**Abstract**

In Sri Lanka 4 to 6 % of harvested paddy is lost during storage due to pest attack. Angoumois grain moth, *Sitotoga cerealella* (Oliv), (Lepidoptera: Gelechiidae) is considered as the major problem in storages in many parts of Sri Lanka. Both adult and larvae damage to grain in storage condition as well as field level. The objective of the research was to find the capability of biogas to control the Angoumois grain moth in stored paddy as a fumigant. Stored paddy samples infested by Angoumois grain moth were taken into air tight plastic containers and treated with biogas using syringe in different time intervals of 15 minutes, 30 minutes, 45 minutes and 60 minutes with three replicate and treatments were repeated 3 times within 2 weeks intervals. Each replicate contain 1 kg of stored paddy. Number of adult moths was counted before application of biogas. Number of dead bodies was counted after 24 hours of application. The application rates of biogas for each treatment were also measured. The average number of live insects after the first application (15 minutes) was 5 and it was decreased into 4 and 2 in second and third applications respectively. The percentage of dead insects were 100 % in third (45 minutes) and fourth treatments (60 minutes). It was 75 % in first treatment (15 minutes). The percentage of dead insects was varied from 87.5 % to 100 % in second treatment (30 minutes) in second and third applications. The applied average volume of biogas were  $(0.01015 \pm 0.001759)$  m<sup>3</sup> for 15 minutes treatment and  $(0.01835 \pm 0.002556, 0.0234 \pm 0.004056, 0.0259 \pm 0.002914)$  m<sup>3</sup> for 30, 45 and 60 minutes treatments respectively. When comparing the control there was a significant effect in Angoumois grain moth control by using biogas. According to the mortality rates there was no significant difference among the treatments two (30 minutes), three (45 minutes), and four (60 minutes) except treatment one (15 minutes). Therefore it is concluded that, paddy grain moths could be effectively controlled by applying biogas for more than 15 minutes having the volume of  $(0.01015 \pm 0.001759)$  m<sup>3</sup> for 1kg of stored paddy. It is suggested that biogas is low cost sustainable and renewable energy source that can be easily produced by paddy farmers themselves by using paddy waste (straw) and it also has a good potential for control of paddy grain moth at paddy storage under modified atmospheric condition.

**Key Words:** *Sitotoga cerealella*, pest control, biogas, post harvest losses, paddy storage

**Acknowledgement:** Financial assistant from NSF research grant RG/2006/EPSPD/02 and contribution of Dr. L. Nugaliyadda are highly appreciated.

9. Potential and threat of e-waste accumulation: A case study at Faculty of Agriculture, University of Ruhuna. 6th Academic Sessions, University of Ruhuna, 26th March, 2009.

**Potential and threat of e-waste accumulation: A case study at Faculty of Agriculture, University of Ruhuna**

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**Abstract**

E-waste or Waste Electrical and Electronic Equipment (WEEE) can simply be defined as broken or unwanted electrical or electronic devices. The use of advanced technological electronic/electrical equipments leads to generate more e-waste. Majority of these e-wastes contain heavy metals (Copper, Mercury, Cadmium, etc.), non degradable organics and carcinogenic compounds. Non-systematic e-waste disposal creates severe environmental and health hazards. This study was performed to estimate the potential of e-waste generation in the Faculty of Agriculture, University of Ruhuna. Data were collected from the documents and reports maintained by the Faculty of Agriculture and from the informal discussion with respective personals. The potential of e-waste generation was estimated using the electronic and/or electrical equipments obtained during the last three years (2006, 2007 and 2008). The electronic and/or electrical equipments includes non alkaline batteries, fluorescent tubes, compact fluorescent lamps (CFL), computers, monitors, scanners, printers, cartridges (printer), toners (photocopier), photocopiers, uninterrupted power supply units (UPS) and flash drives. Average use of non alkaline batteries was 1028 ( $\pm 182.90$ ) per year. The replacement of 2 and 4 feet fluorescent tubes has been reduced considerably due to use of CFL bulbs instead of fluorescent tubes. The computers (desktop/laptops) obtained in 2006, 2007 and 2008 were 11, 32 and 21 respectively. The number of scanners and printers had been increased from 2007 to 2008. It appears that almost all electronic/electrical equipments consumed in the faculty, which contribute for the e-waste generation are being increased. At present, there is no proper method of recycling or disposal of e-wastes in the Faculty of Agriculture. Current legal system imposed some restrictions to the disposal of certain equipments. Based on the study, it can be concluded that there is a potential of e-waste accumulation in the Faculty of Agriculture and, therefore, it is essential to have a proper, systematic recycling or disposal procedures to be implemented, in the near future for e-waste disposal in higher education institutes to tackle the arising e-waste accumulation problem.

