Islamic University of Technology

Effectiveness of SODIS (Solar Disinfection) in Urban and Rural Areas of Bangladesh

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DECLARATION

This is to declare that the thesis entitled “Effectiveness of SODIS in Rural and Urban Areas of Bangladesh”, by Mostansir Billah Nayeem and J.M. Rakibul Hasan have been approved, in partial fulfillment of the requirements for the Bachelor of Science degree in Civil and Environmental Engineering. The following thesis has not been submitted elsewhere for reward of any degree or diploma (except for publication).

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Abstract

Most of the people in the developing countries have less access to the safe drinking water. Bangladesh is one of the developing countries. Most of the health problems in Bangladesh are water borne. The financial condition of the people, living in the rural and semi urban areas of Bangladesh is very poor. Most of them don't have the budget for drinking water treatment. Keeping that in mind, solar disinfection system (SODIS) can be effective in reducing level of water contamination in Bangladesh. At present More than 5 million people Worldwide clean their drinking water with the SODIS method. Presently SODIS projects have been conducted in 15 countries of Africa, Asia and Latin America.

In SODIS solar energy is used in the form of ultra violate radiation and to a lesser extend infrared heat to disinfect or destroy pathogenic microorganisms in the water. This process is carried out with several steps like collecting PET (2-L Poly Ethylene Terephthalate) bottles, filling with contaminated water, shake and close, placing bottles in the full sun for at least 6 hours. The concentrated sunlight radiation and synergistic effect of thermal energy reduce the fecal contamination in water. To study the effects of solar radiation and heating on the inactivation of Total Coliform (T.C), Fecal Coliform (F.C), Escherichia Coli (E.Coli), and Heterotrophic Plate Count (HPC) experiments were conducted. Water samples were exposed to sunlight in plastic bottles. Plastic bottles were used because they are common, inexpensive containers that can be found worldwide. Different types of media are used to test different parameters. For each experiment, the test bottles were prepared. The initial temperature of each test bottle was recorded and samples were taken to enumerate the starting concentration of bacteria. The test bottles were then exposed to sunlight and samples were collected at predetermined intervals to determine the Total Coliform (T.C), Fecal Coliform (F.C), Escherichia Coli (E.Coli), Heterotrophic Plate Count (HPC) concentration. During each sampling time, air temperature, water temperature and solar irradiance were measured. To quantify the inactivation effects of heating only, laboratory experiments were conducted. So From All our Experiments, We have seen significant reduction of bacteria so SODIS is applicable in our atmosphere. PET bottle with Foil Backing surface may be the best among variations. SODIS is cheaper and Helpful for the Poor people.

SODIS requires sufficient solar radiation. Therefore it depends on the weather and climatic conditions. SODIS requires clear water. SODIS does not change the chemical water quality. SODIS is not useful to treat large volumes of water. In case of Laboratory testing we are not counting vibrio Cholera, Salmonella and Shigella bacteria. Also not testing the amount of turbidity.

CONTENT

CHAPTER ONE
INTRODUCTION

1.1 General

Bangladesh is a country in South Asia located at the apex of the Bay of Bengal. The United Nations Development Program's (UNDP) “2013 Human Development Report” ranked Bangladesh 146th among the 187 countries in the Human Development Index (HDI). Bangladesh is one of the world's most densely populated countries with 150 million people, 49 percent of whom live below the national poverty line (According to World Bank in 2005). About 20% of rural and 37% of urban population living below the national poverty line. These people have limited access to clean drinking water. The poor health condition Water and sanitation have a major impact on health. 780 million people worldwide lack access to clean water and 2.5billion lack adequate sanitation. Lack of access of safe drinking water increases the risk of contracting water borne diseases including cholera, diarrhea, typhoid, hepatitis A and Amoebic dysentery. The World Health Organization says that every year more than 3.4 million people die as a result of water related diseases, making it the leading cause of disease and death around the world.

in Bangladesh is mostly attributed by the lack of safe drinking water. Many Bangladesh’s health problems, including high infant and child mortality and high incidence of fecal-orally transmitted disease, are related to contaminated water.
Salinity in ground and surface water in the coastal regions, arsenic contamination of shallow aquifer, lack of aquifer and difficulties in extracting saline free water are some of the causes of insufficient safe water in Bangladesh. The available methods of house hold disinfection of water in Bangladesh include filtration, boiling or heating water with fuel, Rain water Harvesting (RWH), Chlorination of water. As Bangladesh is developing country, we need more economic and effective process for disinfection of water. The SODIS method is ideal for treating water for drinking in developing countries. All it

requires is sunlight and PET bottles. As early as the 1984s, Lebanese scientist Aftim Acra, Professor at the American University of Beirut discovered that exposing water to the sunlight decreased the number of microorganisms (see publication). This became the starting point for the development of solar water disinfection. In the 1990s the water research institute EAWAG, the Swiss Federal Institute of Aquatic Sciences and Technology, decided to investigate the idea and create a safe, simple method that can be used in developing countries. An interdisciplinary research team consisting of microbiologists, virologists, engineers and drinking water specialists then worked out a method that only needs PET bottles and sunlight: the SODIS method. To see how effective and how applicable this method was, Eawag ran tests in the laboratory and under field conditions in developing countries. In these tests, the SODIS method was shown to be effective and user-friendly, and also cost-effective. Eawag set up projects in developing countries to make sure that the method was made available to the people who needed it most urgently. At the moment we are working in 24 countries. Famous research establishments such as the Royal College of Surgeons, Ireland, or the University of Uppsala, Sweden, also studied the SODIS method. Their studies confirmed that the method does kill germs and has a positive effect on people's health. It was concluded that there was an outstanding acceptance of SODIS technology in both rural and urban populations and a high demand for the technology from important institutions. This resulted in the creation of the SODIS Foundation all over Latin America from October 2000. Thousands of families from Latin America and other regions have started using SODIS ever since, and the results are significant.

1.2 Objectives of the Study

The objective of this study is to test the inactivation of various parameters by solar disinfection. Parameters like

Total Coliform (T.C),

Fecal Coliform (F.C),

Escherichia Coli (E.Coli),

Heterotrophic Plate Count (HPC).

The purpose of this experiment is to compare the effectiveness of SODIS in the perspective and different conditions of Bangladesh. The Effectiveness is compared by undertaking the SODIS experiment with some variations like

1. In Different seasons (Summer, Rainy, Winter season)
2. By changing the backing surface. (Black surface, Aluminum surface etc.)
3. By using different material (PET bottle, Glass bottle etc.)
4. Various angular positions (Standing, Lying, Angle 45 degree etc.)

1.3 Study Area

The research work is to be carried out by collecting samples from Khulna the south-west of the country and Mongla Upazilla. Because Salinity in ground and surface water in this coastal regions is severe.

1.4 Scope of this Study

To study the effects of solar radiation and heating on the inactivation of Total Coliform (T.C), Fecal Coliform (F.C), Escherichia Coli (E.Coli), Heterotrophic Plate Count (HPC) experiments were conducted. Water samples were exposed to sunlight in plastic bottles. Plastic bottles were used because they are common, inexpensive containers that can be found worldwide. Different types of media are used to test different parameters. For each experiment, the test bottles were prepared. The initial temperature and turbidity of each test bottle were recorded and samples were taken to enumerate the starting concentration of bacteria. The test bottles were then exposed to sunlight and samples were collected at predetermined intervals to determine the Total Coliform (T.C), Fecal Coliform (F.C), Escherichia Coli (E.Coli), Heterotrophic Plate Count (HPC) concentration. During each sampling time, air temperature, water temperature and solar irradiance were measured. To quantify the inactivation effects of heating only, laboratory experiments were conducted.

1.5 Limitations of this Study

SODIS requires sufficient solar radiation. Therefore it depends on the weather and climatic conditions. SODIS requires clear water. SODIS does not change the chemical water quality. SODIS is not useful to treat large volumes of water. In case of Laboratory testing we are not counting vibrio Cholera, Salmonella and Shigella bacteria. Also not testing the amount of turbidity.

CHAPTER TWO
LITERATURE REVIEW

Chapter 2 discusses the worldwide problem regarding the shortage of drinking water, and the impacts of poor water quality on people in developing countries. Also the poor water quality in the respective areas of Bangladesh from where the samples for the experiments are collected. The specific water treatment options are presented, including chemical treatment options and physical treatment options

2.1 Developing Countries

People in the developing countries have less access to the safe drinking water. The term “developing country” is broad and far-reaching. It is a common term, but one that is used to describe countries of varying degrees of wealth, infrastructure, education, agriculture, industry, and communications. . Bangladesh is one of the developing countries. In Developing countries the ingestion of water-based pathogens is of frequent concern and in which a significant portion of the population does not have access to water of acceptable drinking water standards. The World Health Organization defines acceptable drinking water as that in which no *Total Coliform (T.C), Fecal Coliform (F.C), Escherichia Coli (E.Coli), Heterotrophic Plate Count (HPC)* bacteria are detected in any 100 mL sample (WHO, 1997).

2.2 Condition in Bangladesh

Bangladesh is a country in South Asia located at the apex of the Bay of Bengal. The United Nations Development Program's (UNDP) “2013 Human Development Report” ranked Bangladesh 146th among the 187 countries in the Human Development Index (HDI). Bangladesh is one of the world's most densely populated countries with 150 million people, 49 percent of whom live below the national poverty line (According to World Bank in 2005). About 20% of rural and 37% of urban population living below the national poverty line. These people have limited access to clean drinking water. The poor health condition in Bangladesh is mostly attributed by the lack of safe drinking

water. Many Bangladesh's health problems, including high infant and child mortality and high incidence of fecal-orally transmitted disease, are related to contaminated water. Salinity in ground and surface water in the coastal regions, arsenic contamination of shallow aquifer, lack of aquifer and difficulties in extracting saline free water are some of the causes of insufficient safe water in Bangladesh.

2.3 Disinfection options

When large community-wide water treatment and distribution systems are not available, people may treat water individually or for their families. There are several water disinfection options available for small-scale use. Water disinfection methods can be divided into two categories. The first category is chemical disinfection. Chemical disinfection includes methods such as chlorination and iodine treatment. Chlorine is the most common method of drinking water treatment due to its effectiveness at inactivating several types of pathogens and its low chemical cost. Chlorinated water also retains a residual that further protects from recontamination after the water is treated (Burch and Thomas, 1998). Iodine is a second chemical treatment option and one that is commonly used by hikers and backpackers in the U.S. as an effective and transportable method of water treatment. However, iodine is not used to treat large amounts of drinking water because, weight for weight, it costs approximately 20 times more than chlorine (Ellis, 1991). Chemical costs may render such options unavailable to low-income families.

Other reasons chemical treatment is undesirable include the training needed to calculate proper chemical dosages and the unpleasant odor and taste of the drinking water. An additional disadvantage with all chemical treatment methods is that chemicals oxidize over time and therefore have limited shelf lives.

Physical treatment methods such as boiling water and UV treatment may also be used to treat drinking water. Boiling water is a simple process, but requires resources that may not be readily available. This is especially true for areas concerned with the effects of desertification and deforestation because boiling one liter of water requires approximately one kilogram of wood. The process is also time consuming and boiling water has been

found to impart a disagreeable taste (Acra *et al.*, 1984; Ellis, 1991). UV radiation is the process where water is exposed to a lamp generating light at a wavelength of approximately 250 nm. This wavelength is in the middle of the germicidal band and is responsible for damaging the DNA of bacteria and viruses. However, UV treatment is only effective for low turbidity waters and therefore pretreatment such as filtering is required for poor water quality sources. Also, developing and maintaining UV radiation treatment requires the initial cost of purchasing equipment, a knowledgeable operator to properly use the equipment, and sufficient funds for maintenance. For areas that are unable to financially support such a treatment scheme, UV radiation is not a viable treatment option (Burch and Thomas, 1998).

The available methods of house hold disinfection of water in Bangladesh include filtration, boiling or heating water with fuel, Chlorination of water. As Bangladesh is a developing country, it needs more economic and effective process for disinfection of water.

2.4 Solar Disinfection

SODIS, Solar water disinfection is a simple method to improve the quality of drinking water by using sunlight to inactivate pathogens. During the exposure, the sun destroys the pathogens. For over 4000 years, sunlight has been used as an effective disinfectant (Conroy *et al.*, 1996).

2.4.1 Solar Radiation as a Disinfection Mechanism

For over 4000 years, sunlight has been used as an effective disinfectant (Conroy *et al.*, 1996). When organisms are exposed to sunlight, photosensitizers absorb photons of light in the UV-A and early visible wavelength regions of 320 to 450 nm. The photosensitizers react with oxygen molecules to produce highly reactive oxygen species. In turn, these species react with DNA; this leads to strand breakage, which is fatal, and base changes, which result in mutagenic effects such as blocks to replication. For bacteria, the process is reversible as the bacteria may again become viable if conditions allow cells to be repaired (Kehoe *et al.*, 2001; McGuigan *et al.*, 1999). Viruses are

unable to repair DNA damage and are therefore sensitive to optical inactivation (McGuigan *et al.*, 2001).

2.4.2 Solar Disinfection Process Variables

Previous studies have found that solar disinfection is affected by numerous variables. These variables include solar radiation wavelengths, water temperature, turbidity, and container selection. Several process enhancements have also been studied.

2.4.2.1 Solar Radiation Wavelengths

Studies have shown that visible violet and blue light have little disinfection capability. However, the other components of sunlight, UV-A, UV-B, and UV-C radiation, are able to inactivate organisms. UV-C radiation, at approximately 260 nm, has the greatest potency because it corresponds to maximum absorption by DNA. Municipal treatment plants use UV-C (at 254 nm) to disinfect drinking waters and secondary wastewater effluents because of its germicidal ability to initiate changes in nucleic acids and other structures such as enzymes and immunogenic antigens. However, near ultraviolet (UV-A) light has been found to be the most significant component of sunlight that is responsible for the inactivation of microorganisms, with an increase in effectiveness due to the synergistic effects of UV-A and violet light. This is because the UV-C component of solar radiation does not reach the earth (Wegelin *et al.*, 1994).

Acra *et al.* (1984) compared the germicidal effects of different wavelengths of light by measuring the average number of coliforms inactivated upon exposure to the varying wavelengths. They found that the most significant decrease in viable bacterial organisms occurred when they were exposed to wavelengths between 260 to 350 nm (compared to inactivation at wavelengths between 550 to 850 nm). Because wavelengths below 290 nm do not reach the earth, Acra *et al.* (1984) concluded that the most bactericidal wavelengths were between 315 to 400 nm, which corresponds to the wavelengths of the near-ultraviolet region that are not visible to the eye. The findings of Acra *et al.* (1984) are further supported by the research of others. Davies and Evison (1991) attributed half of the toxic effects of sunlight to wavelengths lower than 370 nm. Wegelin *et al.* (1994)

concurred, stating that wavelengths between 300 and 370 nm have significant effects on inactivating bacteria and viruses.

Natural sunlight has been shown to have germicidal properties. Wegelin *et al.* (1994) found that a fluence of natural light of approximately 2000 kJ/m2 or 555 Wh/m2 resulted in a 3-log inactivation of *E. coli*. This is equivalent to 5 hours of midday summer sun as measured at Duebendorf, Switzerland. Viruses required higher fluences than bacteria for the same inactivation level: F2 coliphage, rotavirus and encephalomyocarditis virus required 9,000, 6,800, 34,300 kJ/m2 for 3-log inactivation. Davies and Evison (1991) also found solar disinfection to be effective, with 1 log inactivation of *E. coli* in 10 hours of exposure to sunlight, and 4 log inactivation of *Salmonella typhimurium* in 4 hours of exposure.

2.4.2.2 Heating

Temperatures at or above boiling can be used to effectively pasteurize water. Liquids may also be pasteurized using lower than boiling temperatures, provided the liquids are kept at such temperatures for an extended period of time. For example, enteric viruses in water can be pasteurized in approximately 1 hour at 62°C or in 1 day at 50°C (Burch and Thomas, 1998). It is known that 10 minutes at 56°C will inactivate *Giardia lamblia, G. muris* and *Entamoeba histolytica*. If a temperature of 50°C is attainable, amoebic cysts are inactivated (Acra *et al.*, 1984). Ciochetti and Metcalf (1984) state that milk pasteurization occurs at 62.8°C for 30 minutes or at 71.7°C for 15 seconds, and Burch and Thomas (1998) state that the typical pasteurization of any liquid is at 75°C for 10 minutes.

Pasteurization may not be ideal for some drinking water treatment situations. Effective treatment by heating requires knowledge of the water quality in order to determine the temperature the water must reach and the duration of heating that is needed. In addition, disinfection by heating may be impractical for wide scale use because pasteurization is a labor-intensive process and requires a significant amount of fuel (Burch and Thomas, 1998). However, heating may be accomplished by using sunlight, thus alleviating the

problem of needing wood or other fuels for boiling.

In 1984, Ciochetti and Metcalf published the results from a study to determine the effectiveness of using a solar box cooker to pasteurize river water that had an initial *E. coli* count of 33 to 350 cfu per 100 mL. They were able to attain temperatures of 65°C in two 3.7 L jugs between mid-March to mid-September in California, with no coliforms detected at 60°C and 65°C. In heating tests, Ciochetti and Metcalf (1984) detected coliforms at 59°C, but none at 61°C or 63°C. Although the samples had reached pasteurization temperatures at the end of the solar pasteurization and heating tests, it is likely the samples were not held at a pasteurization temperature for the recommended period of time. Therefore, it is possible that temperatures lower than 63°C have disinfection capabilities as well.

Conroy *et al.* (1996) exposed water samples to full sunlight in Kenya and confirmed that sunlight has a bactericidal effect on turbid water, with reductions in the initial bacterial count of over 103 cfu per mL. The disinfection was attributed to pasteurization effects, rather than ultraviolet light. This was confirmed with laboratory experiments by Joyce *et al.* (1996), who heated contaminated water samples to a maximum of 55°C in 7 hours and observed a 5-log inactivation of *E. coli*.

Jorgensen *et al.* (1998) tested a flow-through copper-piped system that used solar radiation to pasteurize naturally contaminated water from the Mlalakuva River near Dar es Salaam, Tanzania. They found that while fecal indicator bacteria were inactivated in water that was heated to 62°C or above, other organisms such as spore-forming bacteria were never completely inactivated, even when water temperatures of 75°C were attained. They found that temperatures of 65°C or above inactivated coliform bacteria and Thermo tolerant coliform bacteria, which were present in the naturally contaminated river water. Such temperatures also inactivated *Salmonella typhimurium, Streptococcus faecalis* and *Escherichia coli* that were cultured and added to the raw river water.

Rijal and Fujioka (2001) observed the effectiveness of heating using a modified Family Sol*Saver System (FSP). The FSP is a high-density, black polyethylene double-walled collector that was designed for liquid pasteurization. However, by exchanging the original non-UV-transmittable plastic cover for a UV-transmittable cover, Rijal and

Fujioka were able to determine the effectiveness of pasteurization versus pasteurization and solar radiation on numerous organisms, including fecal coliforms, *E. coli*, enterococci, *C. perfringens*, total heterotrophic bacteria, hydrogen sulphide producing bacteria and FRNA virus. Tests were carried out using a low turbidity (<2 ntu) water from the Manoa stream in Hawaii, diluted sewage (2.5 ntu), or seeded tap water. On the experiment conducted on a sunny day, the pasteurization only sample was able to achieve a temperature of 65°C with a corresponding inactivation of more than 3-log of *E. coli* in 3 hours. The solar radiation and pasteurization sample heated to 56°C, with the same log inactivation in 2 hours. Therefore, solar radiation and heating acted synergistically to inactivate the bacteria.

Pasteurization is an effective treatment option for liquids. However, a false sense of security may mislead one to under treat the drinking water. As detailed above, certain organisms cannot survive temperatures of 55°C while others are still viable at 75°C. Without knowing the exact composition of organisms in the water, the user may not adequately treat the drinking water before use. There is also a high capital cost associated with purchasing pasteurization equipment if the process is used for a community. However, pasteurization of liquids is independent of turbidity and pH. This, coupled with the fact that solar energy is free and solar disinfection is a simple process to employ, warrants further study for use by individuals or small families in developing countries.

2.4.2.3 Impurities

Turbidity is a significant factor in the disinfection process. The effectiveness of solar disinfection has been tested on samples with turbidities ranging from less than 10 ntu to approximately 300 ntu. Researchers have found that higher turbidity samples exposed to sunlight attained consistently higher water temperatures, which was attributed to absorption of radiation by the particulate matter (Kehoe *et al.*, 2001; McGuigan *et al.*, 1999). More turbid samples, at 300 ntu, also had less inactivation of *E. coli* compared to samples with little or no turbidity. This may be in part due to shielding of organisms by particles (Kehoe *et al.*, 2001; McGuigan *et al.*, 1999; Sommer *et al.*, 1997). Joyce *et al.*

(1996) reported that less than 1% of the total incident UV light is able to penetrate beyond a water depth of 2 cm from the surface in samples with turbidities greater than 200 ntu. Therefore, it may be necessary to filter turbid waters before sun exposure. Impurities in a water sample that cause it to be colored also have an effect on the disinfection potential for a given drinking water sample. In highly colored samples, sunlight may not have a lethal effect because the colored water may absorb wavelengths in a certain range. In these cases, it is recommended that the water sample be treated to reduce coloration before sun exposure (Acra *et al.*, 1984).

2.4.2.4 Container Selection

Container shape and color may have significant impacts on the effectiveness of solar disinfection. The bottle shape may interfere with the sun's disinfection capabilities: as the sun moves across the sky, the intensity will change and may be reduced depending on the bottle shape. Acra *et al.* (1984) therefore recommend using round, conical bottles as opposed to square or irregularly shaped containers. However, the major limiting factor is the availability of the bottles themselves, with variables such as plastic thickness and light transmittance characteristics being difficult to assess in the field.

Acra *et al.* (1984) also noted that colorless containers allow the most transmittance of ultra-violet wavelengths and are therefore the optimal choice for use in solar disinfection. Blue and violet tinted containers also transmit radiation, yet other colors, such as orange, yellow, red and green, will absorb wavelengths with the most lethal bactericidal effects and therefore must be avoided (IDRC, 1998). With regard to pasteurization, a water sample exposed to sunlight increases in temperature due to the red and infrared components of sunlight. Blue containers would therefore absorb these components and minimize any temperature increases (Acra *et al.*, 1984). Therefore, to maximize the effects of both solar radiation and heating, colorless containers are recommended.

Container size may also be an important parameter in the solar disinfection process. Acra *et al.* (1984) specify that container size is a variable that affects solar disinfection. However, their studies do not specifically test the effect of volume size on solar disinfection. Kehoe *et al.* (2001) found no significant difference in the population dynamics of 0.5 and 1.5 L samples. In contrast, Reed *et al*. (2000) compared the time

needed to achieve a 99.9% reduction in the initial fecal coliform counts of 22 L and 25 L samples and found that exposure times of 150 minutes and 290 minutes were required, respectively. A more extensive study on volume variations may be useful.

2.4.2.5 Process variations

A number of process enhancements have been studied in order to increase the effectiveness of solar disinfection. Such efforts have included periodic agitation, using foil to increase reflectivity, and painting half the bottle black to increase achievable temperatures.

In a field experiment, Kehoe *et al.* (2001) used sterilized reagent grade water samples that they had spiked with *E. coli* and exposed to the sun. Some samples were agitated for 1 minute every 15 minutes. They found no significant difference in *E. coli* inactivation rates of the agitated versus non-agitated samples that were exposed to sunlight if the dissolved oxygen (DO) levels did not change significantly. Changes in DO levels did not occur when there were only slight increases in water temperature, such as from 32.5°C to 39°C. However, Kehoe *et al.* (2001) discovered that in samples exposed to both thermal and optical effects, increasing levels of DO did correspond to an increase in inactivation rates. In conclusion, Kehoe *et al.* (2001) recommended against agitating samples to prevent decreases in inactivation rates when significant temperature differences occur.

Reed *et al.* (2000) also found that water samples with greater oxygenation had increased inactivation rates. Complete inactivation of fecal coliforms was achieved in 3 hours in an oxygenated sample, compared to the less than 1-log inactivation after 4 hours for a deoxygenated sample.

During laboratory thermal-only simulations, where sample temperature was raised from 20°C to 50°C, agitation significantly lowered the DO levels of samples. There was no 18significant correlation found between the inactivation of *E. coli* in agitated versus nonagitated samples however, which implies that DO levels are not a significant factor when samples are sufficiently heated (Kehoe *et al.*, 2001).

Using sterilized reagent grade water samples spiked with *E. coli*, Kehoe *et al.* (2001) found that foil-backed samples averaged almost 1°C higher than non-foil-backed samples when exposed to sunlight for 3.5 hours. Over 6-log inactivation was reached in less than

1 hour of exposure time when aluminum foil was placed partway around sample bottles, versus more than 3 hours needed for 6-log inactivation of non-foil-backed samples.

2.5 History of SODIS

As early as the 1984s, Lebanese scientist Aftim Acra, Professor at the American University of Beirut discovered that exposing water to the sunlight decreased the number of microorganisms (see publication). This became the starting point for the development of solar water disinfection. In the 1990s the water research institute Eawag, the Swiss Federal Institute of Aquatic Sciences and Technology, decided to investigate the idea and create a safe, simple method that can be used in developing countries. An interdisciplinary research team consisting of microbiologists, virologists, engineers and drinking water specialists then worked out a method that only needs PET bottles and sunlight: the SODIS method. To see how effective and how applicable this method was, Eawag ran tests in the laboratory and under field conditions in developing countries. In these tests, the SODIS method was shown to be effective and user-friendly, and also cost-effective. Eawag set up projects in developing countries to make sure that the method was made available to the people who needed it most urgently. At the moment they are working in 24 countries. Famous research establishments such as the Royal College of Surgeons, Ireland, or the University of Uppsala, Sweden, also studied the SODIS method. Their studies confirmed that the method does kill germs and has a positive effect on people's health. It was concluded that there was an outstanding acceptance of SODIS technology in both rural and urban populations and a high demand for the technology from important institutions. This resulted in the creation of the SODIS Foundation all over Latin America from October 2000. Thousands of families from Latin America and other regions have started using SODIS ever since, and the results are significant.

