ALTERNATIVE BIOREMEDIATION OF WASTEWATER FROM GAS STATIONS

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Thesis
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ALTERNATIVE BIOREMEDIATION OF WASTEWATER FROM GAS STATIONS

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ABSTRACT

The objective of this work was to remediate hydrocarbons, especially oil, by using microbial bioremediation technology, and applying this technology to wastewater from gas stations in order to make wastewater quality from gas stations comply with the new regulation. Five gas stations from different companies were selected using the same criteria. The wastewater from different activities was analysed for the pH, BOD, COD, SS and FOG. The results were then compared to see how the wastewater quality was improved.

Results showed that bioremediation technology was helpful for gas stations in Thailand because the wastewater was remediated at waste sources. The resulting BOD, COD, SS and FOG of the wastewater discharge at the exit within 30 days were approximately decreased to 54.0%, 61.0%, 40.0% and 55.0% respectively. However, these results showed that the new regulation could be complied within a period of approximately 5 weeks. Moreover, this technology can reduce some operational costs and also investment costs of wastewater systems. Therefore, it can be concluded that bioremediation using microbes is capable of being used as a part of wastewater management in gas stations.

KEY WORDS: BIOREMEDIATION / WASTEWATER / GAS STATIONS

136 pp.

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ทางเลือกในการประยุกต์ใช้เทคโนโลยีชีวภาพในการบำบัดน้ำเสียจากสถานีบริการน้ำมัน

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์ เพื่อบำบัดน้ำเสียภายในสถานีบริการน้ำมันที่มีสารประกอบพวกไฮโดรคาร์บอนปะปนอยู่โดยเฉพาะน้ำมัน โดยการประยุกต์ใช้เทคโนโลยีชีวภาพ ทั้งนี้เพื่อให้สอดคล้องกับกฎข้อบังคับของสถานีบริการน้ำมัน โดยการคัดเลือกสถานีบริการน้ำมันทั้งหมด 5 แห่งจากบริษัทฯ ต่างๆ ภายใต้เงื่อนไขที่กำหนดไว้ ตัวอย่างน้ำเสียจากกิจกรรมได้มีการนำไปวิเคราะห์หาค่า pH, BOD, COD, SS และ FOG จากนั้นนำผลการวิเคราะห์ที่ได้มาเปรียบเทียบเพื่อดูประสิทธิภาพของเทคโนโลยีชีวภาพในการบำบัดคุณภาพของน้ำเสีย

ผลการศึกษาแสดงให้เห็นว่าการใช้เทคโนโลยีชีวภาพสามารถบำบัดน้ำเสียจากกิจกรรมต่างๆ ของสถานีบริการน้ำมันได้ เนื่องจากผลการวิเคราะห์ BOD, COD, SS, และ FOG มีค่าลดลงอย่างมีนัยสำคัญ ร้อยละ 54.0, 61.0, 40.0 และ 55.0 ตามลำดับภายใน 30 วัน อย่างไรก็ตามผลทั้งหมดแสดงให้เห็นว่าสามารถลดลงให้อยู่ภายใต้ค่ามาตรฐานที่รัฐบาลกำหนดได้ในระยะเวลาประมาณ 5 สัปดาห์ ดังนั้นเทคโนโลยีนี้สามารถช่วยลดค่าใช้จ่ายในการบำบัดน้ำเสียของสถานีบริการ รวมถึงการไม่ต้องลงทุนสำหรับอุปกรณ์บำบัดน้ำเสียใดๆ สรุปได้ว่าการใช้กระบวนการเทคโนโลยีชีวภาพโดยการใช้จุลินทรีย์สามารถใช้เป็นส่วนหนึ่งในการจัดการน้ำเสียของสถานีบริการน้ำมันได้

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LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
FOG	Fat, Oil and Greases
PTIT	Petroleum Institute of Thailand
QAS	Quality Assurance System
SS	Suspended Solid
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WW	Wastewater
WWQ	Wastewater Quality

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CHAPTER 1
INTRODUCTION

1.1 Background and Justification

In a 1985 U.S National Research Council report it was estimated that between 1.7 and 8.8 million metric tones of oil enter the world's oceans each year. Eighty percent or more of oil contamination of the marine environment results from human activities, and more than half of this is related to its transportation. Dealing with oil spills often presents a balance between protecting natural resources and public amenities. Their unpredictability makes the remedial process a very difficult one. The most important factors influencing oil spill damage are proximity to land, type of shoreline, proximity to valuable natural resources (such as, fisheries, hatcheries, wildlife refuges), type of oil, wind/sea conditions and climate. Physicochemical factors, in particular, play an extensive role in determining the time course of processes acting on spilled oil. The relative importance of these processes will depend on the initial chemical composition of the spilled oil. Heavier hydrocarbon compounds, such as in crude oil, are essentially insoluble in water, whereas the smaller molecules, particularly aromatics such as benzene and toluene, are partially soluble. Lighter compounds are more volatile, and evaporation plays a significant role in oil dispersion rather than dissolution. Typically, evaporation is 10 to 100 times more rapid than water "solubilisation." Photo-oxidation, by sunlight, of oil components, especially aromatics, will result in the formation of more polar compounds such as phenols and "sulphoxides", although this is a slow process. A more important consequence of photooxidation of aromatic compounds is the formation of surface active resins that stabilise water-in-oil emulsions resulting in the formation of persistent solid products such as tar-balls.

It is very difficult to predict the rate of dispersion of oil because it is influenced by many factors. Consequently, the overall ecological impact of an oil spill may have to do with physical conditions and proximity to important natural resources rather than with the volume of spill (Writght and Welbourn, 2002).

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Minor oil spills and oil contamination from non-point source discharges, such as, urban runoff or oil spills from gas stations are no less threats to public health and the environment, although they have received much less attention in the past. According to recent *National Water Quality Inventory* reports, non-point source pollution remains the Nation's largest source of water quality problems. It is the main reason that approximately 40 % of surveyed rivers, lakes, and estuaries are not clean enough to meet basic uses such as fishing of swimming. Oil pollution is recognized as one of the most frequent type of water pollution. Oil spills and careless disposal of oil wastes into drainage systems can ultimately reach surface water levels, ground water and land areas. Consequently, this will have severe impact on the environment. Contamination of water sources by oil, chemicals, suspend solids and other similar wastes may also have negative impacts on birds, aquatic organisms, such as fishes and ultimately on humans. The number one source of river or ocean water pollution today is each one of us working and living in urban areas and contributing small amounts of contaminants that add up to one huge problem for the environment (Department of Public Works, 2002).

Gas stations or Petrol stations are one of facilities, which are a daily aspect in many people's lives. The operation of gas stations, vehicles service centers activities, has a large potential of creating pollution. The major activity of potential pollution includes refilling of storage tanks, fueling of vehicles, de-waxing and cleaning of vehicles, disposal of polluting liquids. Examples of mentioned pollutants are oil wastes, paints solvents, other coolant additives, brake fluids and solid wastes, such as, oil filters, exhaust systems, batteries and tires. Accordingly, poor management of transportation, storage, using and disposal petroleum products cause several hazards to human health as well as the environment. Petroleum, a mixture of organic compounds, has different properties. Generally, it is a volatile liquid that emits vapor at low temperatures. The vapor is heavier than air and has a tendency to sink and accumulate in tanks, pits and other hollows under calm air conditions. When the vapor is present in air at certain proportions (between 1-8% petroleum in air, commonly referred to as LEL), an explosive atmosphere is created. Petroleum also floats on water surfaces and may be transported over long distances via drainage canals and other watercourses (Michael et al, 2001). It is the free-floating form of oil and grease. It contains a wide variety of

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hydrocarbon compounds that have an affinity for sediments and much of the hydrocarbon load absorbs to particles and settles out. The primary petroleum products being used or distributed at filling stations comprise unleaded gasoline, Octane 95, Octane 91, Diesel and Gasohol.

Gas station can be a source of several contaminants (Department of Public Works, 2002). Oil spilled onto paved areas are easily washed away by water, either from houses or rainfall. One gallon of oil can contaminate one million gallons of water. Engine and brake residues contain antifreeze, grease, oil, copper, and even asbestos. Engine degreasers contain copper and brass. Lead, oil and grease are residues of radiator flushing. Oil, grease and detergents drain from car washing. Engine washing releases aluminum and iron. Brakes are a source of asbestos and cadmium washes from tires. Over last 10 years, in addition, gas station has adopted new business such as food court, coffee shop and convenient store in which food waste has been generated.

At present, rapid economic development and population expansion has generated growth in a number of sectors, especially communities, industries, tourism, transportation, commercial and services business. For this reason, Thailand needs more a sharp increasing demand in energy consumption and most of all, petroleum hydrocarbons particularly oil. The demand for this highly valuable energy source is rising steadily. This has led to a host of problems, one of which is always of major concern – oil spill, slop oil and oil contaminated environment from the human activity. However, oil spills are rarely caused by major organization, such as, petroleum refinery companies or petroleum industries. Because there are high standard to minimize oil pollution in order to protect the well-being of the general public which posses the people to deal with such accidents. But small organizations (sometime unknown sources) can also be involved in several processes, for instance, the discharge of oily wastewater from garages, gas stations, oil storage, leakage from the underground storage tanks and so on. Moreover, there are new business, such as, food shop, coffee shop and convenient store, also generated high polluted organic matters to drainage system. All of these consequently cause various damages to the environment.

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In the past, Thai Government did not have firm regulation to control all wastes from gas stations. Owing to lack of law gas stations may be subject to own discretion and subsequent discharge of petroleum oil and wastes can easily be “out of management.” (Pollution Control Department, 2003). The small amount of petroleum oil and wastes from each one of gas station may add up, impacting the entire environmental pollution.

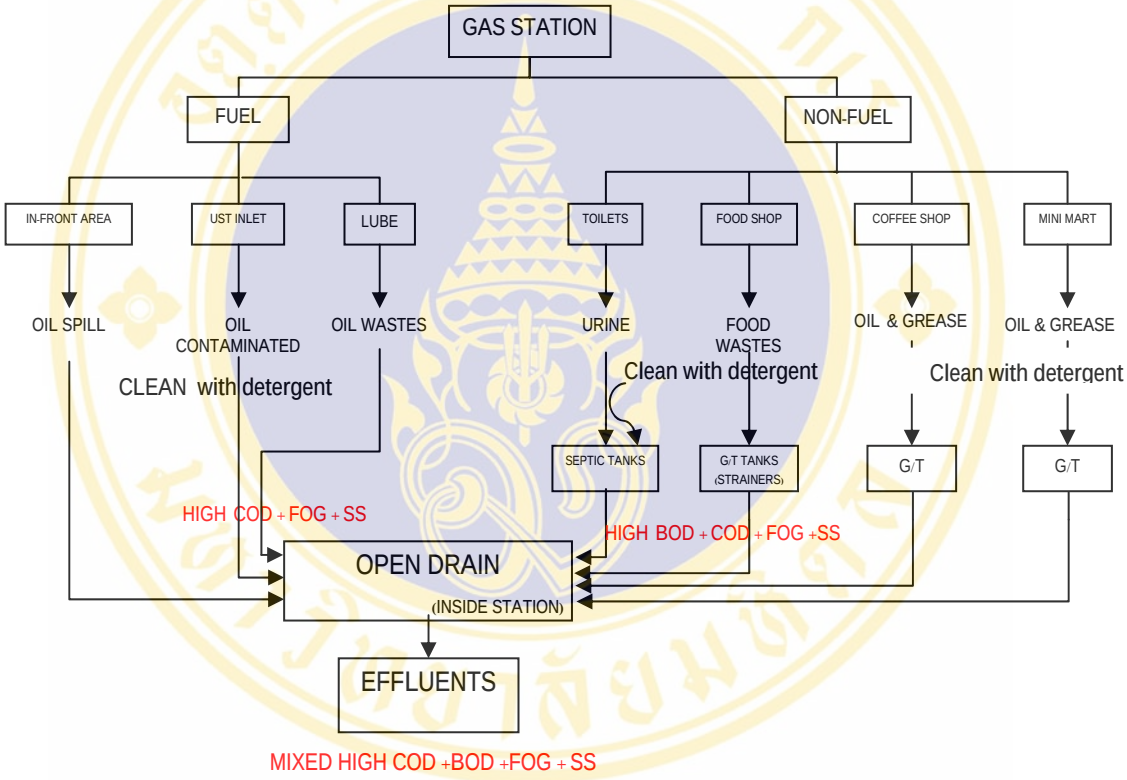

Figure 1-1: Gas Station Activities Pathway

Simply, wastewater in gas stations can be identified into two main sources. One is wastewater from fuel activities and the other is wastewater from non-fuel activities, as shown in Table 1-1.

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Table 1-1: Fuel and Non-Fuel Activities in Gas Station

Activities in Gas Station	Waste Source
Fuel	In-front area
	Lube (Oil changing shop)
	UST inlet
Non-fuel	Food shop
	Coffee shop or kiosk
	Convenient store (minimart)
	Toilets

Various problems are commonly found in gas station. Petroleum hydrocarbons on surface are often difficult to remove because they will adsorb to surfaces and can be retained by capillary action as an immiscible, separate phase. Nevertheless, Thai Government did not have substantial regulations to control all wastes from gas stations. Currently, most of gas stations involve in more activities, such as, convenient store or food shops. In the meantime, petroleum and grease oil are difficult or impossible to remediate with conventional detergents. The nature of oil waste is effects badly to FOG, SS, BOD, and pH. Also organic wastes from food shop and toilet can lead to pipeline clog problem.

With respect to the aboved problems, the research on 'Wastewater Discharge Management System and Wastewater Treatment in Gas Stations' has been carried out by Petroleum Institute of Thailand (PTIT, 2004). The study covered all styles of gas stations. The results of physical wastewater analysis demonstrated that most gas stations were not able to control pollutants in wastewater. In order to solve this problem, the installation wastewater treatment plant are recommended with acquiring approximately 475,000 Baht for a new plant and improvement. The research, moreover, mentioned to the other effective oil remediation methods such as Spinifex. Likely, this method needed about 500,000 baht as similar as the former one (PTIT, 2004). However, it seem to be impossible to have gas station install physically wastewater treatment equipment as many limitation are involved such as availability of space and investment. Therefore, biotechnology is probably be possible as an alternative treatment for wastewater in gas station. Due to cost of wastewater treatment using biotechnology is quite low in comparison with the others (Bioremediation Report, 1993).

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Bioremediation of Organic Contaminants

Environmental biotechnology for pollution control uses a biological process to remove pollutants from contaminated water, wastewater, or other media. A biological process is an engineered system that accumulates desired microorganisms to a sufficiently large mass that the pollutant concentration is lowered to meet treatment standards during the time that the microorganisms are in contact with the material being treated (Csuros, 1999). Bioremediation has become a general term describing a process of degrading harmful or hazardous contamination into less harmful or benign components. In the industrial fields, the process harnesses microbial activities and products to aid in the cleanup of sites contaminated with organic pollutants (Cornell University Science News, 1993). It is an emerging treatment technology that can restore contaminated sites quicker, at a lower cost, and at lower human risk than alternative remediation technologies (Soil, Water and Environmental Science dept., University of Arizona, 1993).

Bioremediation has been a commercially available technology since the 1970s. It has gained increasing acceptance and publicity since the U.S.Environmental Protection Agency (EPA) and Exxon Company, USA, demonstrated its effectiveness on Alaskan beaches contaminated by the Valdez oil spill. Much of the early literature on bioremediation derived from the petroleum industry practice of landfarming oily wastes.

The first-year Valdez project was limited to biostimulation by an Alaskan state directive that no “nonindigenous bacteria” could be used in the cleanup. Subsequently, testing was performed to determine if commercial bioaugmentation products could improve on the biostimulation results. Neither commercial augmentation products nor enrichment cultures derived from the local environment effectively increased oil biodegradation in beach media (Mueller et al., 1992 and Venosa et al., 1992a, 1992b). In this case, indigenous hydrocarbon-degrading species were present in relatively high concentrations, and fertilization alone stimulated populations five- to ten fold (ADEC et al, 1990). Thus, starting in the 1970s, a large amount of research has been devoted to the determination of biodegradability of petroleum and manufactured compounds. While the bulk of the research focused on isolation and characterization of bacterial

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strains, several investigators addressed the ability of isolates to degrade compounds in situ.

Many attempts have been made to seek for availability of biotreatment especially for petroleum hydrocarbon and also other group of hydrocarbon (Neralla et al.,1995; Venosa et al.,1995; Burlage et al.1955; Maxwell and Baqai, 1995; Schmauder et al.,1995). Emerging of biotechnology currently moves from laboratory to the field especially technology that can be applied to site contaminated with petroleum hydrocarbon which are now commercially available and have been applied to thousands of sites.

Bioremediation with commercial microbial additives also has a long history; the first large-scale cleanup involving bioaugmentation was of beaches in the United Kingdom contaminated by the Torrey Canyon spill in the 1970s. The strains of microorganisms used in commercial products are usually isolated from contaminated soil or water and selected for their ability to grow with minimal nutritional requirements and rapid degradation kinetics for the target contaminants. Additional desirable characteristics may be used for selection, such as:

- The ability to grow at low or high temperatures
- The ability to withstand high concentrations of contaminant
- Heavy metal tolerance
- The ability to survive in a wide range of conditions and/or media
- The ability to produce surfactants to make contaminants more accessible.

All of these processes are considered “natural” selection processes. No strains produced by genetic engineering have as yet been used commercially, although a strain has been described and patented for environmental bioremediation (Chakrabarty et al, 1981). Commercial products are blended to provide an inoculum that will degrade a spectrum of contaminants usually produced by specific industries, to complex contaminants, such as, petroleum fuels, organic compounds.

In conclusion, bioremediation is a proven alternative treatment tool that can be used to treat certain oil-contaminated environments. It is a relatively slow process, requiring weeks to months to effect cleanup. If done properly, it can be very cost-effectively, although an in-depth economic analysis has not been conducted to date (Atlas, 1981).

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It has the advantage that the toxic hydrocarbon compounds are destroyed rather than simply moved to another environment.

As above mentioned, it is reasonable to investigate the effectiveness of wastewater treatment using biotechnology to see if they can improve wastewater quality from gas station.

1.2 Objectives

The purposes of this research are as follows:

1) To study the problems, waste sources and conventional treatment that commonly found in gas station.

2) To determine the effectiveness of biotechnology using microbe for treatment of wastewater from gas stations.

3) The potential profitability of wastewater treatment from gas stations by using new alternative biotechnology and other technology was compared for the better decision making.

1.3 Scope of the Study

The scope of this research is as follows:

1) Gas stations of COCO (Company Own, Company Operated) were selected because they were fully controlled by their own officers.

2) The selected activities of both fuel and non-fuel in gas station were toilets, convenience store, food shop, coffee kiosk, vehicle dispenser area, UST inlet and lube shop (if available, but not necessary).

3) Conditional characteristics of qualified gas station were as follows:

- Level of drainage system outside gas station must be lower than effluent tanks (entrance, exit side).
- No leakage along the open drainage system within gas stations.
- Wastewater should be continually flow to effluent tank or drainage system outside gas station.

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4) The selected microbes used in this research were commercially produced for fat, grease & oil and organic waste treatment.

5) The five parameters of pH, BOD, COD, SS, and Grease& Oil were selected for wastewater quality analysis.

1.4 Hypotheses

To find out the answer for the research questions and objectives, two hypotheses were formed as follows:

1) A new alternative biotechnology treatment can improve wastewater quality from gas station better than the conventional treatment

2) Wastewater quality from gas station can comply with new regulation of wastewater standard by using alternative bioremediation treatment

1.5 Expected Results

The outcome of this research can show the positive feedback to gas stations, improving effluent discharge from gas stations and comply with governmental regulation on effluent standard. Also the people understand the benefits of the technology and enhance the public's ability in achieving a healthier environment.

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1.6 Conceptual Framework

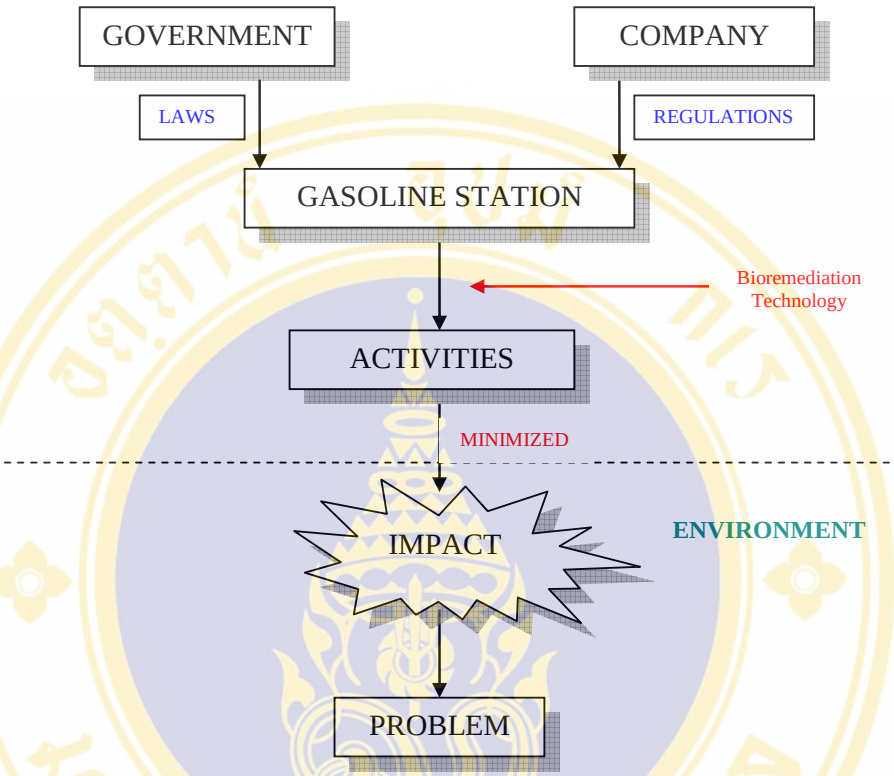

Figure 1-2: Conceptual Framework

1.7 Definitions of Terms

Service gas Station: - means service gas station type I and type II according to Notification of Public Work Department, Ministry of Interior.

Effluent :- means treated wastewater meeting service gas station effluent standards established in the Notification.

Wastewate :- means liquid waste including pollutants contained in it.

Public Waters :- means water bodies for general public use and including public wastewater collection pipes.

Wastewater Treatment :- means the process of treating wastewater to meet effluent standards established in the Notification. However do not dilution.

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Service Gas Station Effluent Standards :- are 2 notifications as follow:

1. Notification of the Ministry of Science, Technology and Environment on effluent standards from service gas station.

2. Notification of the Ministry of Science, Technology and Environment on service gas station to be designated as pollution sources, which require effluent control.

Petroleum hydrocarbon: - defined as naturally occurring oily, flammable liquid composed principally of hydrocarbons and constitute 50-98 % of petroleum, and the remainder is composed chiefly of organic compounds containing oxygen, nitrogen, or sulfur and trace amounts of organo-metallic compounds. *(McGraw-Hill Concise Encyclopedia of Science & Technology)*

The hydrocarbon types found in petroleum are;

Aliphatic hydrocarbons: carbon atoms are joined in open chains structure and consisting of the paraffin, olefin, acetylene hydrocarbons and their derivatives.

Aliphatic hydrocarbons can be classified as Alkanes (C_nH_{2n+2}), Alkenes (C_nH_{2n}), Alkynes (C_nH_{2n-2})

Alicyclic hydrocarbons: combining the properties of aliphatic and cyclic compounds.

Aromatic hydrocarbons: of, relating to, or characterized by the presence of at least one benzene ring structure C_6H_6

Aromatics are chemically defined here as the class of compound that contain a closed benzenoid ring of six carbon atoms, but the term aromatic is also applied to ring compounds that contain heteroatoms and have a fully conjugated double bond system. Aromatic compounds may also have more than one ring in their structure and additionally, have aliphatic chains or rings attached to one or more of the basic aromatic rings. This latter category is of great importance when the aromatic content of diesel fuel is considered. The majority of the hydrocarbons in diesel fuel have between 10 and 20 carbon atoms and if this were single-ring compounds then the aliphatic portion could contain from 4 to 14 carbon atoms. This means that any molecule considered aromatic could include a non-aromatic part either equal to or greater than the actual aromatic portion. The level of aromatics that is measured is,

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therefore, dependent on what is defined as aromatic and the technique used to obtain the information. There are two widely used terms relation to aromatics in petroleum fractions and these are aromatically and aromatic content.