**Key words:** - e-waste, electronic equipments, recycling, waste disposal

10. Weaknesses and Opportunities towards Effective Water Utilization in Institutions: A case Study in Faculty of Agriculture, University of Ruhuna. Second National Symposium, Faculty of Agriculture, University of Ruhuna, 10th September 2009.

**Weaknesses and Opportunities towards Water Conservation in Institutions: A Case Study in Faculty of Agriculture, University of Ruhuna**

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**Abstract**

The predominant strategy of water conservation is the minimizing the water wastages. In this study it was attempted to estimate the water wastage in the Faculty of Agriculture, University of Ruhuna, and to suggest the possibilities to minimize the water wastage and to reduce the cost bared for water. Primary data were collected from the documents and informal discussion with the officers of the different sections in the faculty. Water leakages were measured in a stipulated time period. Faculty has 6 water tanks, each with a well and a pump. According to the water pumping hours and volume of tanks, daily water consumption from the wells was 188.76 m<sup>3</sup> during study period. Additional water obtained from National Water Supply and Drainage Board (NWSDB) in 2007 and 2008 was 48.03 and 35.02 m<sup>3</sup>/day, as a percentage of total water consumption it was 20.28 % and 14.78 %, respectively. Average cost for water bill in 2007 and 2008 was Rs. 726342.00 and 530283.96, respectively. The reduction of water consumption (6%), basically, due to the awareness programs conducted in 2008. Students consumed 100.08 m<sup>3</sup> (44.69 %) of water while other sections such as department, administration complex and canteen used 112.39 m<sup>3</sup> (50.19 %). And farm (only for cattle shed) was used 11.46 m<sup>3</sup> (5.12 %) of water daily during study period. Per capita water consumption of students was 0.274 m<sup>3</sup> which was quite higher than the Sri Lankan per capita water consumption (0.115 m<sup>3</sup>). Water usage for toilet flushing was estimated using number of cistern tanks, volume of each tank and flushing frequency and it was 39.69m<sup>3</sup>/day. Approximately 17.73 % of water (out of total consumption) was used for toilet flushing. Due to the leakages, 186.224 m<sup>3</sup> of water was lost in every month costing about Rs. 7821.40. Preventing the water leakages alone, it was found that ~18% of water bill could be reduced. Huge amount of water is used for toilet flushing and it can easily be replaced by harvested rainwater. And it enables the total reduction of cost for water obtained from NWSDB. Even though water consumption in the faculty is higher due to laboratory work and farm activities, there is a great possibility to reduced water consumption by improving the attitudes and attention of the community for water conservation. It is further suggested that attention should be given to water conservation by using community awareness programs and frequently repairing of water distribution systems.

**Key Words:** - Water wastage, Water conservation, Community attitudes,

11. Evaluation of Simple Wastewater Treatment System for Restaurants. 14th International forestry and environment symposium, University of Sri Jayewardenepura. Sri Lanka, 18<sup>th</sup> – 19<sup>th</sup> December, 2009. ISBN 978-955-9054-81-8.