2.6 Drinking Water Challenges

In most of the developing world, there are no funds to develop a drinking water system infrastructure. Where treatment systems do exist, there are several issues that often preclude adequate water treatment. These include misemployment, under-employment, in operational equipment, lack of spare parts, unavailability or cost of chemicals, inadequately trained staff, and lack of supervision (Ellis, 1991). It is estimated that $150 billion is needed for developing countries to address these issues and establish full water supply coverage (Wegelin *et al.*, 1994).

Although water disinfection is a crucial step in preventing waterborne diseases, there are several aspects of the water collection, treatment, and distribution cycle that affect whether drinking water arrives at a home in potable condition. First, source water should be carefully selected and protected to ensure it is free of contaminants. Water that receives runoff from land used for agriculture and livestock farming is likely to have pesticides, fecal matter, and other constituents that were applied to the surrounding grounds. Ellis (1991) suggests relocating cattle and other livestock from the vicinity of drinking water sources. In addition, improving the sanitation practices of the local population can reduce the potential for water supplies to be polluted. It is not considered uncommon, especially in developing countries, for defecation and urination to occur in rivers, lakes, and other bodies of water that are also used for domestic and recreational purposes (Kloos *et al.*, 1997). These practices continue a cycle of recontamination. The second factor in preventing waterborne disease is adequate and reliable water treatment. This can be addressed by properly training water plant operators and by providing funding to ensure all necessary chemicals and equipment can be purchased. Third, distribution systems must be built and improved to prevent recontamination of treated water. Other intervention measures, such as increasing public awareness, should also be employed (Burch and Thomas, 1998; Somboonsub, 2001).

2.7 Field Applications

Conroy *et al.* (1996, 1999, 2001) established the potential for field use of solar disinfection by demonstrating that this process reduced the risk of diarrhea in children. The studies were conducted in the Kajiado province of Kenya using Maasai children between 5 and 16 years of age. In 1996, the first test group consisted of 108 children that drank solar treated water. These children were given two 1.5 L plastic bottles to be filled with drinking water and put on the roof of their huts from dawn until midday. The water could then be used for drinking. The control group consisted of 98 children that were given the same directions, but rather than putting the bottles on the roof, they kept the bottles indoors. The results of this study showed that the children in the first group averaged 4.1 diarrheal episodes over a twelve-week period, versus an average of 4.5 episodes in the control group (Conroy *et al.,* 1996). In 1999, the test group was expanded to children less than six years of age. The children drinking treated water had a two-week period diarrhea prevalence of 48.8%, versus 58.1% in the control children (Conroy *et al.,* 1999). Five years later, the researchers learned of a cholera outbreak in the test villages. They returned and found that the test families had continued to treat their drinking water with solar disinfection. However, while there was no statistical difference in the risk of contracting cholera between families using solar disinfection and those that did not, the continued use of the process by the villagers was promising as shown by the earlier successes in reducing diarrheal incidences.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The SODIS method is ideal for treating water for drinking in developing countries**.** In order to study the effectiveness of SODIS method in the rural and urban areas of Bangladesh, The laboratory test requires several steps. The Methodology of SODIS consists of Sampling, Laboratory Experiment, Preparation of Media, Testing Method, Incubation, Counting and Documentation and Data Interpretation.

3.2 SAMPLING

To quantify the inactivation of bacteria in the test bottles, samples were taken at 15 minutes, 30 minutes, or 1 hour intervals. During each sampling session, the time, sun intensity, weather conditions, water temperatures, air temperature, and sample volumes collected were recorded. The sun intensity was recorded first while the detector was horizontal and then while the detector was held above the head and pointed directly at the sun to avoid scattered light interference. Sun intensity readings during full sun exposure and during cloud cover were averaged. Because the test bottles are cylindrical, and therefore the test water is exposed to direct Sunlight**.**

Basically pond water and Rain water are taken in the plastic bottle. The bottle is ringed with the source water. The bottle should be air tight in order to avoid the contaminations. The water is collected for per hour exposure in the intense sunlight. First sample is picked in the 0 hour exposure in sunlight, then consecutively 1^{st}, 2^{nd} , 3^{rd}, 4^{th}, 5^{th}, 6^{th} ,7^{th} hours sample are collected by each hour exposure in sunlight.

Figure 3.1: Exposing samples into the sun.

3.3 BACTERIA CULTURE

A microbiological culture, or microbial culture, is a method of multiplying microbial organisms by letting them reproduce in predetermined culture media under controlled laboratory conditions. Microbiological cultures can be grown in petri dishes of differing sizes that have a thin layer of agar-based growth medium. Once the growth medium in the petri dish is inoculated with the desired bacteria, the plates are incubated at the best temperature for the growing of the selected bacteria (for example, usually at 37 degrees Celsius for cultures from humans or animals, or lower for environmental cultures).

3.3.1 Method of culture

For our experiment we used streak plate method. Bacterial culture streaking allows bacteria to reproduce on a culture medium in a controlled environment. The process involves spreading bacteria across an agar plate and allowing them to incubate at a certain temperature for a period of time. Bacterial streaking can be used to identify and isolate pure bacterial colonies from a mixed population.

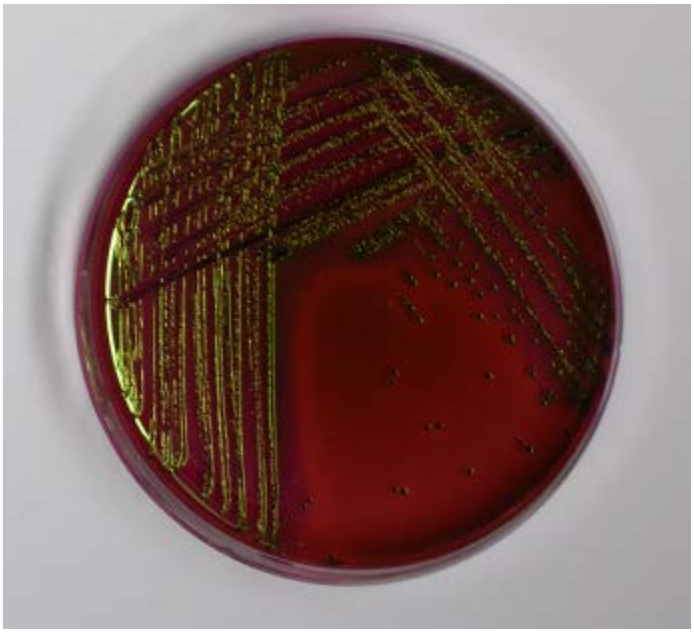


Figure 3.2: Streak culture of bacteria

3.3.2. Procedure of culture

For streak culture we sterilized an inoculating loop by placing it at an angle over a flame. Then we removed the lid from a culture plate containing the desired microorganism. We cooled the inoculating loop by stabbing it into the agar in a spot that does not contain a bacterial colony. Picked a colony and scrape off a little of the bacteria using the loop. It is to be ensured to close the lid. Using a new agar plate, lift the lid just enough to insert the loop. Streaking the loop containing the bacteria at the top end of the agar plate moving in a zig-zag horizontal pattern until 1/3 of the plate is covered. Sterilized the loop again in the flame and cooled it at the edge of the agar away from the bacteria in the plate. Rotated the plate about 60 degrees and spread the bacteria from the first streak into a second area using the same motion. Again we sterilized the loop. Rotated the plate about

60 degrees and spread the bacteria from the second streak into a new area in the same pattern. Sterilized the loop again. Replace the lid and invert the plate. Incubate the plate over night at definite degrees Celsius. After 24 hours we saw bacterial cells growing in streaks and in isolated areas.

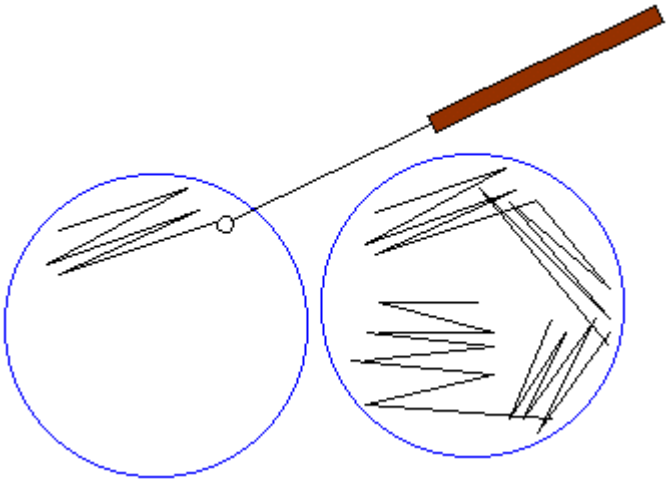


Figure 3.3: Procedure of streak culture

3.4 Exposure Time

The total exposure time of experiments varied from 6 to 8 hours. Sunlight is strongest from 10 am to 2 pm so initial experiments were conducted to encompass this time bracket by up to 1.5 hours before and up to 3 hours after (from 8:30 am to 4:30 pm). Results of these experiments showed that significant inactivation of *Total Coliform (T.C),Fecal Coliform (F.C), Escherichia Coli (E.Coli), Heterotrophic Plate Count (HPC)* occurred within 6-hour exposure time.

3.5 Solar Radiation measurement

The global solar radiation incident on an inclined surface was measured by using an Eppley Radiometer Pyranometer (PSP) coupled to an instantaneous solar radiation meter model HHM1A digital, Omega 0.25% basic dc accuracy and a resolution of ±0.5% from 0 to 2800 W/m^2. The pyranometer was fixed beside the glass cover of the collector.

A pyranometer is a type of actinometer used to measure broadband solar irradiance on a planar surface and is a sensor that is designed to measure the solar radiation flux density (in watts per meter square).There is a probe with the Pyranometer which is placed at 23.5 degree angle with sun at the specific time of sampling. Consecutively zero, 1^{st}, 2^{nd} , 3^{rd}, 4^{th}, 5^{th}, 6^{th} ,7^{th} hours of solar radiation data are collected.

Figure 3.5: Equipment's used in the experiment a Pyranometer.

3.5 Laboratory Experiments

In the laboratory, the hourly samples are collected for testing. First of all we prepared media for different parameters. For the preparation of media we used several agars and broth. Such as: MFC agar, mEndo broth , Nutrient agar etc. MFC media is used for the enumeration of total coliform(TC) and fecal coliform (FC), mEndo broth is used for the enumeration of Escherichia Coli (E.Coli), Nutrient Agar is used for the enumeration of Heterotrophic plate count.

3.6 Analytical Methods

All processes were carried out using aseptic technique, including the use of 70% ethanol to sterilize workspaces and hands. All glassware, test solutions, and media were sterilized by autoclaving at 121°C for an amount of time recommended by the autoclave manufacturer (Sterilmatic Sterilizer, Market Forge Industries Inc., Everett, MA), according to the volumes being autoclaved. Pre-sterilized pipette tips and petri dishes were used.

Figure 3.4: Autoclave machine.

3.7 Preparation of media

MFC Agar, Bacto Agar and rosalic acid is combined with distilled water to prepare MFC media. For the preparation of mEndo and NA media, mEndo broth and nutrient agar is mixed with distilled water. MFC and mEndo are heated and then cooled down then taken in the petri dish. Only nutrient agar is taken for autoclave and then taken to the petri dish.

Figure 3.3: Different types of Agar and Broth

3.7.1 Preparation of m Endo broth

This media is used for enumerating E.Coli in water by membrane filtration. m Endo Broth contains peptones as sources of carbon, nitrogen, vitamins and minerals. Yeast extract supplies B-complex vitamins, which stimulate bacterial growth. For convenience and better result we added Bacto Agar with m Endo Broth to convert Broth medium into Agar medium.

The preparation of the media is done by the followings:

- 48 gm of m Endo Broth is dissolved in 1 liter of distilled water.
- 15.6 gm of Bacto Agar is also dissolved in that 1 liter of distilled water.
- Mixed water is heated to boiling temperature with constant shaking in every 25 seconds.
- After boiling, it is kept into the water bath to reduce the temperature.
- When it cools down to desired temperature the mixture is then poured into the Petri Dish and wait until it transfers from liquid to a stabilized state.

3.7.2 Preparation of MFC Agar

This media is used for enumerating Total coliform and Fecal Coliform in water by membrane filtration. Suspend 43 gm. in 1 liter of distilled or deionized water. 10 ml of a 1 % solution of rosolic acid in 0.2 N NaOH was added. Mixed water is heated to boiling temperature with constant shaking in every 25 seconds. After boiling, it is kept into the water bath to reduce the temperature. When it cools down to desired temperature the mixture is then poured into the Petri Dish and wait until it transfers from liquid to a stabilized state.

3.7.3 Preparation of NA Agar

This media is used for enumerating Heterotopic plate count. 23 gm. of nutrient agar is mixed with 1000 ml of distilled water. Then the solution is boiled for 1 minute. Then the solution is put into the Autoclave machine at 121 degree celsius temperature. After autoclaving, it is kept into the water bath to reduce the temperature. When it cools down to desired temperature the mixture is then poured into the Petri Dish and wait until it transfers from liquid to a stabilized state. Pouring is done in the laminar flow because nutrient agar media very active.

3.8 Testing Method

The testing method is consisting filter, droplet and diluted droplet of the sample.

3.8.1 Filter

For filtration of sample 22 micro meter filter paper is used. In each case, filter paper is taken over a vacuum pump then 10 ml of raw sample is passed through it. The filter paper is then carefully placed on the media.

3.8.2 Droplet

100 micro liter of each raw sample in dropped over the media by micro pipette. They are dropped such a way that each drop is posited individually and are identical.

Figure 3.4: Dropping by micro pipette

3.8.3 Diluted Droplet

Sample is diluted once, twice, thrice based on the quality of the water. Then the diluted sample is dropped on the media by using micro pipette. They are dropped such a way that each drop is posited individually and are identical. Diluted droplet is done mainly for HPC. For necessity Diluted droplet can also be done for TC and FC.

3.9 Incubation

After placing the sample on media , we kept them in the incubator in different temperature for different media for 24 hours. HPC, mEndo and TC are kept at 35-37 degree Celsius temperature and FC is kept at 44 degree Celsius.

Figure 3.5: Lab Incubator

3.10 Counting

After keeping the media for 24 hours in the incubator the the petri dishes are observed and counted.

E.coli showed Golden metallic shin, FC and TC showed bluish black spot, Heterotrophic plate counts showed white colored spots.

3.11 DOCUMENTATION

We noted down our counted result in Excel sheet for evaluation.

3.12 Conclusions

This thesis research was conducted to study the effects of numerous variables on the disinfection properties of solar radiation. The variables tested Different seasons (Summer, Rainy, Winter season), Changing Backing surface (Black surface, Aluminum surface etc.), Using different material (PET bottle, Glass bottle etc.), Various angular positions (Standing, Lying, Angle 45 degree etc.), and exposure time. Experiments were also conducted in the laboratory to quantify the effect of only Solar disinfection a sample.

CHAPTER FOUR
RESULT AND DATA ANALYSIS

4.1 INTRODUCTION:

In this chapter, the results from experiments are included and discussed briefly. Various comparisons have been made through analysis of the results of different sources. A total 9 experiments were performed. We performed our experiments in different days, there are variation in weather condition, Also variation with the material like glass bottle and PET bottle, Some of the experiments are done with bacteria cultured sample. The effects of solar radiation and heating on the inactivation of Total Coliform (T.C), Fecal Coliform (F.C), Escherichia Coli (E.Coli), Heterotrophic Plate Count (HPC) several experiments were conducted. Water samples were exposed to sunlight in variable conditions.

4.2 Data of Source Water Sample

The following experiment was done in 9.6.13 for PET Bottle.

From the analysis of data from Appendix A the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 1840 cfu/100 ml and at the Final hour the TC reduces to 360 cfu/100 ml

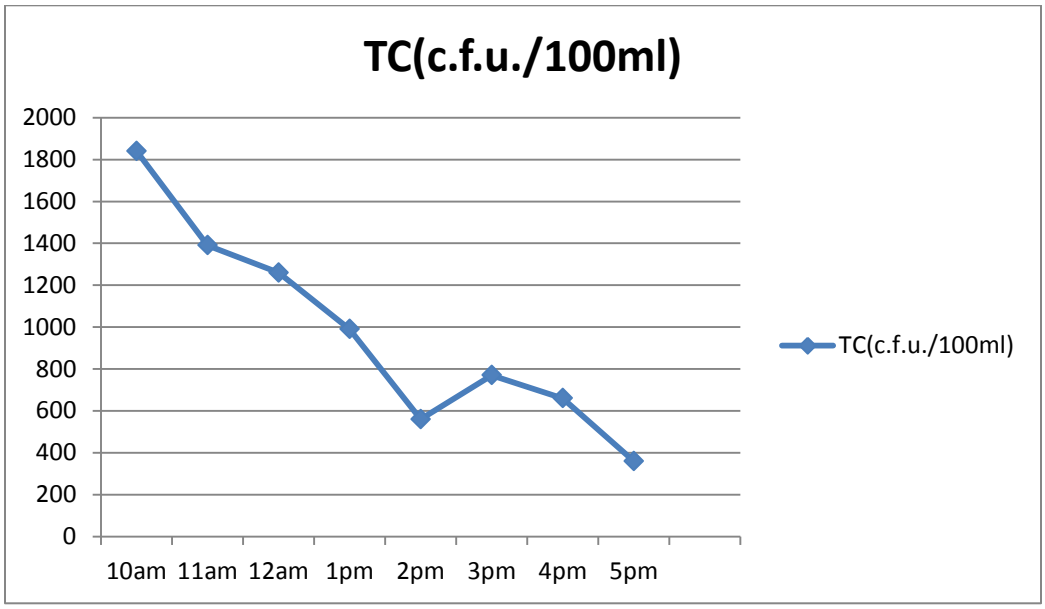


Figure 4.1 shows the TC vs Time Graph

Table:4.1 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	1840		47	430
11am	2nd	P1	1390	24.46	45	437
12am	3rd	P2	1260	9.35	45	490
1pm	4th	P3	990	21.43	32	470
2pm	5th	P4	560	43.43	37	500
3pm	6th	P5	770	-37.50	43	450
4pm	7th	P6	660	14.29	38	430
5pm	8th	P7	360	45.45	34	370

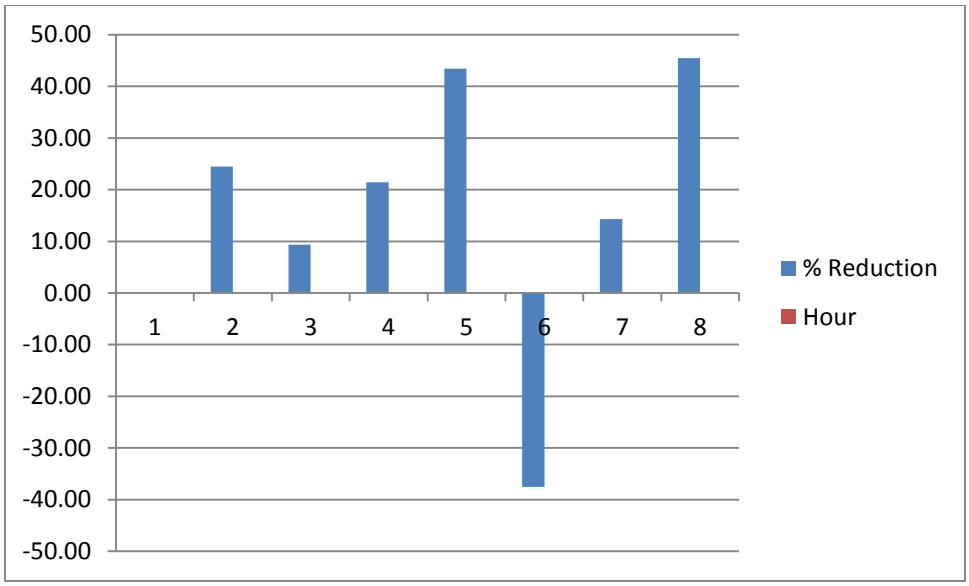


Figure 4.2 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix A the following graphs can be computed: in the Graph the blue line represents the Fecal Coliform. Initially amount of total coliform is 1120 cfu/100 ml and at the Final hour the TC reduces to 0 cfu/100 ml

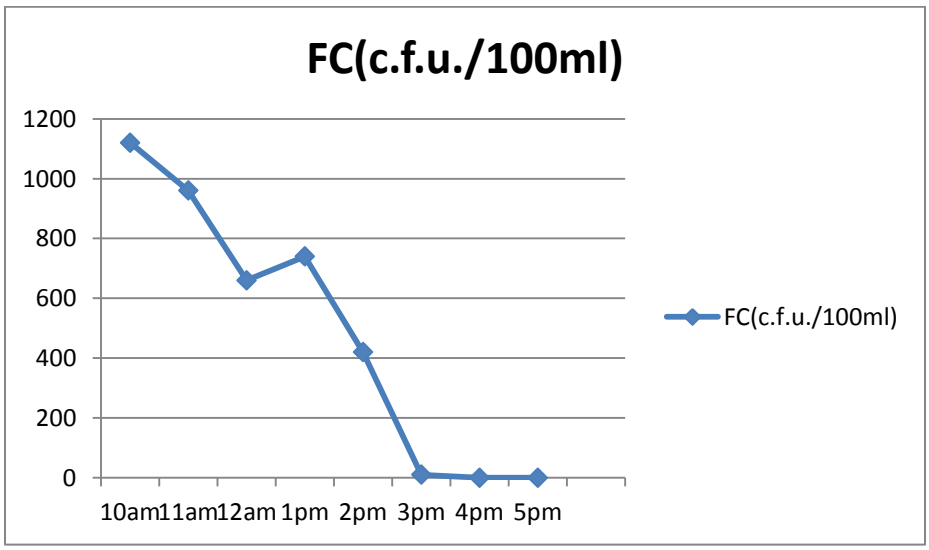


Figure4.3 shows the FC vs Time Graph

Table:4.2 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	1120		47	430
11am	2nd	P1	960	14.29	45	437
12am	3rd	P2	660	31.25	45	490
1pm	4th	P3	740	-12.12	32	470
2pm	5th	P4	420	43.24	37	500
3pm	6th	P5	10	97.62	43	450
4pm	7th	P6	0	100.00	38	430
5pm	8th	P7	0		34	370

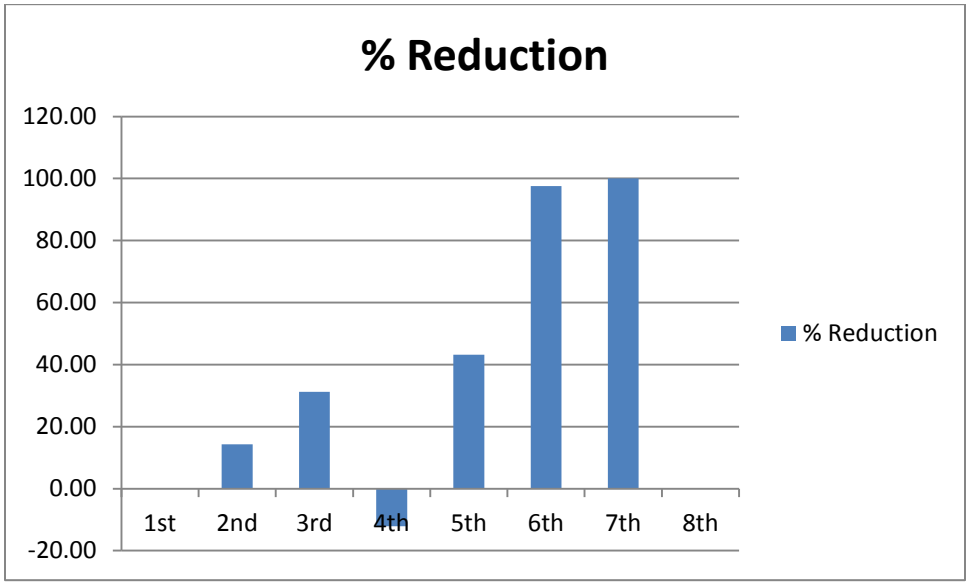


Figure 4.4 shows the % Reduction of FC vs Time Graph

From the analysis of data from Appendix A the following graphs can be computed: in the Graph the blue line represents theHPC. Initially amount of total coliform is 605 x10^4 (c.f.u./1ml) and at the Final hour the TC reduces to 94 **x10^4 (c.f.u./1ml)**

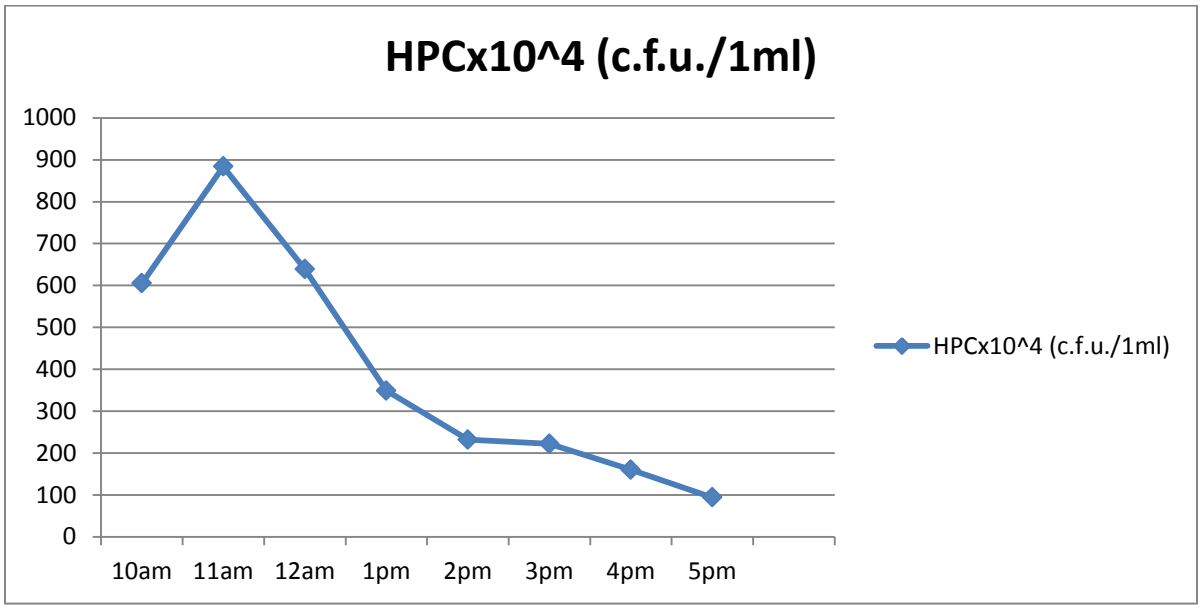


Figure 4.5 shows the HPC vs Time Graph

Table:4.3 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of HPC

Time	Hour	Sample ID	HPCx10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	605		47	430
11am	2nd	P1	884	-46.12	45	437
12am	3rd	P2	639	27.71	45	490
1pm	4th	P3	349	45.38	32	470
2pm	5th	P4	232	33.52	37	500
3pm	6th	P5	222	4.31	43	450
4pm	7th	P6	160	27.93	38	430
5pm	8th	P7	94	41.25	34	370