Bioremediation: - refers to a process that uses naturally occurring or genetically engineered microorganisms such as yeast, fungi, and bacteria to transform harmful substances into less toxic or nontoxic substances. Microorganisms break down a variety of organic compounds in nature to obtain nutrients, carbon, and energy for growth and survival (Csuros, 1999).

Biochemical Oxygen Demand (BOD):-means the indirect measure of the amount of decomposable matter (significant organic matter) present and the direct measure of the respiratory oxygen requirements of the living organisms that are responsible for decomposition. The standard time for the test is 5 days, and the temperature 20 C (68 F) in the United States (Imhoff and Fair, 1956).

Chemical Oxygen Demand (COD):- means the measure of the amount of carbon in many types of organic matter. The test for oxygen consumed from potassium dichromate in acid solution. The amount of chemical oxidizing agent used is expressed as equivalent oxygen (Imhoff and Fair, 1956)

Grease: - means Fats, waxes, free fatty acids, mineral oils, and other sewage matters are soluble in solvents such as ether. The matter extracted is called *grease*

pH value or Acidity, alkalinity:- means the pH value identifies the activity of the hydrogen ions. It is intensity rather than a capacity factor. The reaction of sewage or wastewater, as measured by its pH, is important because living organisms (including organisms of decomposition) are sensitive to the reaction of their environment, because chemical precipitation generally responds to changes in reaction, and the nature of different disinfecting chlorine compounds released in wastewater is affected by its pH value (Imhoff and Fair, 1956).

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CHAPTER 2
LITERATURE REVIEW

2.1 Waste treatment

At present, due to high energy, raw material as well as service costs, many industries have been experiencing intense pressure on how to minimize cost in order to run business smoothly. One area of interest to industry is waste management cost. To manage waste management cost effectively, auditing waste in each factory is an important tool to minimize unnecessary as well as avoidable costs. Due to increasing awareness on ISO 14000 certification and benefits, auditing waste generation has been practiced as one tool to implement ISO 14000 certification. Many of industries usually talks about how much money has been spent to improve their system in order to achieve ISO 14000 certificates. Many industries failed to achieve financial benefits after achieving certification due to ambiguity in monitoring and implementation process.

The waste treatment cost depends on waste characteristics, limiting standards and treatment technologies adopted. It has been found worldwide that this cost component amounts to 2-5 % of industry's capital investment and 15-30% of the industry's operation and maintenance cost (Industrial Waste Auditing Seminar, 2006). This research focus on how to do waste treatment in gasoline station with simple and practical ideas in order to manage their waste generation in effective manner. It is up to each one of gas stations to take the simple steps necessary to eliminate their small contribution of contaminants to protect the environment.

Conventional oil spill countermeasures include various physical, chemical, and biological methods. Commonly used physical methods include booming and skimming, manual removal (wiping), mechanical removal, water flushing, sediment relocation, and tilling. Physical containment and recovery of bulk or free oil is the primary response option of choice in the United States of the cleanup of oil spills in

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marine and freshwater shoreline environments. Chemical methods, particularly dispersants, have been routinely used in many countries as a response option.

However, chemical methods have not been extensively used in the United States due to the disagreement about their effectiveness the concerns of their toxicity and long-term environmental effects (U.S. EPA, 1999). With the recent development of less toxic chemical dispersants, the potential for their applications may increase.

Although conventional methods, such as physical removal, often are the first response option, they rarely achieve complete cleanup of oil spills. According to the Office of Technology Assessment, current mechanical methods typically recover no more than 10-15 percent of the oil after a major spill, although significantly higher recoveries have been achieved, depending on the environment. Bioremediation is beginning to emerge as a promising technology, particularly as a secondary treatment option for oil cleanup. Bioremediation has been defined as “the act of adding materials to contaminated environments to cause an acceleration of the natural biodegradation processes” (Gale, 1992). This technology is based on the premise that a large percentage of oil components are readily biodegradable in nature (Martin, 1994). Bioremediation has several potential advantages over conventional technologies, such as being less costly, less intrusive to the contaminated site, and more environmentally benign in terms of its end products.

The success of oil spill bioremediation depends on one’s ability to establish and maintain conditions that favor enhanced oil biodegradation rates in the contaminated environment. Numerous scientific review articles have covered various factors that influence the rate of oil biodegradation (Zobell, 1946; Alef and Paolo, 1995; Atlas and Bartha, 1992; Pearce et al., 1994; Focht and Westlake, 1987; Leahy and Colwell, 1990). One important requirement is the presence of microorganisms with the appropriate metabolic capabilities. If these microorganisms are present, then optimal rates of growth and hydrocarbon biodegradation can be sustained by ensuring that adequate concentrations of nutrients and oxygen are present and that the pH is between 6 and 9. The physical and chemical characteristics of the oil and oil surface area are also important determinants of bioremediation success. There are two main approaches to oil spill bioremediation: **Bioaugmentation**, in which known oil-degrading bacteria

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are added to supplement the existing microbial population, and **Biostimulation**, in which the growth of indigenous oil degraders is stimulated by the addition of nutrients or other growth-limiting co-substrates.

2.2 The current number of gas stations

At present there are approximately 19,082 stations in Thailand. They are classified in regional as shown in Table 2-1 (Department of Energy Business, 2005). All gas stations can be classified by the companies such as PTT, SHELL, ESSO, CALTEX, BANGCHAK, THAI OIL, SUSCO, COSMO, Petronas, PT, TPI, JET, PC and independents as shown in Table 2-2.

Table 2-1: The number of gas stations in Thailand at 1st quarter 2005

REGIONAL	NUMBER OF GAS STATIONS
BKK	923
OUTSKIRT	568
CENTRAL	1,268
UPPER NORTH	1,629
LOWER SOUTH	2,702
UPPER NORTH EASTERN	2,932
LOWER NORTH EASTERN	3,222
EASTERN	1,581
WESTERN	2,027
UPPER SOUTH	1,337
LOWER SOUTH	893
TOTAL	**19,082**

Source: Department of Energy Business, 2005. Data from Registered list on 31 March 2005

Table 2-2: The number of gasoline stations classified in companies

Company name	Number of stations
PTT	1354
SHELL	619
ESSO	606
CALTEX	435
BANGCHAK	1148
THAI OIL	3
SUSCO	147
COSMO	91
Petronas	116
PT	220
TPI	73
JET	143
PC	26
INDEPENDENT	14081
TOTAL	19082

Source: Department of Energy Business, 2005

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In addition, the companies are also sub-classified into 2 types; the first ones are called COCO (dependents) and another one is called CODO and DODO (independents).
The COCO as Company own, Company operated which is managed by own companies. (DEPENDENTS)

The CODO as Company own, Dealer operated which are operated by the Dealer but the land is belong to Company. (SEMI-INDEPENDENTS)

The DODO as Dealer own, Dealer operate which are operated by dealer and the land also belong to the dealer. (FULLY INDEPENDENT)

Among these types of gas station, their practices are quite different. The dependent gas stations have internationally implemented environmental practices, but the independent gas stations do not have implemented by firm and being audited from the company inspector. Unfortunately, the number of independents gas stations is higher than those of firm dependency.

2.3 Contaminants from Gas station

It has been reported that gas stations can be the sources of several contaminants (Department of Public works, 2002):

1) Oil and gas spilled onto paved areas are easily washed away by water, either by hosing or precipitation. One gallon of oil can contaminate one million gallon of water.

2) Engine and brake residues contain antifreeze, grease and oil, copper and even asbestos.

3) Engine degreasers contain copper and brass. in addition to alcohol products and caustic soda derivates

4) Lead, oil and grease are residues of radiator flushing compounds.

5) Oil, grease and detergents drain from car washing.

6) Engine washing releases aluminum and iron.

7) Brakes are a source of asbestos and cadmium washes from tires.

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2.4 Gas station Activities

The Department of Pollution Control had reported normal activities in a gas station can be listed as follows: (Pollution Control Department. 2003)

1) Vehicle Dispensing: All vehicles come to fill fuel/oil etc. There are some spillages of oil and emit volatile organic vapors (VOCs)

2) Vehicle Washing: This point discharges a lot of wastewater containing detergents, sediments, oil and road salts etc.

3) Automotive repairing service: There is a lot of contaminants such as paint molecules, wastes with heavy metals, oil wastes, antifreeze and solvents etc.

4) Wheel repairing: There are much solid waste in this point; a piece of wheel or metal joint and some part of wheel rubber.

5) Underground storage tanks (UST): The leaking of the tanks can contaminate ground water. The incident come from spill, oil overfill and tank corrosion**.**

6) Toilet or resting room: Most of people make a lot of wastewater and this point use a large number of water and detergents to clean floor**.**

7) Food shop and convenience store: There are many kinds of wastes such as grease and oil from food, detergent, and any domestic wastes**.**

2.5 Problem Identification

There have been many activities (this includes people- so the table show how they are involved) from various types of operations that related to the pollution are shown in Table 2-3, (The Petroleum Institute of Thailand, 2004)

Unmanaged transport, storage, use and disposal of the pollutants may result in several hazards to human health, as well as the environment. The engine oil, or oil waste, is one of the petroleum products. It is a mixture of organic compounds, its properties may vary, but generally, it is a volatile liquid that emits vapor at low temperatures. The vapor is heavier than air and has a tendency to sink and accumulate in tanks, pits and other hollows under calm air conditions. When the vapor is present in air at certain

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proportions (between 1-8 % petroleum in air), an explosive atmosphere (LEL) is created. Petroleum also floats on water surfaces and can be transported over long distances via canals and other watercourses (Oil Care Campaign, 2004).

Table 2-3: Identification of problems

Actor	Activities	Affect	Actual/possible problem	Possible solution
1.Worker	- Changing engine oil	Oil is in drainage	Oil pollute water	Oil separator Absorbant, Good practices management
2.Station-boy	- Dispensing engine oil	- Oil spill - VOC emitting	-Polluted floor - VOC conc. of vapor	Drainage facilities, Absorbant VRU Stage 2
3. Worker	Change vehicle wheel	Solid wastes	Polluted water	Filter screen
4. Cooker	Cooking Food	Grease and oil, detergent	Polluted water	Grease Trap, Good practices management, Bacteria water treatment
5. People	Use toilet	Sanitary waste	Bad smell, increase BOD	Waste water treatment, Good practices management
6. Engineer	Fill oil in underground tank	- Oil leak from tank corrosion Vapor during product load	Contaminated ground water Air pollutants	Leakage and corrosive detector Double wall tank and double wall piping, Cathodic protection VRU Stage 1
7. Worker	Vehicle washing	Detergent in floor drain	Emulsify oils captured in separator	Filtration and grit remover
8. Worker	General activities	Careless disposal of oil wastes	Unclean place and polluted drain water	Waste disposal operation, Good housekeeping

2.6 Characteristic of Petroleum Products

Petroleum products intended for use as a fuel in engines or for use in engineered processes. Use in other applications may result in higher exposures and require additional controls, such as local exhaust ventilation and personal protective equipment (Gasoline safety datasheet, 1999).

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Reformulated gasoline is a complex mixture of hydrocarbons from a variety of chemical processes blended to meet standardized product specifications. Composition varies greatly and includes C1 to C70 hydrocarbons with a boiling range of about 80-473 degrees F. The characteristic of gasoline are presented in Table 2-4 and in MSDS (Source: Quality Control Division, Oil business, 2005) as follows:

The Material Data Sheet of Gasoline: PTT ALPHA-X (Octane 95)

1.) Product data

1.1) Trade name: PTT Alpha-X, Octane 95

1.2) Usage: use as fuel in gasoline engine which octane requirement is 95 minimum

1.3) Manufacturer/Importer: PTT Public Company Limited

2.) Chemical Classification

2.1) U.N Number: UN1203

2.2) Carcinogenicity: carcinogen

3.) Hazardous Ingredients

- Benzene less than 3.5 %
- Aromatic less than 35 %

4.) Physical and Chemical Data

4.1) Boiling Point: maximum 200 celcius

4.2) Vapor Pressure: maximum 62kPa

4.3) Solubility in water: negligible

4.4) Specific Gravity: 0.70-0.77 kg/l

4.5) Appearance Color and Odor: yellow

5.) Fire and Explosion Hazard Data

5.1) Flash Point: minimum -43 celcius

5.2) Flammable limits: LEL = 1.4 and UEL = 7.6

5.3) Autoignition Temperature: 275 celcius

5.4) Chemical Reactivity: Stable under ordinary conditions of use and storage but should be away from high heat, open flames and other sources of ignition.

5.5) Material to avoid: strong oxidizing agents, chlorate, nitrates, and peroxides.

5.6) Hazardous Decomposition Products: fumes, CO, CO_2, and other decomposition products.

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6.) Health Hazard Data

6.1) Way of Exposure

- Inhalation: yes
- Skin: yes
- Ingestion: yes

6.2) Local effect (skin, eye, mucous membranes): irritation

6.3) Overexposure Short-term effect:

Inhalation of vapors may cause central nervous system depresion, convulsion, loss of consciousness. Ingestion has symtoms similar to inhalation & aspiration hazard. Eye/Skin contact causes irritation.

6.4) Overexposure Long-term effect:

Dermatitis, Nervous system, Kidney, Liver & Blood disorder. Including anemia, kidney cancer.

Table 2-4: The Composition of Gasoline

Component or Material Name	%	CAS Number	ACGIH Limits TLV -- STEL -- Units	OSHA Exposure Limits PEL -- STEL -- C/P -- Units
Gasoline	90-100	Mixture	300--500--ppm	NA--NA--NA -- ----
Butane	<9	106-97-8	800--NA--ppm	NA--NA--NA -- ----
Pentane	<6	109-66-0	600--750--ppm	1000--NA--NA--ppm
n-Hexane	<4	110-54-3	50--NA--ppm	500--NA--NA--ppm
Hexan(other isomers)	<8	NA	500--1,000--ppm	NA--NA--NA-- ----
Benzene	1.2 - 4.9	7-4-2	0.5--2.5--ppm	1--5--NA--ppm
N-heptane	<2	14-82-5	400--500--ppm	500--NA--NA--ppm
Ethylbenzene	<2	100-41-4	100--125--ppm	100--NA--NA--ppm
Xylene (o,m,p, - isomers)	<11	1330-20-7	100--150--ppm	100--NA--NA--ppm
	<2	110-82-7	300--NA--ppm	300--NA--NA--ppm
Trimethylbenzene	<4	25551-13-7	25--NA--ppm	NA-NA-NA- ----
Methyl-t-butyl ether (MTBE)	0-15	1634-04-4	40--NA--ppm	NA-NA-NA- ----
Toluene	<12	108-88-3	50-NA-ppm	200-300/500-NA-ppm
Ethyl-t-butyl ether (ETBE)	0-7	637-92-3	N/A-NA-ppm	NA-NA-NA- ----
t-amyl-methyl-ether	0-5	994-05-8	N/A-NA-ppm	NA-NA-NA- ----
Ethanol	0-11	64-17-5	1,000-NA-ppm	1,000-NA-NA-ppm

Source: Material datasheet of Gasoline, 1999, California
Remark: C=Ceiling concentration not to be exceeded at any tume. P= Peak concentration for a single10

2.7 Pollution impacts

2.7.1 Impacts on the Environment

It is depending on the concentration and properties, petroleum can be toxic to both plants and animals. Once it has been released to the environment, it is difficult to predict how it will move. Petrol vapors can lead to the formation of ozone in the lower

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atmosphere. Atmospherics ozone has many negative impacts – it affects the health of humans and animals, and hinders the growth of plants. It also contributes to the formation of photochemical smog, which is harmful to the respiratory systems. Petrol in watercourses is also harmful to the environment, particularly to the plants and animals the water may come in contact with. Of even more significance is the release of petroleum products into our ground water. A large percentage of the water the people drink comes from the aquifers (ground water veins) and contamination may therefore affect severely. Degradation of petroleum products in groundwater is significantly slower than for surface water and it is imperative to reduce any likelihood of this contamination occurring.

2.7.2 Impacts on Health

Petroleum can affect the human body via a number of ways, primarily through excessive contact with the skin inhalation and ingestion. Repeated or prolonged contact with the skin caused dryness and cracking, due to the degreasing properties of petroleum. Skin may become irritated and less resistant to other chemicals. In extreme cases, excessive exposure may result in chemical burns. Exposure of the eyes to petroleum may result in them becoming irritated, or in more serious cases, conjunctivitis. Inhalation of petroleum vapor can cause irritation of the respiratory system, depending on the amounts inhaled. Generally, concentrations between 500 and 1000 ppm can cause respiratory irritation and over prolonged periods of time, headaches, nausea, dizziness and mental confusion. It may cause stomach irritation and diarrhea for ingestion. Ingestion of large quantities may be harmful, and in extreme cases, fatal to small children (Wright and Welbourn, 2002).

2.8 Hazards Identification

2.8.1 Health Hazard:

The major effect of exposure to this product is central nervous system depression and polyneuropathy. Following the laboratory are reported from gasoline safety datasheet shown that repeated exposure of laboratory animals to high concentrations of whole gasoline vapors at 67,262 and 2056 ppm has caused kidney damage and cancer of the kidney in rats and liver cancer in mice.

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IARC has listed gasoline as possibly carcinogenic (2B) to humans with limited evidence in humans in the absence of sufficient evidence in experimental animals. NIOSH lists gasoline as a carcinogen with no further classification. N-heptane and cyclohexane cause narcosis and irritation of eyes and mucous membranes. Cyclohexane has been reported to cause liver and kidney changes in rabbits. N-heptane has been reported to cause polyneuritis following prolonged exposure (Material datasheet of Gasoline, 1999).

2.8.2 Hazards of Combustion Products:

Carbon monoxide and carbon dioxide can be found in the combustion products of this product and other forms of hydrocarbon combustion. Carbon monoxide in moderate concentrations can cause symptoms of headache, nausea, vomiting, increased cardiac output, and confusion. Exposure to higher concentrations of carbon monoxide can cause loss of consciousness, heart damage, brain damage, and/or death. Exposure to high concentrations of carbon dioxide can cause simple asphyxiation by displacing available oxygen. Combustion of this and other similar materials should only be carried out in well-ventilated areas (Material datasheet of Gasoline, 1999).

2.8.3 The environmental toxicology of oil

The toxic effects of oil can be divided in two categories: Heavy viscous components may have a blanketing effect on variety of static filter-feeding organisms causing starvation and oxygen deprivation. The latter effect may be exacerbated by the process of microbial degradation of oil, which may expand and prolong the incidence of anoxia conditions in the benthic environment. Birds coated with oil lose the insulating and water-repellant qualities of their feathers and become water-logged and hypothermic. Preening behavior may also result in the ingestion of toxic levels of hydrocarbons.

Systemic toxicity of oil to marine life is generally associated with lighter fractions and is increased where refined products are involved. Of the known components of crude and refined oil, only relatively few are highly toxic to marine organisms. Most of the toxic effects of petroleum can be attributed to the low-molecular-weight alkanes (methane to decane), monocyclic (BTEX-benzene, tolouene, ethyl benzene, and

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xylene) aromatics, two and three ring PAHs, and related heterocyclic compounds (Neff and Anderson, 1981). The highly volatile BTEX fraction also contributes a narcotic effect, which would lead to lethal stranding of crustaceans and finfish.

Acute toxicity is related, in part, to water solubility, which correlates logarithmically with molecular size within each hydrocarbon group (Figure 2). Although this relation ship breaks down in normal alkanes larger than 12 carbon atoms, the principal petroleum hydrocarbons sort neatly into three groups. Toxicity studies on complex oil mixtures remain problematic (Wright and Welbourn, 2002).

2.9 Biotechnology and Oil spill

Biotechnology can be defined as the controlled and deliberate manipulation of biological systems (whether living cells or cell components) for the efficient manufacture or processing of useful products. The fact that living organisms have evolved such an enormous spectrum of biological capabilities means that by choosing appropriate organisms it is possible to obtain a wide variety of substances, many of which are useful to man as food, fuel and medicines. Over the past 30 years, biologists have increasingly applied the methods of physics, chemistry and mathematics in order to gain precise knowledge, at the molecular level, of how living cells make these substances. By combining this newly-gained knowledge with the methods of engineering and science, what has emerged is the concept of biotechnology which embraces all of the above-mentioned disciplines (Chapella, 1993).

Bioremediation has become a general term describing a process of degrading harmful or hazardous contamination into less harmful or benign components. Bioremediation is an emerging treatment technology that can restore contaminated sites quicker, at a lower cost, and at lower human risk than alternative remediation technologies.

In addition to the lower costs of bioremediation, there is no long-term or “cradle to grave” liabilities for the contamination like there is with land filled pollutants because the contaminants have been digested and turned into harmless by-products of CO_2, water and traces of inorganic salts. Contaminated sites that can benefit from bioremediation exist in a variety of environments including surface soils and water as well as shallow or deep subsurface environments (Castaldi, F.J, 1992).

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There are two main avenues of bioremediation operation:

In situ can be used where excavation is impractical - under highways, buildings, runways, etc. This process can simultaneously treat soil and groundwater in one step, without the generation of hazardous waste products.

Using an engineered treatment setup where contamination is placed for bioremediation is called ***ex situ*** process (bio slurry, bioreactor, land farming, etc.)There exists in all the world's soils and waters resident microbes that take care of digesting the usual waste streams found in its surrounding ecosystem. These are called *indigenous microbes*.

Testing has been done to see if using these existing microbial populations, a process called *natural attenuation*, would remediate the contamination that entered the area. More often than not, very little remediation has occurred.

Bio stimulation, using aeration and adding fertilizers to supply nutrients to the indigenous microbes, also has drawbacks. It relies on the assumption that the existing microbes will be in large enough numbers to effectively degrade the contaminant and that they can readily adapt to the foreign contamination to start any degradation. This method usually results in a lengthy timeline for a project to come to closure. Adding microbes that already have an aggressive affinity towards common hydrocarbon and organic contamination is described as ***bio augmentation*** (Cornell University Science News, 1993).

Applying a sufficient amount of adapted microbes to the pollution site takes care of the contamination in a timely and efficient manner. There are variables to the amount of microbes to use - volume of contaminant, type and volatility of contaminants, pH of the soil or water, temperature, etc.

As a result, the biotechnology waste management or bioremediation treatment becomes a new alternative remediation technology for gas stations. The bioremediation technology can be applied for all service gas stations. Pollution may be largely avoided, or significantly minimized, in all their activities as well as reducing their waste treatment cost.

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2.10 Cost analysis microbial concentrate used as Manual Procedure cleaner:

The commercial microbes are usually in contracted liquid, it has to be diluted before use to required concentration which will be depending on contaminant loading.

$\int_{o}^{10} x(dx)$ 10 m^2 - Average application thickness on rough surface 10-40 μ

Text	Integral	Integral 0-10	Average thickness	Volume ml	Cost	Cost per IU
MB Concentrate	Simpson	10	40	1000	1700	42.5
MB Concentrate	Simpson	10	20	1000	1700	85
MB Concentrate	Simpson	10	10	1000	1700	170

Source: SLSM, 2006

Cost with an application thickness 10>x>40 μ appears to be 42.5>x>170 Baht.

This volume of MB concentrate can be recycled multiple times with diminutive efficiency. One liter 1% concentrate applied will efficiently remediate HC oils of 20 m^2. The roughness of the surface may be a dependent factor of consumption.

2.11 Regular use of Microbial Concentrate:

The microbial products will require presence of the three elements namely food, water and oxygen. If one element is missing, the remediation process may halt. Lack of food may turn the microbes into cannibalism, thus, reducing the biomass until there is balance between supply and demand. In case of lack of water or lack of oxygen will cause high mortality and hibernation.

The hibernation stage consists of microbes in spore state. Activation will occur when adding water, taking into account that dissolved oxygen in the water may be less than 4 mg per 1000 ml, which is not sufficient to maintain a high microbial growth rate. The biomass will be dependent on oxygen supply through the air.

Cleaning the service area – petrol/diesel pump site and supply manifold as well as the parking area regularly, will accumulate large numbers of microbes enjoying, or being confined to the spore state.

This spores will activate when water is added, and the effect can be observed without magnification tools, as large emission of CO_2 appearing as bubbles on top of and internally of the water column (slick).

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This defined advantage is a significant with regard to preventive action derived from using microbial technology, and does not appear on the surface when utilising secondary pollutants as detergent.

Continuously observing the microbes' ability to activate can be used to reduce the consumption of microbial concentrate at an applicable area. Score card effects may be derived by integral analysis of biomass per unit combined with operational and management parameters.