## Evaluation of Simple Wastewater Treatment System for Restaurants

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### Abstract

Domestic wastewater (DWW) generated from residences and restaurants are one of the major sources of environmental pollutants. The treatment of DWW, where it is generated, is a promising option over centralized treatments systems. The objective of this study was to design and evaluate the simple DWW treatment system for the restaurants. The treatment system comprised of a filtering and a bio-purification units. The filtering unit was constructed using 200 L and 500 L plastic water tanks and a wire mesh. The primary function of the filtering unit is to remove the large solid particles contained in DWW. Bio-purification unit was an open tank (400 L) filled with DWW where water spinaches (*Ipomea aquatica*) could be grown. Major function of this unit is to remove the organic pollutants in DWW. Daily discharge amount of DWW from the restaurant, where about four hundred persons were served in three times a day, was estimated and characterized for several physical and chemical parameters. DWW generated from the restaurant was first diverted to the filtering unit through which it was fed to the bio-purification unit. The removal of total solid (TS), pH, Orthophosphate, total kjeldhal nitrogen (TKN) were determined in the filtering unit. Total solid removal was ~45 % and also slight reduction of pH, Orthophosphate and TKN were noted in the filtered DWW. Total suspended solid (TSS) and total dissolved solids (TDS) were removed remarkably after ten days operation period of bio-purification unit. The pH was in the range of 5.5 to 6.1 during this period. However, first five days, pH was decreased down to ~5.6 and it was increased up to 6.1 at the end of ten days operation period. Orthophosphate content was increased while TKN was decreased. Chemical oxygen demand (COD) was decreased to the standard in effluent discharge regulations in Sri Lanka. The growth performance of water spinach was increased considerably during the operation of bio-purification unit. In this study, it was observed that pollutants in DWW were effectively removed in the bio-purification unit, where water spinach was used, within retention time of 9 days up to standards required. Therefore, it can be concluded that simple treatment system with filtering unit and bio-purification unit is a good option for the treatment of DWW generated from restaurants.

**Keywords:** Domestic wastewater, Bio-purification, organic pollutants, water spinach

12. Use of broiler offal silage-rice bran pellets in a qualitative feed restriction strategy for mature broilers. Sri Lanka Association for the Advancement of Science, 65<sup>th</sup> Scientific Sessions, 7 – 11<sup>th</sup> December, 2009.

**Use of broiler offal silage-rice bran pellets in a qualitative feed restriction strategy for mature broilers**

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**Abstract**

Broilers show a compensatory growth when a high quality feed is offered *ad libitum* following growth retardation either due to qualitative or quantitative feed restriction. This study used the pellets of broiler offal silage-rice bran mixture (BOSRBP) in a quantitative feed restriction strategy to evaluate the production and economic performance of broilers. Twenty seven day old broiler chicks (n=54) in 18 pens were subjected to three dietary regimes: 1-birds were fed BOSRBP during day time and commercial finisher feed during night time until day 34(BOSRBP<sub>d</sub>), 2-same as regime 1 except BOSRBP were fed during night (BOSRBP<sub>n</sub>) and 3- fed the same broiler finisher diet *ad libitum* (control). From day 35-41 birds in all three treatments were fed the same commercial feed *ad libitum*. Rice bran and broiler offal silage were mixed at 2:1 and dried (BOSRB). Dried BOSRB mixture was mixed with water (1:1) pelleted and then dried. The total commercial feed intake was significantly reduced when BOSRBP were given either day or night time from day 27-34. When birds were offered the commercial feed in night or day time following a session of BOSRBP feeding their commercial feed intake were significantly higher than the commercial feed intake of the respective sessions of the birds who received commercial feed uninterruptedly. Both during day time and night time water feed ration was significantly higher when BOSRBP were given. Birds in BOSRBP<sub>d</sub> and BOSRBP<sub>n</sub> feeding regimen showed significantly lower live weight on day 34 and weight gain from day 27-34. Those birds were unable to show a compensatory growth sufficient enough to equate the final live weight with the birds in control group. Although the total feed cost of the birds in control group significantly reduced from Rs 181 to Rs 166 under BOSRBP<sub>n</sub> feeding regime and to Rs 161 under BOSRBP<sub>d</sub> feeding, the feed cost per unit live weight gain showed no benefits. It was concluded that restricted feeding strategy which used BOSRBP has no beneficial effects on growth or financial performance of mature broiler chicken.