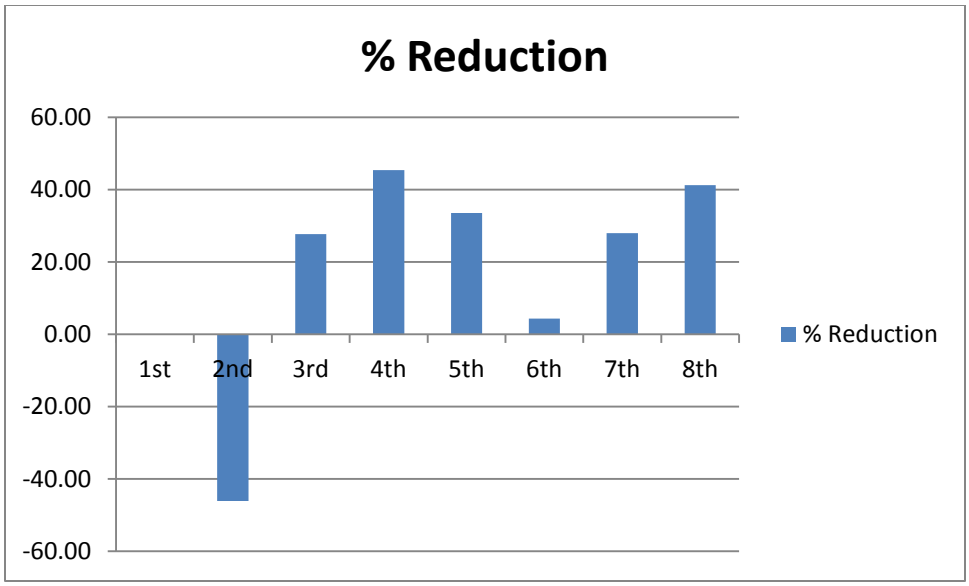


Figure 4.6 shows the % Reduction of HPC vs Time Graph

The following experiment was done in 12.6.13 for Foil Backing Surface Bottle:

From the analysis of data from Appendix C the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 430 cfu/100 ml and at the Final hour the TC reduces to 40cfu/100 ml

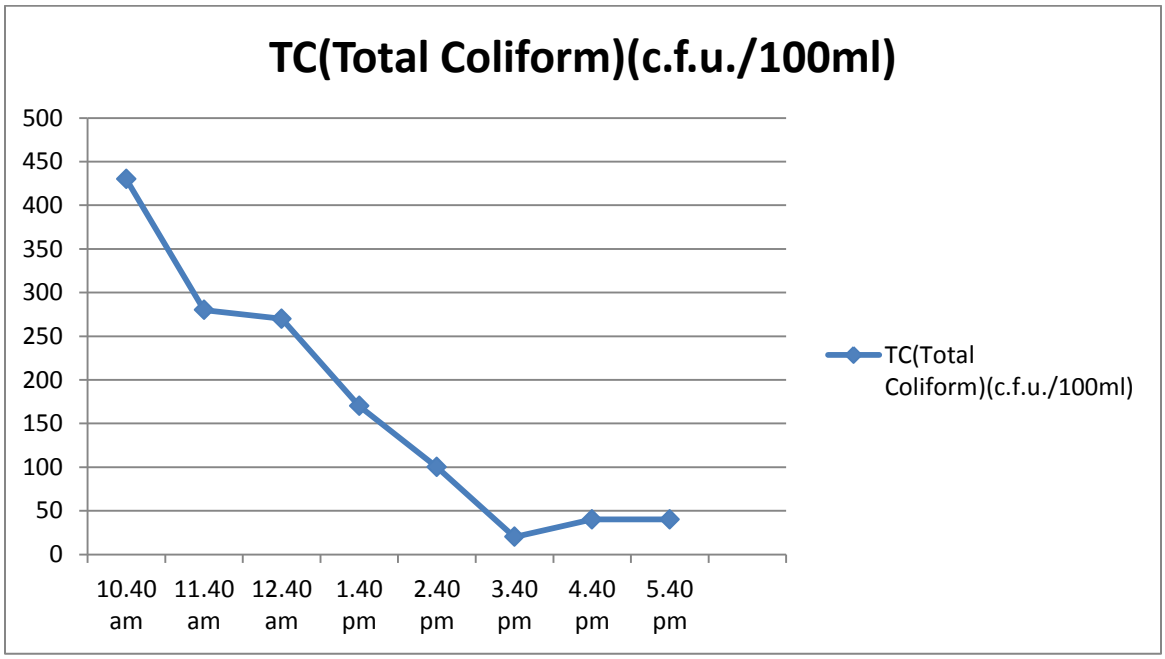


Figure 4.7 shows the TC vs Time Graph

Table:4.4 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	430		35	260.9
11.40 am	2nd	P1	280	34.88	39	290.3
12.40 am	3rd	P2	270	3.57	45	310.5
1.40 pm	4th	P3	170	37.04	42	360.4
2.40 pm	5th	P4	100	41.18	45	409.3
3.40 pm	6th	P5	20	80.00	42.5	430.5
4.40 pm	7th	P6	40	-100.00	39	410.3
5.40 pm	8th	P7	40	0.00	36	390.7

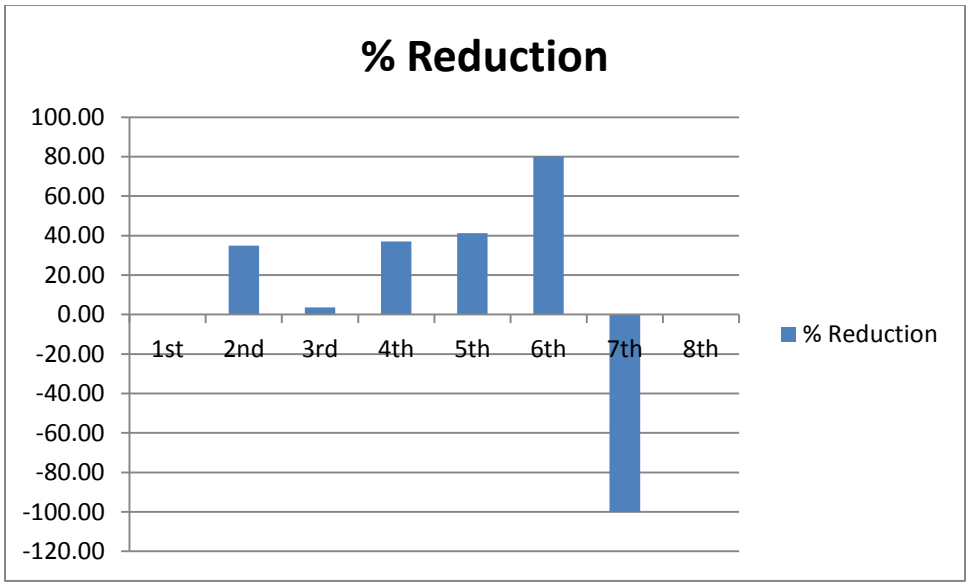


Figure 4.8 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix A the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 620 cfu/100 ml and at the Final hour the TC reduces to 70 cfu/100 ml

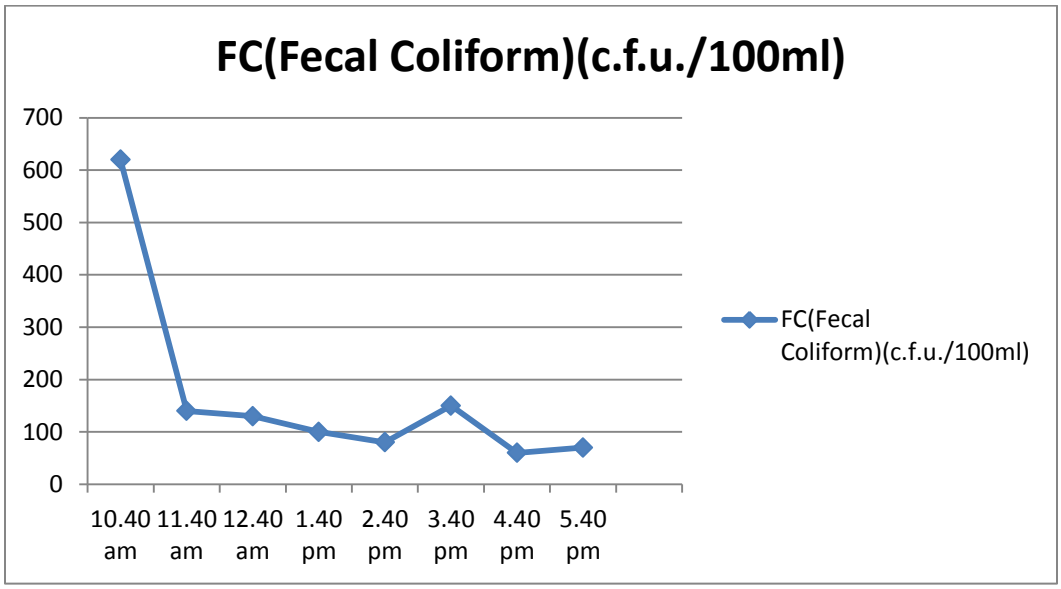


Figure 4.9 shows the FC vs Time Graph

Table:4.5 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	620		35	260.9
11.40 am	2nd	P1	140	77.42	39	290.3
12.40 am	3rd	P2	130	7.14	45	310.5
1.40 pm	4th	P3	100	23.08	42	360.4
2.40 pm	5th	P4	80	20.00	45	409.3
3.40 pm	6th	P5	150	-87.50	42.5	430.5
4.40 pm	7th	P6	60	60.00	39	410.3
5.40 pm	8th	P7	70	-16.67	36	390.7

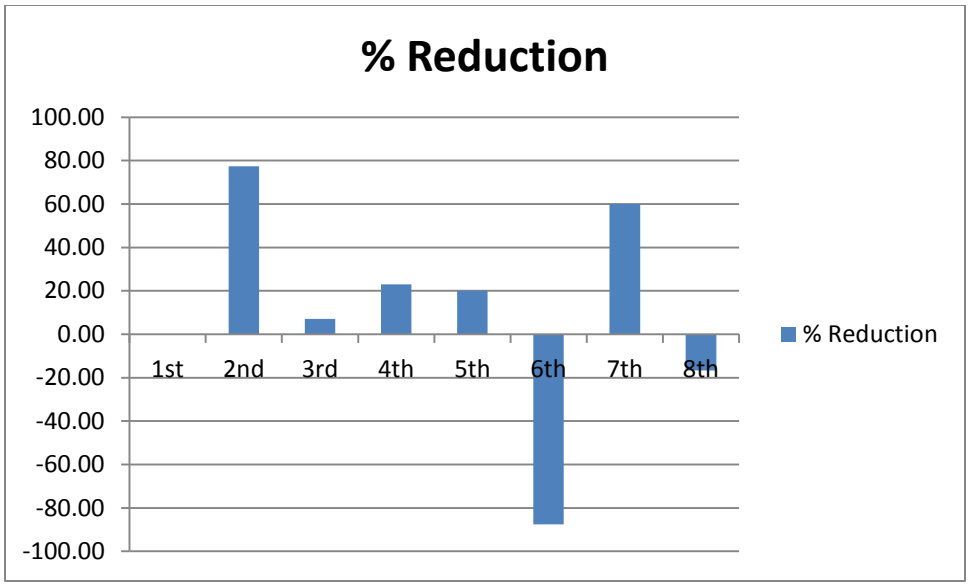


Figure 4.10 shows the % Reduction of FC vs Time Graph

From the analysis of data from Appendix B the following graphs can be computed: in the Graph the blue line represents the Heterotopic plate count . Initially amount of HPCis 730 x10^4 (c.f.u./1ml) and at the Final hour the HPC reduces to 396 x10^4 (c.f.u./1ml)

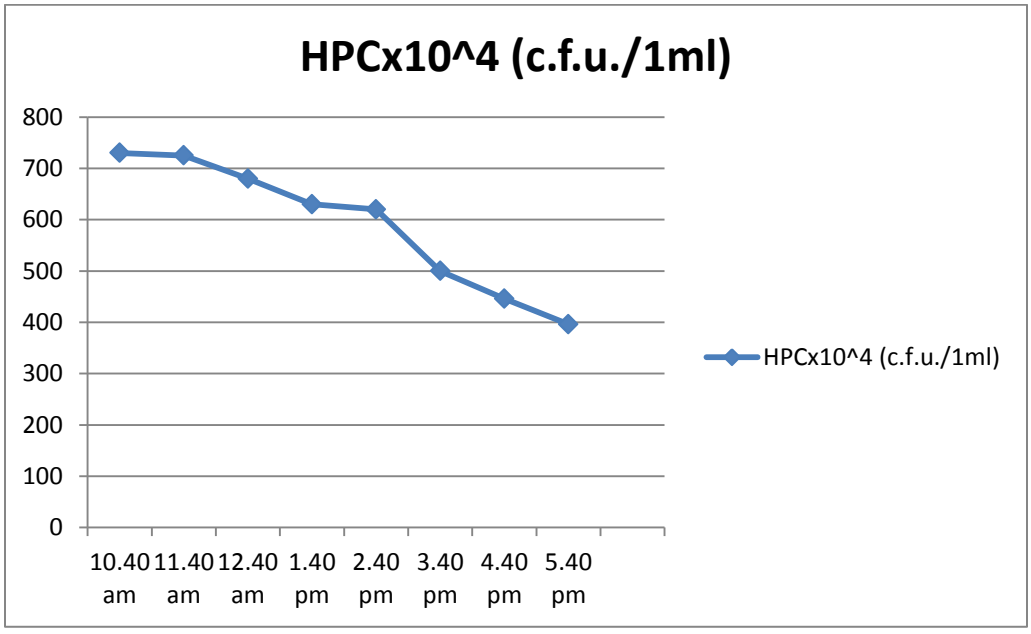


Figure 4.11 shows the HPC vs Time Graph

Table:4.6 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of HPC

Time	Hour	Sample ID	HPCx10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	730		35	260.9
11am	2nd	P1	725	0.68	39	290.3
12am	3rd	P2	680	6.21	45	310.5
1pm	4th	P3	630	7.35	42	360.4
2pm	5th	P4	620	1.59	45	409.3
3pm	6th	P5	500	19.35	42.5	430.5
4pm	7th	P6	446	10.80	39	410.3
5pm	8th	P7	396	11.21	36	390.7

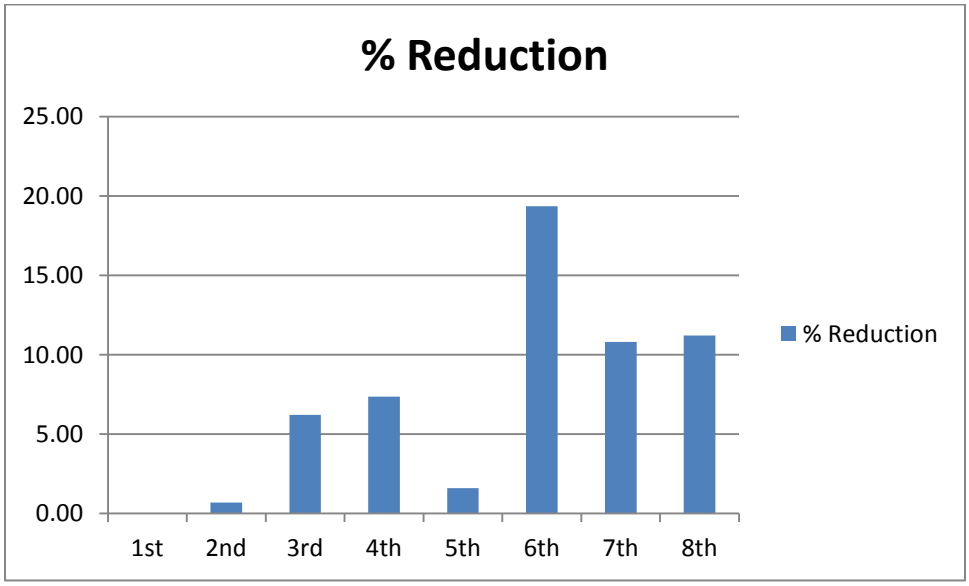


Figure 4.12 shows the % Reduction of HPC vs Time Graph

The following experiment was done in 12.6.13 for PET Bottles:

From the analysis of data from Appendix B the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 190 cfu/100 ml and at the Final hour the TC reduces to 0 cfu/100 ml

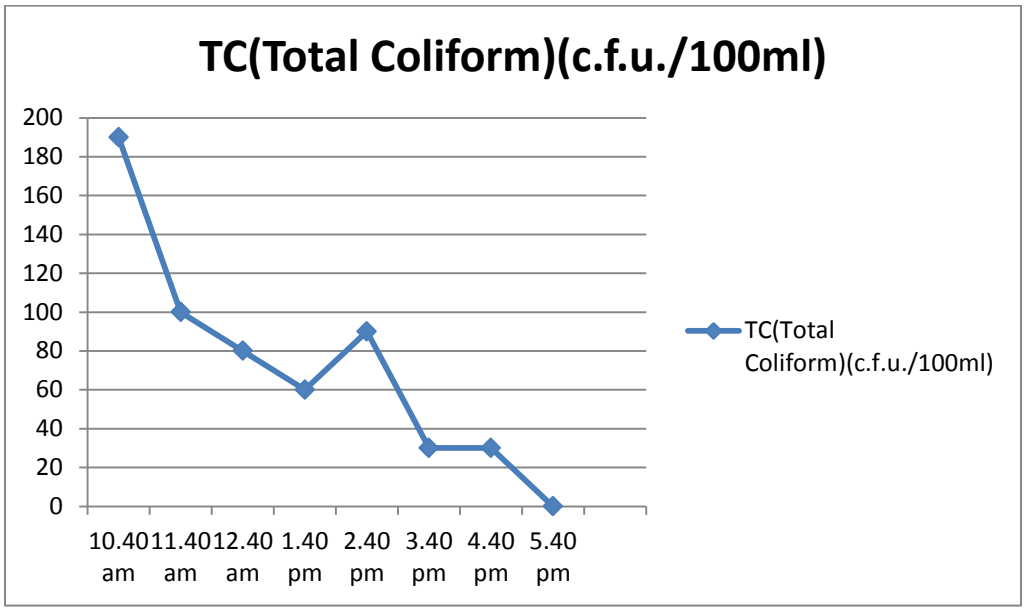


Figure 4.13 shows the TC vs Time Graph

Table:4.7 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	190		32	410.3
11.40 am	2nd	P1	100	47.37	38	510.9
12.40 am	3rd	P2	80	20.00	40	570.7
1.40 pm	4th	P3	60	25.00	43	630.3
2.40 pm	5th	P4	90	-50.00	42	590.4
3.40 pm	6th	P5	30	66.67	39	510.3
4.40 pm	7th	P6	30	0.00	36	497.2
5.40 pm	8th	P7	0	100.00	34	481.2

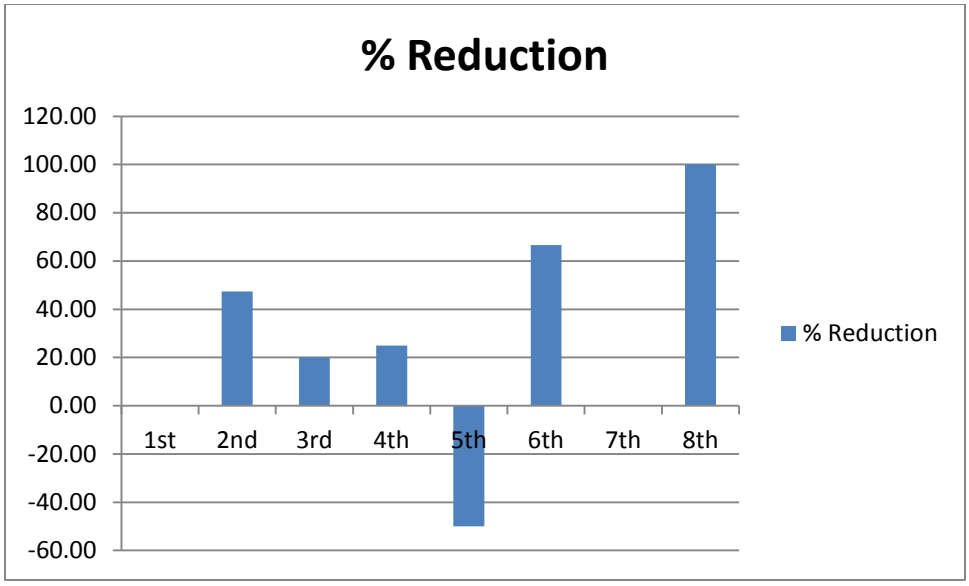


Figure 4.14 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix C the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 1070 cfu/100 ml and at the Final hour the TC reduces to 90 cfu/100 ml

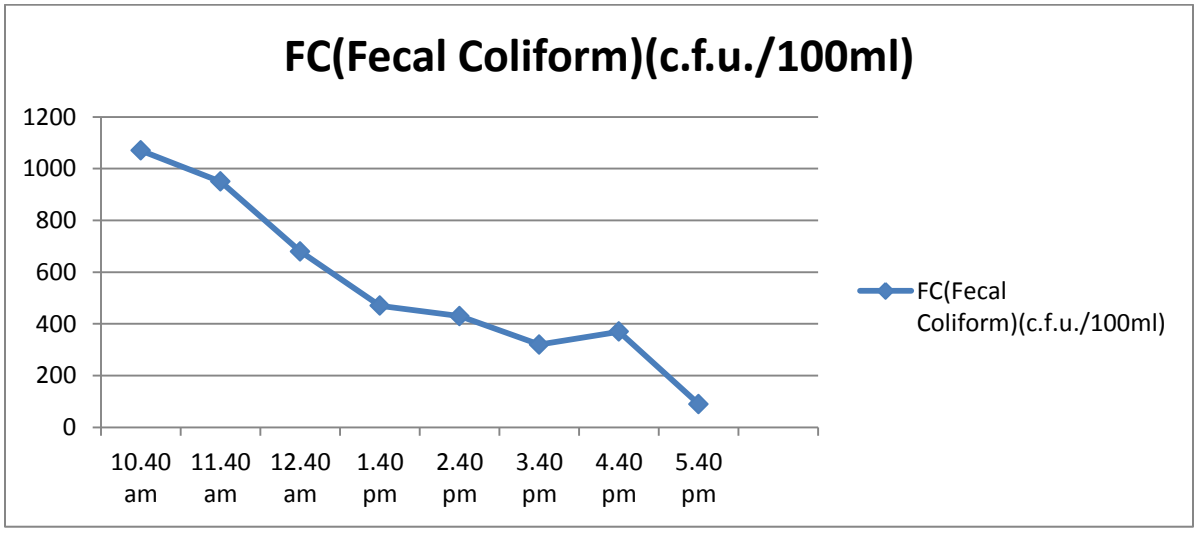


Figure 4.15 shows the FC vs Time Graph

Table:4.8 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	1070		32	410.3
11.40 am	2nd	P1	950	11.21	38	510.9
12.40 am	3rd	P2	680	28.42	40	570.7
1.40 pm	4th	P3	470	30.88	43	630.3
2.40 pm	5th	P4	430	8.51	42	590.4
3.40 pm	6th	P5	320	25.58	39	510.3
4.40 pm	7th	P6	370	-15.63	36	497.2
5.40 pm	8th	P7	90	75.68	34	481.2

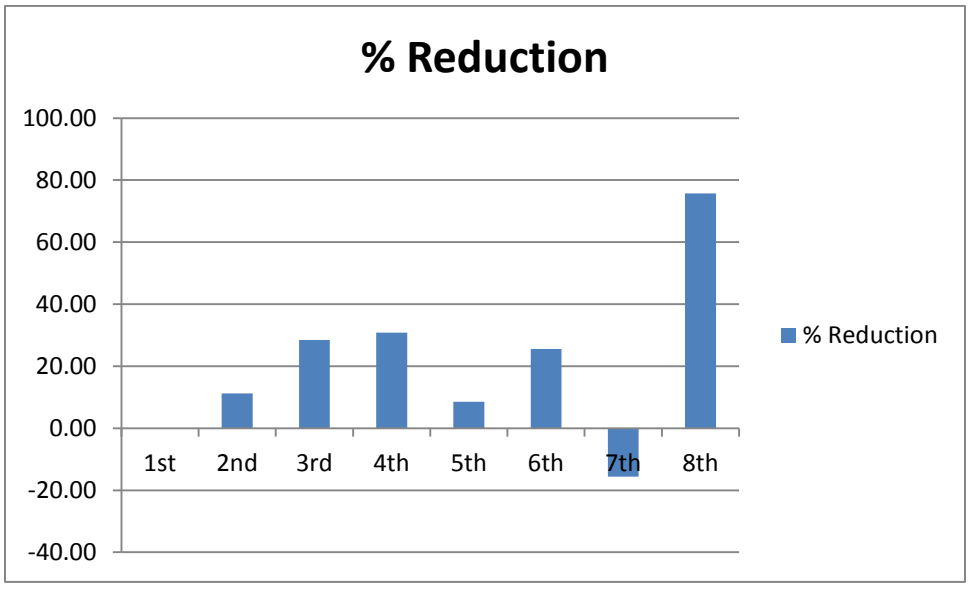


Figure 4.16 shows the % Reduction of FC vs Time Graph

From the analysis of data from Appendix C the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 787 cfu/100 ml and at the Final hour the TC reduces to 510 cfu/100 ml