The acceptable benefits derived from operational costs as far as the correct utilisation of microbial technology is concerned should be in vicinity of 50-90 % of previous cost level, where conventional products and caustic soda were being applied for cleaning purposes.

Macro correlation/Score Card Effects
Correlation Area: 100 m^2
Correlation of procedure:
MB FOG and conventional detergent may be applied and used the same way, of which HP Jet cleaning method may be the most efficient cleaning method in both instances at industrial sites.

Text	MB FOG	MB ELSC	Grease Rem.	Phosphate	Standard
Type of dillutant to be used	**Water**	**Water**	**None**	**Water**	
pH	7	7	3.5	12	
Area (m^2) covered one litre	20	20	25	3	
Dillution ratio with water	1%	1%	NA	10%	
Consumption 100 m^2 litres	5.00	5.00	4.00	3.33	
Price per litre for product ready for use	16	16	55	35	
Cost for cleaning 100 m^2	80	80	220	116.67	
COD	+	+	-	-	<200
BOD	+	+	-	-	
SS	+	+	-	-	<60
pH	+	+	-	-	5.5-9.0
Agumentation	+	+	NA	NA	+
Effluent impact	+	+	-	-	NA
Impact on environment	+	+	-	-	NA
Delta cost analysis Microbial vs. Solvents Phosph.	80	0	140	36.67	NA

Note:

- Adding microbes that already have an aggressive affinity towards common hydrocarbon and organic contamination is described as *bioaugmentation*. Applying a sufficient amount of adapted microbes to the pollution site takes care of the contamination in a timely and efficient manner. There are variables to the amount of microbes to use - volume of contaminant, type and volatility of contaminants, pH of the soil or water, temperature, etc.

Source: SLSM, 2006

As shown in Table 2.5, in comparision between the conventional and microbial technology in removing oil and grease, it is the fact that the conventional detergents are less efficient than microbial products, duing to conventional detergents work on

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the principle of diluting and bleaching the impurities on the surface. The washing water soon become saturated with SS and HC oil accumulations, causing the cleaning effect to diminish rapidly. But microbial products – containing microbial biomass - will dramatically renew it selves, through the ability of multiplication (reproduction) in the interval. The reproduction rate is dependent on the three elements – food, water and oxygen.

Table 2-5: Contaminants from gas stations vs. Microbial Technology

Text	Conventional technology	Microbial technology
Diesel oil and gasoline, as well as lub-oil etc. spilled onto paved areas are easily washed away by water, either by hosing or precipitation. One gallon of oil can contaminate one million gallon of water.	Currently using secondary pollutants as degreaser, causing long lasting lateral effects from the primary and secondary pollutants	Easily applied with great success in situ. Remediates successfully most common oil spills with no negative lateral effects
Engine and brake residues contain antifreeze, grease and oil, copper and even asbestos.	Difficult cleaning process with toxic pollutants.	Easily applied with great success in situ.
Engine degreasers contain copper and brass. in addition to alcohol products and caustic soda derivates	Difficult cleaning process with toxic pollutants.	Easily applied with great success in situ.
Lead, oil and grease are residues of radiator flushing compounds.	Difficult cleaning process with toxic pollutants.	85-99% successful cleaning with Microbial Technology
Oil, grease and detergents drain from car washing.	Dilution of oil spill may improve the image. Excessive use of detergent may require treatment with phosphoric or sulphuric acid to reduce pH	95-99% successful cleaning with Microbial Technology
Engine washing releases aluminum and iron.	No effect	Electro chemical effect reduced by stabilising pH. Reduced and cleaned TSS also one lateral result.
Brakes are a source of asbestos and cadmium washes from tires	No effect	Electro chemical effect reduced by stabilising pH. Reduced and cleaned TSS also one lateral result.
All vehicles come to fill fuel/oil etc. There are some spillages of oil and emit volatile organic vapors (VOCs)	Sand as oil absorbent, still generated secondary pollutant.	In situ, and instant remediation of oil spill
This point discharges a lot of wastewater containing detergents, sediments, oil and road salts etc	No effect	60-85% successful remediation in situ

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Table 2-5: Contaminants from gas stations vs. Microbial Technology (cont.)

Text	Conventional technology	Microbial technology
There is a lot of contaminants such as paint molecules, wastes with heavy metals, oil wastes, antifreeze and solvents etc.	No effect	Cleaning in situ of TSS, as well as removing solvents and antifreeze
There are much solid waste in this point; a piece of wheel or metal joint and some part of wheel rubber.	No effect	10-15% remediation of asphalt/bitumen contaminants. Remaining waste considered to be TSS
The leaking of the tanks can contaminate ground water. The incident come from spill, oil overfill and tank corrosion	No effect. Incineration of soil only viable solution.	Remediation of contamination in situ
Most of the people indirectly contribute to a lot of wastewater at this point. A large amount of water and detergent to clean floor is imperative.	OK for cleaning, but will contribute to change of pH, higher COD and effluent waste values	An appropriate location to benefit from Microbial Technology for the WWS
There are many kinds of waste such as grease and oil from food, detergent, and any type of domestic wastes	No effect	85-97% efficient

Source: SLSM, 2006

It can be seen from Table 2-6 that treatment cost of bioremediation is lower than the others. In case of price level on microbial products is apparently higher than what we are used too. But we can benefit from a product that more expensive than others. Considerably, price, costs and expenses are terms in the economic concept, which must be stringently regarded as relative. By following the guidelines from the manufacturer and distribution network, the cleaning tasks will be easier and less expensive. In addition, recycling alone will reduce the cost about 75% each time of reuse, which is a pleasant figure to face up to.

Table 2-6: Waste Management Cost Correlation

Method of treatment	Year 1	Year 2	Year 3
Incineration	$ 530	none	none
Solidification	$ 315	none	none
Landfill	$ 670	none	none
The desorption	$ 200	none	none
Bioremediation	$ 125	$ 27	$ 20

Source: Bioremediation Report, King Publishing Group, Washington, D.C.,1993

Another considerable way is the application of microbe that normal rate setting is only 1% of microbial concentrate, and 99% water. However, the product may be diluted more than 1%, but at times we do not have applicable abundance of the three elements required for reproduction. Thus, we may buffer with some redundant concentrate to

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attain the predicted efficiency. Only experience will indicate how to maintain the required biomass for your conditions. With under favourable conditions it may appear as a net producer of microbial products for an unlimited interval.

2.12 Current approaches for solving the problem

2.12.1 Law Enforcement

Currently, gas stations will be controlled by the pollution Control Officer as specified in Section 69 of the Enhancement of National Environmental Quality Act.B.E. 2535(1992) and effective May 29, B.E. 2545 (2002) exception (Pollution Department Control, 2002). The involved issues to gas station are shown below:

- Old gas station located in municipal area, Bangkok Metropolitan Area (BMA) and Pattaya city will be controlled after 2 years of operation.

- Old gas station located out of municipal area, Bangkok Metropolitan Area (BMA) and Pattaya city will be controlled after 5 years of operation.

Table 2-7: Methods of Examination (for wastewater):

Parameter	Method
pH	pH Meter Electrometric Method
COD	Potassium Dichromate Digestion
Suspended Solids	Glass Fiber Filter Disc
Fat, Oil and Grease	Soxhlet Apparatus

Source: Environmental Engineering Association of Thailand and Standard Methods for the Examination of Water and Wastewater by APHA, AWWA and WEF

Table 2-8: Effluent Standards

Parameter	Unit	Range or Maximum Permitted Values for These Categories		Method
		Gas Station	Oil Terminal	
pH	-	5.5-9.0	5.5-9.0	pH Meter
COD	mg/l	200	200	Dicromate Method
Suspended Solids	mg/l	60	60	Glass Fiber Filter Disc
Oil and Grease	mg/l	15	5	Extract with solvent after solvent evaporation is weighed to determine the oil and grease content

Source: Notification of the Ministry of Science, Technology and Environment, 2002

Remark: *This Draft has been approved by Technical Committee and being considered by the Pollution Control Committee & the vironmental Board respectively.*
To be issued by notification by MOSTE as prescribed in section 55 of the Act.
Both categories will be monitored and controlled by the Pollution Control Officer, as prescribed in section 69 of the Act.
Standard Methods for the Examination of Water and Wastewater recommended by APHA : American Public Health Association, WWA : American Water Works Associaton and WPCF : Water Pollution Control Federation

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2.12.2 Company Enforcement

At the present the companies have sub-classification in two types; dependent and independent. The companies include PTT, SHELL, ESSO, CALTEX, BANGJAK, THAI OIL, SUSCO, COSMO, Petronas, PT, TPI, JET, PC etc. All companies already have the environmental practice for their gas stations. For dependent (called COCO) have to allow theirs own enforcement, but for independent, there are only some inspector from the company go to check them sometime (Exxon green practice, 2000).

2.13 Waste sources of gas station

Waste sources of gas station can be divided into 2 main activities namely fuel activities and non-fuel activities. Apart from infront area which comprise of fuel activities such as fuel dispenser for transferring to the vehicles, underground storage tank inlet (UST inlet) and lubricating oil transfer service on the entrance side. There still be also non-fuel activities which are mostly on the exit side such as toilets, food shop, coffee shop or kiosk and convenient store or minimart, as shown in Figure 2-1.

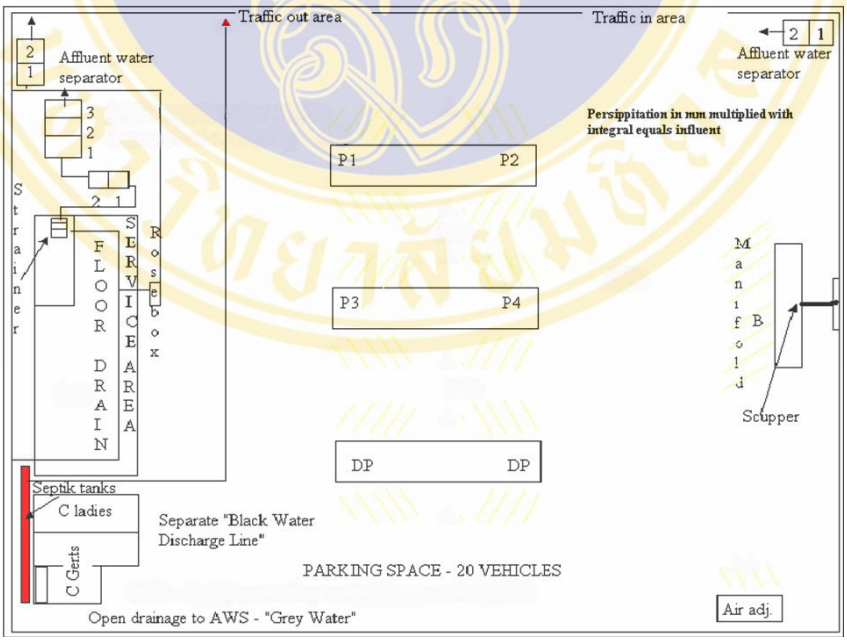

Figure 2-1: Layout of a standard gas station

(*Source: SLSM, 2006)*

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2.13.1 In-front area

Oil spills around service area and Fuel dispenser while transferring to the vehicles. Most of wastes will go to open drain then go to effluent at both entrance& exit side. The characteristics of waste are highly in COD from oil waste and also from using detergent to clean in-front area.

2.13.2 UST (Underground Storage Tank) inlet

Wastewater which contaminated oil from inlet or manifold inside UST tanks, directly discharged to open drain and go through effluent tank at entrance side. Wastewater characteristics are also highly in COD from oil waste.

2.13.3 Lube (Lubricating oil transfer service)

Oil waste and wastewater which mixed with detergent from cleaning discharged to open drain. Wastes will also go to open drain then go through effluent at the entrance or exit side. Wastewater characteristics are also highly in COD from oil waste and detergents.

2.13.4 Toilets

Urine and all excrements discharged to Septic tanks (Gent & Lady) and accumulated inside tanks. Some wastewater overflows from septic tanks to open drain.

All wastes will go to septic tank then pass through the drainage system to effluent tank before discharge to public drainage system. The problems usually occurred from toilet are odor, wastewater with high in COD and BOD from detergent and wastes (urine, excrements)

2.13.5 Food shop

Food waste or grease & oil from kitchen will be discharged to G/T strainer or tanks and accumulated on the water surface of strainer. Then go to effluent tank at the exit side before discharge to the environment. Highly BOD, COD and FOG (Fat and Grease) are problems of wastewater duing to detergent or cleaning agent. Pipeline clog is also the significance problem.

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2.13.6 Coffee shop or kiosk

Milk, oil or coffee powder from coffee making process are the main contaminated source will be discharged to G/T strainer and also accumulated on the water surface of strainer. Highly BOD, COD and FOG (Fat and Grease), therefore, are the significance problems of wastewater. Unfortunately, of coffee shops or kiosks located mostly in front of station and near effluent tank. The retention time of wastewater is not enough for treatment.

2.13.7 Convenient store or minimart

The same problems as food shop but only low grease are shown for this activities. This is duing to most of them are take home food. The wastewater are also the same problems of COD from detergent or cleaning agent; washing dish and cleaning floor.

2.14 Wastwater from Gas Station

It can be seen that most of the wastewater from fuel business are of oil waste, oil contaminated water, and oil spill around in-front area. And the wastewater from non–fuel business are wastewater contaminated oil, chemicals and organic waste.

Generally, grease is a byproduct of cooking and food preparation. It is found in such things are meat fats, Lard, Cooking oil, Butter and margarine, Food scraps, Baking goods, Sauces and Dairy products. Restaurant, Food shop and other related businesses must have grease traps to prevent the introduction of grease into sewers. However, without the proper plumbing, kitchen cleaning procedures, and grease trap maintenance, excessive amounts of grease can still enter the sewers and subject the user to discharge violations. When grease enters the sewer, it sticks to the insides of sewer pipes (both on own shop property and outside drainage. Overtime, the grease buildup can block the entire pipe and cause sewer backup into the business.

Most of the time, these problems mentioned above are usually solved by chemical agents either for cleaning or adjusting standard effluent of waste water. However, the conventional treatment mostly uses commercial additives, including detergents and enzymes, that claim to dissolve grease, can just move grease farther down the line, still resulting in plugged sewer lines. According to most chemical agents are detergents

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and have high pH, most of microbes in the system are not able to remediate organic wastes and high mortality.

Fat, Oils and greases accumulate in pipes, pumps and equipment, leading to the costly and hazardous flow of waste grease into drain lines, sewer lines. Improper disposal can result in high BOD and COD levels, increasing operation costs, and clogged collection systems (P^2AD's Fact Sheet for Best Management Practices for Fat, Oils and Grease).

Grease trap strainer or tank

A grease trap is designed to prevent grease, oil, solids, and other debris from entering the waste stream, where it becomes a problem by clogging sewers and disrupting the water flow in the system. The grease trap captures those wastes and contains them until removing or disposes them.

Grease traps capture the oil and grease from the flow of wastewater by slowing down the flow of hot greasy water through the grease trap (actually a tank) and allowing it to cool. As it cools, the grease and oil separate out of the water and float to the top of the trap. The cooler water continues to flow down the drain pipe to the sewer while baffles prevent the accumulated grease and oil from flowing out of the grease trap.

The size of the grease trap depends largely on how much waste produced and how often performs trap maintenance. Grease traps may be located inside or outside of the building. Traps that are located inside the building tend to be larger and may be less disruptive to maintain. Outside grease traps will operate differently in winter versus summer and are more prone to clogging during cold weather. Accordingly, it is important to know where the grease trap, drain lines and clean-outs are located at food shop (Colorado Dept. of Public Health and Environment, 2002).

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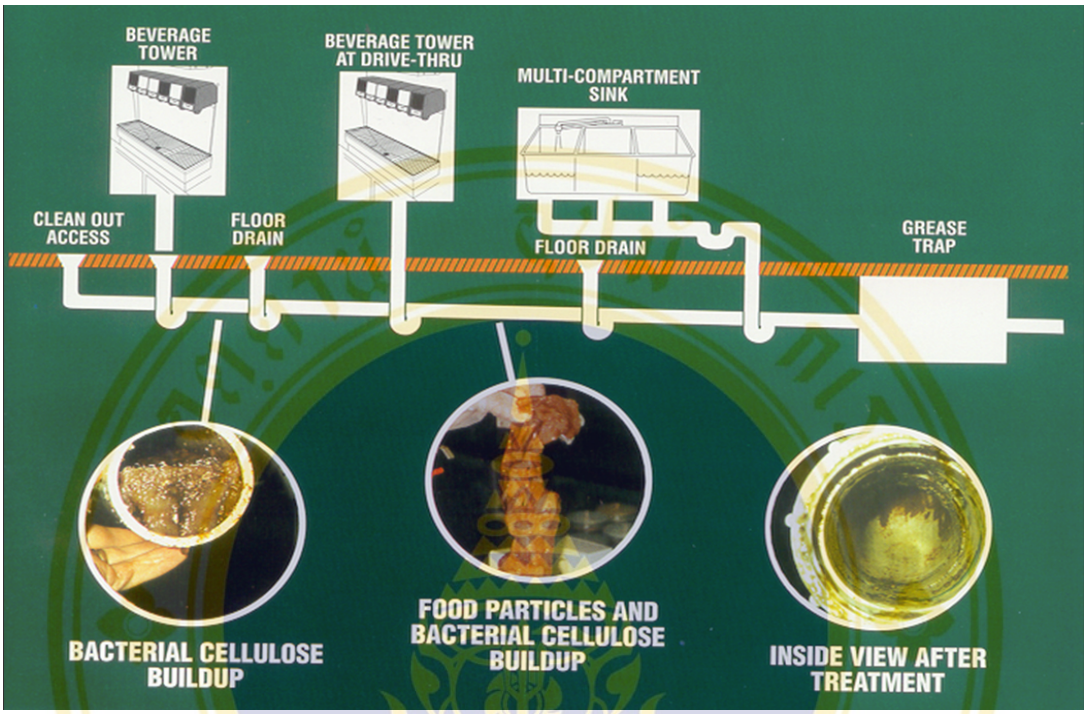

Figure 2-2: Clogged greases in pipeline system

Source: Handbook for Suggested Uses And Application, Verdes Environmental, Inc.

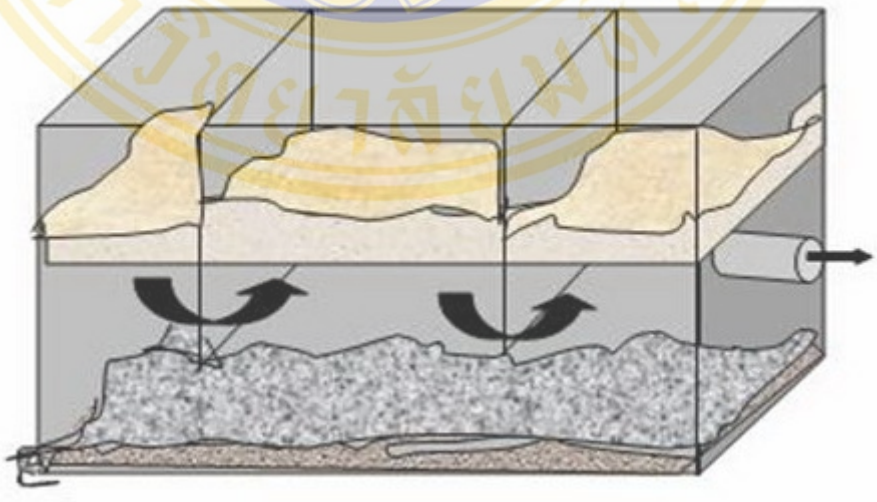

Figure 2-3: Basic Grease Trap Design

Source: Handbook for Suggested Uses And Application, Verdes Environmental, Inc.

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Chemical treatment drawback

The conventional procedures with using chemical agents make recurring problems on pipeline system. There are some problems as following:

- Chemical agent is diluted and removed from drain with water flow.
- Chemical agent effectiveness is gone once washed through drain line.
- As water dilutes and moves chemical agent to downstream, there is little beneficial activity.
- Cause corrosion of pipes.
- Highly toxic to humans and environment.
- No additional benefits to the plumbing system.
- Generally negative effects on the environment.

Wastewater from kitchen and general cleaning

Wastewater contaminated with food or fat, oil and grease are mixed with detergents or chemical cleaning agent still generated secondary pollutants in drainage system.

Detergents are currently in the market, there are three general types of synthetic detergents (syndets) comprising of anionic, cationic, and non-ionic. The anionic detergents have found ever increasing use in household as well as industry. When they are discharged into the wastewater or sewage system in sufficient concentration, some of their properties cause a reduction in the efficiency of wastewater treatment. Among these properties are:

- Lowering of the surface, or interfacial, tension of water and thereby increasing the wetting of substances with which the water comes into contact.
- Emulsification of grease and oil
- Dispersion or deflocculation of colloidal matter
- Floatation and foaming
- Destruction of bacteria and other living organism (more particularly, a property of cationic detergents)

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Although the BOD of the synthetic detergents is smaller than that of soap, the emulsification of grease and oil and the deflocculation of colloids produced by them may result in the escape of suspended matter from settling units. This would place an increase load on biological treatment units (Imhoff and Fair, 1956).

Wastewater from Septic tank

Septic systems are one of the oldest forms of bioremediation. The system relies on retention time, good microbial growth and proper drainage. Overuse of modern chemical cleaners and deodorizers kill off the necessary microbes needed to digest the waste, and chemicals may travel out to the field lines, contaminating the ground. Washline grease traps can also become malodorous and fouled (Handbook For Suggested Uses And Application, Verdes Environmental).

2.15 The Theory Biological Treatment

A bacterium or microbe uses enzymes to gather and retrieve food in the form of hydrocarbons. In the process of converting these hydrocarbons to food for the bacteria, enzymes break the hydrocarbons down aerobically (in the presence of free oxygen) into carbon dioxide (CO_2) and water (H_2O), or aerobically (in the presence of combined oxygen) though the Kreb's cycle in to CO_2, hydrogen sulfide (H_2S), methane (CH_4) and H_2O. If these by-products of decomposition are acceptable, aerobic or anaerobic treatment is an alternative means of converting organic pollutants into non-polluting chemicals. A bacterium or microbe, whether aerobic or anaerobic, requires a certain environment to grow. Upon growth, the bacterium reproduces by splitting at a logarithmic rate (Atlas et al., 1987).

During the initial growth phase, the bacteria split and logritherically increase until one or more of the environmental factors is depleted. If there is no depletion, the growth phase will continue. With a given amount of food, bacterial growth will eventually reach a stationary phase upon depletion of food, followed by a death phase and finally, endogenous respiration or cannibalism. During endogenous respiration declines, the remaining non-biodegradable residue (NBDR),commonly called "bug bones" by some theorists, remain as solid particles (Alley, 2000).

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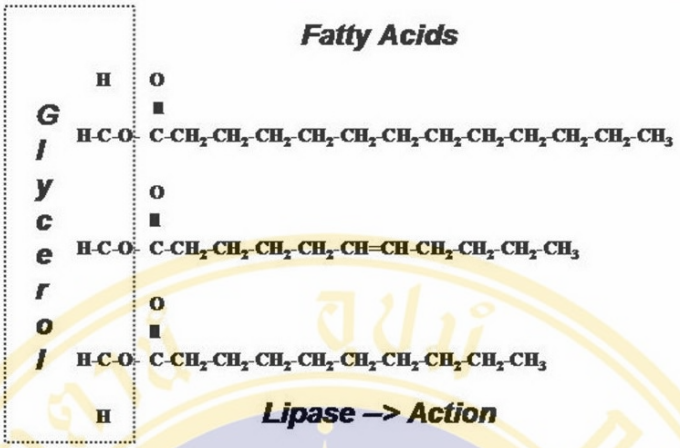

Figure 2-4: Figure Hydrocarbon molecule
Source: Martin, A, 1971

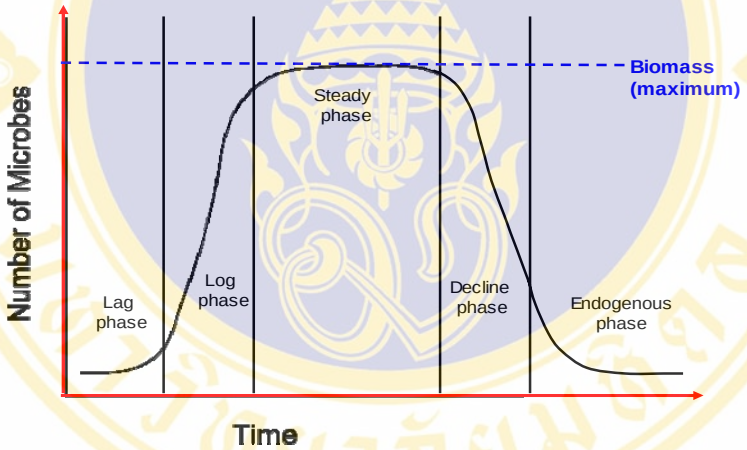

Figure 2-5: Bacterial Growth
source: Brock et al, 1991

Bacterial growth refers to an increase in bacterial cell number and it normally happens by binary fission (Csuros, 1999). The normal growth curve of bacteria has four phases, the lag phase, the log phase or exponential growth phase, the stationary phase, and the death or logarithmic decline phase (Frobisher et al., 1974).