13. Evaluation of Efficacy in the Treatment of Domestic Wastewater by Different Aquatic Macrophytes; Journal of Environmental Research and Development 2009;4:297-309

## Evaluation of Efficacy in the Treatment of Domestic Wastewater by Different Aquatic Macrophytes

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### Abstract

The use of phytoremediation is an emerging technology as an environmentally friendly and a low cost technology for the treatment of different kind of wastewaters. Application of phytoremediation techniques for the treatment of domestic wastewater was inadequately reported. Therefore the objective of this study was to evaluate the locally available wetland plants for the possible application of the treatment of domestic wastewater. Four different aquatic macrophytes, *Ipomoea aquatica*, *Limnocharis flava*, *Monochoria vaginalis* and *Colocasia spp* were evaluated for the treatment of domestic wastewater generated from student's cafeteria in the University. The root dipping technique was practiced for the study. Seventy five liter Styrofoam boxes were used and experiment was arranged according to the Randomized Complete Block Design (RCBD). The water quality parameters such as Chemical Oxygen Demand(COD), Total Solids(TS), Total Suspended Solids(TSS), Total Kjeldahl Nitrogen(TKN), Orthophosphate, Electrical Conductivity(EC) and pH were monitored to evaluate the treatment efficiency of different plants and the fresh weight gain of the plants were also determined at the end. The average COD removal efficiency, 68.39% was the highest in the system of *Limnocharis flava*, while lowest 36.77% was observed in the *Colocasia sp.* system. TS, TSS, TKN, removal efficiencies were highest in the treatment system of *Limnocharis flava*, while TDS is removed efficiently by *Ipomoea aquatica*. During the study period pH was initially increased from 5.5 to 6.5 at the 6<sup>th</sup> day and it was constant until the end of the study in all aquatic plant systems and control units. The highest weight gain was observed in the *Limnocharis flava* and *Ipomoea aquatica*. According to the results *Limnocharis flava* is the most suitable plant for the treatment of domestic wastewater. Nevertheless, *Ipomoea aquatica* was also considerably removed different pollutants present in the domestic wastewater. *Colocasia sp.* did not show any progress in the treatment of pollutants in the study wastewater. Therefore, the treatment system with *Limnocharis flava* and *Ipomoea aquatica* could be recommended for the removal of pollutants present in the domestic wastewater as an effective, environmentally friendly and low cost treatment system.

**Key Words:** Phytoremediation, Aquatic Macrophytes, Wastewater Treatment, Domestic Wastewater

**Acknowledgement** The financial support offered by National Science Foundation of Sri Lanka (RG/2006/EPSP/02) for the study is highly appreciated.

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**Influence of Undergraduates Activities on the Waste Composition and Generation Rates In A Residential University – Case Study**

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**ABSTRACT**

The information with respect to waste composition, generation rate and its variation with time are required for the planning of proper waste management system. In this study, it was attempted to evaluate the composition and the variation of waste generation rate in the hostels of the undergraduates. The study was conducted in the premises and surroundings of the hostels of the undergraduates for a period of one year. The waste was collected from each and every hostel once in two months. The wastes were separated, weighted and determined the percentages of different components. The types of waste found in hostels of girls were less in numbers than that of boys. Over ~95 % of waste found in girls' hostels were food remains and boys generate food waste about ~71%. Per capita food waste generation by girls was ~ 207 g/day while it was ~23 g/day by boys. It appears that the amount of waste generation varied in different months basically due to examinations and other activities of the students. Based on this study, it can be concluded that major component of waste found in undergraduate hostels was food wastes and the generation rate slightly varies with the activities of undergraduates.

**Key Words:** Waste, Undergraduates, Waste Composition, Generation Rate, Temporal Variation

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