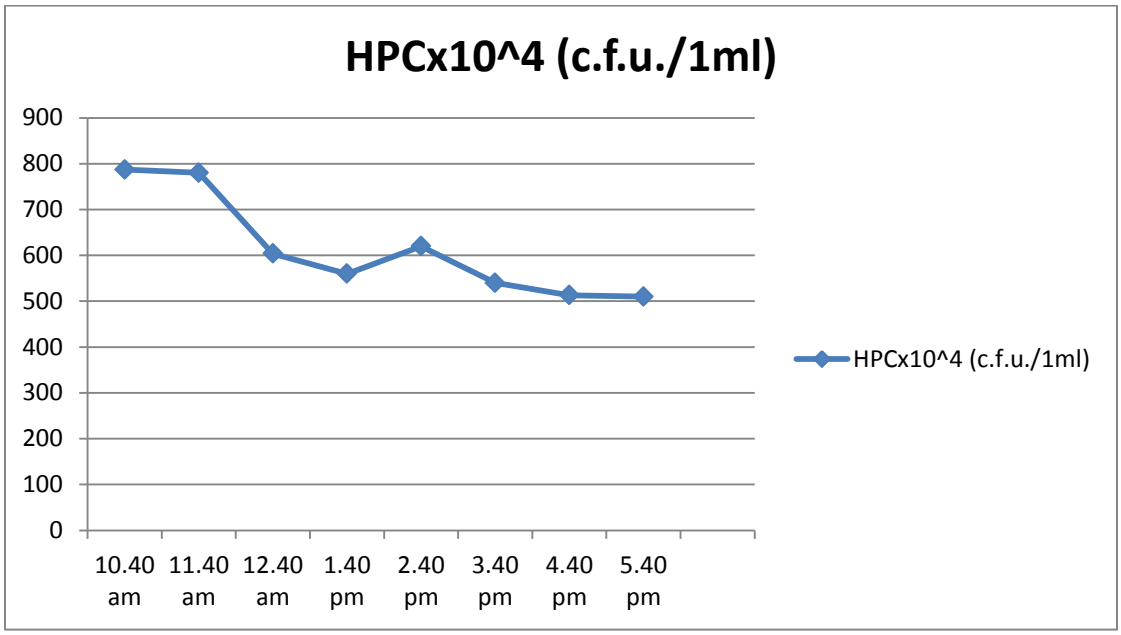


Figure 4.17 shows the HPC vs Time Graph

The following experiment was done in 17.6.13 for Glass Bottle and PET Bottle
From the analysis of data from Appendix E the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 360 cfu/100 ml and at the Final hour the TC reduces to 70 cfu/100 ml

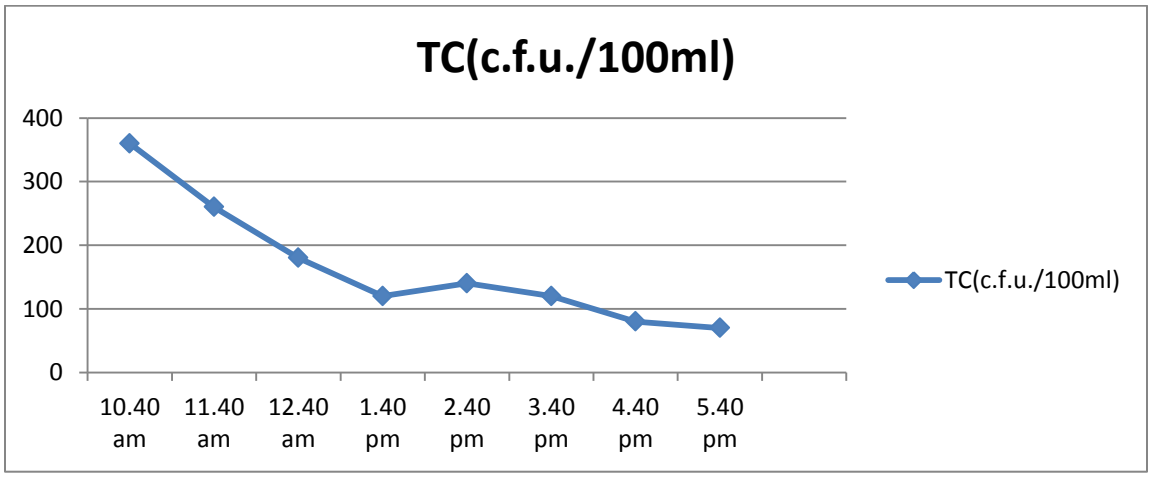


Figure 4.18 shows the TC vs Time Graph

Table:4. Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	360		34	258.3
11.40 am	2nd	P1	260	27.78	47	309.7
12.40 am	3rd	P2	180	30.77	45	405.2
1.40 pm	4th	P3	120	33.33	46	410.3
2.40 pm	5th	P4	140	-16.67	32	370.3
3.40 pm	6th	P5	120	14.29	37	390.8
4.40 pm	7th	P6	80	33.33	43	410.7
5.40 pm	8th	P7	70	12.50	38	387.2

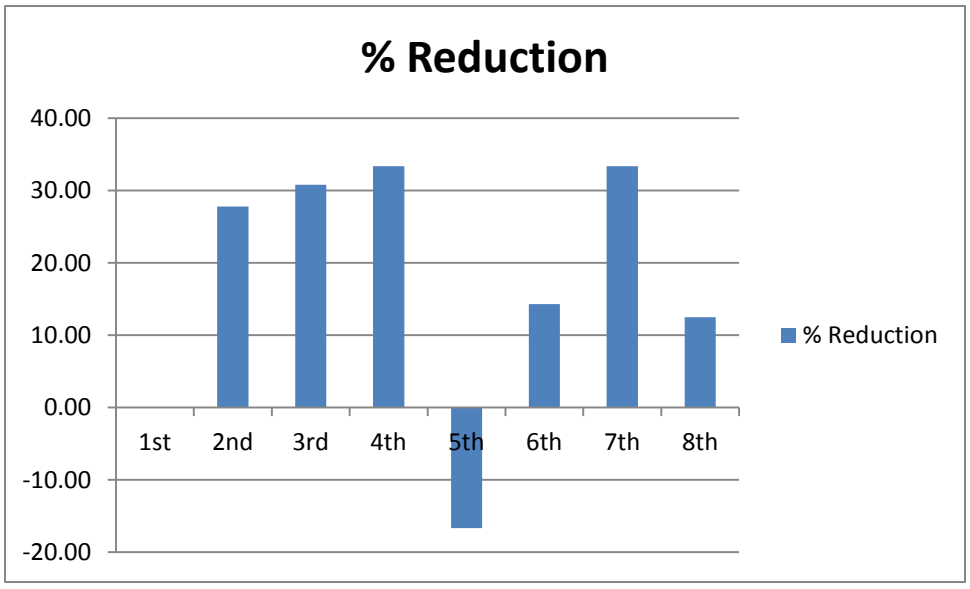


Figure 4.19 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix E the following graphs can be computed: in the Graph the blue line represents the Fecal Coliform. Initially amount of FC is 160 cfu/100 ml and at the Final hour the FC reduces to 0 cfu/100 ml

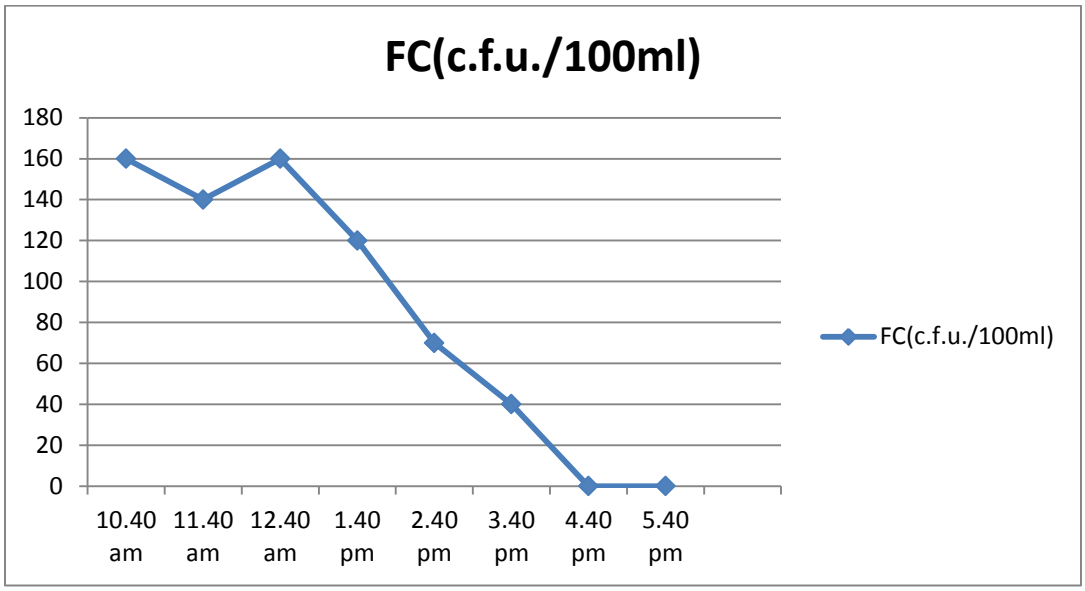


Figure 4.20 shows the FC vs Time Graph

Table:4.10 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	160		34	258.3
11.40 am	2nd	P1	140	12.50	47	309.7
12.40 am	3rd	P2	160	-14.29	45	405.2
1.40 pm	4th	P3	120	25.00	46	410.3
2.40 pm	5th	P4	70	41.67	32	370.3
3.40 pm	6th	P5	40	42.86	37	390.8
4.40 pm	7th	P6	0	100.00	43	410.7
5.40 pm	8th	P7	0	0.00	38	387.2

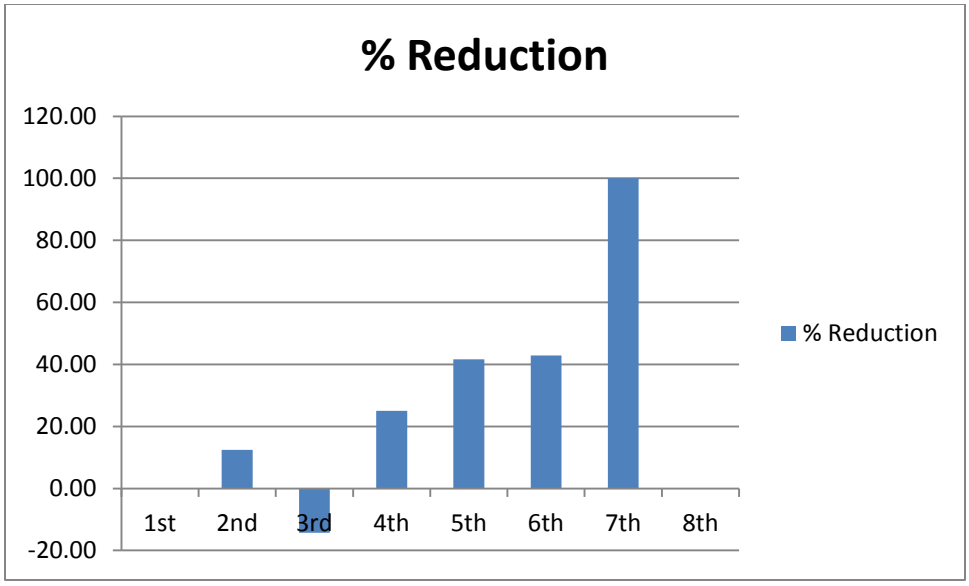


Figure 4.21 shows the % Reduction of FC vs Time Graph

From the analysis of data from Appendix E the following graphs can be computed: in the Graph the blue line represents the Heterotopic plate count. Initially amount of total coliform is 529x10^4 (c.f.u./1ml)and at the Final hour the TC reduces to 160x10^4 (c.f.u./1ml)

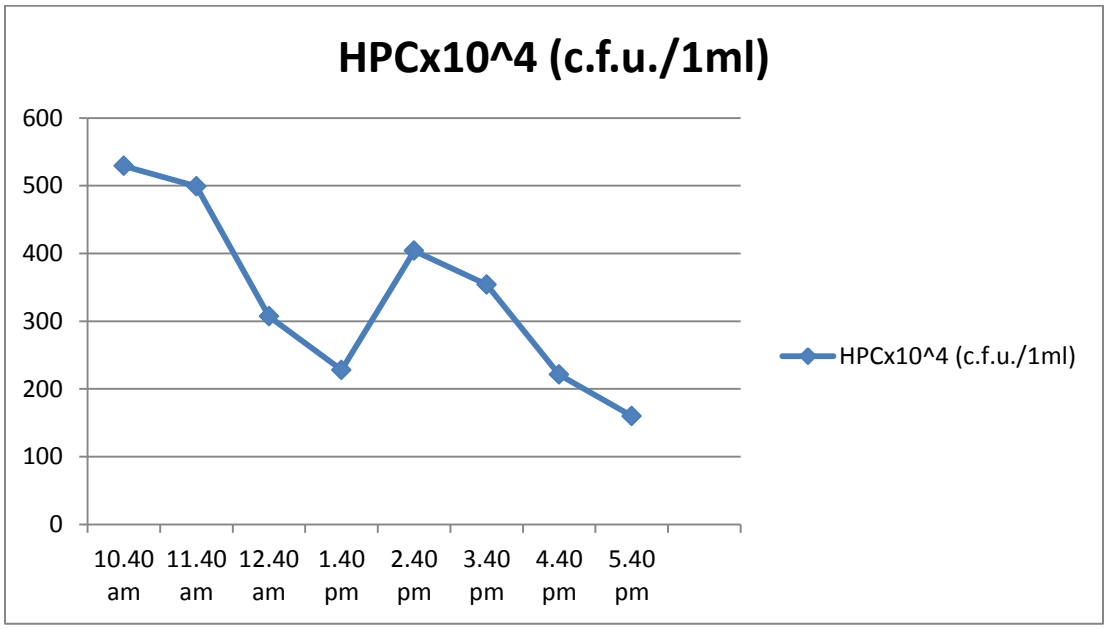


Figure 4.22 shows the HPC vs Time Graph

Table:4.11 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of HPC

Time	Hour	Sample ID	HPCx10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	529		34	258.3
11am	2nd	P1	499	5.67	47	309.7
12am	3rd	P2	307	38.48	45	405.2
1pm	4th	P3	228	25.73	46	410.3
2pm	5th	P4	404	-77.19	32	370.3
3pm	6th	P5	354	12.38	37	390.8
4pm	7th	P6	221	37.57	43	410.7
5pm	8th	P7	160	27.60	38	387.2

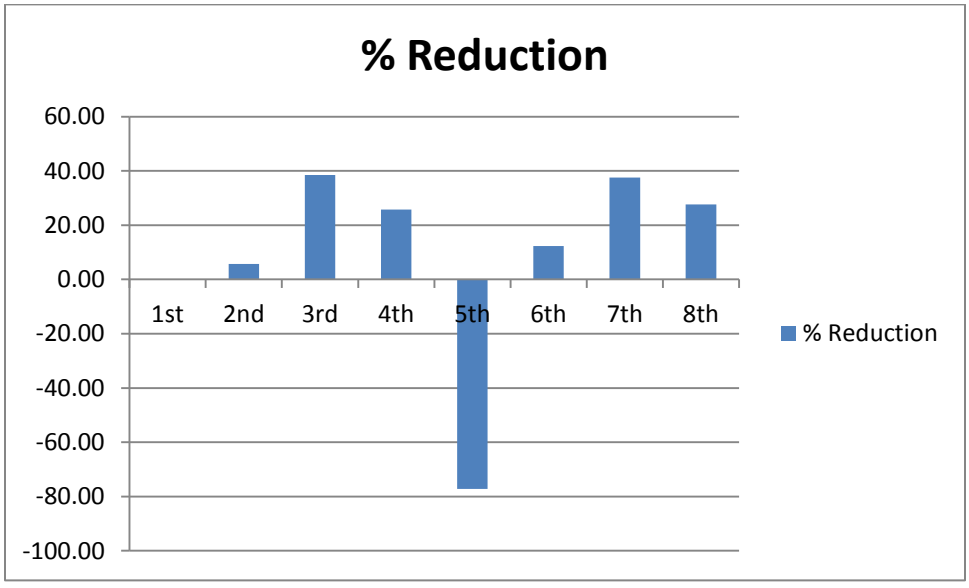


Figure 4.23 shows the % Reduction of HPC vs Time Graph

From the analysis of data from Appendix D the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 370 cfu/100 ml and at the Final hour the TC reduces to 0 cfu/100 ml

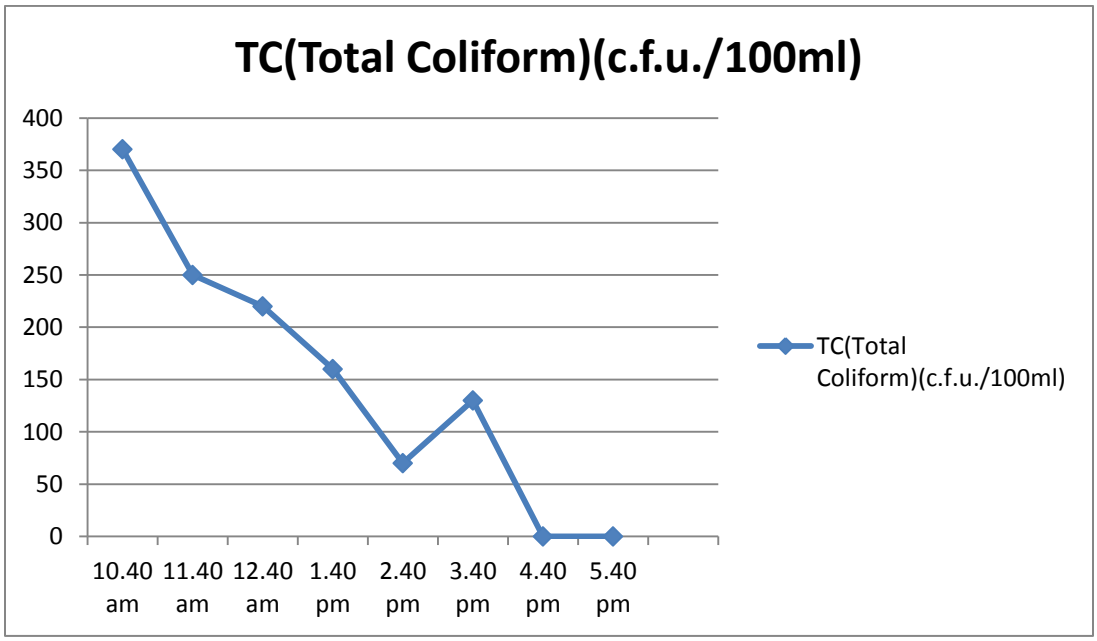


Figure 4.24 shows the TC vs Time Graph

Table:4.12 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	370		34	258.3
11.40 am	2nd	P1	250	32.43	47	309.7
12.40 am	3rd	P2	220	12.00	45	405.2
1.40 pm	4th	P3	160	27.27	46	410.3
2.40 pm	5th	P4	70	56.25	32	370.3
3.40 pm	6th	P5	130	-85.71	37	390.8
4.40 pm	7th	P6	0	100.00	43	410.7
5.40 pm	8th	P7	0	0.00	38	387.2

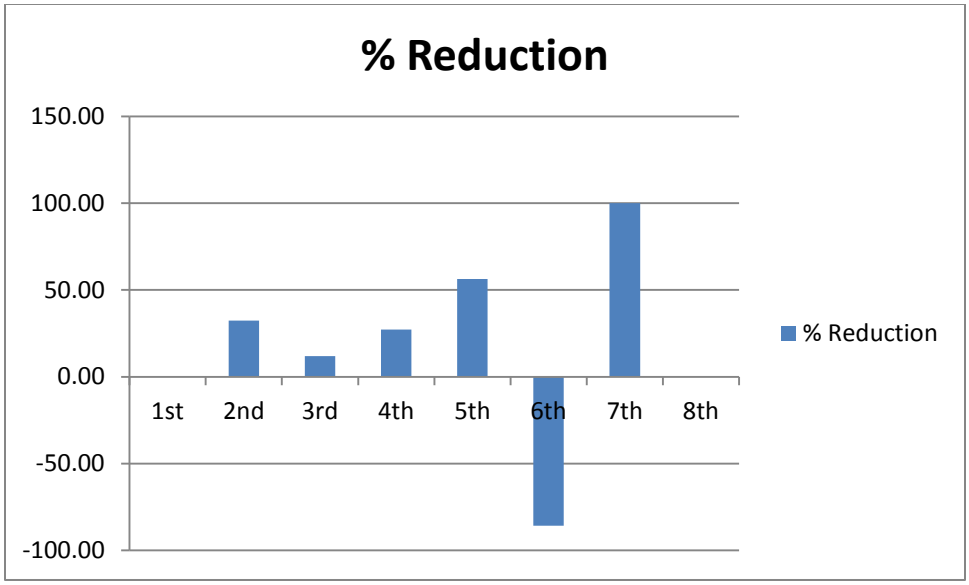


Figure 4.25 shows the % Reduction vs Time Graph

From the analysis of data from Appendix D the following graphs can be computed: in the Graph the blue line represents the Fecal Coliform. Initially amount of FC is 160 cfu/100 ml and at the Final hour the FC reduces to 0 cfu/100 ml

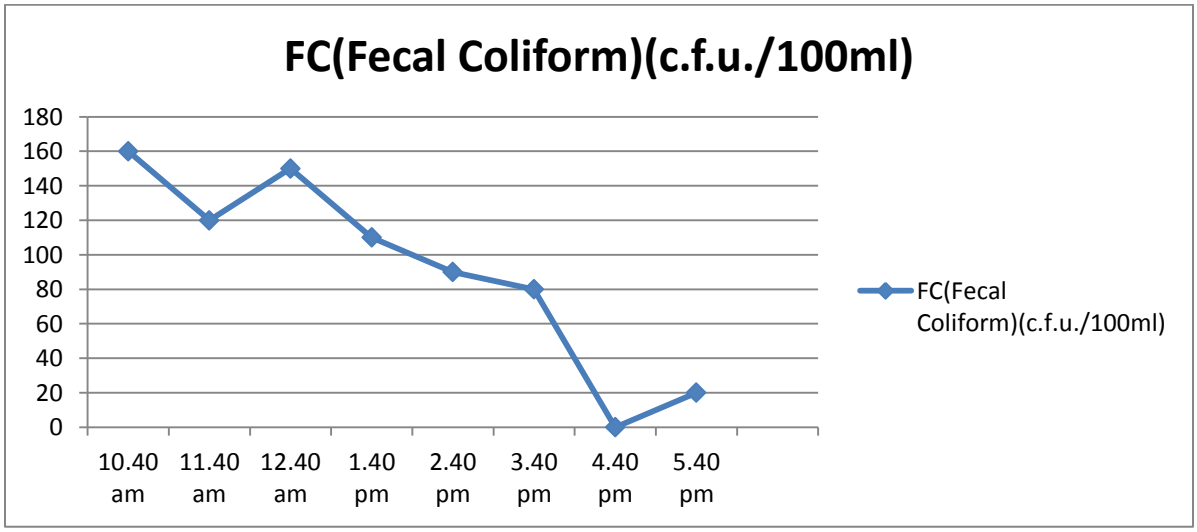


Figure 4.26 shows the FC vs Time Graph

Table:4.13 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	160		34	258.3
11.40 am	2nd	P1	120	25.00	47	309.7
12.40 am	3rd	P2	150	-25.00	45	405.2
1.40 pm	4th	P3	110	26.67	46	410.3
2.40 pm	5th	P4	90	18.18	32	370.3
3.40 pm	6th	P5	80	11.11	37	390.8
4.40 pm	7th	P6	0	100.00	43	410.7
5.40 pm	8th	P7	20	0.00	38	387.2

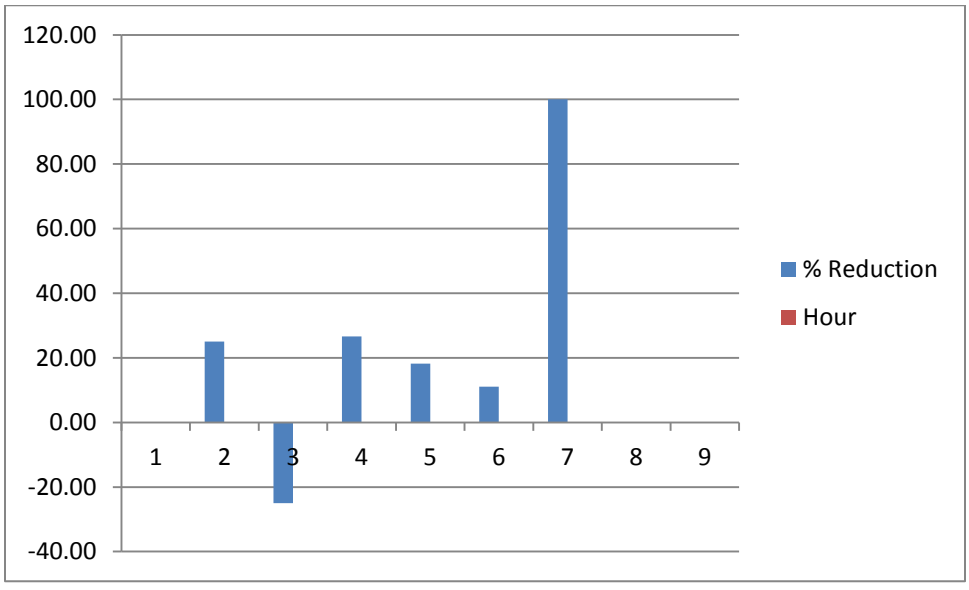


Figure 4.27 shows the % Reduction of FC vs Time Graph

From the analysis of data from Appendix D the following graphs can be computed: in the Graph the blue line represents the HPC. Initially amount of HPC is 605x10^4 cfu/1 ml and at the Final hour the HPC reduces to 94 cfu/1 ml