The Lag Phase **-** The lag phase can last for an hour or several days and it is practically an adaptation period. There is no increase of cell number, but the organism is not in a dormant state during which the bacteria is preparing for division.

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The Log Phase - This phase begins when bacteria start to divide and inter a period of growth or the exponential growth phase. Cellular reproduction is most active during this period and shows a minimum constant generation time.

The Stationary Phase (Steady Phase)- This phase often occurs when the maximum population density that can be supported by the available resources is reached. There is no further net increase in bacterial cell numbers. During this phase, the growth rate is equal to the death rate and cell number, therefore, remains constant and the population stabilizes.

The Death Phase - This phase occurs when the number of living cells decreases because the rate of cell death exceeds the rate of new cell formation. This phase continues until the population is diminished to a tiny fraction of more resistant cells or the population dies out entirely. Some species pass through the entire series of phases in only a few days, others retain some surviving cells almost indefinitely.

Specialized (Selective) Effective Bacteria Process

Bacteria are the primary decomposers of all organics and provide the natural solution to organic waste disposal through their biological oxidation process of converting organic matter to simple compounds of CO_2 and H_2O (Sally, 1967).

Bacteria are living organisms with complicated requirements. They have difficulty living and functioning in the presence of a toxic environment or slow to degrade compounds such as disinfectants, detergents, grease, fats, oils or heavy tissue loadings. Today's waste is difficult for the bacteria to degrade to acceptable discharge limits within most system design parameters. Heavy loading of disinfectants and other cleaners can reduce or even eliminate the bacteria that is required to keep the waste treatment system operating effectively.

The technique of bacterial augmentation to waste system is by no means a new tool – its function is to re-establish the biological process and to insure system performance.

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However, these bio-strains offer no more resistance to bad housekeeping practices than the naturally occurring bacteria which has been depleted. While the addition of selected bacteria is helpful, they offer no lasting resolution to system difficulties (Doi, and McGloughlin, 1992).

The cultures of Micro-Blaze can generate the proper quantity and type of biomass required for effective waste reduction. They are designed to make good systems operate better and significantly improve conditions in poorly operating systems. Micro-Blaze is a synergistic blend of several strains of selectively adapted spore forming microbes. These strains of microbes will digest difficult detergents, fats, oils, greases and cellulose. It is designed to provide rapid recovery as well as system stability. They are non-toxic, non-pathogenic and easily degradable.

The synergistic blends of several microbial strains (such as, Bacillus) quickly digest the following commonly found contaminants: (Handbook For Suggested Uses And Application, Verdes Environmental).

- Spent **Hydrocarbons**; e.g. diesel fuel, gasoline, motor oils
- **Glycols**; such as antifreeze compounds
- **AFFF** wastes from fires, training exercises
- **Oils**
- **Fats**
- **Cellulose**; such as, refuse paper products
- **Greases** from residential, institutional and commercial outputs

The microbial strains are suspended in the Micro-Blaze formulations by a stabilizing agent until they are ready to be put to work. They lie dormant in a spore form and become activated within 15 – 20 minutes after being applied to an organic food source (i.e. hydrocarbons, other wastes) with water.

If a component, e.g. water or food source, is taken away, the microbes go dormant. Once it rains or water is applied, the microbes become active again, seeking out contaminants to digest into harmless carbon dioxide and water. Vegetative microbes will die off as their necessary components are taken away.

Although the formulations are close to a neutral pH, the bacteria work in a wide range of pH from 4.5 – 11.5, a greater range than most other bacteria. The microbes in

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Micro-Blaze actually digest the contaminants in the affected media, resulting in by-products of harmless carbon dioxide and water. The **organic wastes are eliminated, not rearranged to another site.** There are minimal or no “dig and haul’charges. “Cradle-to-grave” liability is minimized.

The Genus Bacillus

Bacteria belonging to the genus Bacillus are widely distributed in soils and are generally capable of respirative (aerobic) and fermentative metabolism. Bacillus is one of several groups of microorganisms capable of forming endospores. These are round, oval, ellipsoidal or cylindrical and highly refractive structures formed within vegetative cells, they are termed endospores (Gould and Hurst, 1969). Spores are an integral part of a developmental cycle in which a vegetative cell can form a spore that, in turn, can germinate into a vegetative cell. Bacillus subtilis is the type species of the genus Bacillus, and is considered a harmless saprophyte of the soil (Martin, A, 1977).

It is generally believed that endospore-forming bacteria such as Bacillus subtilis remain dormant for long periods of time, as spores, only germinate and outgrow to the vegetative form for short periods of time under suitable environmental conditions. However, when environmental conditions persist that promote germination and growth, the vegetative state, rather than the spore state, can become the dominant form. Examples of such habitats include acid hot springs; rumens of cattle; and aerobic sewage sludge treatment plants (Abraham, 1993).

It is particurly relevant to note that Bacillus ssp. are common members of the sewage sludge microbial community as mentioned above. Consequently, it is not likely that augmentation with Bacillus ssp. cells or dormant endospores (as in the case when using Micro-Blaze as additive microbial product) have any detrimental effect on the operation of activated sludge treatment facilities. It is more likely that the presence of Bacillus ssp. enhances the mineralization of organic wastes. Bacillus ssp. are versatile chemoheterotrophs capable of utilizing a considerable range of organic compounds as respiratory substrates, and in some cases also ferment carbohydrates (Strainer et al., 1986).

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CHAPTER 3
METHODOLOGY

This research was mainly conducted by quantitative method. Gas stations within Bangkok were selected under four specific conditions in order that the variation of results presents the least.

3.1 Experimental Framework

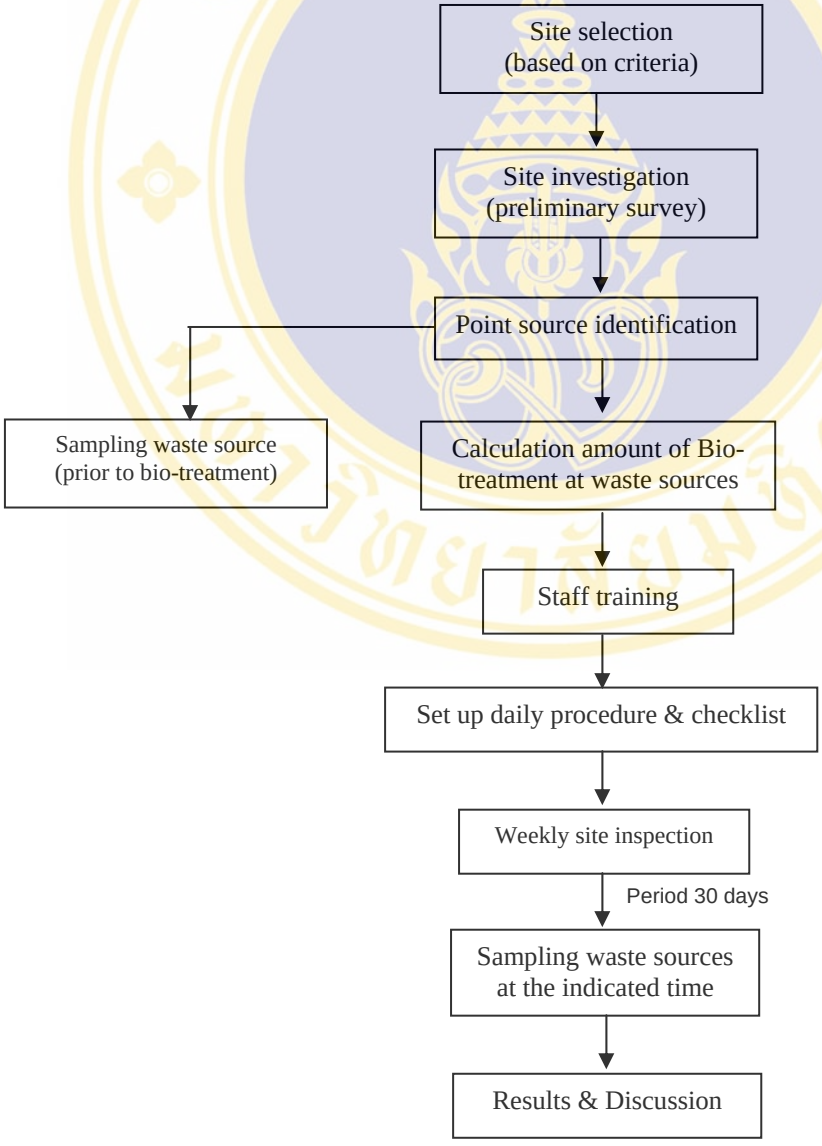

Figure 3-1: Experimental Framework

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3.2 Materials and Equipments

3.2.1 Materials

- Commercial microbes (Micro-blaze: kindly provided by SLSM Co. Ltd.)

3.2.2 Equipments

1) Digital pH meter
2) Glassware
3) Water pump
4) Ice container
5) Incubator
6) Pipets (0.2 ml-10 ml)
7) Millipore water

3.2.3 Chemical reagents

1) Concentrated Sulfuric Acid
2) 0.0375 N Sodium Thiosulfate
3) Starch indicator
4) Crystalline D-glucose and glutamic acid
5) Bleach (5.25%)
6) Acetic Acid
7) Potassium Iodide
8) Sodium hydroxide pellets
9) Manganese sulfate
10) Sodium sulfite
11) Deionized water
12) Mercuric sulphate

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13) Sulfuric acid

14) Ferroin indicator

15) Standard Potassium dichromate (conc.) 0.250 N

16) - Potassium hydrogen phthalate (KHP) Standard

17) Standard Ferrous ammonium sulphate (FAS)

3.3 Experimental Preparation

3.3.1 Site selection

In order to select gas stations, the following criterias have been applied to the gas stations that located within Bankok and peripheral area:

1) Construction of all service area should be slope to drainage system that connected to effluent tank at both sides of the station.
2) No leakage of open drainage system.
3) The level of public road must be lower than gas station floor.
4) Wastewater direction must flow into the effluent tank.
5) Amount of visiter is significant.
6) Various activity in the gas station

The five gas stations based on criteria mentioned above were selected from five oil companies. All gas station named Gas station A, B, C, D, and E (GSA, GSB, GSC, GSD, and GSE) were used instead of the real name.

3.3.2 Preliminary survey

After already selected station, preliminary survey have been carried out in order to investigate all the environment and also any waste sources in each gas station. Before starting project, the gas station have to remove all sediments in any consolidated tanks, such as, septic tanks from toilets, grease trap tank from kitchen in food shop or coffee kiosk. In order to make sure all system are closed to initial stage. In addition, all sediments in drainage system must be removed and also good cooperation from all the

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staff must be obtained to follow the manual and do checklist stringently.

3.3.3 Point source identification

The following identified points sources of pollution in various activities in the five gas stations are as follows:

Coffee Shop

- G/T Strainer
- G/T Tank (outside shop)
- Water Drain from G/T Tank

Food Shop

- G/T Tank (outside shop)
- G/T Strainer inside kitchen
- G/T Strainer inside shop
- Kitchen basin

Gas Station In-front Area

- Effluents (exit side)
- Effluents (entrance side)
- Oil Spills at Dispenser (in front area)
- UST Inlet system

Toilets

- Urinaries and basins
- Urinaries for gent
- Basins behind toilets
- Septic Tank (Gent and Lady)
- Water Drain from toilet (behind station)

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3.3.4 Staff Training

After preliminary survey, the wastewater at initial stage at waste sources and both effluent tanks were collected for analysis. Then training officers have been carried out about how to apply microbes, what are cautions (stop using any detergents and stop removing grease or excrements) and how to control their procedure or even amount of microbe with checklists (see Appendix B). During launching the project, using chemical agent or detergent for cleaning do not allow. Only the 1 % of Micro-blaze for general cleaning instead of detergents. In addition, the routine investigation are significantly performed for reliable result every week until 30-45 days. And the project timeline of the activities are as follow:

Table 3-1: Project timeline sheet

ID	Task Name	Start	Finish	Resource Names
1	Inspection (Preliminary survey)			
2	Documentation pictures			
3	Empty Septic tanks			
4	*First Testing WW parameter (prior to MB)*			
5	Training Treatment with MB			
6	Daily treatment (30 days)			
7	Additional treatment			
8	*Second Testing WW parameters (30 days)*			
9	Processing test parameters			
10	Reporting			

3.3.5 Application of microbes at waste sources

1) Calculation of microbes used in experiment The calculation applied to the microbial used in different activities were as follows:

Toilets and urinaries:

- Find the application integral in m^2
- Calculate with 0.2 microns application thickness as consumption on the entire integral
- Continue treatment until you have a biomass of about $5* 10^9$ (5,000,000,000) per 1000 ml
- An integral of 1000 m^2 must be treated with 0.0002 m^3 = 0.2 litres = 200 ml per day until there are indications that the biomass is under control – and

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increasing

- Multi-targeting: Treat the furthest point from the septic tank
- Multi-targeting: Calculate the flow of water into the septic tank (influent)
- Multi-targeting: Calculate the flow of water from the septic tank into the effluent WWS
- Find the delta value. Adjust for evaporation and emission of gas
- Additional treatment: Add 0.01 ppm per m^3 black water flow – 5 m^3 will require 0.05 litre or 50 ml per day
- Total consumption per day for toilet, urinaries and associated area being considered as Black Water will normally amount to < 250 ml per day

Black water difference volume:

$$\int_0^5 x(dx), > 5{,}000{,}000{,}000/105{,}000{,}000{,}000 + 0.2 = 250\ ml$$

Above derivation indicates that you must build up the biomass by applying 250 ml concentrate per day – assumed equal to > 26,250,000,000 microbial units. Mortality estimated to 80%. A mortality of 80% appears to be near the expected level, where part of the value may be influenced by hibernation, which may be dependent on the required elements but will gradually decrease to about 30% at such time as the reproduction is established. Ensuring that limited dehydration of excrements appears in the septic tank, by adding water, will enhance the multiplication of biomass significantly. Proportional assessment is possible for deviating conditions.

Floor and Wall cleaning:

- Mix 1% MB FOG or ELSC when applied as GP cleaner.
- Calculate application of 45 m^2 per litre and evaporation about 10% (based on volume) per day.
- In areas where a certain amount of oil can be found, the reproduction will be of significant level.
- Before new MB FOG or ELSC is replenished check the biomass i.e. just check if it is foaming.

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- If no foam fill in water and then mix with MB to 1%.
- If foam indications present add water only, until there is no sign of microbial activity.

Kitchen strainer:

- Treatment is dependent on number of meals, amount of oil and inorganic sauces etc. dumped into the strainer.
- In a company with 2 x 1000 meals the following equation can be adopted:

First meal	Second meal	Water flow	Cooking oil	Deduction	Total cons MB
1000 persons * 0.02 factor/1000 per mil = 23 ml	1000 persons * 0.02 factor/1000 per mil= 23 ml	1*2000/1000*0.02 = 20ml	2litres * 2% 40 ml	Biomass in G/T 29,000,000,000 63 ml	43 ml

Note: Do not empty G/T

$$\int_{o}^{2000} x(dx) > 2000,\ 46 > 20, 40, -63 = 43\ ml$$

- Considering that the accumulated biomass in the G/T amounts to 29 B (29*109), only ensure that the level of microbes is growing.
- Microbial treatment is a proportional distribution of a sufficient number of microbes with a defined affinity towards organic pollutants (HC) relatively correlating to the number of HC molecules present. *(Ref.: Newton's best approximation with equidistance of x vs. an elementary strip of dx for the entire integral of the two equations.)*
- Ensure presence of the three elements at start up to support multiplication and repro at desired level.

2) Application at waste sources Application 1% of Micro-Blaze at waste sources in gas station with daily procedure in gas station as follows:

- *Toilets:* Apply microbes (in pure concentrate) of Micro-Blaze at any outlet drain points and estimated amount of microbes from amount of service and number of outlet points in toilets, such as, urinals, lavatories, basin.
- *Food shop*: Apply microbes at grease/trap strainer or grease/trap tank and

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estimated amount of microbes from amount of services.

- *Coffee shop or kiosk:* Apply microbes at grease/trap strainer or grease/trap tank and estimated amount of microbes from amount of services.
- *In-front area:* Apply microbes at oil spill area and only flushing with water and also for weekly floor cleaning. It is not necessary to use sand for oil absorbent.
- *UST inlet:* Apply microbes at oil spill around UST inlet everyday.
- *Lube (Lubricating oil transfer service):* Apply microbes at oil spill area and using the 1 % of Micro-Blaze instead of detergents for general cleaning.

Table 3-2: Daily procedure

ID	Location	Morning (ml)	Afternoon (ml)	Night (ml)	FOG/day ml	Ratio	Optional 1:100 (ml)
a	Coffee shop	2	3	0	5	100%	500
b	Coffee shop	2	3	0	5	100%	500
c	Kiosk	0	0	0	0	100%	0
d	Restaurant/cafeteria	3	3	4	10	100%	1,000
e	Restaurant/cafeteria	2	1	2	5	100%	500
f	Parking and PDP area	2	0	0	2	100%	200
g	Car wash facility	0	0	0	0	100%	0
h	Manifold	1	0	0	1	100%	100
i	Toilets W/C	6	6	8	20	100%	2,000
j	Toilets W/C options	20	20	20	60	100%	6,000
k	Toilets Black water	12	12	16	40	100%	4,000
l	Urinaries Black W	6	6	8	20	100%	2,000
m	Kitchen	3	3	4	10	100%	1,000
n	Kitchen WWS	3	3	4	10	100%	1,000
o	Kitchen Grey	4	4	6	14	100%	1,400
p	Cleaning Tool Store	3	3	4	10	100%	1,000
	Sum	69	67	76	212		21,200

3.4 Experiments

3.4.1 Sampling Procedure

Sampling point: The sampling points of different activities in gas station were selected as follows:

1) G/T tank from Food shop
2) Septic tank from Toilets
   - Male (Gent): second or final stage tank

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- Female (Lady): second or final stage tank

3) G/T tank from Coffee shop

4) Effluent tank

- entrance
- exit

The condition of those sampling point are shown below:

G/T tank from food shop

Septic tank from toilets

Effluent tank from entrance side

Effluent tank from exit side

Male (Gent) and (Lady): samples were taken from the second or final tank it can be seen that there were a lots of excrement in initial tank and low retention time. Regarding to high accumulation of excrement, it is necessary to empty the septic tank (gent, lady) prior to starting the project. High accumulation of excrement in septic tank may be obstacle microbial activity underneath surface layer of excrement. In case of G/T tank from food shop the oil food waste are floating on the surface where 2-3 times removal per week are usually burden.of the officer. While the condition of

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the effluent tank seems to be more clean than waste source.

Sampling time: As the peak of service time were among 7.00-9.00 am. and 18.00-20.00 pm. Therefore, the sampling time at 10.00-11.00 am., which is the 2 hours after peak time, were chosen.

3.4.2 Sampling Method

After the sediments in both septic tanks and effluent tanks were emptied, the samples were taken from any waste sources prior to apply bio product (0 day) and then sampling again after 3, 15, 30 and 30 days for the GSA in order to observe microbial trends and performance, in which data collection period of the others (GSB, GSC, GSD and GSE) will be correlated.

The wastewater sample from different activities were collected at the point before discharge to the drainage system and the point where the discharge from all activities source were combined in effluent tank before drained out to the public drainages system. The grab sampling method was used for wastewater collection at the time interval between 10:00 am – 11:00 am.

3.4.3 Analysis

The collected samples were analyzed for the wastewater quality parameters of pH, BOD, COD, SS, and FOG, using the following method:

pH: pH-Meter Electrometric Method

Biochemical Oxygen Demand (BOD): Azide Modification Method

Chemical Oxygen Demand (COD): Dichromate Reflux Method to APHA.

Total Suspended Solid (TSS): Glass Fiber Filter Disc (Standard Method 2540 D)

Fat, Oil and Grease: Soxhlet Extraction Method

(The methods used for analysis of wastewater quality parameters are detailed in Appendix B)

3.4.4 Data Process

Analyzed data were aggregated and plotted into graphs and compared with the wastewater discharge standard. Apart from the graph, data was explained part by part. The results could be illustrated the trend of bioremediation efficiency.

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CHAPTER 4
RESULTS AND DISSCUSSION

In this chapter, the results can be explained by categories. There were seven activities in five selected gas stations namely toilet, food shop, minimart, coffee shop, lube, effluent (entrance), and effluent (exit). All activities, as shown in Table 4-1, were varied among those selected gas station, ranging from 5 to 6 activities in each station. And five parameters were tested for each activity.

Table 4-1: Activities in Each Gas Station

Gas Station	Toilet	Food shop	Minimart	Coffee shop	Lube	Effluent (entrance)	Effluent (exit)
GSA	✓	✓	✓	✓	-	✓	✓
GSB	✓	-	-	✓	-	✓	✓
GSC	✓	-	✓	-	✓	✓	✓
GSD	✓	✓	✓	✓	-	✓	✓
GSE	✓	✓	✓	✓	-	✓	✓

4.1 Gas Station A (GSA)

GSA's activity could be described as full customer service level except oil change (Lube). All the potential source of pollution from GSA's activities were coffee shop, minimart and toilet situated on the exit and only food shop on the entrance as shown in Figure 4-1.

It could be seen that application of microbe influence to wastewater in the effluent tank at both sides. The wastewater quality (WWQ) from all activities, except for minimart in which no grease trap wastewater, were collected 4 times within a period of 45 days, namely at the date of 1, 3, 30 and 45 from the beginning date. This GSA was tested more frequently than the other gas stations in order to observe microbial trends and performance, in which data collection period of the others were correlated.