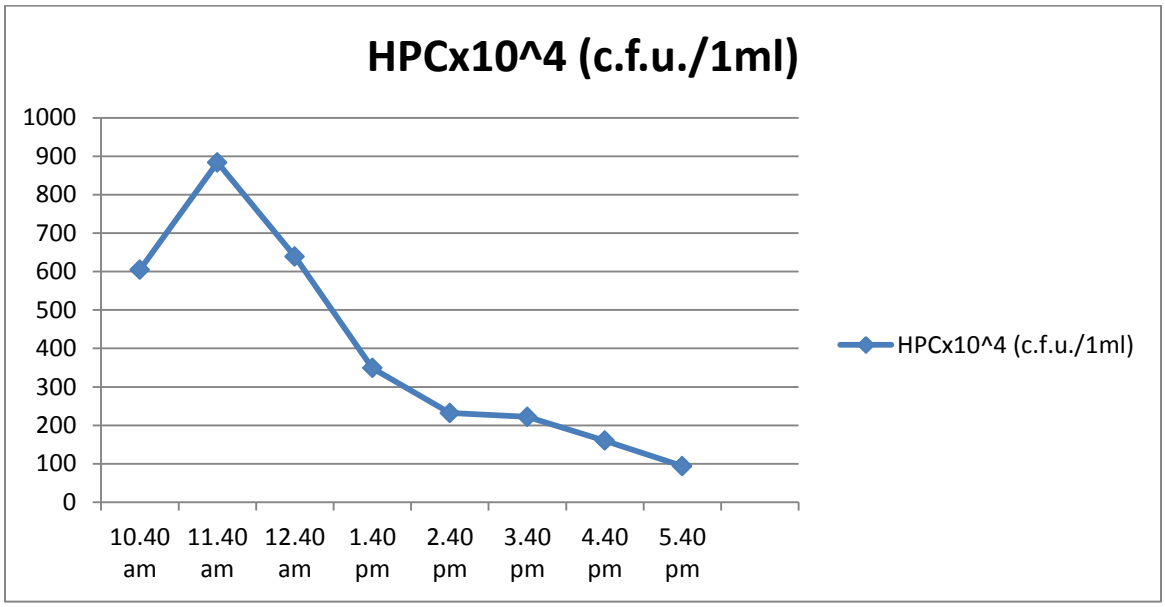


Figure 4.28 shows the FC vs Time Graph

Table:4.14 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of HPC

Time	Hour	Sample ID	HPCx10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	605		34	258.3
11am	2nd	P1	884	-46.12	47	309.7
12am	3rd	P2	639	27.71	45	405.2
1pm	4th	P3	349	45.38	46	410.3
2pm	5th	P4	232	33.52	32	370.3
3pm	6th	P5	222	4.31	37	390.8
4pm	7th	P6	160	27.93	43	410.7
5pm	8th	P7	94	41.25	38	387.2

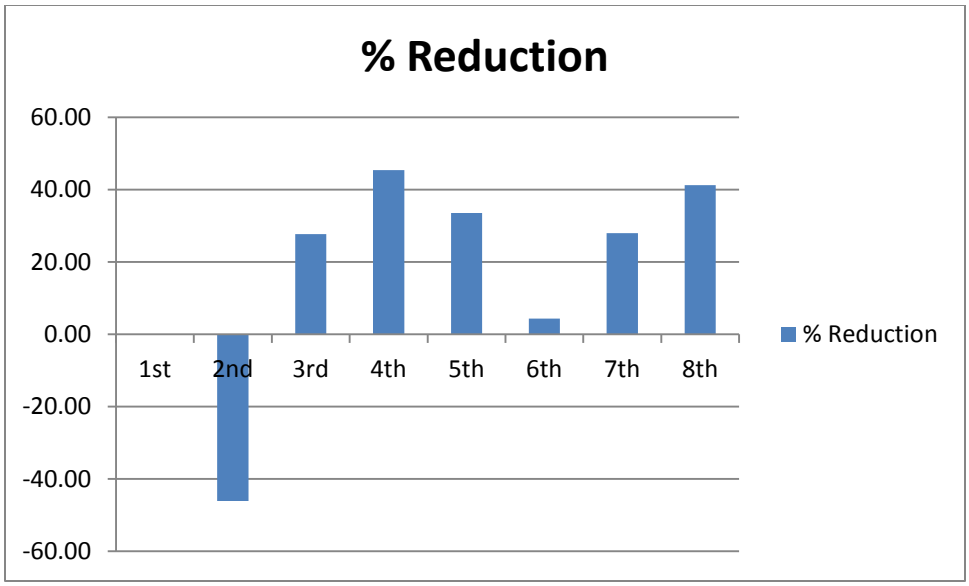


Figure 4.29 shows the % Reduction vs Time Graph

The following experiment was done in 24.6.2013 for Iut pond+psf water in Foil Backing Surface Bottles:

From the analysis of data from Appendix G the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is1240 cfu/100 ml and at the Final hour the TC reduces to 160 cfu/100 ml

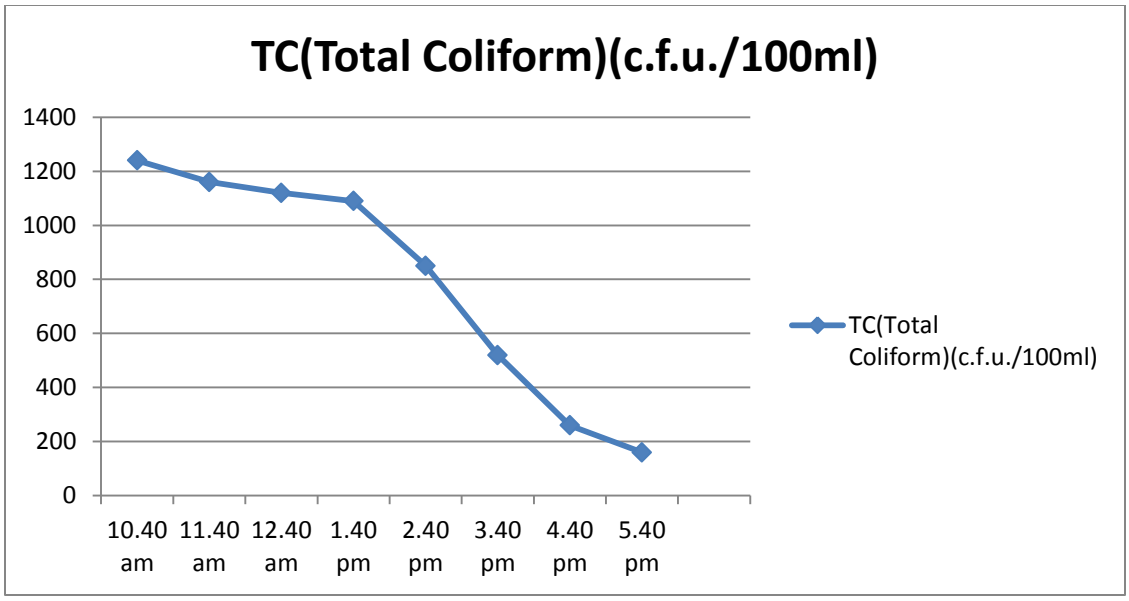


Figure 4.30 shows the TC vs Time Graph

Table:4.15 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	1240		43	325.3
11.40 am	2nd	P1	1160	6.45	45	370.7
12.40 am	3rd	P2	1120	3.45	46	430.9
1.40 pm	4th	P3	1090	2.68	36	420.2
2.40 pm	5th	P4	850	22.02	32	360.1
3.40 pm	6th	P5	520	38.82	43	450.4
4.40 pm	7th	P6	260	50.00	38	385.9
5.40 pm	8th	P7	160	38.46	35	370.2

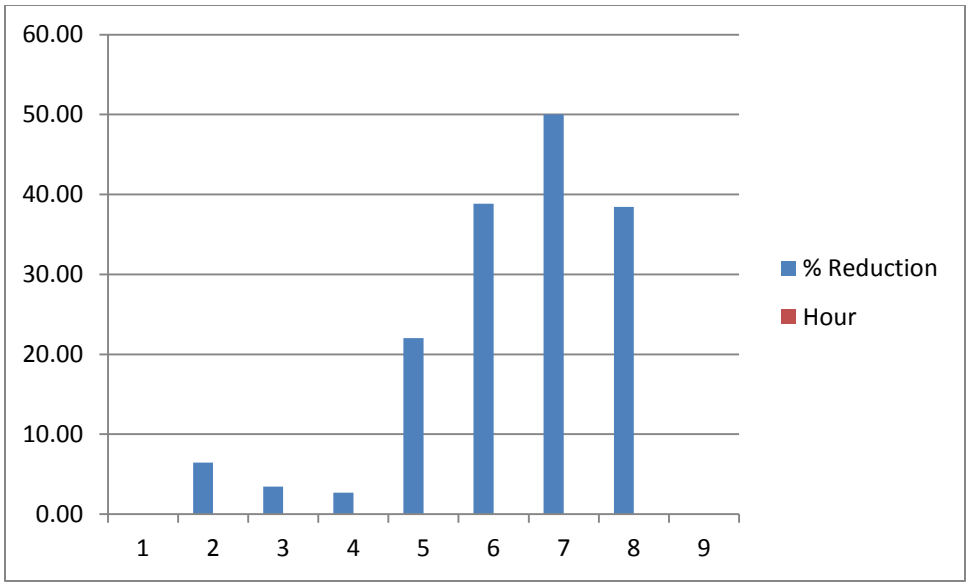


Figure 4.31 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix G the following graphs can be computed: in the Graph the blue line represents the Fecal Coliform. Initially amount of FC 940 cfu/100 ml and at the Final hour the FC reduces to 80 cfu/100 ml

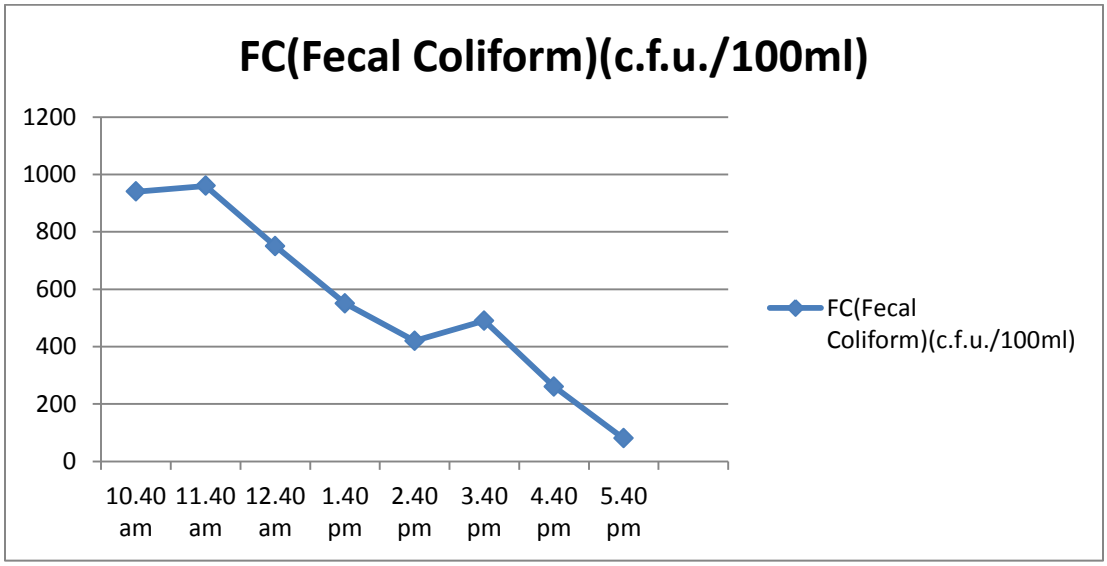


Figure 4.32 shows the FC vs Time Graph

Table:4.16 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	940		43	325.3
11.40 am	2nd	P1	960	-2.13	45	370.7
12.40 am	3rd	P2	750	21.88	46	430.9
1.40 pm	4th	P3	550	26.67	36	420.2
2.40 pm	5th	P4	420	23.64	32	360.1
3.40 pm	6th	P5	490	-16.67	43	450.4
4.40 pm	7th	P6	260	46.94	38	385.9
5.40 pm	8th	P7	80	69.23	35	370.2

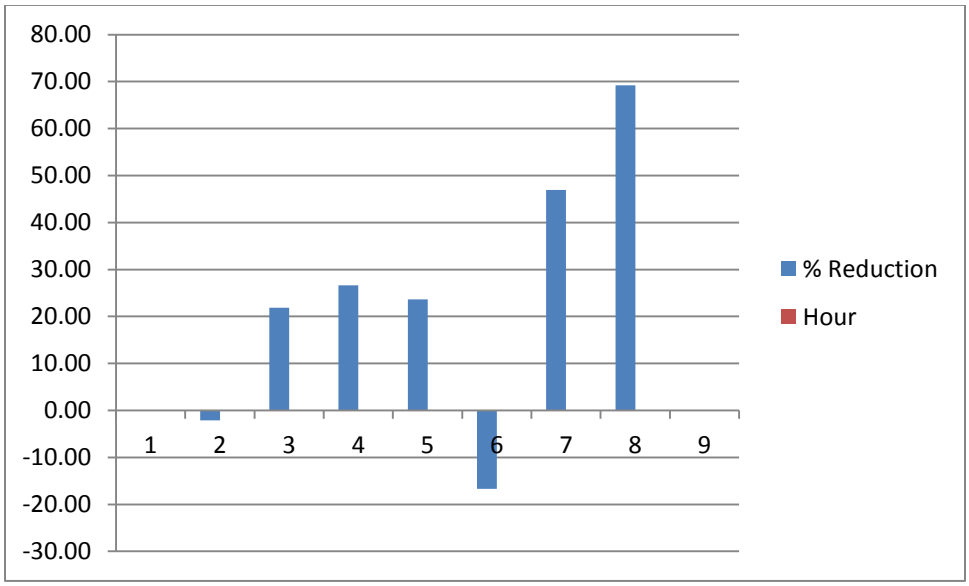


Figure 4.33 shows the % Reduction of FC vs Time Graph

From the analysis of data from Appendix G the following graphs can be computed: in the Graph the blue line represents the HPC. Initially amount of HPC is 655 x10^4 (c.f.u./1ml)and at the Final hour the HPC reduces to 141 x10^4 (c.f.u./1ml)

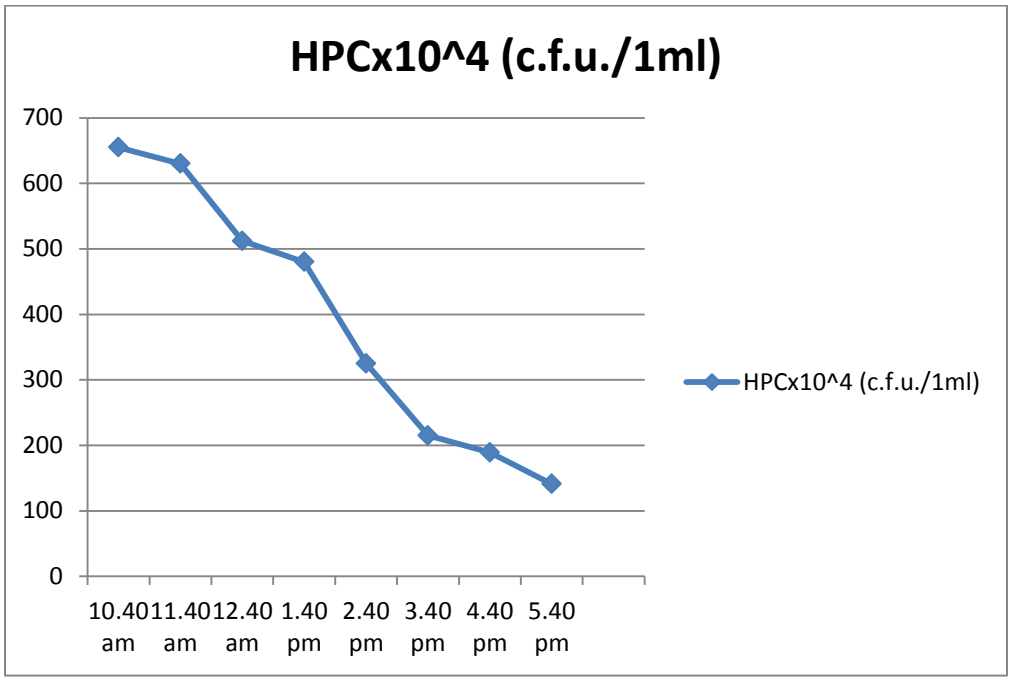


Figure 4.34 shows the FC vs Time Graph

Table:4.17 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of HPC

Time	Hour	Sample ID	HPCx10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	655		43	325.3
11am	2nd	P1	630	3.82	45	370.7
12am	3rd	P2	512	18.73	46	430.9
1pm	4th	P3	480	6.25	36	420.2
2pm	5th	P4	325	32.29	32	360.1
3pm	6th	P5	215	33.85	43	450.4
4pm	7th	P6	189	12.09	38	385.9
5pm	8th	P7	141	25.40	35	370.2

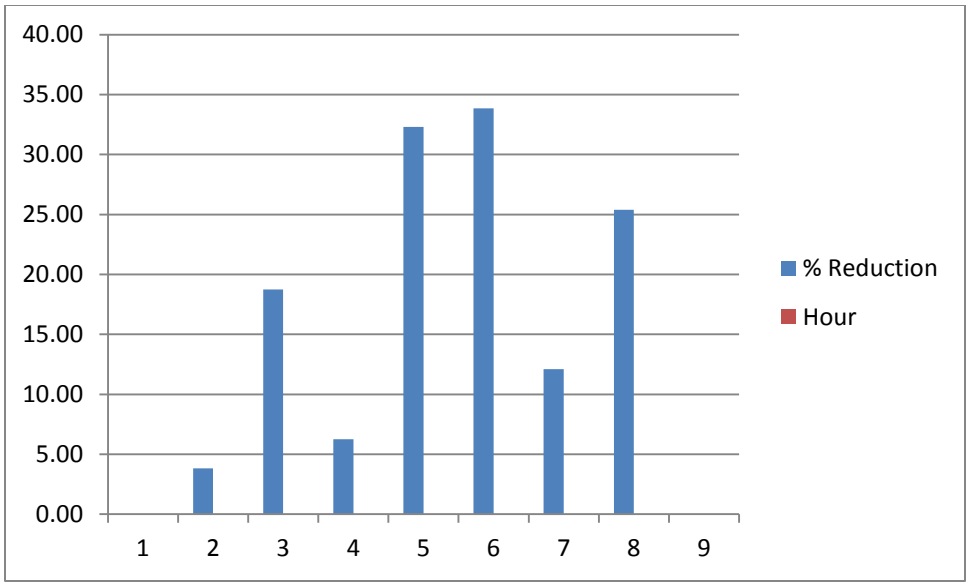


Figure 4.35 shows the % Reduction of TC vs Time Graph

The following experiment was done in 24.6.2013 for Iut pond+psf water in Glass Bottles:

From the analysis of data from Appendix H the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 1160 cfu/100 ml and at the Final hour the TC reduces to 840 cfu/100 ml

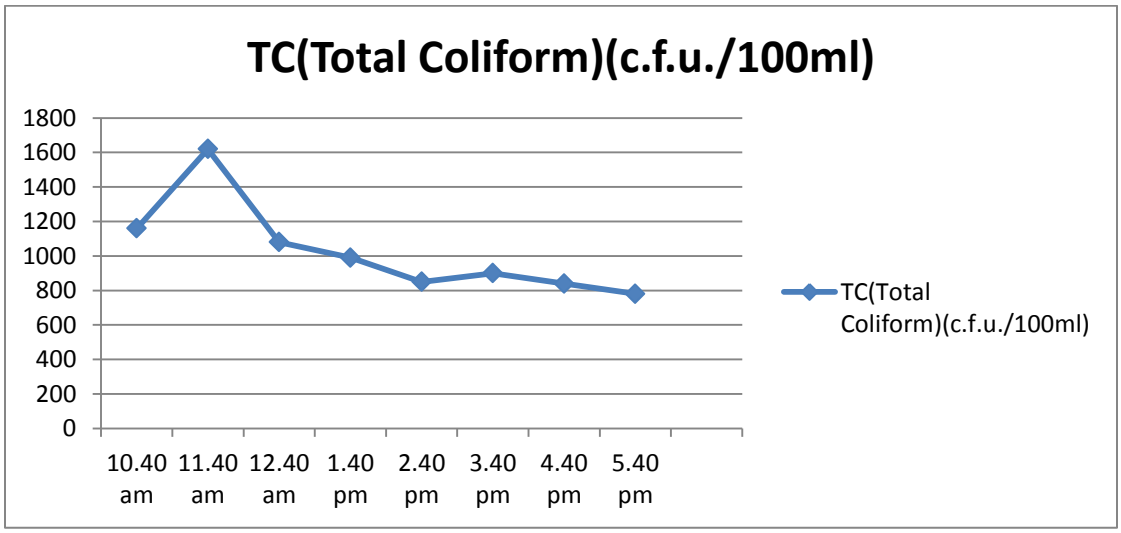


Figure 4.36 shows the TC vs Time Graph

Table:4.18 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	1160		32	410.3
11.40 am	2nd	P1	1620	-39.66	38	510.9
12.40 am	3rd	P2	1080	33.33	40	570.7
1.40 pm	4th	P3	990	8.33	43	630.3
2.40 pm	5th	P4	850	14.14	42	590.4
3.40 pm	6th	P5	900	-5.88	39	510.3
4.40 pm	7th	P6	840	6.67	36	497.2
5.40 pm	8th	P7	780	7.14	34	481.2

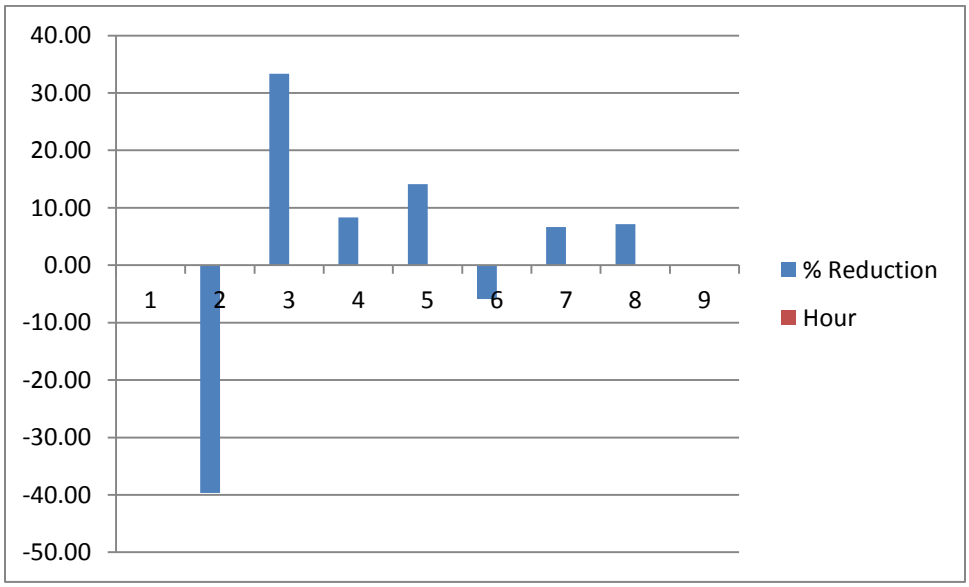


Figure 4.37 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix H the following graphs can be computed: in the Graph the blue line represents the Fecal coliform. Initially amount of Fecal coliform is 1040 cfu/100 ml and at the Final hour the FC reduces to 580 cfu/100 ml

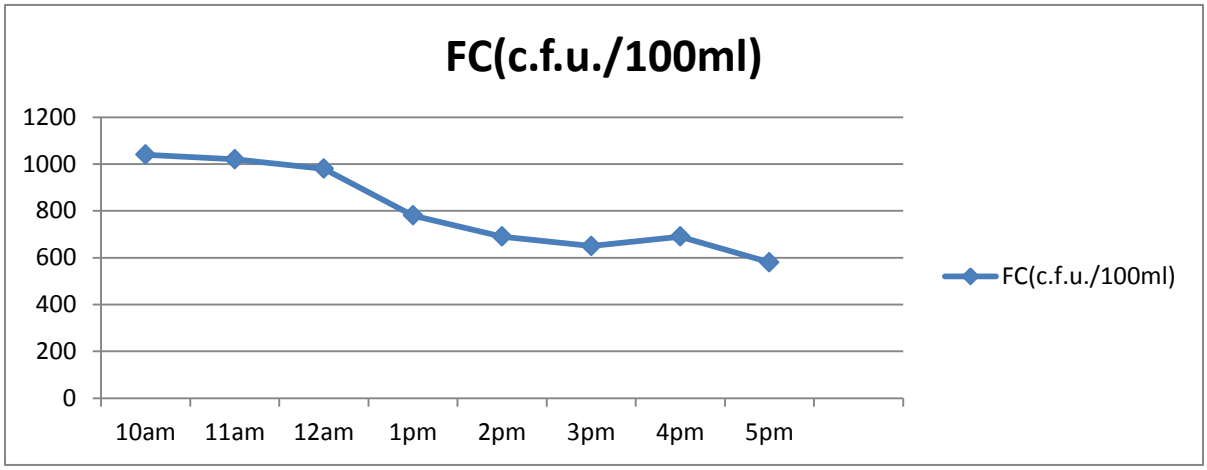


Figure 4.38 shows the FC vs Time Graph

Table:4.19 Hourly Exposure, Temperature, percentage reduction, solar radiation and TC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	1040		32	410.3
11am	2nd	P1	1020	1.92	38	510.9
12am	3rd	P2	980	3.92	40	570.7
1pm	4th	P3	780	20.41	43	630.3
2pm	5th	P4	690	11.54	42	590.4
3pm	6th	P5	650	5.80	39	510.3
4pm	7th	P6	690	-6.15	36	497.2
5pm	8th	P7	580	15.94	34	481.2

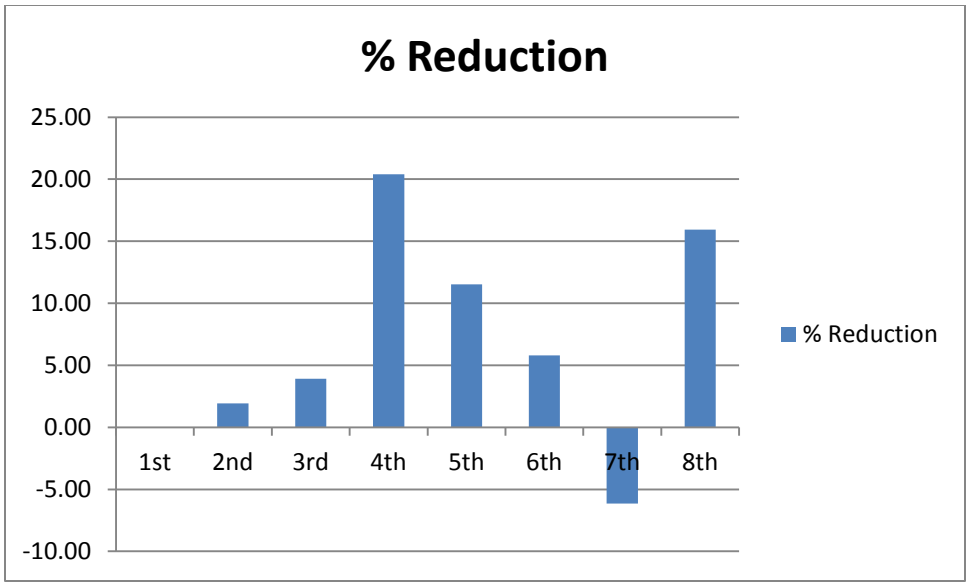


Figure 4.39 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix H the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 755 x10^4 (c.f.u./1ml) and at the Final hour the TC reduces to 189 x10^4 (c.f.u./1ml)

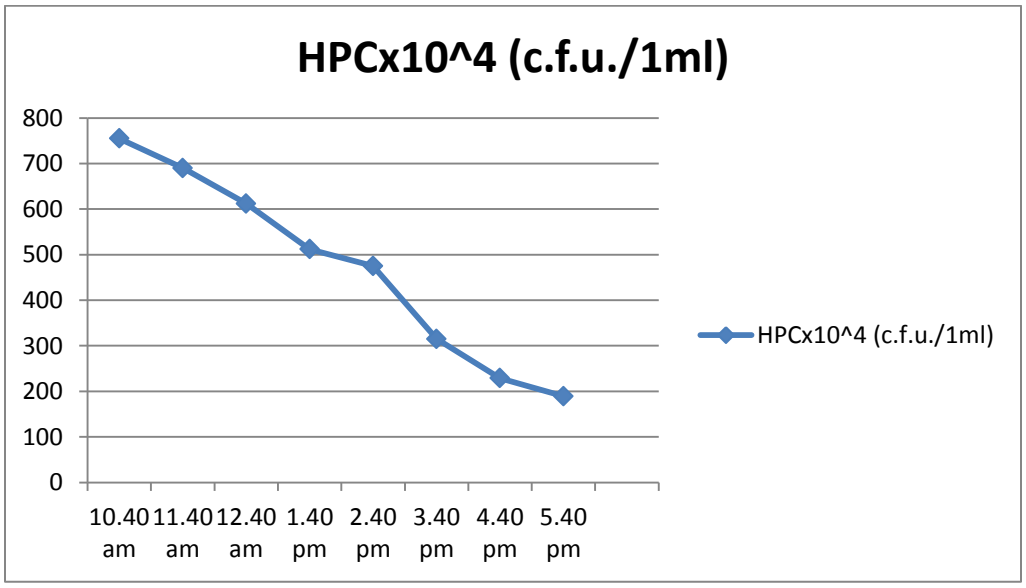


Figure 4.40 shows the HPC vs Time Graph

Table:4.20 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	HPC x10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	755		32	410.3
11am	2nd	P1	690	8.61	38	510.9
12am	3rd	P2	612	11.30	40	570.7
1pm	4th	P3	512	16.34	43	630.3
2pm	5th	P4	475	7.23	42	590.4
3pm	6th	P5	315	33.68	39	510.3
4pm	7th	P6	229	27.30	36	497.2
5pm	8th	P7	189	17.47	34	481.2

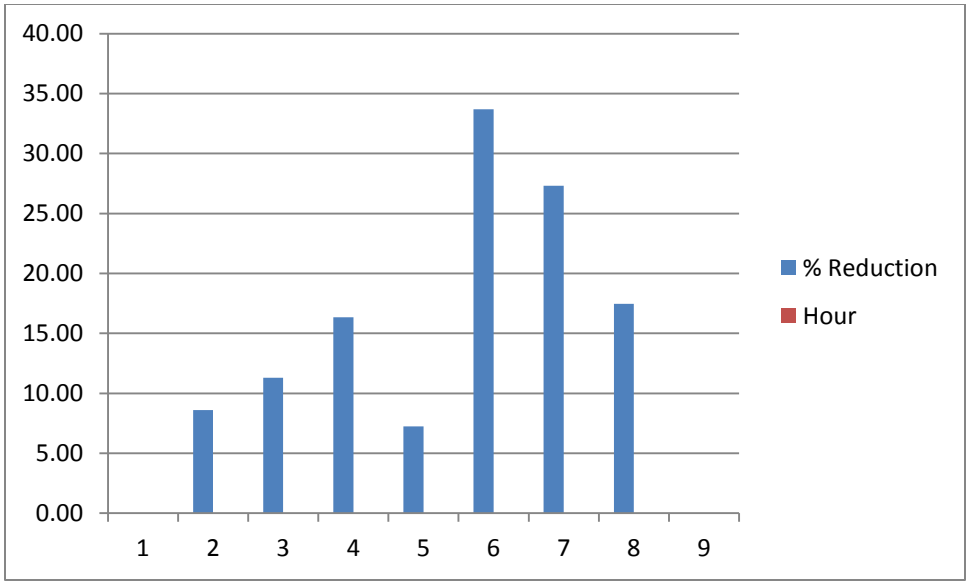


Figure 4.41 shows the % Reduction of HPC vs Time Graph

The following experiment was done in 24.6.2013 for Iut pond+psf water in PET Bottles:

From the analysis of data from Appendix F the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 1120 cfu/100 ml and at the Final hour the TC reduces to 360 cfu/100 ml

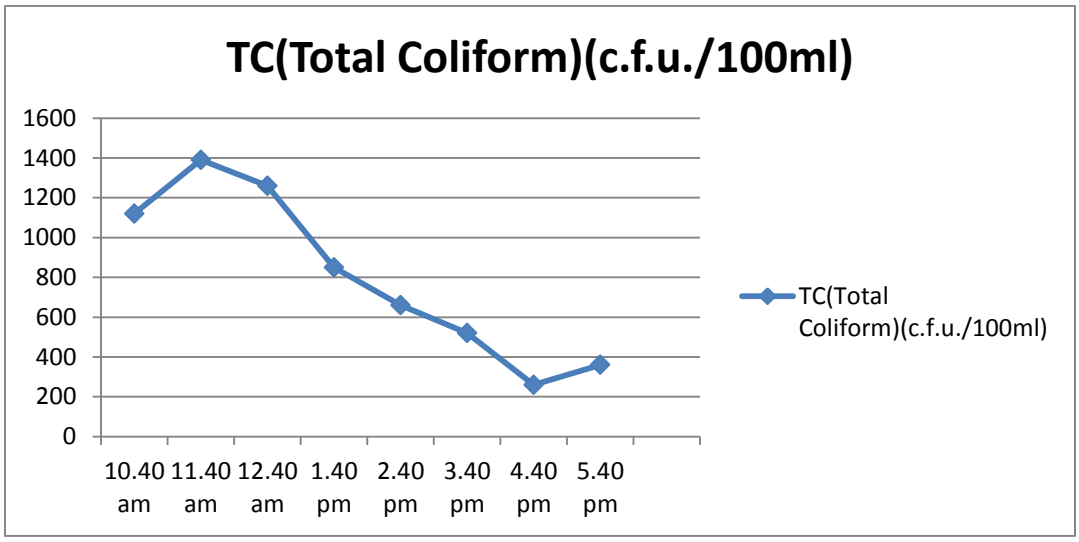


Figure 4.42 shows the TC vs Time Graph

Table:4.21 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	1120		43	325.3
11.40 am	2nd	P1	1390	-24.11	45	370.7
12.40 am	3rd	P2	1260	9.35	46	430.9
1.40 pm	4th	P3	850	32.54	36	420.2
2.40 pm	5th	P4	660	22.35	32	360.1
3.40 pm	6th	P5	520	21.21	43	450.4
4.40 pm	7th	P6	260	50.00	38	385.9
5.40 pm	8th	P7	360	-38.46	35	370.2

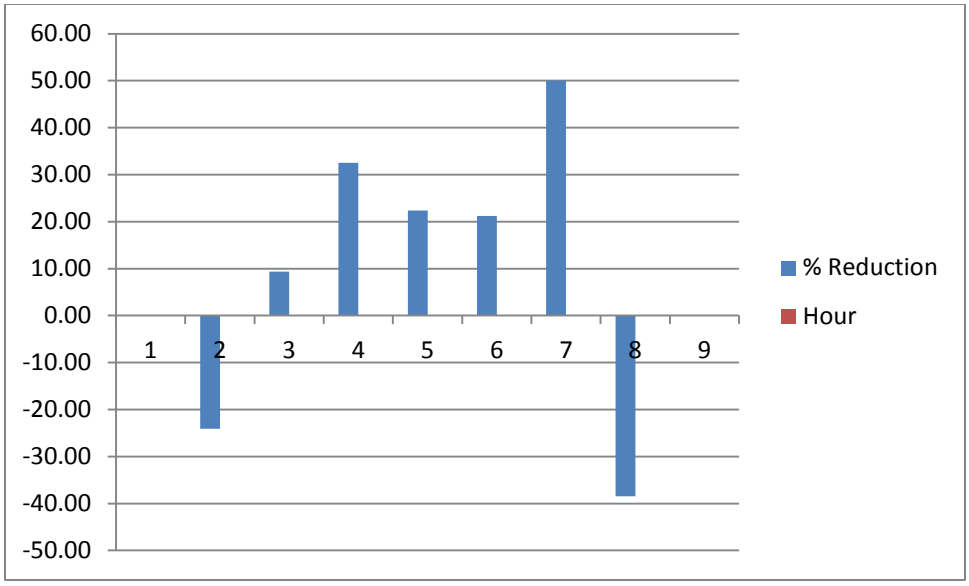


Figure 4.43 shows the % Reduction of TC vs Time Graph

From the analysis of data from Appendix F the following graphs can be computed: in the Graph the blue line represents the FECAL Coliform. Initially amount of FC is 840 cfu/100 ml and at the Final hour the FC reduces to 160 cfu/100 ml

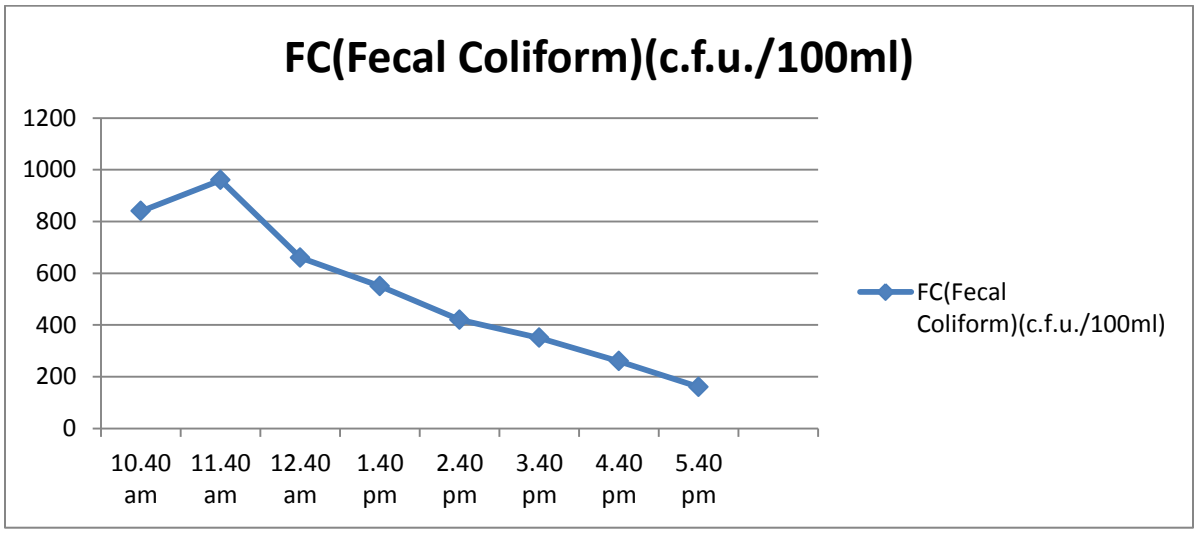


Figure 4.44 shows the FC vs Time Graph

Table:4.22 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	FC(c.f.u./100 ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10.40 am	1st	P0	840		43	325.3
11.40 am	2nd	P1	960	-14.29	45	370.7
12.40 am	3rd	P2	660	31.25	46	430.9
1.40 pm	4th	P3	550	16.67	36	420.2
2.40 pm	5th	P4	420	23.64	32	360.1
3.40 pm	6th	P5	350	16.67	43	450.4
4.40 pm	7th	P6	260	25.71	38	385.9
5.40 pm	8th	P7	160	38.46	35	370.2

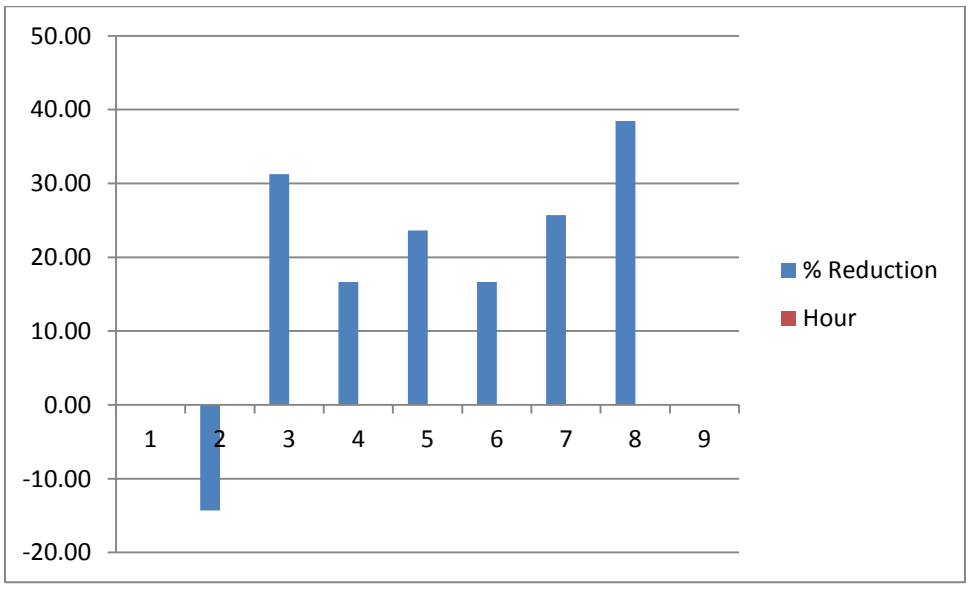


Figure 4.45 shows the % Reduction of FC vs Time Graph

From the analysis of data from Appendix F the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 605 cfu/100 m x10^4 (c.f.u./1ml) and at the Final hour the TC reduces to 199 x10^4 (c.f.u./1ml).

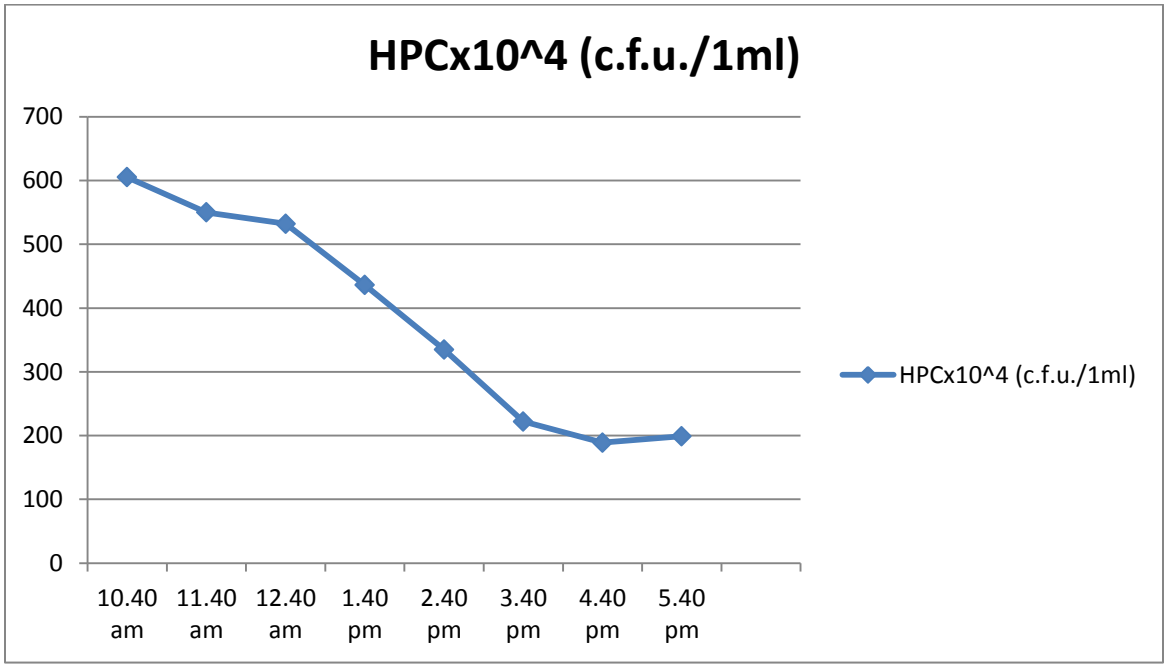


Figure 4.46 shows the HPC vs Time Graph

Table:4.23 Hourly Exposure, Temperature, percentage reduction, solar radiation and Amount of TC

Time	Hour	Sample ID	HPC x10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	605		43	325.3
11am	2nd	P1	550	9.09	45	370.7
12am	3rd	P2	532	3.27	46	430.9
1pm	4th	P3	436	18.05	36	420.2
2pm	5th	P4	335	23.17	32	360.1
3pm	6th	P5	222	33.73	43	450.4
4pm	7th	P6	189	14.86	38	385.9
5pm	8th	P7	199	-5.29	35	370.2

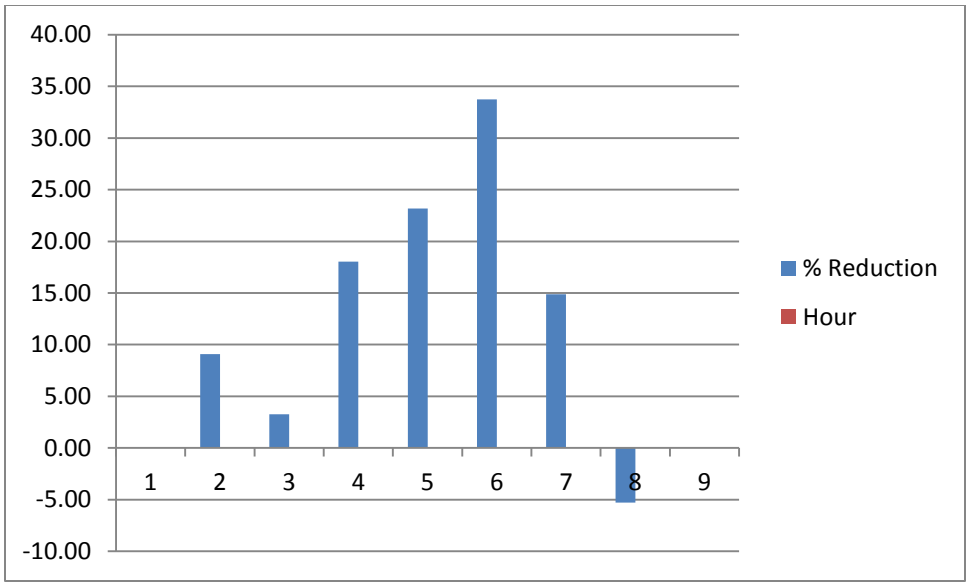


Figure 4.48 shows the % Reduction of HPC vs Time Graph

4.3 Data of Cultured Bacteria Sample

The following experiment was done in 1.9.13 for PET Bottle

From the analysis of data from Appendix I the following graphs can be computed: in the Graph the blue line represents the Escherichia Coli. Initially amount of total coliform is 112000 cfu/100 ml and at the Final hour the TC reduces to 58000 cfu/100 ml

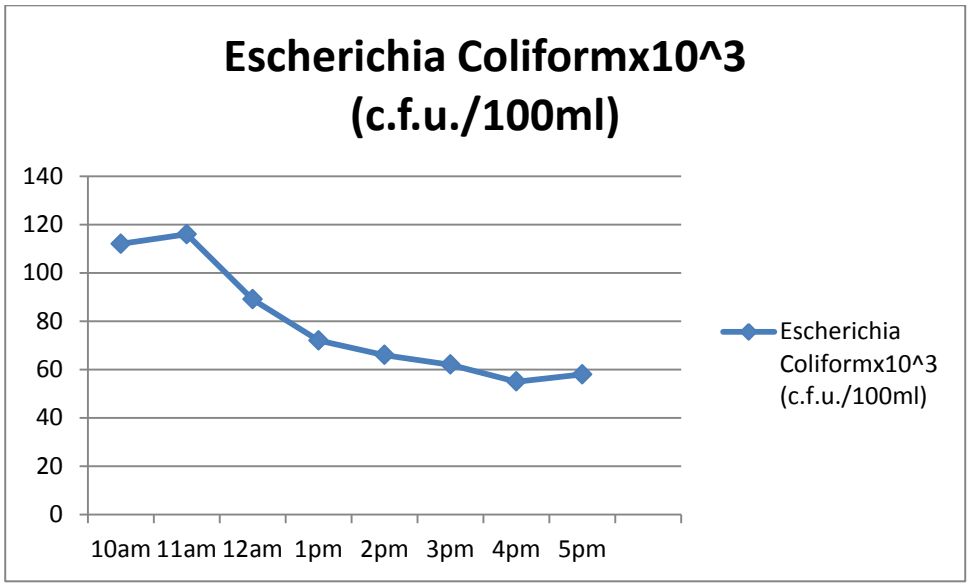


Figure 4.1 shows the TC vs Time Graph

Table:4.Hourly Exposure,Temperature,percentage reduction, Solar radiation , Amount of TC

Time	Hour	Sample ID	E.Coli(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	112000		32	265.3
11am	2nd	P1	116000	-3.57	35	283.2
12am	3rd	P2	89000	23.28	34	283.3
1pm	4th	P3	72000	19.10	36	298.5
2pm	5th	P4	66000	8.33	38	310.5
3pm	6th	P5	62000	6.06	38	327.5
4pm	7th	P6	55000	11.29	33	312.5
5pm	8th	P7	58000	-5.45	30	275.5

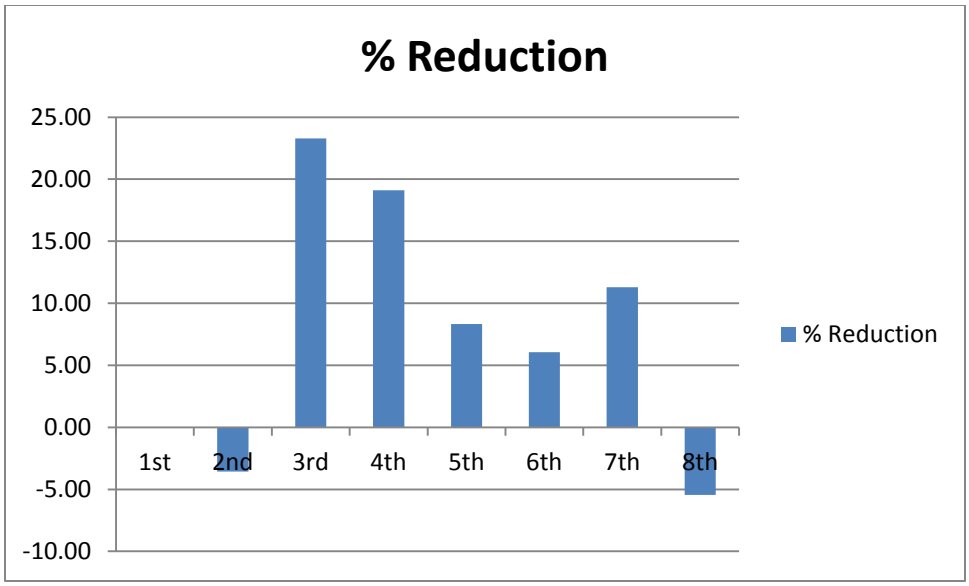


Figure shows the % Reduction vs Time Graph

The following experiment was done in 5.9.13 for PET Bottle

From the analysis of data from Appendix J the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 2260000 cfu/100 ml and at the Final hour the TC reduces to 1660000 cfu/100 ml

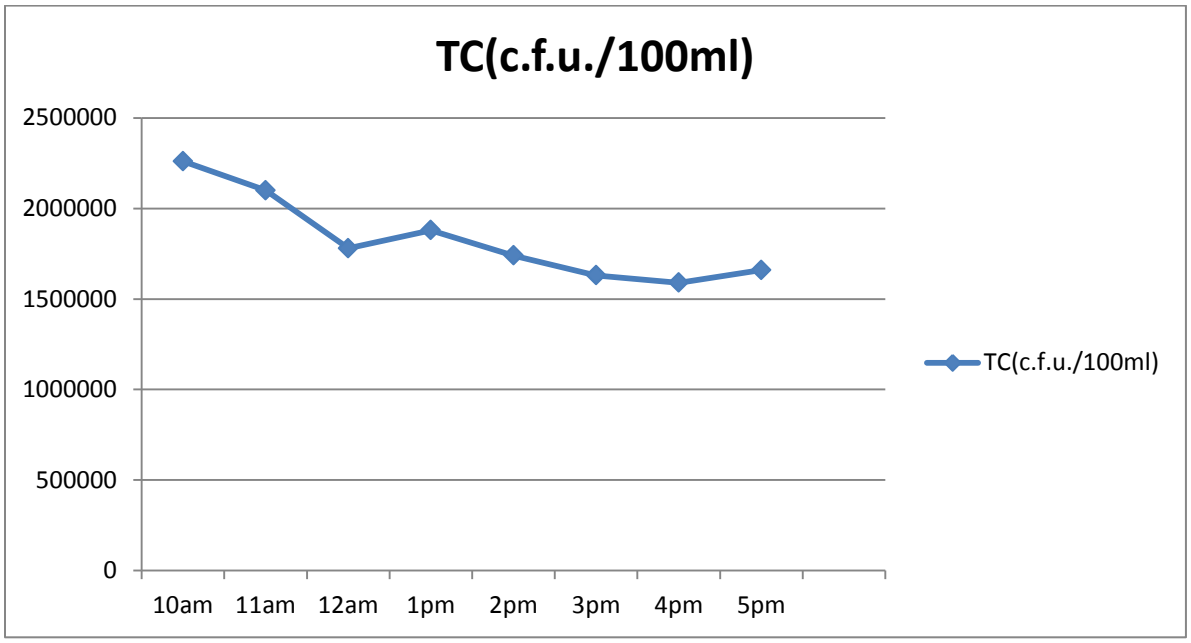


Figure 4.1 shows the TC vs Time Graph

Table:4.Hourly Exposure,Temperature,percentage reduction, Solar radiation , Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	2260000		41	430
11am	2nd	P1	2100000	7.08	38	510
12am	3rd	P2	1780000	15.23	36	490
1pm	4th	P3	1880000	-5.61	36	430
2pm	5th	P4	1740000	7.44	32	410
3pm	6th	P5	1630000	6.32	43	450
4pm	7th	P6	1590000	2.45	39	405
5pm	8th	P7	1660000	-4.4	35	365