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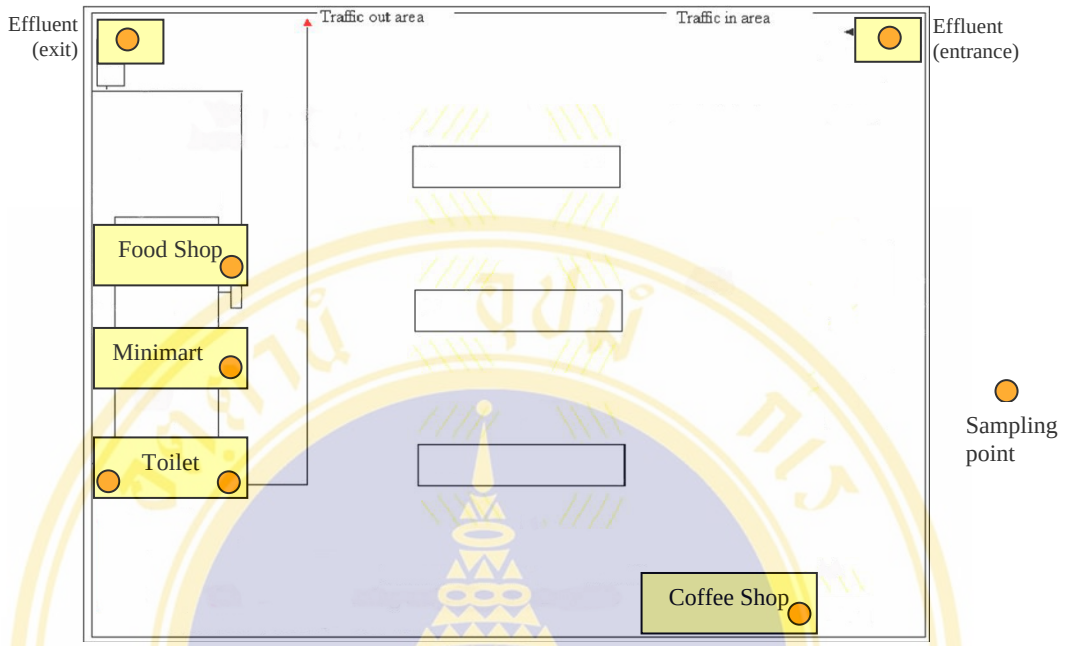

Figure 4-1: Top view layout of GSA

4.1.1 Gentleman Toilet

Table 4-2: Results of WWQ from gentleman toilet of GSA

Parameter	Day 1	Day 3		Day 30		Day 45	
pH	7.8	7.8		8.1		7.6	
BOD (mg/L)	392.0	351.0	-10.5 %	378.0	-3.6 %	181.0	-53.8 %
COD (mg/L)	834.0	1036.0	24.2 %	934.0	12.0 %	456.0	-45.3 %
SS (mg/L)	165.0	224.0	35.8 %	223.0	35.2 %	112.0	-32.1 %
FOG (mg/L)	23.7	24.0	1.3 %	24.7	4.2 %	55.0	132.1 %

Note: % refers to the decreasing percentage compared to Day 1

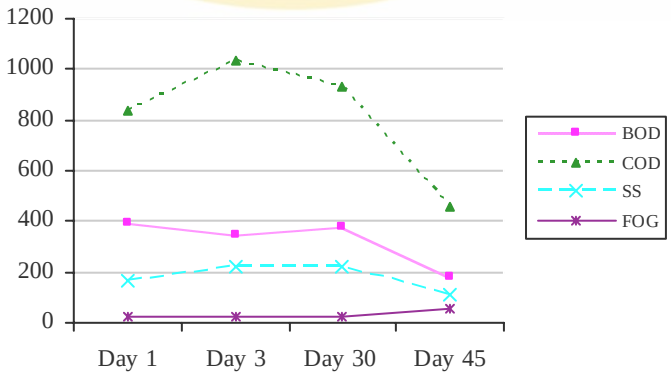

Figure 4-2: Charts of WWQ from gentleman toilet of GSA

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According to Table 4-2 and Figure 4-2, the results illustrated a little change of pH value in range of 7.6 - 8.1 while the standard interval were during 5.5 to 9. In case of BOD, the values were slightly changed from the beginning to Day 3 and Day 30 about 10.5% and 3.6% (392 to 378 mg/L), before gradually decreased about 53.8% (392 to 181 mg/L) at Day 45. These results could be explained that a little change during a month before declining that might be due to large number of visits, shortened retention time will impact degradation of organic matter in the septic tank. In addition, the gas station's procedure might get out of control by using detergent for cleaning. These influenced greatly to the growth of the biomass and mortality. They were likely to be suffered according to pH condition in the tank, causing Bacillus strains unable to remediate oxidized organic matters effectively in high pH environment. However, a little change during this time also shows that there still was bio reaction in septic tank, and that the amount of excrements has accumulated on the water surface and at the bottom of the septic tank. These circumstances prevent the microbes from remediating waste above water surface and settled particles at the bottom. The microbes were only capable of remediating organic matter in the water column. Despite the mentioned restraints, at Day 45 or fifth week, the BOD trend decreased about 53.8%. This deviation is due to biochemical reactions upon adding microbial concentrate, showing fully degradation of the waste (excrements, urine, etc.) in septic tank by the abundance microbes, and significant degradation related to the scheduled application of microbial concentrate was evident.

Accordingly, the suspended solids (SS) values were increased from the beginning to about 35.8% at Day 3. Then, it was rather constant until Day 30 at 35.2% (392 to 378 mg/L) before gradually decreased to about 32.1% (to 112 mg/L) at Day 45. It showed that there were high amount of suspended matter in the septic tank derived from efficient bio-reaction, at which time the organic matters have been largely remediated or oxidized. The bio-reaction converted a significant amount of waste into more liquefied consistency (easier mixable with water) after cleaning sticky HC components, de facto, generating "purified" suspended solid. However, at Day 45, the SS decreased about 32.1%, demonstrating a significant number of the biomass (microbes) is able to remediate unclean suspended solids which generated during the

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first period. Longer retention time to degrade the organic matters will be imperative when microbes attempt to access heavy impenetrable molecules with a undefined content.

Regarding the COD level, which did indeed increase about 24.2% (834 to 1036 mg/L) during the interval ending at Day 3. These might be the consequence of using detergent for a long time, there is a high remaining pH or high COD-values in the septic tank. At Day 30, the COD were increased only 12% (834 to 934 mg/L) showing they were gradually decreased since after Day 3 approximately 12.0%, before sharply decreasing about 45.3% (834 to 456 mg/L) at Day 45. This situation showed that there were abundance of microbes in the septic tanks at the fifth week, and the septic pH condition became less important owing to daily replenishment of microbial concentrate to the septic tank. Consequently the microbial remediation of organic FOG in the septic tank gained momentum and decreased about.

In consideration of FOG or Grease & Oil, they were gradually increased about 1.3%, 4.2% and 132.1% at Day 3, Day 30 and Day 45 respectively. It is evident that the microbes are not able to remediate impenetrable fat or grease at ambient temperatures and conditions. According to its nature, human excrements contain undigested organic matter, such as, carbohydrates, proteins or molecules with high fat content. Basically, microbes degrade organic matter found in larger molecules to smaller molecules, and some of these fatty molecules were oxidized to fatty acid. A significant enzymatic process might account for the success of the microbes' ability to access the molecules. The significance of the enzymatic process increased with the course of the remediation process – particularly in confined spaces, with limited runoff as described in this example.

4.1.2 Lady Toilet

Table 4-3: Results of WWQ from lady toilet of GSA

Parameter	Day 1	Day 3		Day 30		Day 45	
pH	7.9	7.7		7.7		7.4	
BOD (mg/L)	324.0	341.0	5.2 %	190.0	-41.4 %	213.0	-34.3 %
COD (mg/L)	622.0	936.0	50.5 %	457.0	-26.5 %	549.0	-11.7 %
SS (mg/L)	74.0	208.0	181.1 %	46.0	-37.8 %	139.0	87.8 %
FOG (mg/L)	15.0	23.0	53.3 %	9.3	-38.0 %	19.0	26.7 %

Note: % refers to the percentage of change compared to Day 1

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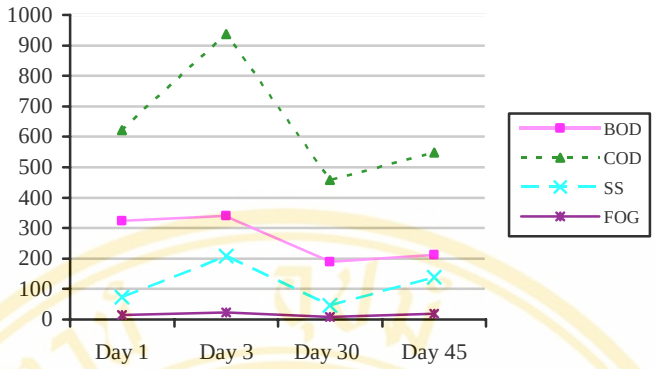

Figure 4-3: Charts of WWQ from lady toilet of GSA

As shown in Figure 4-3 and Table 4-3, during 45 days the results of pH value were varied from 7.9 to 7.4 that close to the neutral condition. However, they varied in the standard range of 5.5 to 9. In addition, it can be seen that those of BOD, SS and COD were concurrent in changing during 45 days of experiment except for the FOG which were continuously increased. In case of BOD, they were slightly increased about 5.2% (324 to 341 mg/L), then gradually decreased about 41.4% (324 to 190 mg/L) and 34.3 (324 to 213 mg/L) at Day 30 and Day 45. The increasing rate of BOD-level was not high, it was opposite to the gentleman toilet in the first three days (Day 3), showing the lower input waste that microbes were bearable the incoming waste load. Consequently, most of the waste (excrements, urine, etc.) in the septic tank were easier degraded by microbes within three days, the biodegradability of microbes were clearly seen in relation to daily replenishment of microbial concentrate to the septic tank thereafter. Although, - slightly increase of BOD appeared at the fifth week. This might be due to amount of excrements has accumulated in the septic tank preventing a large number of microbes from remediating waste above the water surface and settled particles at the bottom.

Accordingly, the change of SS (Suspend solids) is concurrent to that of BOD. They have increased about 181.1% (74 to 208 mg/L) and 38% (74 to 46 mg/L) at Day 3 and Day 30, and again increased about 87.8% at Day 45 (74 to 139 mg/L). It showed that there were high suspended solids in the septic tank from high bio-reaction. Most organic matter have been degraded by the microbes, this bio-reaction made most of the waste become more liquid and generated more suspended solids. Longer retention

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time to degrade the organic matters would be an advantage. However, it was noticed that even if the level of suspended solids were still high or fluctuating, the BOD value gradually decreased. It showed that most of the suspended solids were completely degradable – HC coated core only.

With regard to COD, its value increased about 50.5% (622 to 457 mg/L) at Day 3 and sharply decreased at Day 30, then slightly increased again about 26.5% (622 to 457 mg/L) at Day 45. At this period, although there still be abundance of microbes in the septic tanks, but the septic pH condition became less important owing to daily replenishment of microbial concentrate to the septic tank causing high biodegradability. However, the excrements accumulation in the septic tank, preventing a large number of microbes from remediating waste above the water surface and in settled particles at the bottom. They are only capable of remediating organic matter in the water column. Accordingly, the COD value decreased in the first period, then gradually increased thereafter.

The FOG or Grease & Oil increased in first week, about 53.3% (15 to 23 mg/L) at Day 3, and decreased thereafter about 38% (15 to 9.3 mg/L) at Day 30, and reversed again about 26.7% (15 to 26.7 mg/L) at Day 45. Accordingly, as in the gentlemen toilet, its nature, human excrements contain undigested organic food and associated microbes basically degrade organic matter found in larger molecules to smaller molecules, and some of these fatty molecules were oxidized to glycerol and fatty acid, protein to amino acids and so on. Consequently, the FOG-level still fluctuated and was expected to depend largely on the organic matter in the excrements.

4.1.3 Food Shop

Table 4-4: Results of WWQ from food shop of GSA

Parameter	Day 1	Day 3		Day 30		Day 45	
pH	4.5	4.8		4.4		4.5	
BOD (mg/L)	812.0	1151.0	41.7 %	817.0	0.6 %	770.0	-5.2 %
COD (mg/L)	1370.0	1904.0	39.0 %	1557.0	13.6 %	1529.0	11.6 %
SS (mg/L)	131.0	290.0	121.4 %	194.0	48.1 %	210.0	60.3 %
FOG (mg/L)	65.0	153.0	135.4 %	86.0	32.3 %	77.7	19.5 %

Note: % refers to the percentage of change compared to Day 1

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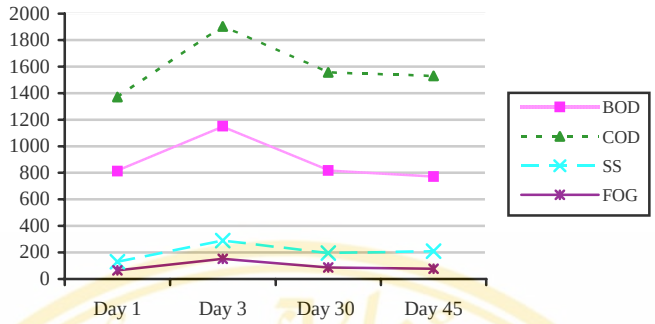

Figure 4-4: Charts of WWQ from food shop of GSA

As the results shown in Table 4-4 and Figure 4-4, the pH value varied between 4.4 to 4.8. They are rather acid and below the standard range of 5.5 to 9.

In addition, the results of BOD from food shop were slightly increased during the first three days about 41.7% (812 to 1151 mg/L) then gradually decreased to 0.6% (812 to 817 mg/L) and 5.2 % (812 to 770 mg/L) at Day 30 and Day 45 respectively. The long pipeline from the kitchen to drainage system (strainer-> grease trap tank -> open drain), contained lots of accumulated grease. This food shop must be considered as a full scale restaurant. The amount of grease in the pipelines was found to be very high. Accordingly, the microbes remediated most accumulated grease in the pipeline during the first week, the BOD value were significantly increased from accumulated grease, which were subjected to enzymatic action and subsequent microbial remediation. Based on interview with the kitchen staff, the release of grease to the grease trap tank during the first week appeared to change consistency to a significant liquid form (different from prior observations). This observation was determined a couple weeks after microbial concentrate was applied in the drainage network. After the forth week, at Day 30, the BOD value gradually decreased up to 5.2% (812 to 770 mg/L) in fifth week, at Day 45 there were microbes in abundance, or high biomass in the pipeline network and also in grease trap tanks. After this point of time the microbes succeeded in remediating existing accumulated grease levels, and the microbial activity was sufficiently high to control BOD input with continuous effluent flow despite of high occupation level.

With regard to COD value, the result showed that they were increased significantly during the first week, at Day 3 about 39 % (1370 to 1904 mg/L) and slightly decreased

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at Day 30 and Day 45 about 13.6 % (1370 to 1557 mg/L) and 11.6 % (1370 to 1529 mg/L). Because of the long pipeline in the kitchen to the drainage system, which accumulated grease in the pipeline, the COD value also increased parallel with the BOD value. The COD value did not significantly decrease until the fifth week because there were still diluted chemical agents in the drainage. The impact originated from dishwashing solution or related chemical agents which were utilised in the kitchen at this time. These circumstances kept the COD value high. However, there were increasingly high levels of biomass in the pipeline and grease trap tank, and it evidenced that the microbes were in control of the COD input which continually emerged from high service (occupation) rates.

According to SS value, they were significantly increase about 121 % (131 to 290 mg/L) and slightly decreased about 48.1% (131 to 194 mg/L) and 60.3% (131 to 210 mg/L) at Day 3, Day 30 and Day 45 respectively. The COD value again slightly increased after a month. It showed that there were high suspended solids in the drainage (pipeline, grease trap tank) from high bio-reaction. Most organic matters have been bio-remediated making accumulated grease became more liquid, thus generating more suspended solids as a lateral effect. The retention time might be insufficient to degrade more organic matter as a result of the system overload i.e. waste accumulation above water level etc.

With respect to FOG value, they were significantly increased about 135.4% (65 to 153 mg/L), and slightly decreased about 32.3% (65 to 86 mg/L) and 19.5% (65 to 77.7 mg/L) at Day 3, Day 30 and Day 45 respectively. It shows that the microbial activity was high, and that the accumulated grease were subjected to degradation and subsequent remediation by the microbes. The microbes degrade organic matter found in larger molecules to smaller molecules, and some of the fatty molecules and grease were oxidized to fatty acid. Significant enzymatic action might account for the success of the microbes' ability to access the molecules. The significance of the enzymatic process would increase with the course of the remediation process. Enzymatic effects will dilute grease and fat significantly and this action will be gauged as increased levels of FOG. Subsequently, the microbial remediation would increase until there was a balance between available food vs. water with satisfactory DO.

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4.1.4 Coffee Shop

Table 4-5: Results of WWQ from coffee shop of GSA

Parameter	Day 1	Day 3		Day 30		Day 45	
pH	4.9	4.3		5.2		5.2	
BOD (mg/L)	1,642.0	1,431.0	-12.9 %	567.0	-65.5 %	541.0	-67.1 %
COD (mg/L)	2,637.0	2,432.0	-7.8 %	1,245.0	-52.8 %	862.0	-67.3 %
SS (mg/L)	654.0	736.0	12.5 %	376.0	-42.5 %	230.0	-64.8 %
FOG (mg/L)	493.0	788.0	59.8 %	198.0	-59.8 %	68.0	-86.2 %

Note: % refers to the percentage of change compared to Day 1

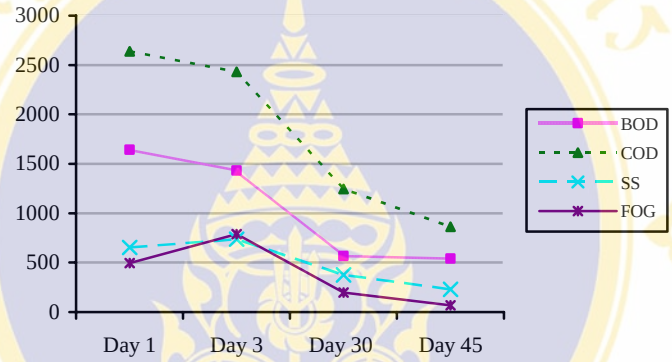

Figure 4-5: Charts of WWQ from coffee shop of GSA

According to Table 4-5 and Figure 4-5, the pH values of wastewater from coffee shop are in range of 4.3-5.2, showing the acidic wastewater the same as food shop. These pH values are below the standard range of 5.5 to 9. This might be due to most of the chemical mixed ingredients previously utilised and flushing out debris of ground coffee.

Regarding the BOD value, they were significantly decreased from Day 3, to Day 30 and Day 45 about 12.9% (1642 to 1431 mg/L), 65.6% (1642 to 567 mg/L) and 67.1% (1642 to 541 mg/L) respectively. Owing to the short pipeline from coffee kitchen to the drainage system (strainer->grease trap tank->open drain) this coffee shop was not a full restaurant, only baking and coffee-making, not much grease accumulated in the pipeline system. Consequently, the BOD significantly decreased from microbial reaction since the first three days. The growth of the biomass was likely remain high as long as the organic matters constitute the main input on continuous bases.

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With respect to COD, they were significantly decreased from Day 3 to Day 30 and Day 45 about 7.8%, (2637 to 2432 mg/L) to 52.8% (2637 to 1245 mg/L) and 67.3% (2637 to 862 mg/L) respectively. The argument being the same as noted above under the BOD comments. Because of the short pipeline, low level of accumulated grease appeared in the pipeline and limited additional activity confined to bakeries & coffee, high bio-reaction made significant decrease of the COD value.

In case of SS, they were slightly increased about 12.5% (654 to 736 mg/L) then significantly decreased from the first three days to Day 30 and Day 45 about 42.5% (654 to 376 mg/L) and 64.8% (654 to 230 mg/L). It shows that there were high suspended solids in drainage (pipeline, grease trap tank) from high bio-reaction. Most organic matters were being degraded or oxidized, and the bio-reaction made accumulated grease became more liquid, which in turn generates more suspended solids. As there were not much grease present, the SS significantly decreased after the forth week, i.e. Day 30.

The FOG were slightly increased about 59.8% (493 to 788 mg/L) then significantly decreased about 59.8% (493 to 788 mg/L) at Day 30 to 86.2% (493 to 68 mg/L) at Day 45. It also shows that there was high bio-reaction, accumulated grease firstly degraded by microbial activity causing FOG slightly increased in first three days. Then microbes degraded organic matter found in larger molecules to smaller molecules, and some of these fatty grease molecules were oxidized to CO_2 and H_2O.

4.1.5 Effluent Tank (entrance side)

Table 4-6: Results of WWQ from effluent tank at entrance of GSA

Parameter	Day 1	Day 3		Day 30		Day 45	
pH	7.0	6.8		7.2		7.2	
BOD (mg/L)	26.0	15.0	-42.3 %	3.7	-85.8 %	25.0	-3.8 %
COD (mg/L)	87.0	43.0	-50.6 %	12.0	-86.2 %	79.0	-9.2 %
SS (mg/L)	40.0	13.0	-67.5 %	11.0	-72.5 %	26.0	-35.0 %
FOG (mg/L)	9.0	0.7	-92.2 %	0.2	-97.8 %	7.0	-22.2 %

Note: % refers to the percentage of change compared to Day 1

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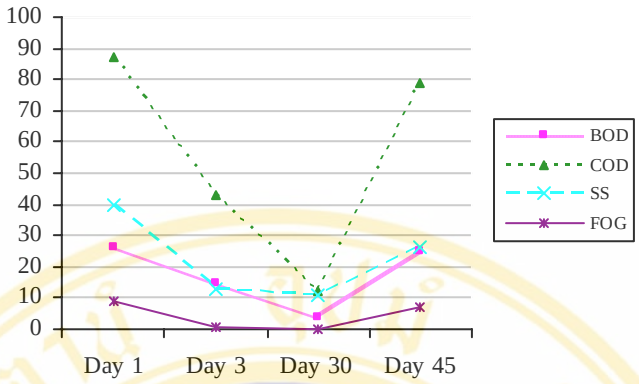

Figure 4-6: Charts of WWQ from effluent tank at entrance of GSA

According to Table 4-6 and Figure 4-6, the results indicated the pH values were varied between 6.8 and 7.2, showing neutral condition of wastewater in the tank and they were within the standard range of 5.5 to 9.

In addition, the results of all parameter, BOD COD SS and FOG, were significantly changed since the first three days approximately 42.3%, 50.6%, 67.5% and 92.2% respectively. Continuously, they were decreased sharply at the fourth week (Day 30) to 85.2%, 86.2%, 72.5% and 97.8% respectively. This because of coffee shop drainage discharge to the effluent stage (entrance side), most microbes from the coffee shop wastewater flow mixed with wastewater in the open drain and directly discharged to the effluent tank (entrance side). Thus, wastewater mixed with microbes helped to continuously remediate until effluent and further. It is shown that all parameters value are gradually decreased from the first week until forth week, then rather high up than further decreasing, owing to the USTs (Underground Storage Tank) have been installed at this side and some oil contaminated water from the manifold might have leaked out into the open drain, this would be gauged at the effluent stage. Another activity which is able to generate high organic matter was taking place during service area cleaning. According to the QAS this area is to be cleaned once every month. The polluted organic runoff was being flushed to the open drain and further to the effluent tank (entrance side). It may be claimed that the value of all parameters were decreased slightly at Day 45 (about only 3.8%, 9.2%, 35.0% and 22.2%) from this effect.

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4.1.6 Effluent Tank (exit side)

Table 4-7: Results of WWQ from effluent tank at exit of GSA

Parameter	Day 1	Day 3		Day 30		Day 45	
pH	7.4	7.2		7.3		7.3	
0BOD (mg/L)	128.0	262.0	104.7 %	202.0	57.8 %	87.0	-32.0 %
COD (mg/L)	252.0	545.0	116.3 %	444.0	76.2 %	155.0	-38.5 %
SS (mg/L)	65.0	60.0	-7.7 %	70.0	7.7 %	51.0	-21.5 %
FOG (mg/L)	14.0	10.3	-26.4 %	15.7	12.1 %	8.0	-42.9 %

Note: % refers to the percentage of change compared to Day 1

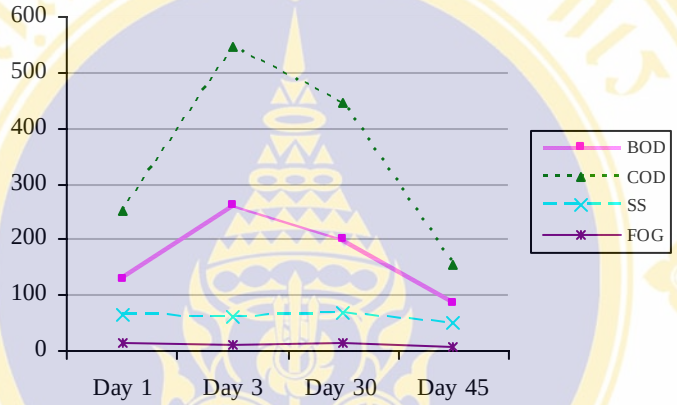

Figure 4-7: Charts of WWQ from effluent tank at exit of GSA

According to Table 4 -7 and Figure 4 -7, the pH values were varied between 7.2 -7.4 showing neutral condition of wastewater in the tank and they were in the standard range of 5.5 to 9.

In addition, the BOD were increased significantly in the first week, at Day 3 about 104.7% (128 to 262 mg/L) still slightly increased about 57.8% (128 to 202 mg/L). And it has just been decreased slightly in the fifth week, at Day 45 about 32% (128 to 87 mg/L). Because there are many activities at the exit side, such as, toilets, food shop, coffee shop etc., you would find justification for the course of the observations. From the result, as above mentioned, in toilets, food shop and coffee shop, all wastewater discharge directly to effluent tank (exit side). The food shop was quite near to the effluent tank (exit) and all parameters were increased. Consequently, the BOD were also significantly changed in parallel with all the other activities. In addition, there were some sediment in the bottom of effluent tank (exit); this sediment also impacts

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the wastewater quality once again. However, the public WWS level in front of the station should be lower than the level of the effluent tank (exit side), otherwise outside wastewater will flow back and impact the WW at this stage again, making tests completely null and void.