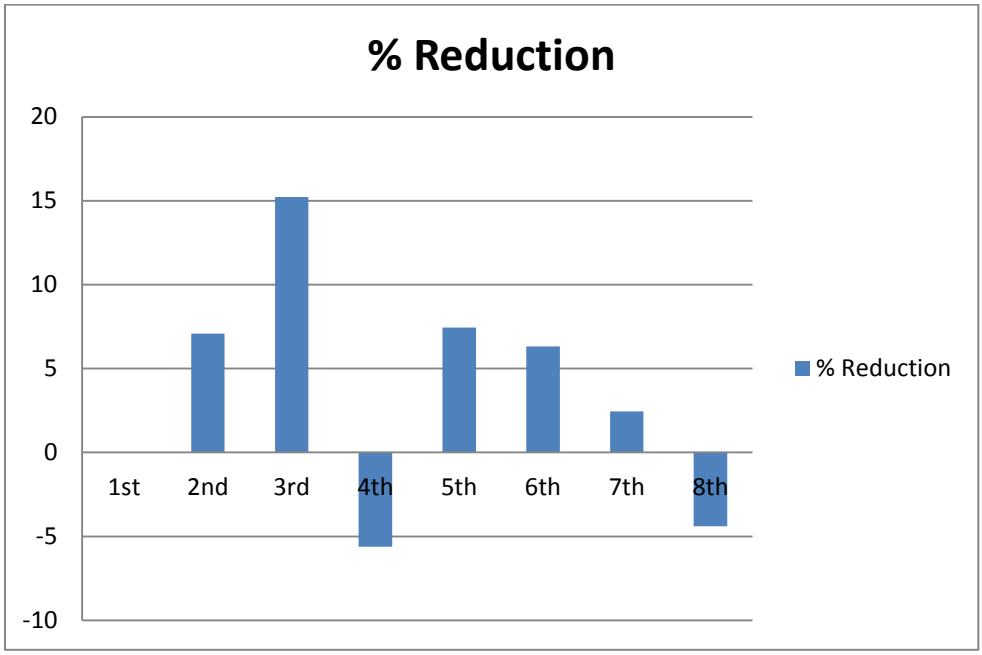


Figure shows the % Reduction vs Time Graph

From the analysis of data from Appendix J the following graphs can be computed: in the Graph the blue line represents the Fecal Coliform. Initially amount of Fecal coliform is 1850000 cfu/100 ml and at the Final hour the FC reduces to 1030000 cfu/100 ml

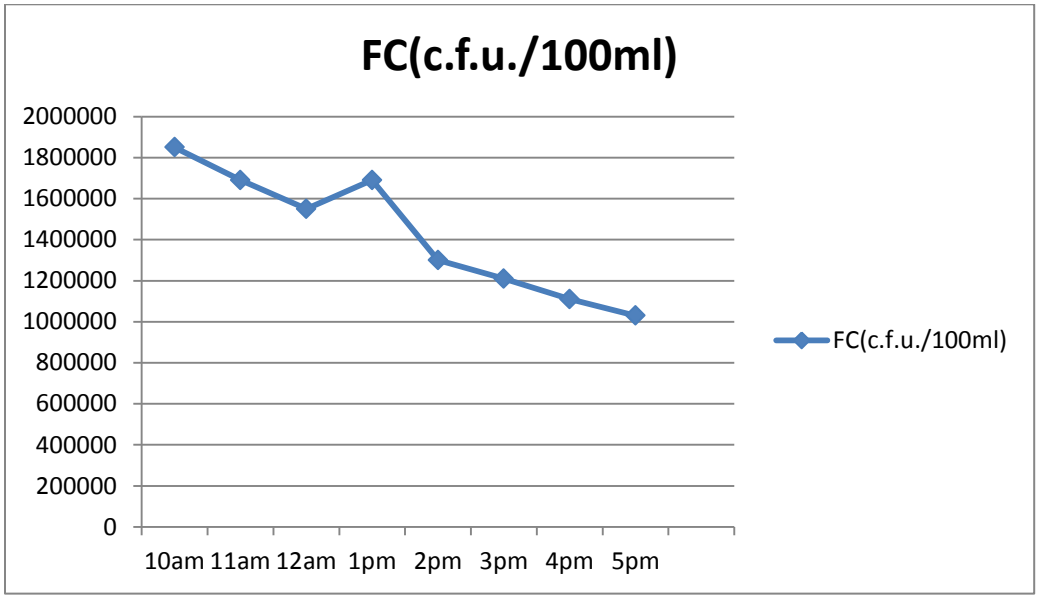


Figure 4.1 shows the FC vs Time Graph

Table:4.Hourly Exposure, Temperature, percentage reduction, Solar radiation , Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	1850000		41	430
11am	2nd	P1	1690000	8.65	38	510
12am	3rd	P2	1550000	8.28	36	490
1pm	4th	P3	1690000	-9.03	36	430
2pm	5th	P4	1300000	23.08	32	410
3pm	6th	P5	1210000	6.92	43	450
4pm	7th	P6	1110000	8.26	39	405
5pm	8th	P7	1030000	7.2	35	365

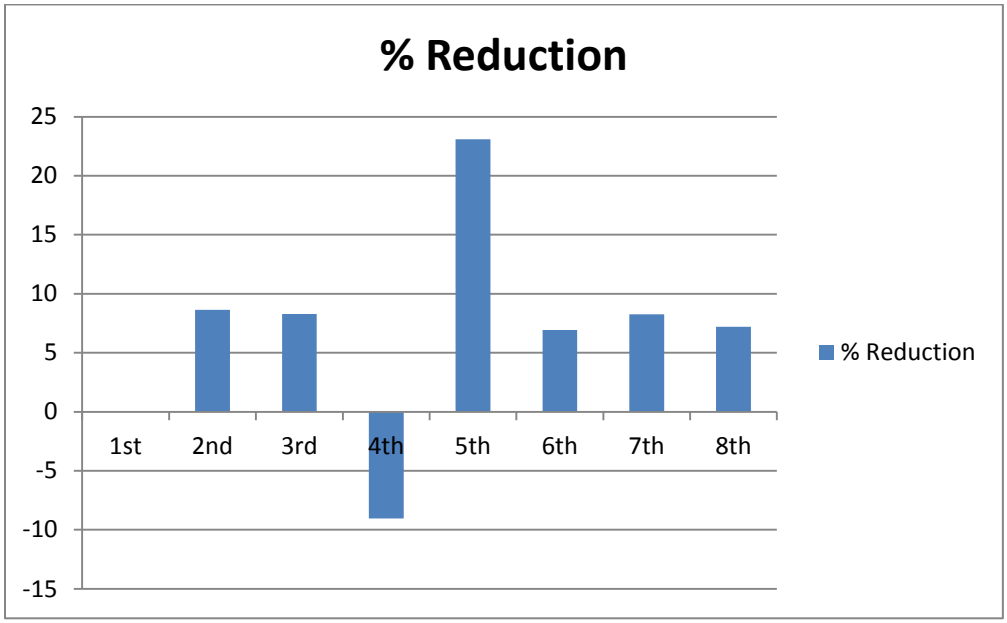


Figure Shows the % Reduction vs Time Graph

From the analysis of data from Appendix J the following graphs can be computed: in the Graph the blue line represents the Escherichia Coli. Initially amount of E.Coli is 560000 cfu/100 ml and at the Final hour the E.Coli reduces to 90000 cfu/100 ml

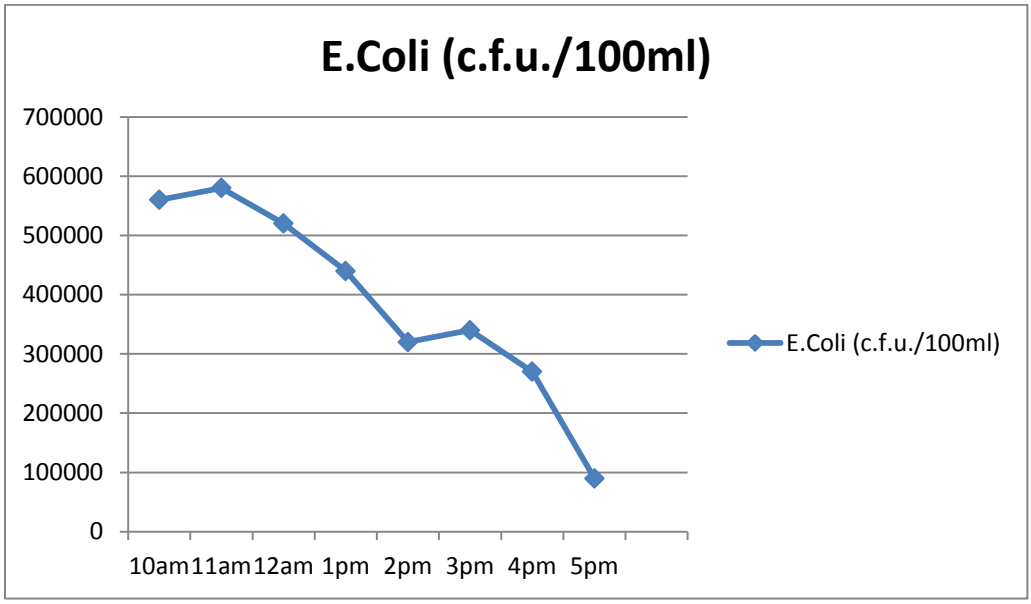


Figure 4.1 shows the E.coli vs Time Graph

Table:4.Hourly Exposure,Temperature,percentage reduction, Solar radiation , Amount of E.Coli

Time	Hour	Sample ID	E.coli (c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	560000		41	430
11am	2nd	P1	580000	-3.57	38	510
12am	3rd	P2	520000	10.34	36	490
1pm	4th	P3	440000	15.38	36	430
2pm	5th	P4	320000	27.27	32	410
3pm	6th	P5	340000	-6.25	43	450
4pm	7th	P6	270000	20.59	39	405
5pm	8th	P7	90000	66.67	35	365

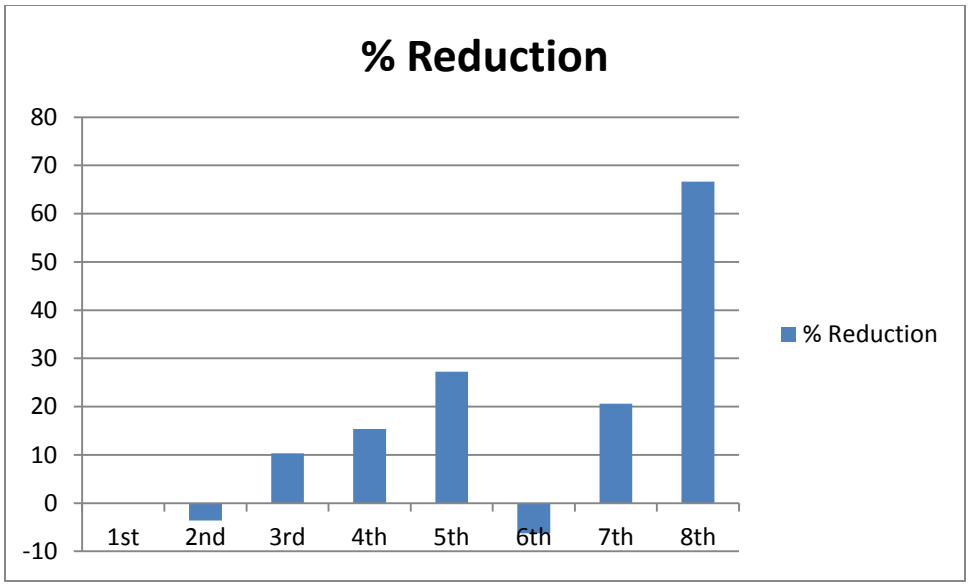


Figure shows the % Reduction vs Time Graph

From the analysis of data from Appendix J the following graphs can be computed: in the Graph the blue line represents the Heterotopic Plate Count. Initially amount of HPC is 136x10^4 cfu/100 ml and at the Final hour the HPC reduces to 65x10^4 cfu/100 ml

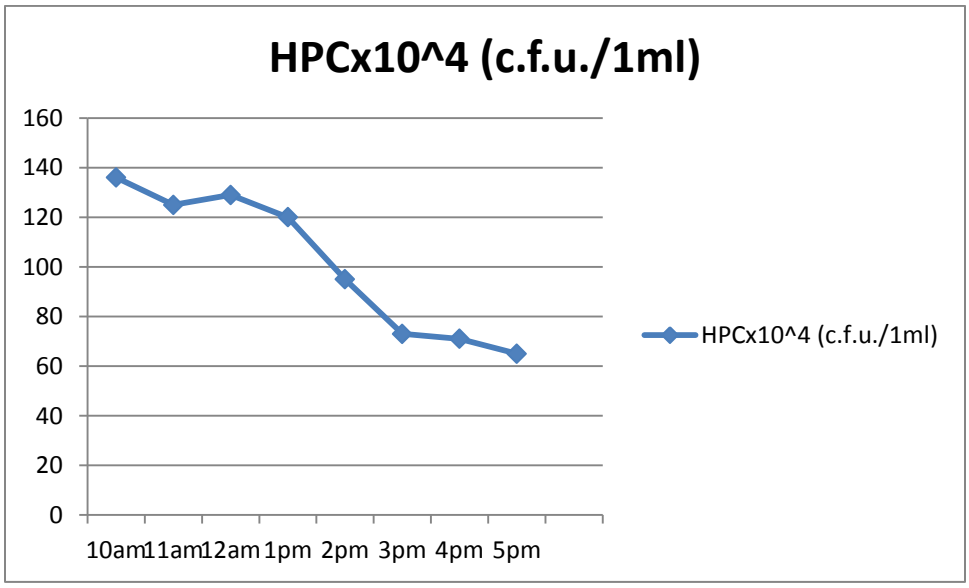


Figure 4.1 shows the TC vs Time Graph

Table:4.Hourly Exposure,Temperature,percentage reduction, Solar radiation , Amount of HPC

Time	Hour	Sample ID	HPCx10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	136		41	430
11am	2nd	P1	125	8.09	38	510
12am	3rd	P2	129	-3.2	36	490
1pm	4th	P3	120	6.97	36	430
2pm	5th	P4	95	20.83	32	410
3pm	6th	P5	73	23.15	43	450
4pm	7th	P6	71	2.73	39	405
5pm	8th	P7	65	8.45	35	365

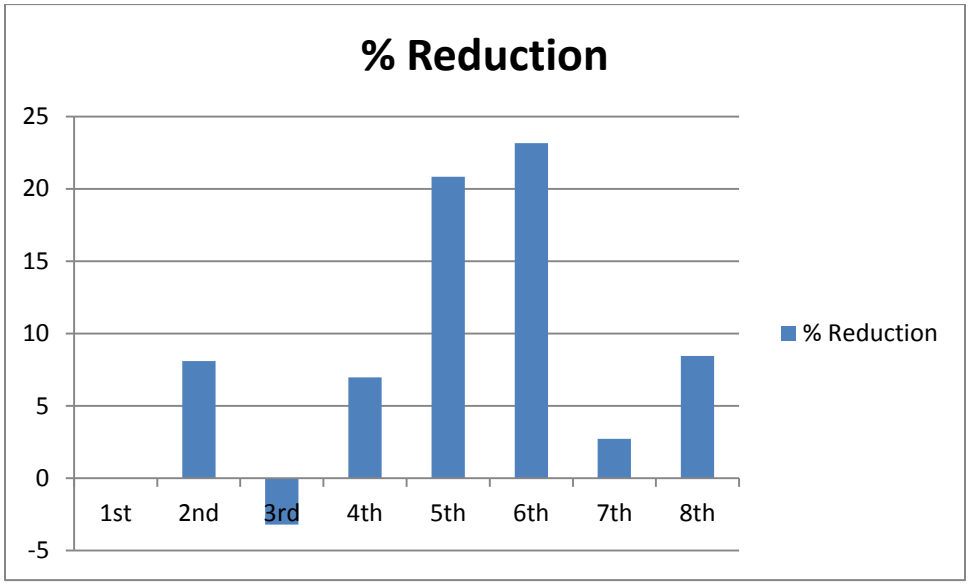


Figure shows the % Reduction vs Time Graph

The following experiment was done in 9.9.2013 for PET Bottle

From the analysis of data from Appendix k the following graphs can be computed: in the Graph the blue line represents the Total Coliform. Initially amount of total coliform is 1670000 cfu/100 ml and at the Final hour the TC reduces to 798000 cfu/100 ml

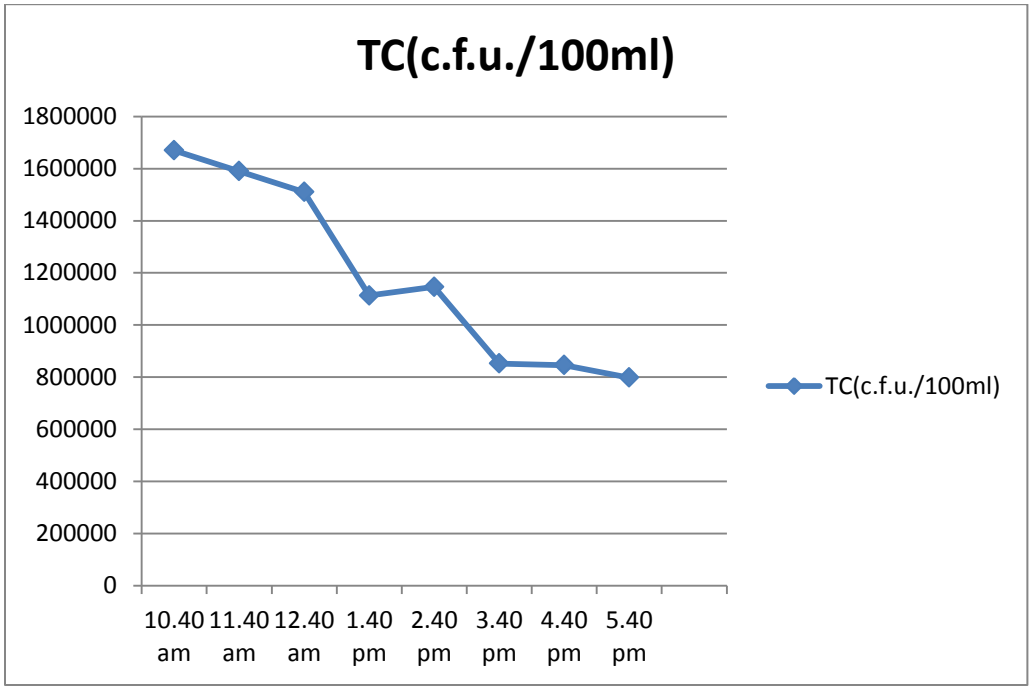


Figure 4.1 shows the TC vs Time Graph

Table: 4.Hourly Exposure, Temperature, percentage reduction, Solar radiation, Amount of TC

Time	Hour	Sample ID	TC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	1670000		32	410.3
11am	2nd	P1	1590000	4.79	38	510.9
12am	3rd	P2	1510000	5.03	40	570.7
1pm	4th	P3	1113000	26.29	43	630.3
2pm	5th	P4	1146000	-2.96	42	590.4
3pm	6th	P5	852000	25.65	39	510.3
4pm	7th	P6	846000	0.70	36	497.2
5pm	8th	P7	798000	5.67	34	481.2

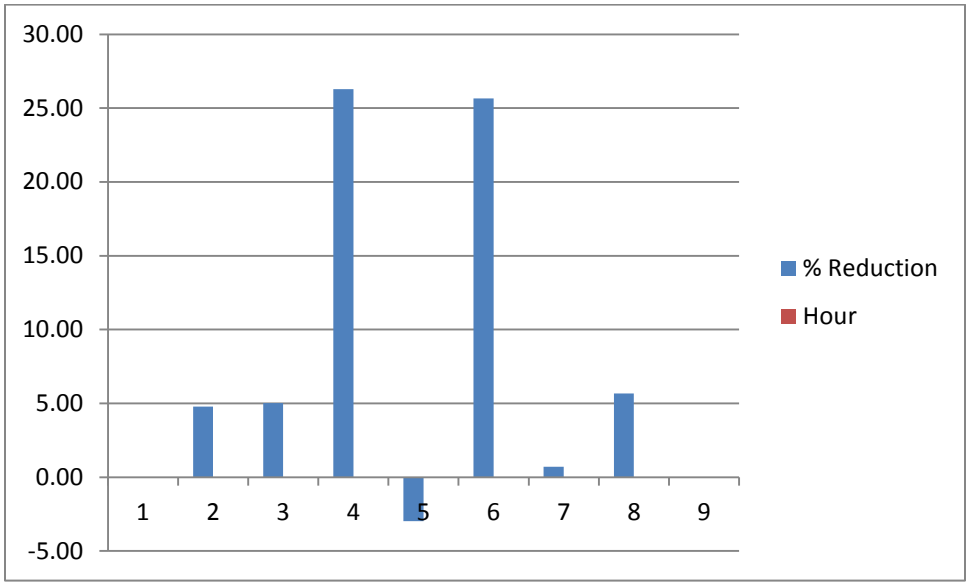


Figure shows the % Reduction vs Time Graph

From the analysis of data from Appendix K the following graphs can be computed: in the Graph the blue line represents the Fecal Coliform. Initially amount of Fecal coliform is 1109000 cfu/100 ml and at the Final hour the FC reduces to 678000 cfu/100 ml

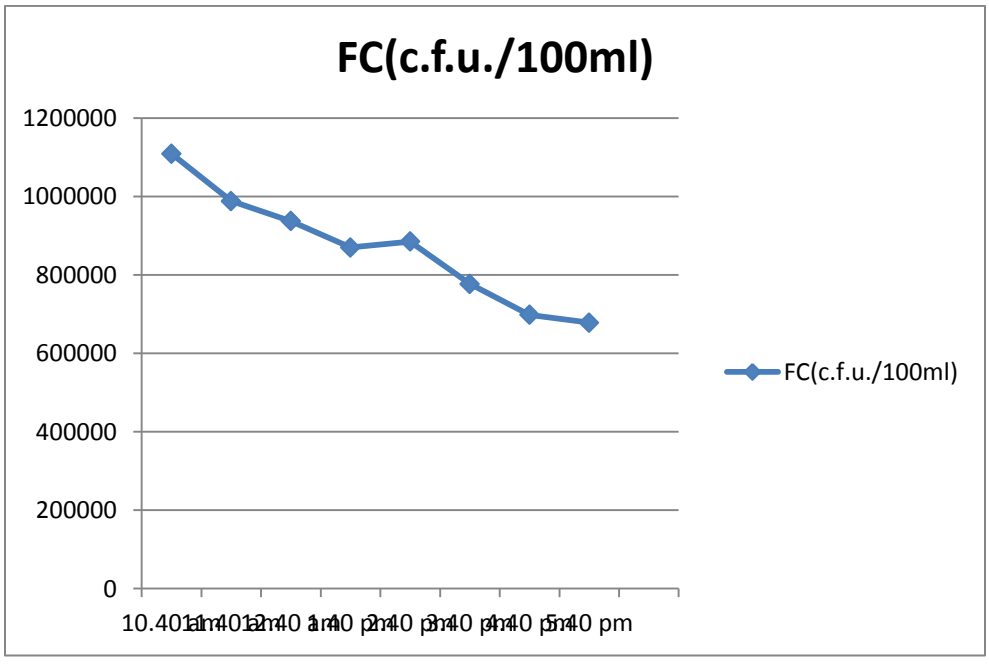


Figure 4.1 shows the FC vs Time Graph

Table:4.Hourly Exposure, Temperature, percentage reduction, Solar radiation , Amount of FC

Time	Hour	Sample ID	FC(c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	1109000		32	410.3
11am	2nd	P1	988000	10.91	38	510.9
12am	3rd	P2	937000	5.16	40	570.7
1pm	4th	P3	870000	7.15	43	630.3
2pm	5th	P4	885000	-1.72	42	590.4
3pm	6th	P5	777000	12.20	39	510.3
4pm	7th	P6	698000	10.17	36	497.2
5pm	8th	P7	678000	2.87	34	481.2

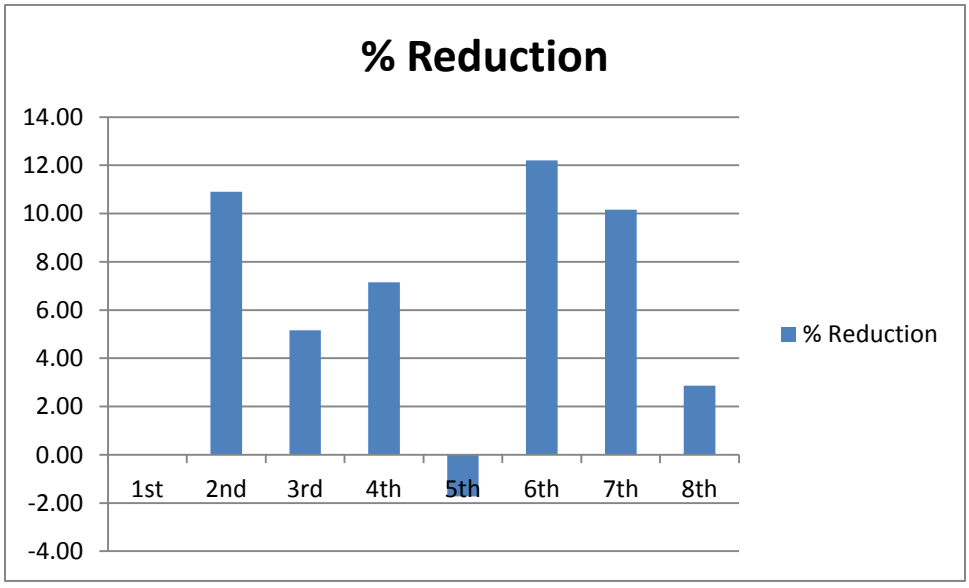


Figure shows the % Reduction vs Time Graph

From the analysis of data from Appendix I the following graphs can be computed: in the Graph the blue line represents the Escherichia Coli. Initially amount of E.coli is 320000 cfu/100 ml and at the Final hour the E.coli reduces to 110000 cfu/100 ml

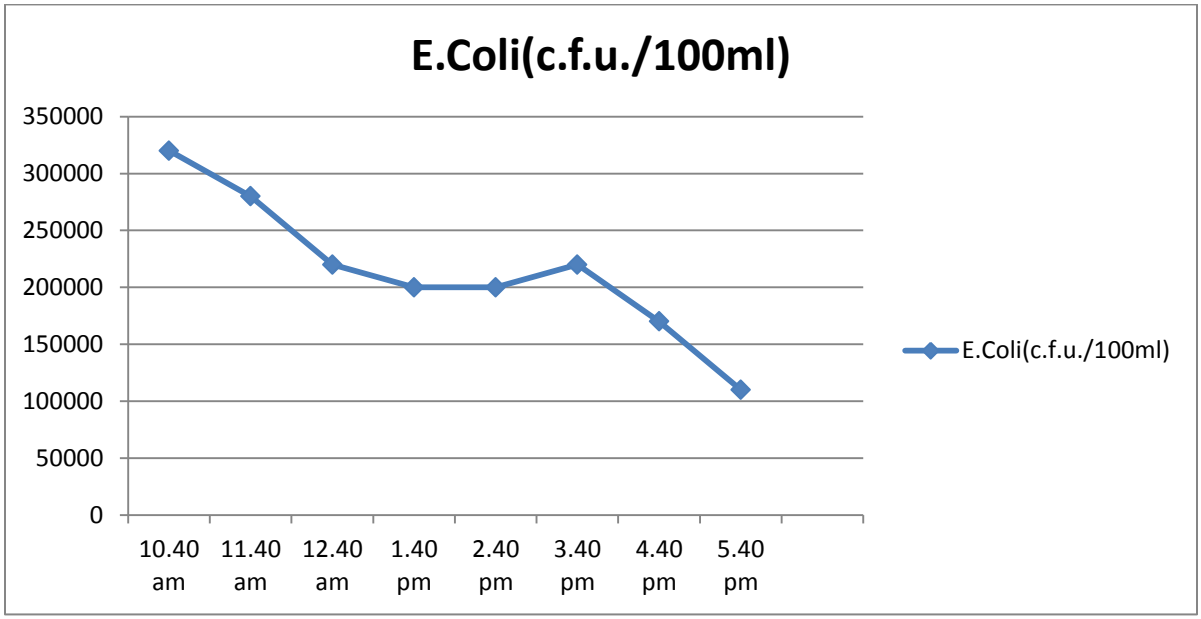


Figure 4.1 shows the TC vs Time Graph

Table: 4.Hourly Exposure, Temperature, percentage reduction, Solar radiation , Amount of E.coli

Time	Hour	Sample ID	E.coli (c.f.u./100ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	320000		32	410.3
11am	2nd	P1	280000	12.50	38	510.9
12am	3rd	P2	220000	21.43	40	570.7
1pm	4th	P3	200000	9.09	43	630.3
2pm	5th	P4	200000	0.00	42	590.4
3pm	6th	P5	220000	-10.00	39	510.3
4pm	7th	P6	170000	22.73	36	497.2
5pm	8th	P7	110000	35.29	34	481.2

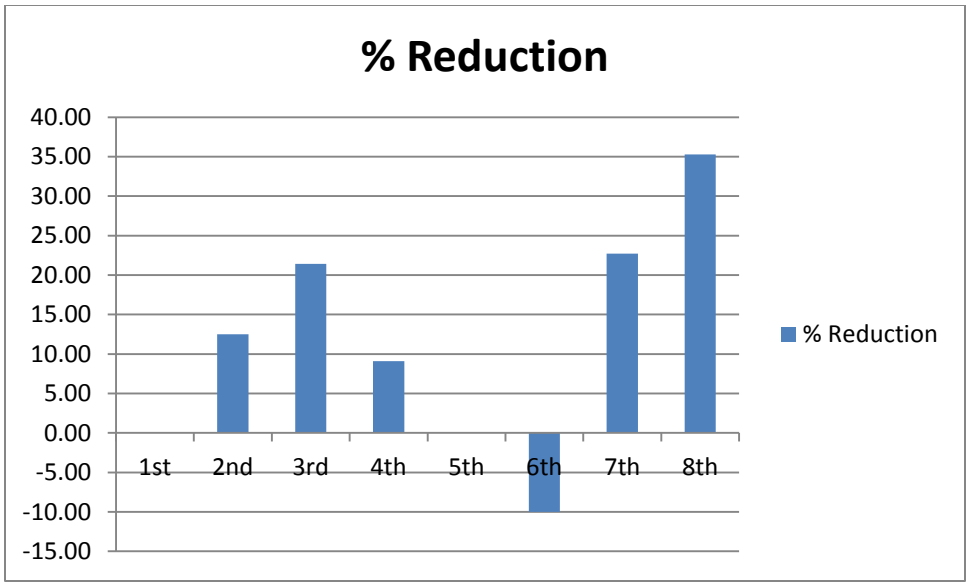


Figure shows the % Reduction vs Time Graph

From the analysis of data from Appendix K the following graphs can be computed: in the Graph the blue line represents the Heterotopic Plate Count. Initially amount of HPC is 926x10^4 cfu/100 ml and at the Final hour the HPC reduces to 469x10^4 cfu/100 ml

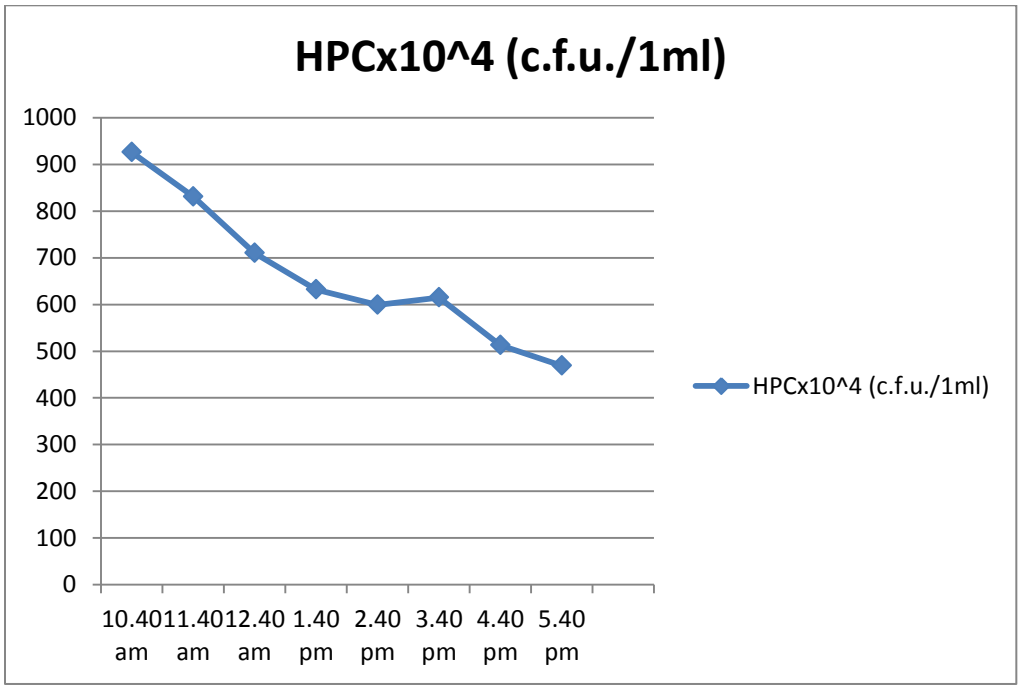


Figure 4.1 shows the TC vs Time Graph

Table:4.Hourly Exposure,Temperature,percentage reduction, Solar radiation , Amount of HPC

Time	Hour	Sample ID	HPCx10^4 (c.f.u./1ml)	% Reduction	Temperature	Solar Radiation (w/m^2)
10am	1st	P0	926		32	410.3
11am	2nd	P1	831	10.26	38	510.9
12am	3rd	P2	710	14.56	40	570.7
1pm	4th	P3	632	10.99	43	630.3
2pm	5th	P4	599	5.22	42	590.4
3pm	6th	P5	615	-2.67	39	510.3
4pm	7th	P6	513	16.59	36	497.2
5pm	8th	P7	469	8.58	34	481.2

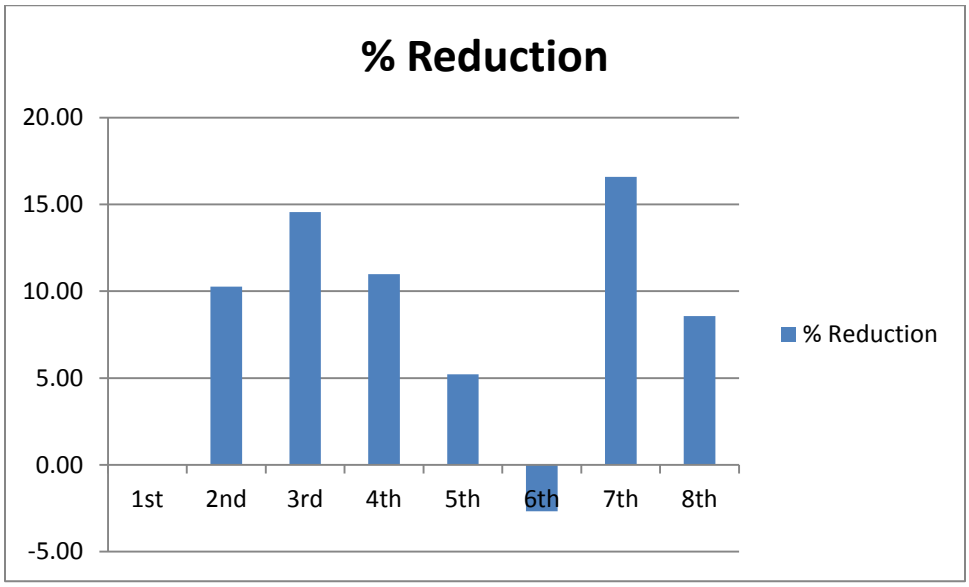


Figure shows the % Reduction vs Time Graph

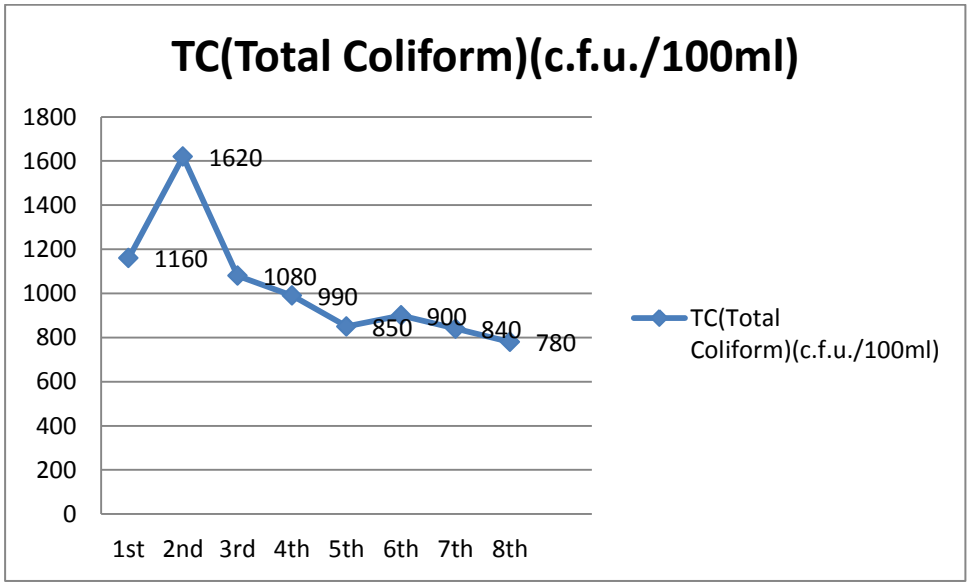
4.4 Irregularity in the Graph

In The Graph in some position we have seen some irregularities.

In the Graph amount of total coliform in 2nd hour suddenly Increases.

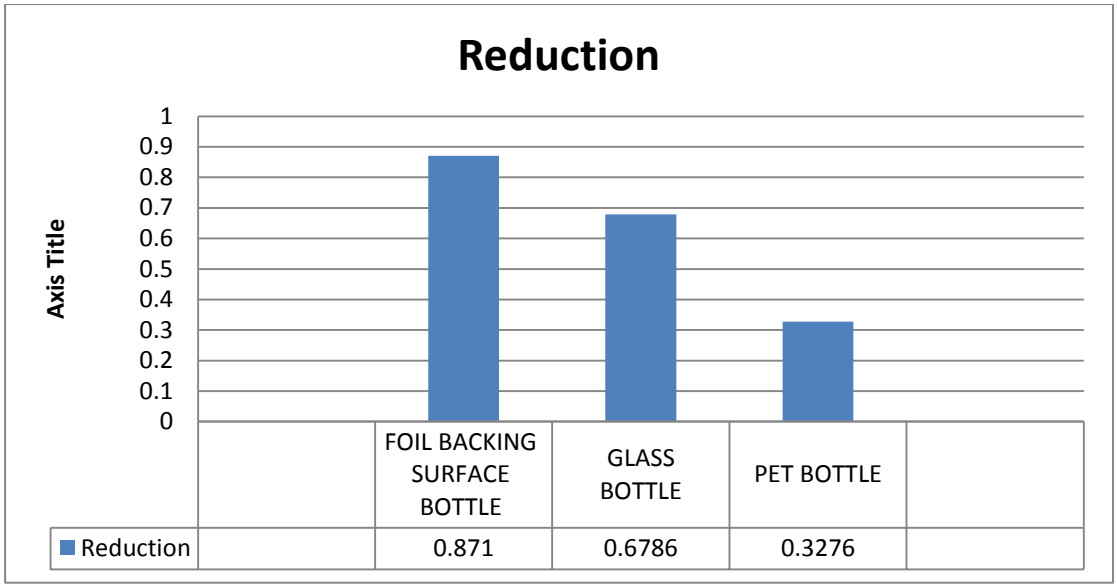
- There can be possible two reason of this phenomena

1. Contaminated 2nd hour bottle.
2. Regrowth of Total Coliform.



4.5 Comparing the Effectiveness of Bacteria Reduction among Glass, Pet and Foil backing surface bottle

Time	Hour	Sample ID	TC(Total Coliform)(c.f.u./ 100ml) From FOIL BACKING BOTTLE	TC(Total Coliform)(c.f.u./ 100ml) From GLASS BOTTLE	TC(Total Coliform)(c.f.u./ 100ml) From PET BOTTL E
10:00 AM	0hr	P0	1240	1160	1120
5.00PM	7th hr	P7	160	780	360
		%REDUCTION	87.10%	32.76%	67.86%
	Bottles	Reduction			
	FOIL BACKING SURFACE BOTTLE	87.10%			
	PET BOTTLE	67.86%			
	GLASS BOTTLE	32.76%			


Reduction
Axis Title
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FOIL BACKING SURFACE BOTTLE
GLASS BOTTLE
PET BOTTLE
Reduction
0.871
0.6786
0.3276

CHAPTER FIVE

CONCLUSION & RECOMMENDATIONS

5.1 CONCLUSION:

This thesis research was conducted to study the inactivation of various parameters by solar radiation and heating. To study the effects of solar radiation and heating on the inactivation of Total Coliform (T.C), Fecal Coliform (F.C), Escherichia Coli (E.Coli), and Heterotrophic Plate Count (HPC) experiments were conducted. The Effectiveness is compared by undertaking the SODIS experiment with some variations like by changing the backing surface. (Black surface, Aluminum surface etc.), By using different material (PET bottle, Glass bottle etc.). To quantify the inactivation effects of heating only, laboratory experiments were conducted. In analyzing the results from these experiments, the following conclusions were drawn:

1. We have seen significant reduction of bacteria so SODIS is applicable in our atmosphere. At least 6 hours of exposure in sunny day may reduce significant number of the bacteria.
2. PET bottle with Foil Backing surface may be the best among variations.
3. Reduction of foil backing surface is about 0.817, Reduction of glass bottle is about 0.6768 and reduction of PET bottle is about 0.3276.
4. In case of partially cloudy day comparatively little inactivation occurs.

5.2 RECOMMENDATIONS:

Due to limited resources and time, the following section details recommendations for Future research.

1. Undertaking the SODIS experiment with some variations of solar radiation and temperature in different seasons (summer, Rainy, winter season) and respective inactivation of several parameters could have been tested.
2. Various angular positions (Standing, Lying, Angle 45 degree etc.) of bottles while exposing into the sunlight and comparing the effectiveness in terms of inactivation of several bacteria.
3. Though SODIS cannot change the Chemical water quality and the turbidity of the water, the Turbidity may play vital role in case of bacterial inactivation, So Turbidity could have been measured in each sample water.
4. SODIS is not useful to treat large volumes of water. So variation could have been tested by sampling different amount of water like 0.5 liter, 1 liter, 1.5 liter etc.
5. In case of Laboratory testing we could test the inactivation of vibrio Cholera, Salmonella and Shigella bacteria, these parameters are also very important.
6. The change in bacterial growth could have been observed in terms of pH.
7. It is likely that the organisms had adhered to the interior of the test bottles and were not inactivated during the alcohol washing and UV treatments. Studies should be conducted to determine whether ingestion of these organisms is harmful and whether inadequate disinfection of the bottles before use could possibly be a downfall of the procedure.

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APPENDIX: A

Values of hourly TC,FC,E.coli,HPC on 9.6.13

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
9.6.13	10am	1st	P0	1840	1120	0	605	47	430
IUT Pond water	11am	2nd	P1	1390	960	0	884	45	437
PET Bottle	12am	3rd	P2	1260	660	0	639	45	490
	1pm	4th	P3	990	740	0	349	32	470
	2pm	5th	P4	560	420	0	232	37	500
	3pm	6th	P5	770	10	0	222	43	450
	4pm	7th	P6	660	0	0	160	38	430
	5pm	8th	P7	360	0	0	94	34	370

APPENDIX:B

Values of hourly TC,FC,E.coli,HPC on 12.6.13 in PET Bottle

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
12.6.13	10.am	1st	P0	190	1070	0	787	35	260.9
Pond Water	11.am	2nd	P1	100	950	0	780	39	290.3
PET Bottle	12.am	3rd	P2	80	680	0	604	45	310.5
	1.pm	4th	P3	60	470	0	560	42	360.4
	2pm	5th	P4	90	430	0	620	45	409.3
	3.pm	6th	P5	30	320	0	540	42.5	430.5
	4.pm	7th	P6	30	370	0	513	39	410.3
	5.pm	8th	P7	0	90	0	510	36	390.7

APPENDIX:C

Values of hourly TC,FC,E.coli,HPC on 12.6.13 in Foil Backing surface Bottle

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
12.6.13	10am	1st	P0	430	620	0	730	35	260.9
Pond Water	11am	2nd	P1	280	140	0	725	39	290.3
Foil Backing Surface	12am	3rd	P2	270	130	0	680	45	310.5
	1pm	4th	P3	170	100	0	630	42	360.4
	2pm	5th	P4	100	80	0	620	45	409.3
	3pm	6th	P5	20	150	0	500	42.5	430.5
	4pm	7th	P6	40	60	0	446	39	410.3
	5pm	8th	P7	40	70	0	396	36	390.7

APPENDIX:D

Values of hourly TC,FC,E.coli,HPC on 17.6.13 in PET Bottle

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
17.6.13	10am	1st	P0	370	160	0	605	34	258.3
PSF Water	11am	2nd	P1	250	120	0	884	47	309.7
PET Bottle	12am	3rd	P2	220	150	0	639	45	405.2
	1pm	4th	P3	160	110	0	349	46	410.3
	2pm	5th	P4	70	90	0	232	32	370.3
	3pm	6th	P5	130	80	0	222	37	390.8
	4pm	7th	P6	0	0	0	160	43	410.7
	5pm	8th	P7	0	20	0	94	38	387.2

APPENDIX:E

Values of hourly TC,FC,E.coli,HPC on 17.6.13 in Glass Bottle

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
17.6.13	10am	1st	P0	360	160	0	529	34	258.3
PSF Water	11am	2nd	P1	260	140	0	499	47	309.7
Glass Bottle	12am	3rd	P2	180	160	0	307	45	405.2
	1pm	4th	P3	120	120	0	228	46	410.3
	2pm	5th	P4	140	70	0	404	32	370.3
	3pm	6th	P5	120	40	0	354	37	390.8
	4pm	7th	P6	80	0	0	221	43	410.7
	5pm	8th	P7	70	0	0	160	38	387.2

APPENDIX:F

Values of hourly TC,FC,E.coli,HPC on 24.6.13 in PET Bottle

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
24.6.13	10am	1st	P0	1120	840	0	605	43	325.3
IUT Pond+PSF Water	11am	2nd	P1	1390	960	0	550	45	370.7
PET Bottle	12am	3rd	P2	1260	660	0	532	46	430.9
	1pm	4th	P3	850	550	0	436	36	420.2
	2pm	5th	P4	660	420	0	335	32	360.1
	3pm	6th	P5	520	350	0	222	43	450.4
	4pm	7th	P6	260	260	0	189	38	385.9
	5pm	8th	P7	360	160	0	199	35	370.2

APPENDIX: G

Values of hourly TC,FC,E.coli,HPC on 24.6.13 in Foil Backing Surface Bottle

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
24.6.13	10am	1st	P0	1240	940	0	655	43	325.3
IUT Pond+PSF Water	11am	2nd	P1	1160	960	0	630	45	370.7
Foil Backing Surface	12am	3rd	P2	1120	750	0	512	46	430.9
	1pm	4th	P3	1090	550	0	480	36	420.2
	2pm	5th	P4	850	420	0	325	32	360.1
	3pm	6th	P5	520	490	0	215	43	450.4
	4pm	7th	P6	260	260	0	189	38	385.9
	5pm	8th	P7	160	80	0	141	35	370.2

APPENDIX:H

Values of hourly TC,FC,E.coli,HPC on 24.6.13 in Glass Bottle

Date and Variation	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli(c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
24.6.13	10am	1st	P0	1160	1040	0	755	43	325.3
IUT Pond+PSF Water	11am	2nd	P1	1620	102	0	690	45	370.7
Glass Bottle	12am	3rd	P2	1080	980	0	612	46	430.9
	1pm	4th	P3	990	780	0	512	36	420.2
	2pm	5th	P4	850	690	0	475	32	360.1
	3pm	6th	P5	900	650	0	315	43	450.4
	4pm	7th	P6	840	690	0	229	38	385.9
	5pm	8th	P7	780	580	0	189	35	370.2

APPENDIX: I

Values of hourly E.coli on 1.9.13

Date	Time	Hr	Sample ID	E.Coli (c.f.u./100ml)	Temperature	Solar Radiation (w/m^2)
1.9.13	10am	1st	P0	112000	32	265.3
	11am	2nd	P1	116000	35	283.2
	12am	3rd	P2	89000	34	283.3
	1pm	4th	P3	72000	36	298.5
	2pm	5th	P4	66000	38	310.5
	3pm	6th	P5	62000	38	327.5
	4pm	7th	P6	55000	33	312.5
	5pm	8th	P7	58000	30	275.5

APPENDIX: J

Values of hourly TC,FC,E.coli,HPC on 5.9.13

Date	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli (c.f.u./100ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
5.9.13	10am	1st	P0	2260000	1850000	560000	136	41	430
	11am	2nd	P1	2100000	1690000	580000	125	38	510
	12am	3rd	P2	1780000	1550000	520000	129	36	490
	1pm	4th	P3	1880000	1690000	440000	120	36	430
	2pm	5th	P4	1740000	1300000	320000	95	32	410
	3pm	6th	P5	1630000	1210000	340000	73	43	450
	4pm	7th	P6	1590000	1110000	270000	71	39	405
	5pm	8th	P7	1660000	1030000	90000	65	35	365

APPENDIX: K

Values of hourly TC,FC,E.coli,HPC on 9.9.13

Date	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli (c.f.u./100 ml)	HPCx10^4 (c.f.u./1ml)	Temp	Solar Radiation (w/m^2)
9.9.13	10.40 am	1st	P0	1670000	1109000	320000	926	32	410.3
	11.40 am	2nd	P1	1590000	988000	280000	831	38	510.9
	12.40 am	3rd	P2	1510000	937000	220000	710	40	570.7
	1.40 pm	4th	P3	1113000	870000	200000	632	43	630.3
	2.40 pm	5th	P4	1146000	885000	200000	599	42	590.4
	3.40 pm	6th	P5	852000	777000	220000	615	39	510.3
	4.40 pm	7th	P6	846000	698000	170000	513	36	497.2
	5.40 pm	8th	P7	798000	678000	110000	469	34	481.2

APPENDIX: L

Values of hourly TC,FC,E.coli,HPC on 5.10.13

Date	Time	Hr	Sample ID	TC(c.f.u./100ml)	FC(c.f.u./100ml)	E.Coli (c.f.u./100 ml)	HPCx10^4 (c.f.u./1 ml)	Temp	Solar Radiation (w/m^2)
5.10.13	10.40 am	1st	P0	2200000	1206000	988000	71	30	276.9
	11.40 am	2nd	P1	2304000	1092000	920000	60	32	278.3
	12.40 am	3rd	P2	1580000	938000	658000	57	38	297.5
	1.40 pm	4th	P3	1113000	771000	560000	51	37	381.2
	2.40 pm	5th	P4	1008000	779000	490000	44	30	360.2
	3.40 pm	6th	P5	852000	697000	498000	48	29	315.8
	4.40 pm	7th	P6	811000	600000	311000	32	27	294.5
	5.40 pm	8th	P7	768000	538000	112000	38	25	270.5