The results of COD were significantly increased during the first week, at Day 3 about 116.3% (252 to 545 mg/L) and slightly increased during the forth week, at Day 30 about 76.2% (252 to 76.2 mg/L). And the COD just slightly decreased during the fifth week, at Day 45 about 38.5% (252 to 155 mg/L). Equal to the note of the BOD section, it explained that the wastewater from all activities of the area, particularly the Food shop was discharged directly to effluent tank (exit), which increased all parameters. Consequently, the COD value also significantly changed in parallel with the other activities. Even the COD value of the Food shop slightly increased during the fifth week, at Day 45 about 11.6%, but the COD value at the effluent tank (exit) decreased slightly. It was observed that the retention time of wastewater (open drain between grease trap tanks to the effluent tank) was sufficiently to enhance the remediation effect of the wastewater.

The SS were slightly decreased during the first week about 7.7% (65 to 60 mg/L) at Day 3 and slightly increased at Day 30 about 7.7% (65 to 70 mg/L). Then, they were significantly decreased again during at Day 45 about 21.5% (65 to 51 mg/L). Equal to above parameters, it could be explained that the wastewater from all activities, particularly the Food shop, discharged directly to the effluent tank (exit) and all parameters were increased. Consequently, the SS also changed significantly in parallel with the other activities. However, the effluent tank should be of “a good design structure, “it is important to suspended solids or have enough volume to accommodate settlement prior to discharge to the public WWS.

The FOG were decreased slightly during the first week, at Day 3 about 26.4% (14 to 10.3 mg/L) and slightly increased during the fourth week, at Day 30 about 12.1% (14 to 15.7 mg/L). Then were decreased during the fifth week, at Day 45 about 42.9% (14 to 8 mg/L).). Equal to the above parameters, it explained that wastewater from all activities, particularly Food shop, discharged directly into the effluent tank (exit) and

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that all parameters were increased. Consequently, the FOG also changed in parallel with the mentioned activities. Even the FOG value of the Food shop and Toilets increased slightly during the fifth week, at Day 45 about 19.5% and 132.1% (gentlemen), 26.7 % (lady) respectively, but the FOG value at the effluent tank (exit) were significantly decreased about 42.9%. It was noted that the additional retention time of wastewater flow (open drain between grease trap tanks to effluent tank) increased the microbial remediation of organic matter significantly.

4.1.7 Correlation with Standard Value

According to Thai Standard Regulations, the study acted in accordance with acceptable wastewater standard from gas station as follow:

Parameter	Effluent tank (Entrance)	Effluent tank (Exit)	Standard
BOD mg/L	25	87	20 (domestic wastewater std.)
COD mg/L	79	155	200
SS mg/L	26	51	60
FOG mg/L	7	8	15

With respect to the above results, it was observed that most of the wastewater parameters at the effluent tanks on both entrance and exit side, were slightly decreased in the first interval and significantly decreased during the fifth week. Most of them were able to reach the standard level except for the BOD at exit side in which the trend to meet the standard are foreseeable. However, this BOD parameter was not under the Thai wastewater standard regulation for gas station. In addition, it was also noticed that the retention time of wastewater (open drain between waste sources to the effluent tank) make higher degradation of organic matter. It was therefore important to control dirt and regularly clean open drain or remove some waste which contaminate or block the wastewater flow.

4.2 Gas Station B (GSB)

GSB's activity can be described as low customer service levels as only toilet and coffee shop are presented. There were only 5 parameters in which the data were collected 2 times within a period of 30 days, namely at the date of 1, and 30 from the

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beginning date. The results of the tests from GSB are presented in Table 4-8 to 4-12 and Figure 4-9 to 4-13. It can be noted that

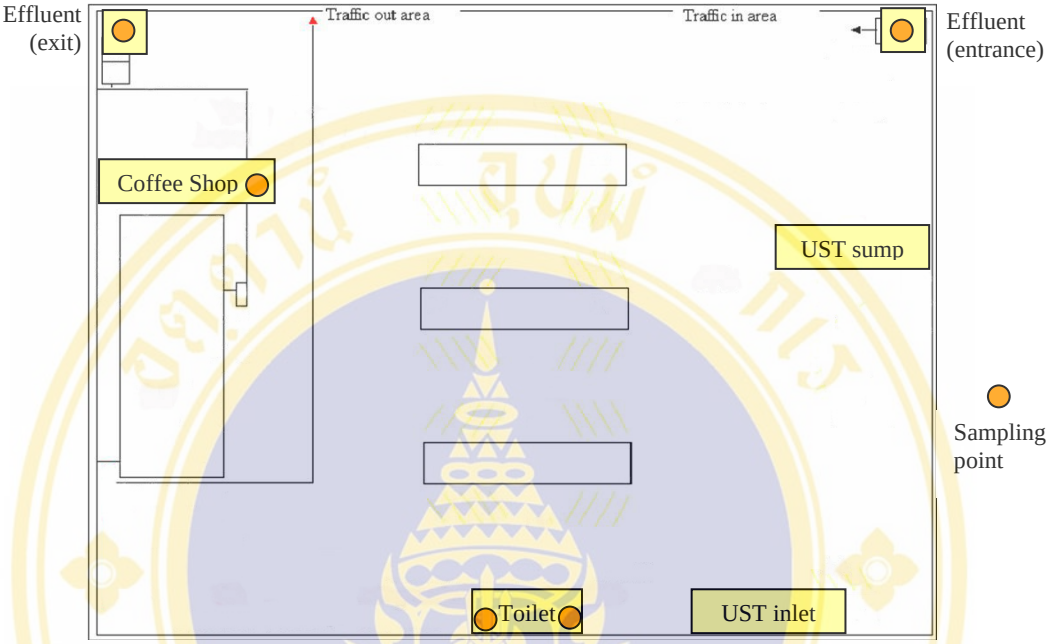

Figure 4-8: Top view layout of GSB

4.2.1 Gentleman Toilet

Table 4-8: Results of WWQ from gentleman toilet of GSB

Parameters	Day 1	Day 30	
pH	7.2	7.1	
BOD (mg/L)	195	141	-27.7 %
COD (mg/L)	1206	419	-65.3 %
SS (mg/L)	352	72	-79.5 %
FOG (mg/L)	34.2	29.3	-14.3 %

Note: % refers to the percentage of change compared to Day 1

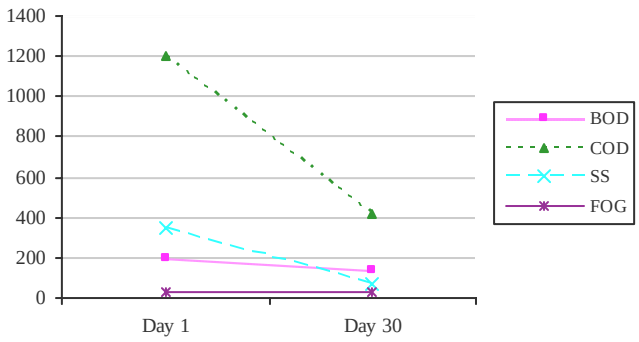

Figure 4-9: Charts of WWQ from gentleman toilet of GSB

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The results of each parameter in gentleman toilet of GSB are shown in Table 4-8 and Figure 4-9. The experiment illustrated that pH values were more or less the same (7.2 to 7.1) in neutral condition and within the standard values of 5.5 to 9 throughout a month of experiment.

The result indicates BOD decreased about 27.7% (195 to 141 mg/L) at Day 30, showing the waste (excrements, urine, etc.) in the septic tank were fully degraded by the microbes. However, this gas station's procedure keeps in control by refraining from using detergents for cleaning and owing to a small number of visitors, longer retention time would enhance degradation of organic matter in the septic tank. This would influence optimum pH condition in the tank greatly. The growth of the biomass would probably be high. It showed that there were microbes in abundance in the septic tanks and significant degradation related to the scheduled application of microbial concentrate was evident. However, the appearance of COD values were sharply decreased about 65.3% (1206 to 419 mg/L) at Day 30, showing there was high biodegradability in septic tank. As low visits cause less amount of floating excrements that would enhance the remediation process. Also, The SS were sharply decreased up to 79.5% (352 to 72 mg/L) during a month, owing to a significant number of biomass (microbes) was able to remediate unclean suspended solids, at which time the organic matters have been largely remediated or oxidized.

It was noticed that most of parameters were significantly decreased about 14.3% (34.2 to 29.3 mg/L). In comparison with the other parameters (BOD, COD, SS), it is evident that the microbes are not able to remediate impenetrable fat or greases at ambient temperatures and conditions. The human excrements contain undigested organic matter, microbes degrade organic matter found in larger molecules to smaller molecules, and some of these fatty molecules were oxidized to fatty acid. Longer retention time to degrade the organic matters would be imperative when microbes attempt to access heavy impenetrable molecules with undefined content.

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4.2.2 Lady Toilet

Table 4-9: Results of WWQ from lady toilet of GSB

Parameters	Day 1	Day 30	
pH	7.8	7.8	
BOD (mg/L)	148	87	-41.2 %
COD (mg/L)	302	165	-45.4 %
SS (mg/L)	54	17	-68.5 %
FOG (mg/L)	20.6	6.6	-68.0 %

Note: % refers to the percentage of change compared to Day 1

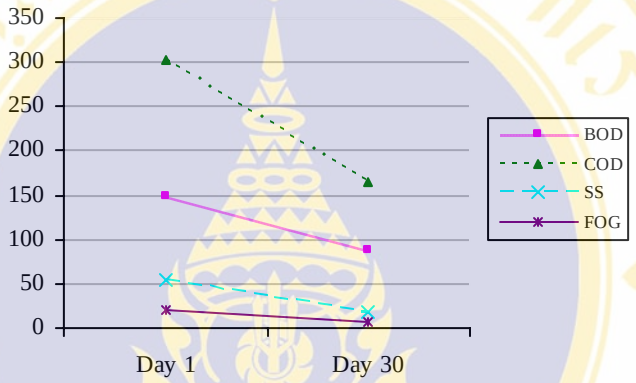

Figure 4-10: Charts of WWQ from lady toilet of GSB

As the results shown in Table 4-9 and Figure 4-10, the pH values were almost neutral at 7.8 and never been changed throughout a month. Apparently, the pH condition in septic tank was close to gentleman toilet in the standard range of 5.5 to 9.

The result of BOD showed that they were significantly decreased about 41.2% (148 to 87 mg/L), and slightly higher (app.10%) than the gentleman toilet. It was noticed during a month that not only BOD decreasing but most of parameters of COD, SS and FOG are also significantly decreased up to 45.4% (302 to 165 mg/L), 68.5% (54 to 17 mg/L) and 68% (20.6 to 6.6 mg/L) respectively. Reasonably, there was high biodegradability taking place in the septic tank. This was evident to most of the waste (excrements, urine, etc.) that completely degraded by microbes in relation to the scheduled application of microbial concentrate. However, the appearance of FOG decreasing was a lot higher than gentleman toilet because of less accumulated excrements.

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4.2.3 Coffee Shop

Table 4-10: Results of WWQ from coffee shop of GSB

Parameters	Day 1	Day 30	
pH	4.9	5.2	
BOD (mg/L)	1117	564	-49.5 %
COD (mg/L)	2231	764	-65.8 %
SS (mg/L)	364	116	-68.1 %
FOG (mg/L)	151	78	-48.3 %

Note: % refers to the percentageof change compared to Day 1

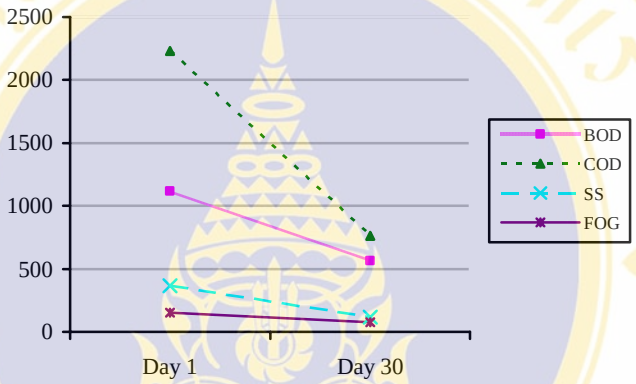

Figure 4-11: Charts of WWQ from coffee shop of GSB

According to the results shown in Table 4-10 and Figure 4-11, the pH value was mostly acid and below the standard range of 5.5-9.0. During a month of experiment the pH value were of 4.9 to 5.2. Although, a little improvement are seen but reaching to the standard range are also expected.

After a month of experiment, the values of BOD, COD, SS and FOG were decreased about 49.5% (1117 to 564 mg/L), 65.8% (2231 to 764 mg/L), 68.1% (364 to 116 mg/L) and 48.3% (151 to 78 mg/L) respectively. This is due to the short pipeline from coffee kitchen to drainage system (strainer->grease trap tank->open drain) and the fact that this was only a shop for baking and coffee-making, not much grease would be accumulated in the pipeline system. The growth of the biomass was likely to remain high as long as the organic matter constitutes the main input on continuous bases. In addition, it could be seen that most of BOD, COD, SS and FOG values were rather high at the point source, but they were significantly decreased after a month of

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microbes application. Decreasing rate within a month was approximately quite high since 50% up to 70%. However, reaching to the standard level was foreseeable.

4.2.4 Effluent Tank (entrance side)

Table 4-11: Results of WWQ from effluent tank at entrance of GSB

Parameters	Day 1	Day 30	
pH	6.5	6.8	
BOD (mg/L)	13	17	30.8 %
COD (mg/L)	45	45	0.0 %
SS (mg/L)	17	38	123.5 %
FOG (mg/L)	0.2	0.2	0.0 %

Note: % refers to the percentage of change compared to Day 1

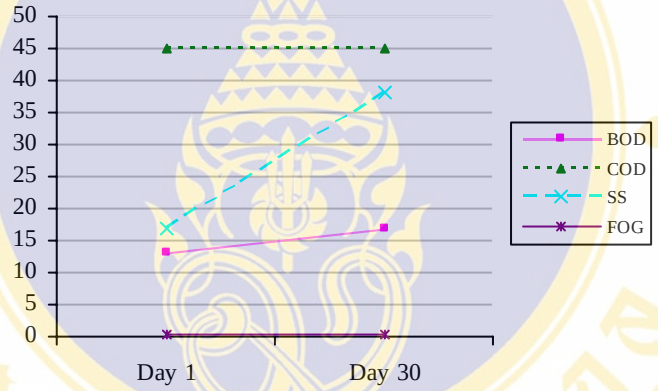

Figure 4-12: Charts of WWQ from effluent tank at entrance of GSB

According to the results in Table 4-11 and Figure 4-12, the results illustrated that pH value were slightly changed between 6.5 and 6.8. from Day 1 to Day 30. These value, however, are within the standard range of 5.5 to 9.

The results of BOD and SS, within a month, were increased about 30.8% (13 to 17 mg/L) and 123.5% (17 to 38 mg/L). It noticed that the SS was despite higher than before but the BOD value was quite less if comparing with the SS value, showing there was still high biomass and the organic matters were mostly degraded with microbes in effluent tank (entrance side). It was important to control other organic matters which able to re-pollute between open drains to effluent tank. In addition, we can see the value of COD and FOG were unchanged. This might be due to the UST (Underground Storage Tank) has been installed at this site; some oil contaminated

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water from the manifold may have leaked out into the open drain. Another activity which was able to generate high organic matter was taking place during service area cleaning. According to the QAS (Quality Assurance System) this area was to be cleaned once every month. The polluted organic runoff was being flushed to the open drain and further to the effluent tank (entrance side). Moreover, there were no microbial application at this side, causing no activities of microbes occur at the effluent tank at this side. However, our suggestion to remediate some oil slick on the water surface in the drip tank at UST manifold, and regularly apply microbial concentrate as preventive action was presented as imperative. It might be claimed that all those uncontrollable change come from this additional effect.

4.2.5 Effluent Tank (exit side)

Table 4-12: Results of WWQ from effluent tank at exit of GSB

Parameters	Day 1	Day 30	%reduction
pH	6.5	6.8	
BOD (mg/L)	109	50	-54.1 %
COD (mg/L)	240	94	-60.8 %
SS (mg/L)	58	35	-39.7 %
FOG (mg/L)	19.4	8.8	-54.6 %

Note: % refers to the percentage of change compared to Day 1

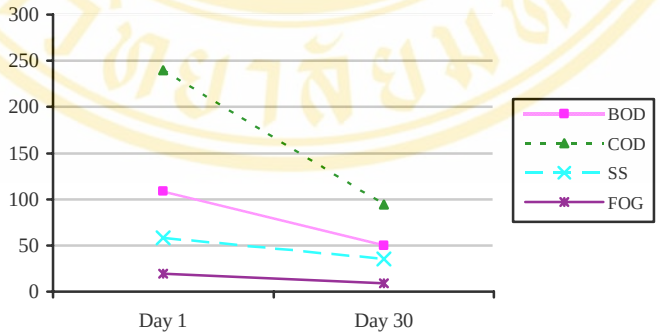

Figure 4-13: Charts of WWQ from effluent tank at exit of GSB

As the results shown in Table 4-12 and Figure 4-13, from Day 1 to Day 30 there are little change of pH value between 6.5 and 6.8. However, they were within the standard range of 5.5 to 9. In addition, we could see during a month that most of parameters, COD BOD SS and FOG, were significantly decreased in parallel about 54.1% (109 to 50 mg/L), 60.8% (240 to 94 mg/L), 39.7% (58 to 35 mg/L) and 54.6% (19.4 to 8.8

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mg/L) respectively. Its results show that there were microbes in abundance in the effluent tank (exit side) and significant degradation related to the scheduled application of microbial concentrate was evident, despite there were many activities at the exit site, such as, toilets, coffee shop. The BOD and COD value are significantly changed in parallel to SS and FOG. As there is no food shop at exit side and there was only a short pipeline in the coffee shop, not much accumulated grease would be presented in the drainage system. These circumstances make high bio-reaction, and easier to benefit wastewater flow satisfactorily to the effluent stage. However, the coffee shop was quite near to the effluent tank (exit), and the wastewater sometimes was re-polluted from this activity prior to discharge to the effluent tank (exit side). It was important to control this at the waste source. In addition, there were some sediment in the bottom of the effluent tank (exit); and this sediment also impacted the wastewater quality once again. However, the public WWS (Wastewater System) level in front of the station should be lower than the level of the effluent tank (exit side), otherwise outside wastewater would flow back and impact the WW at this stage again.

4.2.6 Correlation with Standard Value

According to Thai Standard Regulations, the study acted in accordance with acceptable wastewater standard from gas station as follow:

Parameter	Effluent tank (Entrance)	Effluent tank (Exit)	Standard
BOD mg/L	17	50	20 (domestic wastewater std.)
COD mg/L	45	94	200
SS mg/L	38	35	60
FOG mg/L	0.2	8.8	15

With respect to the above results, it was observed that the WW parameters at effluent tank (entrance side) were not improved owing to the UST (Underground Storage Tank) manifold leaking to the open drain and high levels of organic matter was flushed from the service area during cleaning, the polluted organic runoff was being flushed to the open drain and further to the effluent tank (entrance side). As there were no activities at the entrance side, the amount of microbes might be insufficient for polluted organic matters in the effluent tank. However, our suggestion to remediate oil slick on the water surface in the drip tank at UST manifold, the application procedure

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of microbial concentrate must be considered imperative action. Consequently, some parameters (COD, FOG) were quite firm, even if the biomass at the effluent tank (entrance side) was low.

At effluent tank, (exit side), the wastewater parameters were significantly decreased over 50% during a month. Owing to no food shop at exit side and the short pipeline in the coffee shop, there were not much accumulated grease in the drainage system. These circumstances maintain high bio-reaction, and makes it easier to treat wastewater during the “in-house flow” to the effluent stage. Reaching to the standard level of all parameter was quite promising if the microbe is further applied.

Nevertheless, it was noticed that the retention time of wastewater (open drain between waste sources to the effluent tank) maintains higher degradation of organic matter. It was important to control and regularly clean the open drain or remove sludge/SS which contaminate or block the wastewater flow.

4.3 Gas Station C (GSC)

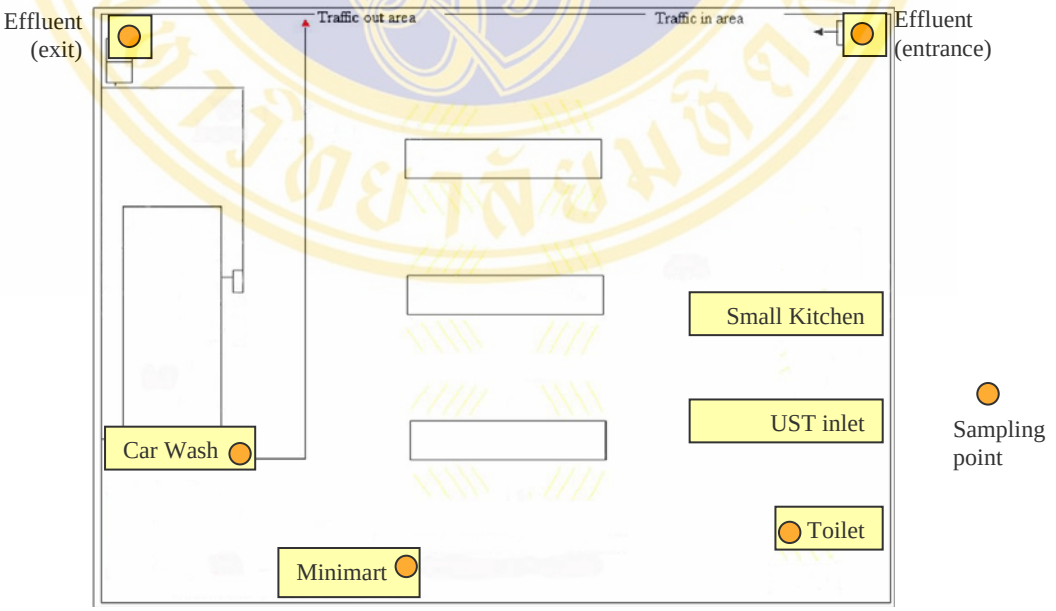

Figure 4-14: Top view layout of GSC

GSC’s activity could be described as low customer service levels as only toilet and minimart and car wash are presented. In addition, there wer also UST inlet and

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office's small kitchen at the entrance side. The data from 5 parameters were collected 2 times within a period of 30 days, namely at the date of 1, and 30 from the beginning date. The results of the tests from GSB are presented in Table 4-8 to 4-12 and Figure 4-9 to 4-13. It can be noted that

4.3.1 Toilet (gentleman and lady)

Table 4-13: Results of WWQ from toilet of GSC

Parameters	Day 1	Day 30	
pH	8.1	8.2	1.2 %
BOD (mg/L)	225	183	-18.7 %
COD (mg/L)	604	859	42.2 %
SS (mg/L)	164	256	56.1 %
FOG (mg/L)	44	51.3	16.6 %

Note: % refers to the percentageof change compared to Day 1

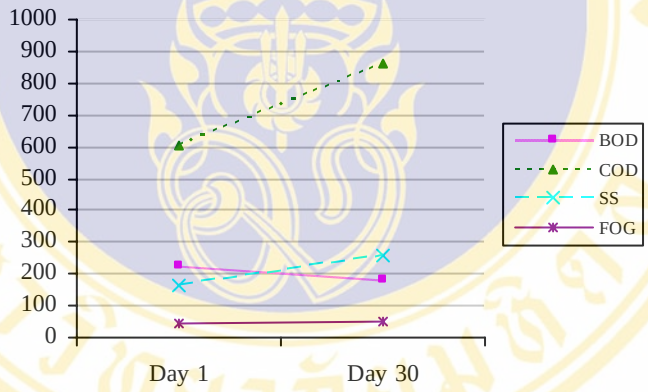

Figure 4-15: Charts of WWQ from toilet of GSC

As the results shown in Table 4-13 and Figure 4-15, the pH value were rather steady at 8.1 - 8.2. Although these results showed the alkaline condition of wastewater but they still be within the standard range of 5.5 to 9.

The result indicated that most of parameters, COD, SS and FOG, have increased except for BOD which were slightly decreased about 18.7% (225 to 183 mg/L) within a month. However, it was observed that the waste (excrement, urine, etc.) in the septic tank were fully degraded by the microbes. This might be due to large number of visits, and shortened retention time impacted degradation of organic matter in the septic tank. The gas station's procedure may get out of control by using detergents for cleaning.

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This will influence pH condition in the tank greatly. Bacillus strains are not able degrade organic matters effectively in high pH environment. The growth of the biomass and mortality was also likely to suffer according to the mentioned impact by phosphate pollutants etc.. The amount of excrements have accumulated on the water surface and at the bottom of the septic tank, causing microbes were capable of remediating organic matter in the water column only. In addition, this septic tank being designed to enhance an aerobic condition, using submersible pump to aerate oxygen in septic tank, there were *higher biomass present in the septic tank (all the time) correlated with passive systems.*

The result indicates that the COD, SS and FOG value were significantly increased about 42.2% (604 to 859 mg/L), 56.1% (164 to 256 mg/L) and 16.6% (44 to 51.3 mg/L) respectively. The deviation of COD is due to biochemical reactions upon adding microbial concentrate. One consequence of using detergent for a long time, is the remains of detergents with high pH or high COD values present in the septic tank. The COD value in the initial period did not decrease, but will gradually decrease after Day 30 (same as GSA). The septic pH condition became less important owing to daily replenishment of microbial concentrate to the septic tank, which gradually turned the condition into manageable treatment. In case of SS (Suspended solids), it showed that there were high suspend matter in the septic tank derived from efficient bio-reaction, at which time the organic matters have been largely remediated or oxidized. The bio-reaction converted a significant amount of waste into more liquefied consistency (easier mixable with water) after cleaning sticky HC components, de facto, generating “purified” suspended solid. It showed that a significant number of the biomass (microbes) was able to remediate unclean suspended solids which generated during the first period. Longer retention time to degrade the organic matters will be imperative when microbes attempt to access heavy impenetrable molecules with an undefined content. For FOG or Grease & Oil, it was evident that the microbes were not able to remediate impenetrable fat or grease at ambient temperatures and conditions. According to its nature, human excrements contain undigested organic matter, such as, carbohydrates, proteins or molecules with high fat content. Basically, microbes degrade organic matter found in larger molecules to smaller molecules, and some of

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these fatty molecules were oxidized to fatty acid. A significant enzymatic process may account for the success of the microbes' ability to access the molecules. The significance of the enzymatic process will increase with the course of the remediation process – particularly in confined spaces, with limited runoff as described in this example.

4.3.2 Minimart

Table 4-14: Results of WWQ from minimart of GSC

Parameters	Day 1	Day 30	%reduction
pH	4.7	5.3	
BOD (mg/L)	800	470	-41.3 %
COD (mg/L)	1312	791	-39.7 %
SS (mg/L)	149	198	32.9 %
FOG (mg/L)	530	161	-69.6 %

Note: % refers to the percentage of change compared to Day 1

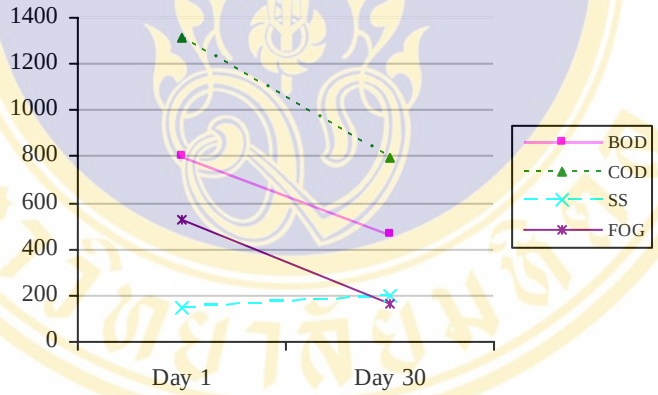

Figure 4-16: Charts of WWQ from minimart of GSC

According to Table 4-14 and Figure 4-16, the pH value was rather acid condition changing between 4.7 and 5.3., which was lower than the standard range of 5.5 to 9. This condition caused by heavy pollution of static water i.e. low flow from the pollution point. In addition, the result showed that after a month of microbe application the BOD, COD and FOG value were significantly decreased about 41.3% (800 to 470 mg/L), 39.7% (1312 to 791 mg/L) and 69.6% (530 to 161 mg/L) respectively. Owing to the short pipeline from kitchen to drainage system (strainer-> grease trap tank -> open drain) and the mini-mart food mostly take home, not much

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grease accumulated in the pipeline system. Consequently, the BOD, COD and FOG value decreased significantly owing to high bio-reaction. The growth of the biomass was likely to remain high as long as the organic matters constitutes the main input on continuous bases. In addition, enzymatic effects will dilute grease and fat significantly and this action would sometimes be gauged as increased levels of FOG (except not much accumulated greases). Subsequently, the microbial remediation would increase until there was a balance between available food vs. water with enough DO.

However, the results of SS were increased about 32.9% (149 to 198 mg/L), showing high suspended solids in the drainage (pipeline, grease trap tank) from high bio-reaction. Most organic matters have been bio-remediated, thus generating more suspended solids as a lateral effect. The retention time might be insufficient to degrade more organic matter as a result of the system overload i.e. waste accumulation above water level etc.

4.3.3 Effluent Tank (entrance side)

Table 4-15: Results of WWQ from effluent tank at entrance of GSC

Parameters	Day 1	Day 30	%reduction
pH	8.1	7.9	-2.5 %
BOD (mg/L)	79	97	22.8 %
COD (mg/L)	338	525	55.3 %
SS (mg/L)	182	536	194.5 %
FOG (mg/L)	35.5	40	12.7 %

Note: % refers to the percentage of change compared to Day 1

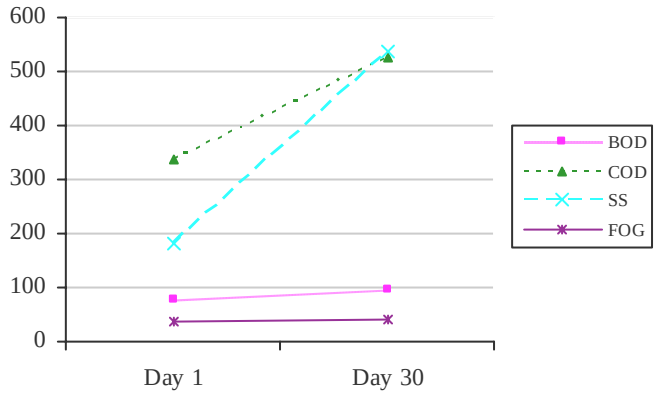

Figure 4-17: Charts of WWQ from effluent tank at entrance of GSC

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As the results shown in Table 4-15 and Figure 4-17, the pH value changed between 8.1 and 7.9 in which still be in the standard range of 5.5 to 9. In addition, the results also showed that all parameters of BOD, COD, SS and FOG value were significantly increased at Day 30 about 22.8% (79 to 97 mg/L), 55.3% (338 to 525 mg/L), about 194.5% (182 to 536 mg/L) and 12.7% (35.5 to 40 mg/L) respectively. According to toilets drainage, probable discharge to the effluent stage (entrance side), and as the USTs (Underground Storage Tank) have been installed at this side and some oil leaked from the manifold into the open drain. In addition, there was a small kitchen for station officers adjacent to the effluent tank (entrance side), which discharge waste directly to the WWS. Toilets were the only waste sources with replenishment of microbial concentrate feeding the septic tanks. Consequently, the small amount of microbes found in the septic tank runoff was insufficient to degrade the organic matter already flushed into the effluent tank (entrance side).

It was recommended that the waste source should be located far from the effluent stage as much as possible. It was noted that the additional retention time of wastewater flow (open drain between grease trap tanks, septic tanks or UST inlet to effluent tank) increase the microbial remediation of organic matter and settlement ability significantly.

4.3.4 Effluent Tank (exit side)

Table 4-16: Results of WWQ from Effluent tank at exit of GSC

Parameters	Day 1	Day 30	
pH	7.5	7.3	-2.7 %
BOD (mg/L)	80	20	-75.0 %
COD (mg/L)	173	133	-23.1 %
SS (mg/L)	117	30	-74.4 %
FOG (mg/L)	12	13	8.3 %

Note: % refers to the percentage of change compared to Day 1

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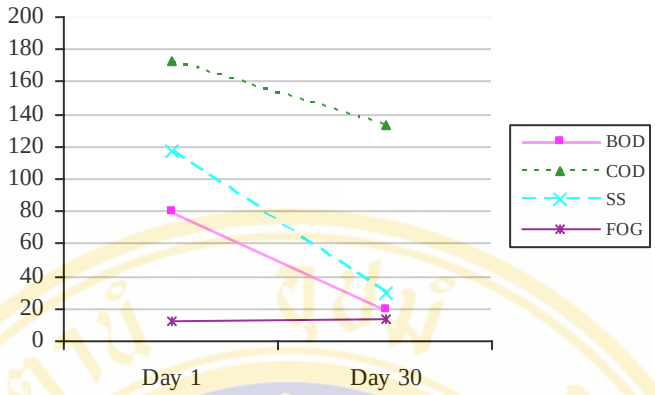

Figure 4-18: Charts of WWQ from effluent tank at exit of GSC

According to Table 4-16 and Figure 4-18, the pH value were varied between 7.5 to 7.3 within the standard range of 5.5 to 9. In addition, the result showed that the BOD, COD, SS and FOG were significantly decreased at Day 30 about 75% (80 to 20 mg/L), 23.1% (173 to 133 mg/L), 74.4% (117 to 30 mg/L), and 8.3% (12 to 13 mg/L) respectively. It could be seen that although some problems occurred to this site but all parameters are finally reached to the WWQ (Wastewater Quality) standard of gas station, owing to some activities at the exit side, such as, minimart, lube (also replenishes microbes instead of detergent for general cleaning), the BOD were significantly changed in parallel with the other parameters. However, some sediment in the bottom of the effluent tank (exit), which may also impact the wastewater quality once again.

However, it was observed that the COD and FOG were slightly decreased owing to restraints from the lube oil pit adjacent to effluent tank (exit side) and the associated lube oil services including car wash. It was, therefore, recommended that the waste source, such as, lube oil or car wash service, should be located as far from the effluent stage as possible. In addition, it was noted that the additional retention time of the wastewater flow (open drain between grease trap tanks, septic tanks or UST inlet to effluent tank) increased the microbial remediation of organic matter and settlement ability significantly.

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4.3.5 Correlation with Standard Value

According to Thai Standard Regulations, the study acted in accordance with acceptable wastewater standard from gas station as follow:

Parameter	Effluent tank (Entrance)	Effluent tank (Exit)	Standard
BOD mg/L	97	20	20 (domestic wastewater std.)
COD mg/L	525	133	200
SS mg/L	536	30	60
FOG mg/L	40	13	15

With respect to the above results, the wastewater parameters were significantly increased at the effluent tank (entrance side), owing to toilets drainage probable discharge to the effluent drain (entrance side), and that the UST (Underground Storage Tank) have been installed at this side and some oil contaminated water from the manifold may have leaked out into the open drain. Together with additional wastewater from small kitchen (for station officers) adjacent to the effluent tank flow into the open drain which discharge wastewater directly into the effluent tank (entrance side). Toilets were the only waste source (toilets) with replenishment of microbial concentrate to the septic tank. Consequently, the small amount of runoff containing free microbes would be insufficient to quickly degrade organic matter at the effluent tank (entrance side).

At the effluent (exit side), the wastewater parameters were significantly decreased during a month causing all parameters at the effluent stage declined and reach to standard level, owing to no food shop at exit side and the short pipeline in the minimart, causing low accumulated grease can be found in the drainage system. These circumstances make high bio-reaction, and easier to treat wastewater en route the effluent stage. Nevertheless, it was noticed that the longer retention time of wastewater (open drain between waste sources to the effluent tank) make higher degradation of organic matter. It was important to control and regularly clean open drain or remove some waste which contaminated or blocked the wastewater flow. It was, therefore, recommended that the waste source, such as, lube oil or car wash service, should be located as far as possible from the effluent stage. It was noted that the additional retention time of the wastewater flow (open drain between grease trap tanks, septic

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tanks or UST inlet to effluent tank) increase the microbial remediation of organic matter and settlement ability significantly.

4.4 Gas Station D (GSD)

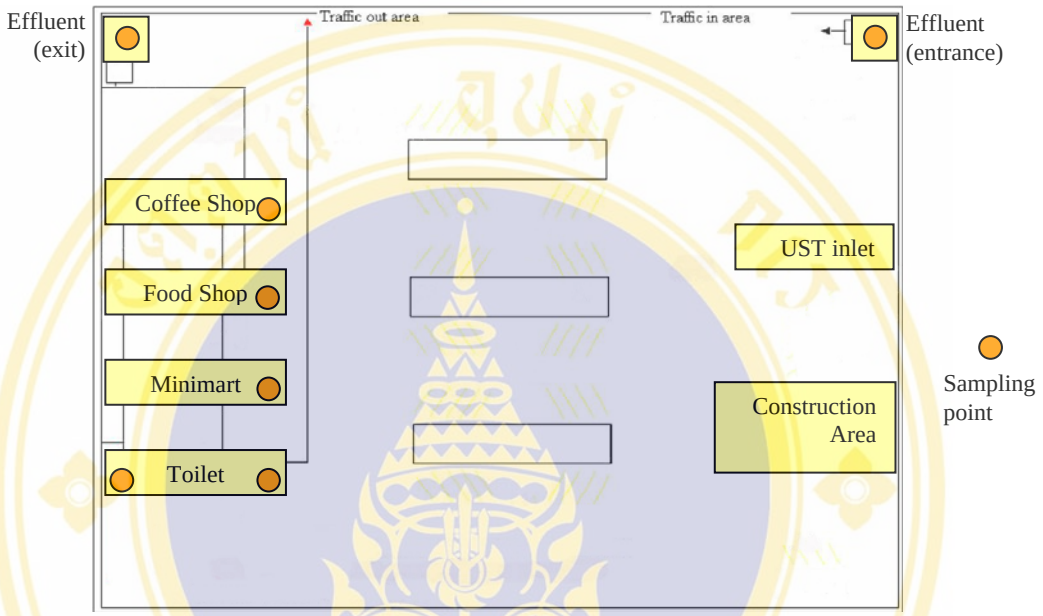

Figure 4-19: Top view layout of GSD

GSD's activity could be described as full customer service level except oil change (Lube). In addition, most of activities, such toilet minimart, foodshop, and coffee shop, are in the exit side except for UST inlet. At this station, the data were collected from 7 parameters at twice times within a period of 30 days, namely at the date of 1 and 30 from the date of commencement. The results of the tests from GSD were presented in Table 4-17 to 4-23 and Figure 4-20 to 4-26.

4.4.1 Gentleman Toilet

Table 4-17: Results of WWQ from gentleman toilet of GSD

Parameters	Day 1	Day 30	
pH	8.8	7.9	
BOD (mg/L)	825	621	-24.7 %
COD (mg/L)	1754	1206	-31.2 %
SS (mg/L)	268	120	-55.2 %
FOG (mg/L)	44	213	384.1%

Note: % refers to the percentage of change compared to Day 1

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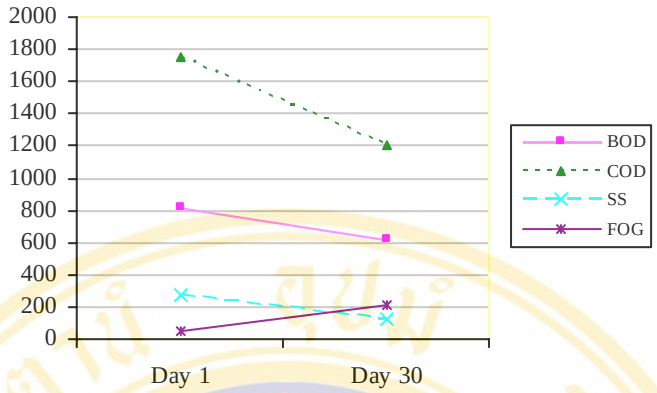

Figure 4-20: Charts of WWQ from gentleman toilet of GSD

As shown in Table 4-17 and Figure 20, the pH value were varied between from 8.8 to 7.9 within the standard range of 5.5 to 9. In addition, the results of BOD, COD and FOG were decreased about 24.7% (825 to 621 mg/L), 31.2% (1754 to 1206 mg/L) and 55.2% (268 to 120 mg/L) respectively. It was observed that the waste (excrements, urine, etc.) in the septic tank were fully degraded by the microbes. The organic matter in septic tanks usually degrades by microbes, which already existed in the tank. However, the procedure presented at this gas station was sufficient for controlling the parameters if/when no conventional detergent for cleaning was being used. Owing to low occupation rate (low number of visits), longer retention time would enhance degradation of organic matter in the septic tank, which would influence pH condition in the tank greatly. The growth of the biomass was likely to remain high. It was evident that there were microbes in abundance in the septic tanks and significant degradation related to the scheduled application of microbial concentrate. It also showed that a significant biomass (microbes) was able to remediate unclean suspended solids, at which time the organic matters have been largely remediated or oxidized. One of consequence, using detergent for a long time, there was a high remaining pH or high COD values in the septic tank. The COD value in the initial period did not decrease, but would gradually decrease until Day 30 (like as GSA). The septic pH condition became less important owing to daily replenishment of microbial concentrate to the septic tank. Accordingly, the COD value decreased slightly at Day 30. However, it was observed that the growth of the biomass was likely to remain high in the septic tank.

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Differently, FOG were highly increased at Day 30 about 384.1% (44 to 213 mg/L). It was evident that the microbes are not able to remediate impenetrable fat or greases at ambient temperatures and conditions. Oxidation would be low as well. The human excrements contain undigested organic matter, whereas, microbes degrade organic matter found in larger molecules to smaller molecules, and some of these fatty molecules were oxidized to fatty acid. Longer retention time would be imperative to successfully degrade organic matter when microbes attempted to access heavy impenetrable molecules with undefined content. The significance of the enzymatic process would increase during the course of the remediation process – particularly in confined spaces, with limited runoff as described in this example.

4.4.2 Lady Toilet

Table 4-18: Results of WWQ from lady toilet of GSD

Parameters	Day 1	Day 30	
pH	7.3	7.2	
BOD (mg/L)	173	84	-51.4 %
COD (mg/L)	1130	276	-75.6 %
SS (mg/L)	340	72	-78.8 %
FOG (mg/L)	37.5	16.6	-55.7 %

Note: % refers to the percentageof change compared to Day 1

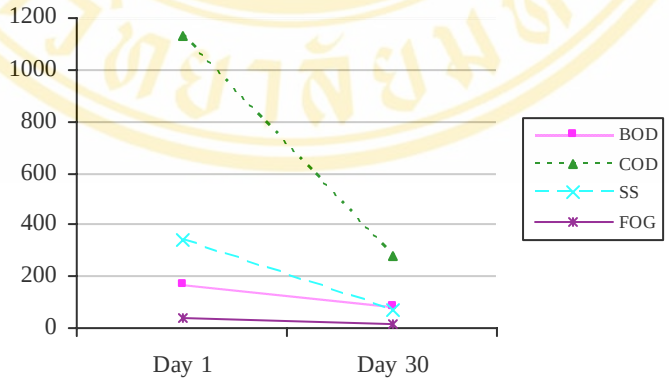

Figure 4-21: Charts of WWQ from food shop of GSD

As the results shown in Table 4-18 and Figure 4-21, the pH value of 7.3 to 7.2 were varied within the standard range of 5.5 to 9. In addition, the results of BOD, COD, SS and FOG were significantly decreased at Day 30 about 51.4% (173 to 84 mg/L), 75.6% (1130 to 276 mg/L), 78.8% (340 to 72 mg/L), and 55.7% (37.5 to 16.6 mg/L)

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respectively. Owing to low occupation rate (low number of visits), longer retention time would enhance degradation of organic matter in the septic tank, which would influence pH condition in the tank greatly. Like the gentleman toilet, it also showed that most of the waste (excrements, urine, etc.) in the septic tank were completely degraded by microbes. The growth of the biomass was likely to high and there were microbes in abundance in the septic tanks and significant degradation related to the scheduled application of microbial concentrate is evident. In addition, it could be seen that a significant biomass (total number of microbes) was able to remediate unclean suspended solids, at which time the organic matters have been largely remediated and/or oxidized. Like the gentleman toilet, suspended solid are completely degradable. It was noticed that the SS values of the lady toilet was less than gentleman toilet, and the decreasing percentage was higher than in the gentleman toilet.

In case of FOG, unlike the gentleman toilet at which the FOG value increased, owing to pipeline repairing construction at lady Toilet at that time. Consequently, there were no excrement and/or microbes in lady septic tank at that time. It was evident that the biomass was sufficient for degradation of all organic matter in septic tank.

4.4.3 Food Shop

Table 4-19: Results of WWQ from food shop of GSD

Parameters	Day 1	Day 30	
pH	5.6	5	
BOD (mg/L)	790	474	-40.0 %
COD (mg/L)	1576	675	-57.2 %
SS (mg/L)	450	172	-61.8 %
FOG (mg/L)	173	202	16.8 %

Note: % refers to the percentage of change compared to Day 1

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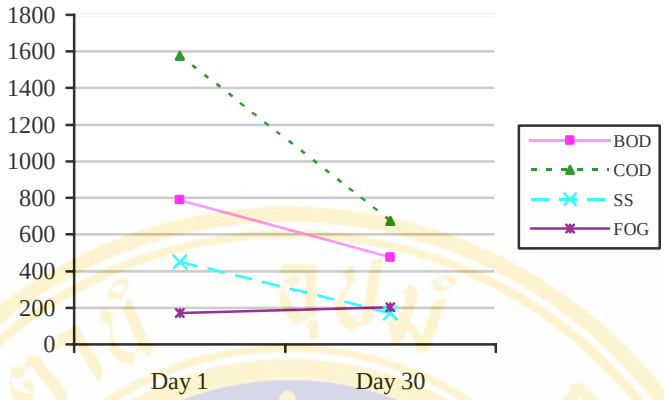

Figure 4-22: Charts of WWQ from food shop of GSD

As shown in Table 4-19 and Figure 4-22, the pH value were varied between 5.6 to 5 showing the acidic condition and were very close to the standard range of 5.5 to 9. In addition, after a month the value of BOD, COD and SS were decreased significantly about 40% (790 to 474 mg/L), 57.2% (1576 to 675 mg/L) and 61.8% (450 to 172 mg/L) respectively. Owing to the short pipeline from kitchen to the drainage system (strainer-> grease trap tank -> open drain), there were not much accumulated grease in pipeline system. Consequently, the BOD value decreased significantly after a month owing to bio-reaction. The growth of the biomass is likely to remain high as long as the organic matters constitute the main input/constituent on continuous bases. It was also evident that the microbes are in control of the COD input which continually emerged from high service (occupation) rates.

The result showed that the COD value were decreased significantly at Day 30 about 57.2% (1576 to 675 mg/L). The COD also decreased parallel with BOD. There were high levels of biomass in the pipeline and grease trap tank and it was evident that the microbes are in control of the COD input which continually emerged from high service (occupation) rates.

Unlike above parameters, the FOG value were slightly increased at Day 30, due to some accumulated grease was subject to oxidation and subsequent remediation by the microbes. The microbes degrade organic matter found in larger molecules to smaller molecules, and some of the fatty molecules and grease have been oxidized to fatty

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acid. Significant enzymatic action may account for the success of the microbes' ability to access the molecules. The significance of the enzymatic process will increase with the course of the remediation process. Enzymatic effects would dilute grease and fat significantly and this action would be gauged as increased levels of FOG. Subsequently, the microbial remediation would increase until there was a balance between available food vs. water with applicable DO.

4.4.4 Minimart

Table 4-20: Results of WWQ from minimart of GSD

Parameters	Day 1	Day 30	
pH	4	4.6	
BOD (mg/L)	4366	1427	-67.3 %
COD (mg/L)	7432	2222	-70.1 %
SS (mg/L)	1392	233	-83.3 %
FOG (mg/L)	304	126	-58.6 %

Note: % refers to the percentage of change compared to Day 1

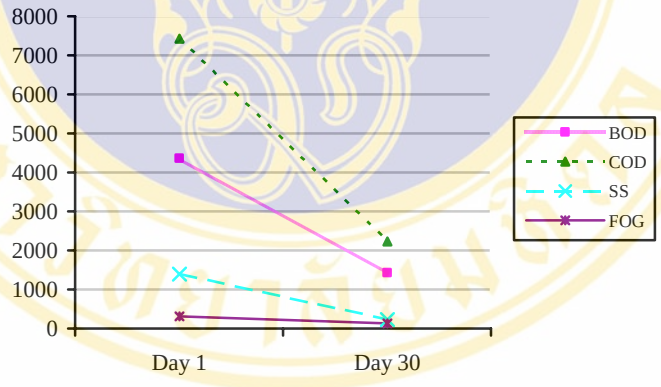

Figure 4-23: Charts of WWQ from minimart of GSD

According to Table 4-20 and Figure 4-23, the pH value were varied between 4 to 4.6 showing the high acid condition of wastewater which lower the standard range of 5.5 to 9. In addition, the value of BOD were decreased significantly at Day 30 about 67.3% (4366 to 1427 mg/L), 70.1 %(7432 to 2222 mg/L), 83.3% (1392 to 233 mg/L) and 58.6% (304 to 126 mg/L) respectively. Owing to the short pipeline from kitchen to drainage system (strainer-> grease trap tank -> open drain) and the minimart food is of a type of "take home," not much grease would accumulated in the pipeline system. Consequently, the BOD, COD and FOG were significantly decreased from bio-

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reaction. The growth of the biomass was likely to remain high as long as the organic matter constitutes the main input on continuous bases. In case of SS, highly degradation was appeared, owing to the large grease trap tank complying with the ISO standard (this minimart had already ISO 14001 achievement), the retention time is adapted to degrade the current organic disposal. Consequently, the microbial remediation of organic SS (Coated core) in the grease trap tank gained momentum and decreased significantly.

4.4.5 Coffee Shop

Table 4-21: Results of WWQ from coffee shop of GSD

Parameters	Day 1	Day 30	
pH	4.65	4.3	
BOD (mg/L)	681	411	-39.6%
COD (mg/L)	1143	667	-41.6%
SS (mg/L)	126	60	-52.4%
FOG (mg/L)	79.3	38.6	-51.3%

Note: % refers to the percentage of change compared to Day 1

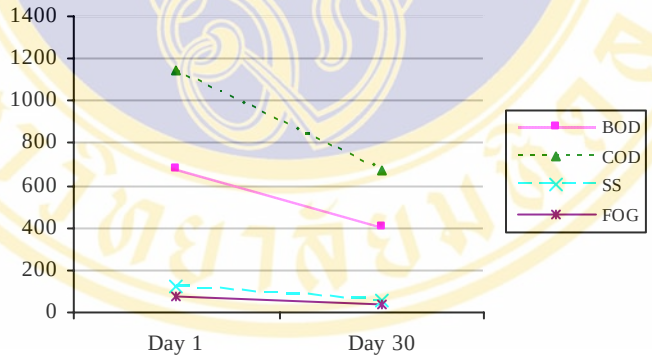

Figure 4-24: Charts of WWQ from coffee shop of GSD

As the results shown in Table 4-21 and Figure 4-24, the pH value were varied between 4.65 to 4.3 showing acidic condition with lower the standard range of 5.5 to 9. In addition, the results of BOD, COD, SS and FOG, they were decreased significantly at 39.6% (681 to 411 mg/L), 41.6% (1143 to 667 mg/L), 52.4% (126 to 60 mg/L) and 51.3% (79.3 to 38.6 mg/L) respectively. Owing to the short pipeline from coffee kitchen to drainage system(strainer->grease trap tank -> open drain) this coffee shop was not a full restaurant, only baking and coffee-making, not much grease would accumulated in the pipeline system. Consequently, the BOD value decreased

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significantly due to bio-reaction. The growth of the biomass was likely to remain high as long as the organic matter constitutes the main input on continuous bases. In addition, high level of biomass in the pipeline and grease trap tank that cause high bio-reaction. Because most of the organic matter was being degraded and/or oxidized and the bio-reaction converted accumulated grease into liquid, which generates more suspended solids. However, this coffee shop has shorter pipeline, there was not much grease in pipeline system and limited additional activity confined to bakeries & coffee, high bio-reaction made significant decrease of the COD value. Also, the SS and FOG values were decreased significantly. (SS cleaning = Removing coating, SS core may be sand)

4.4.6 Effluent Tank (entrance side)

Table 4-22: Results of WWQ from effluent tank at entrance of GSD

Parameters	Day 1	Day 30	
pH	6.8	7.2	
BOD (mg/L)	29	53	82.8
COD (mg/L)	151	148	-2.0
SS (mg/L)	36	98	172.2
FOG (mg/L)	6.8	22.3	227.9

Note: % refers to the percentage of change compared to Day 1

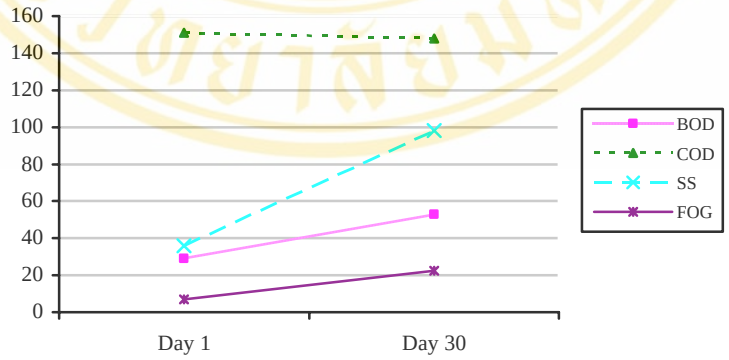

Figure 4-25: Charts of WWQ from effluent tank at entrance of GSD

As the results presented in Table 4-22 and Figure 4-25, the pH value were varied from 6.8 to 7.2, showing neutral condition within the standard range of 5.5 to 9. In case of other parameters it seem to be no effect of the microbe, BOD SS and FOG were increased significantly at Day 30 about 82.8% (29 to 53 mg/L), 172% (36 to 98 mg/L), and 227.9% (6.8 to 22.3 mg/L) respectively, except for COD value only little change

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of 2% (151 to 148 mg/L) was appeared. These appearance might be due to the UST (Underground Storage Tank) has been installed at this side and some oil contaminated water from the manifold may have leaked out into the open drain. Another activity, which is generating high organic deposit was taking place during service area cleaning. According to the QAS this area was to be cleaned once every month. The polluted organic runoff was being flushed to the open drain and further to the effluent tank (entrance side). In addition, there was no any activity at this side that cause no microbial application. Unfortunately, and unexpectedly, some construction work adjacent to this side was going on in that applicable period. (They were constructing some shop while we were running the project.) As a consequence, wastewater was also directly discharged to effluent tank (entrance side). These circumstances made more organic matters re-pollute the open drain and effluent tank (entrance side). As mention above it may be claimed that the COD value were decreased slightly from this effect. Also, the increasing value of SS and FOG may be claimed from the same reason.

4.4.7 Effluent Tank (exit side)

Table 4-23: Results of WWQ from effluent tank at exit of GSD

Parameters	Day 1	Day 30	
pH	7.2	6.8	
BOD (mg/L)	172	341	98.3 %
COD (mg/L)	400	659	64.8 %
SS (mg/L)	118	203	72.0 %
FOG (mg/L)	23	58.6	154.8 %

Note: % refers to the percentage of change compared to Day 1

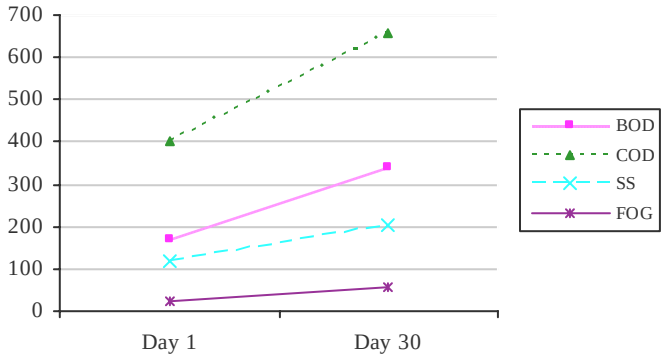

Figure 4-26: Charts of WWQ from effluent tank at exit of GSD

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As the results shown in Table 4-23 and Figure 4-26, the pH value were varied between from 7.2 to 6.8 that close to neutral condition and were within the standard range of 5.5 to 9. In addition, it could be seen that during a month of microbe application the value of BOD, COD, SS and FOG were increased simultaneously about 98.3% (172 to 341 mg/L), 64.8% (400 to 659 mg/L), 72% (118 to 203 mg/L) and 154.8% (23 to 58.6 mg/L) respectively. Absolutely, all parameters from any waste sources changed its trend significantly by increasing instead of decreasing. This might be due to a considerable service area cleaning took place during the forth week according to the QAS auditor who visited the site at that period. The polluted organic runoff was being flushed to the open drain and further to the effluent tank (exit side). Consequently, the retention time of the wastewater (open drain between open drain to effluent tank) was insufficiently to enhance the remediation effect of the WW. Accordingly, the BOD, COD, SS and FOG value reversed and increased relatively to the application of microbes and deviating with the parameters derived from the waste sources as well. Therefore, it was important to control other organic matter, which would pollute between the open drain and the effluent tank.

4.4.8 Correlation with Standard Value

According to Thai Standard Regulations, the study acted in accordance with acceptable wastewater standard from gas station as follow:

Parameter	Effluent tank (Entrance)	Effluent tank (Exit)	Standard
BOD mg/L	53	341	20 (domestic wastewater std.)
COD mg/L	148	659	200
SS mg/L	98	203	60
FOG mg/L	22.3	58.6	15

With respect to the above results, it was observed that the wastewater parameters were increased significantly within a month at both effluent tank (entrance side) and effluent tank (exit side), the wastewater parameters all reversed significantly and increased causing most of parameters could not meet the standard value.

Despite this fact, there are several activities along the exit side, such as, toilets, food shop, coffee shop etc. and the wastewater directly discharged to effluent tank (exit

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side) were not able to sufficiently compensate and provide almost normal microbial activity in the open drain and effluent tank. It could be noted that the retention time of wastewater (open drain between in-front areas to the effluent tank) was insufficient to enhance the remediation of the wastewater at that particular stretch.

Due to regularly control and clean or remove waste in the open drain, which contaminate or block the wastewater flow are very important. It was, therefore, recommended that the waste source should be located as far as possible from the effluent stage. It was also noted that the additional retention time of wastewater flow (open drain between grease trap tanks, septic tanks or UST inlet to effluent tank) increased the microbial remediation of organic matter and settlement of SS significantly.

4.5 Gas Station E (GSE)

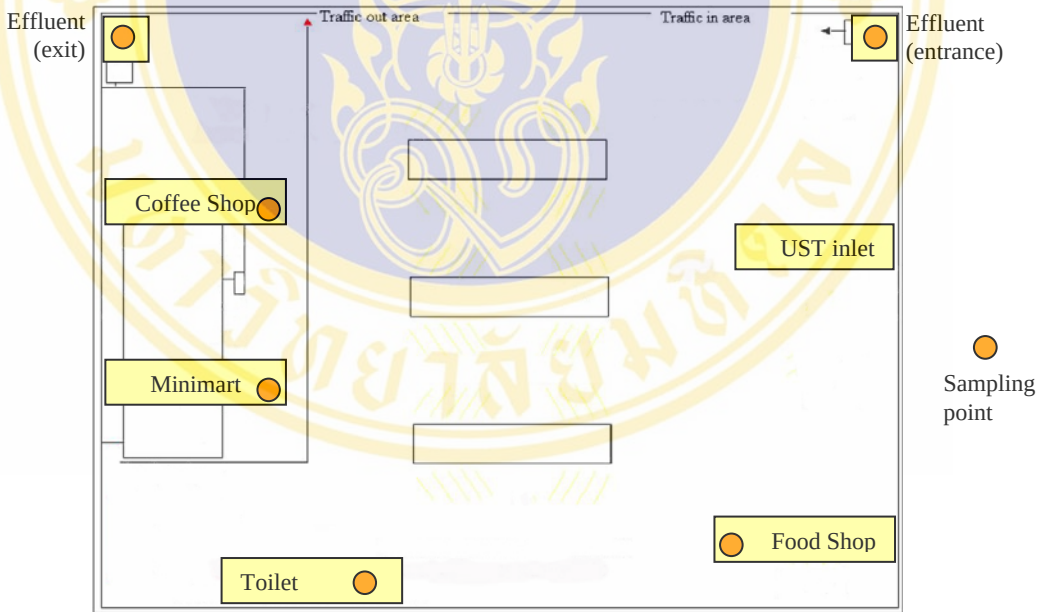

Figure 4-27: Top view layout of GSE

GSE's activities can be described as full customer service level except oil change (Lube). Most of the activities namely toilet, minimart and coffee shop were along the exit site and only foodshop and UST inlet are on another side. The wastewater quality from all six activities were collected 2 times within a period of 30 days, namely at the

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date of 1 and 30 from the beginning date. The results of the tests from GSE are presented in Table 4-24 to 4-29 and Figure 4-23 to 4-28. It could be noted that

4.5.1 Toilet

Table 4-24: Results of WWQ from toilet of GSE

Parameters	Day 1	Day 30	
pH	7.3	7.1	-2.7 %
BOD (mg/L)	152	123	-19.1 %
COD (mg/L)	80	477	496.3 %
SS (mg/L)	200	183	-8.5 %
FOG (mg/L)	22.2	35	57.7 %

Note: % refers to the percentageof change compared to Day 1

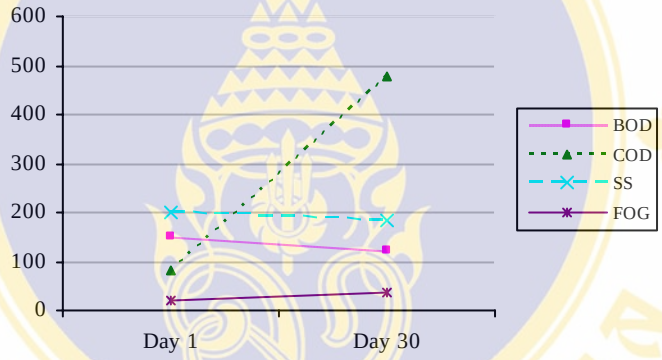

Figure 4-28: Charts of WWQ from toilet of GSE

As the results of wastewater quality (WWQ) obtained from toilet of GSE shown in Table 4-24 and Figure 4-28, the pH value were varied between 7.3 to 7.1 that close to neutral condition and were within the standard range of 5.5 to 9. In addition, the results also indicate that BOD and SS were slightly decreased during a month about 19.1% (152 to 123 mg/L) and 8.5% (200 to 183 mg/L). The organic matter in the septic tanks usually degraded by microbes, which already exist in the tank. But we observed that the waste (excrements, urine, etc.) in the septic tank were fully degraded by the microbes. However, owing to large number of visits, shortened retention time will impact degradation of organic matter in the septic tank. Moreover, the gas station's procedure may get out of control by using detergent for cleaning. This will influence condition in the tank greatly due to Bacillus strains are not able to remediate organic matters effectively in high pH environment. The growth of the biomass and

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mortality is likely to change according to condition as well. Accordingly, the BOD and SS value just slightly decreased at Day 30.

In case of COD and FOG value, which were significantly increased at Day 30 about 496.3% (80 to 477 mg/L) and 57.7% (22.2 to 35 mg/L). The argument being the same as noted above under the BOD comments namely the gas station's procedure may get out of control by using detergent for cleaning. This influence pH condition in the tank greatly. The growth of the biomass and mortality was likely to change according to conditions as well. One consequence of using detergent for a long time, there is a high remaining pH or high COD values in the septic tank. It was noticed that the COD significantly increased, while the BOD slightly decreased, it might claimed that the procedure might get out of control by using detergent for cleaning. However, even there are high pH or high COD condition but there were still applicable biomass in the septic tank and the significant degradation related to the scheduled application of microbial concentrate is evident.

4.5.2 Food Shop

Table 4-25: Results of WWQ from toilet of GSE

Parameters	Day 1	Day 30	
pH	4.95	4.7	-5.1 %
BOD (mg/L)	967	1085	12.2 %
COD (mg/L)	1575	1846	17.2 %
SS (mg/L)	456	805	76.5 %
FOG (mg/L)	98.2	52.5	-46.5 v

Note: % refers to the percentage of change compared to Day 1

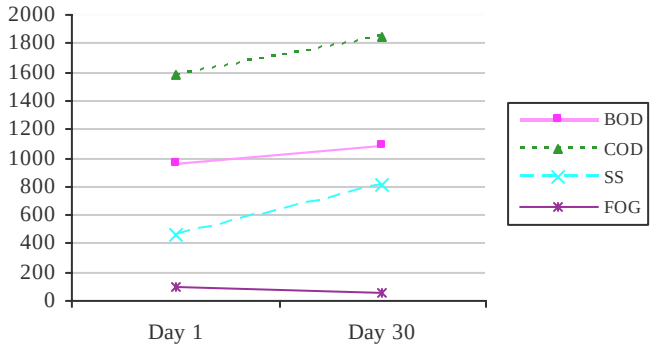

Figure 4-29: Charts of WWQ from food shop of GSE

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According to the results of wastewater quality (WWQ) obtained from food shop of GSE as shown in Table 4-25 and Figure 4-29, the pH value were varied between 7.3 to 7.1 that close to neutral condition and were within the standard range of 5.5 to 9. In addition, the result of BOD and COD were slightly increased at Day 30 about 12.2% (967 to 1085 mg/L) and 17.2% (1575 to 1846 mg/L). Because of the long pipeline from the kitchen to the drainage system (strainer->grease trap tank -> open drain), and that this food shop was full style restaurant in which there are lots of grease accumulated in the pipeline system. The amounts of grease in the pipelines were found to be very high. Accordingly the microbes remediated accumulated grease in pipeline during the first week, and the BOD slightly increased owing to enzymatic impact on the accumulated grease, which in turn the microbes degraded. From the interview with kitchen staff, the release of grease to the grease trap tank in first week appeared to change consistency to a significant liquid form (different from prior observations). This observation was determined a couple weeks after microbial concentrate was applied in the drainage network. The microbial activity was insufficiently high to control BOD input with continuous effluent flow owing to high occupation level. The circumstances make the COD value remain high owing to the chemical agents in drainage, originating from dish washing solution or chemical agents, which were necessary to use in the kitchen.. However, there are high biomass in the pipeline and grease trap tank, and microbes are able to control COD input which continually discharged from high occupation rate.

The result of SS value were increased significantly at Day 30 about 76.5% (456 to 805 mg/L), showing high suspended solids in the drainage (pipeline, grease trap tank) from high microbial remediation. Most organic matters have been bio-remediated making accumulated grease become more liquid, thus generating more suspended solids as a lateral effect. In addition, the retention time may be insufficient to degrade more organic matter as a result of the system overload i.e. waste accumulation above water level etc.

The reversed values of FOG to the others were appeared as they decreased about 46.5% (98.2 to 52.5 mg/L), showing the bio-reaction is high, and that the accumulated grease were subject to degradation and subsequent remediation by the microbes. The

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microbes degrade organic matter found in larger molecules to smaller molecules, and some of the fatty molecules and grease have been oxidized to fatty acid. Significant enzymatic action may account for the success of the microbes ability to access the molecules causing dilution of grease and fat significantly and this action would be gauged as increased levels of FOG. Subsequently, the microbial remediation would increase until there was a balance between available food vs. water with enough DO.

4.5.3 Minimart

Table 4-26: Results of WWQ from minimart of GSE

Parameters	Day 1	Day 30	%reduction
pH	6.2	6.1	-1.6 %
BOD (mg/L)	815	409	-49.8 %
COD (mg/L)	1250	707	-43.4 %
SS (mg/L)	614	270	-56.0 %
FOG (mg/L)	471	376	-20.2 %

Note: % refers to the percentage of change compared to Day 1

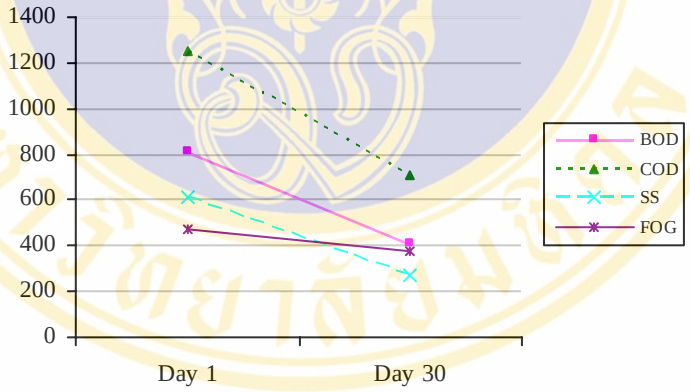

Figure 4-30: Charts of WWQ from minimart of GSE

With regard to the results of wastewater quality (WWQ) obtained from minimart of GSE shown in Table 4-26 and Figure 4-30, the pH value were varied between 6.2 to 6.1 that were slightly acid condition but still be within the standard range of 5.5 to 9. In addition, the result of all parameters (BOD, COD, SS and FOG) were significantly decreased at Day 30 about 49.8% (815 to 409 mg/L), 43.4% (1250 to 707 mg/L), 56% (614 to 270 mg/L) and 20.2% (471 to 376 mg/L) respectively. Owing to the short pipeline from kitchen to drainage system (strainer-> grease trap tank -> open drain) and the mini-mart food is of the type “take home,” not much grease would

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accumulated in the pipeline system. Consequently, the all parameters were significantly decreased after a month from bio-reaction. The growth of the biomass was likely to remain high as long as the organic matter constitutes the main input on continuous bases (constituent/vector).

4.5.4 Coffee Shop

Table 4-27: Results of WWQ from coffee shop of GSE

Parameters	Day 1	Day 30	
pH	6.5	5.1	
BOD (mg/L)	1810	507	-40.6 %
COD (mg/L)	1211	704	-47.8 %
SS (mg/L)	224	126	-54.2 %
FOG (mg/L)	726	403	-53.6 %

Note: % refers to the percentage of change compared to Day 1

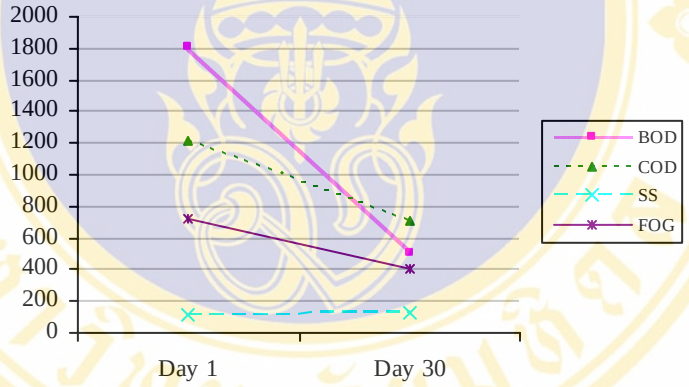

Figure 4-31: Charts of Results from coffee shop of GSE

According to the results of wastewater quality (WWQ) obtained from minimart of GSE as shown in Table 4-27 and Figure 4-31, the pH value were varied between 6.5 to 5.1. that were acidic condition and below the standard range of 5.5 to 9. In addition, the results of BOD, COD, SS, and FOG were decreased significantly at Day 30 about 40.6% (1810 to 507 mg/L), 47.8% (1211 to 704 mg/L), 54.2% (224 to 126 mg/L) and 53.6% (726 to 403 mg/L) respectively. Owing to the short pipeline from the coffee kitchen to the drainage system (strainer->grease trap tank->open drain) and that this coffee shop was not a full restaurant, only baking and coffee-making, not much grease will accumulated in the pipeline system. The growth of the biomass was likely to

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remain high as long as the organic matter constitutes the main input on continuous bases.

4.5.5 Effluent Tank (entrance side)

Table 4-28: Results of WWQ from effluent at entrance of GSE

Parameters	Day 1	Day 30	
pH	6.1	6.0	-1.6 %
BOD (mg/L)	460	337	-26.7 %
COD (mg/L)	883	586	-33.6 %
SS (mg/L)	292	80	-72.6 %
FOG (mg/L)	51.5	33.5	-35.0 %

Note: % refers to the percentage of change compared to Day 1

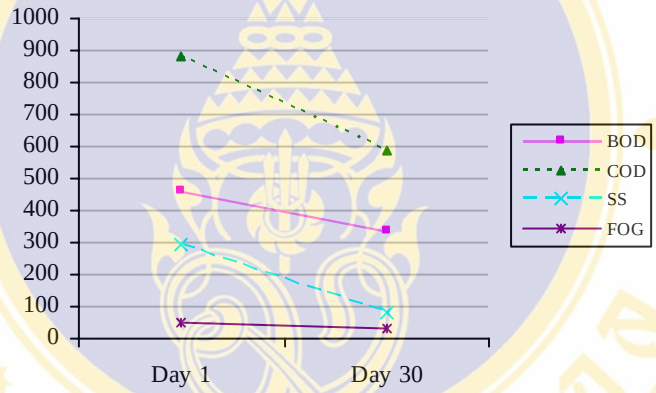

Figure 4-32: Charts of WWQ from effluent at entrance of GSE

According to the results of wastewater quality (WWQ) obtained from effluent tank at the entrance side of GSE as shown in Table 4-28 and Figure 4-32, the pH value were varied between from 6.1 to 6.0 that were within the standard range of 5.5 to 9. In addition, the result of BOD,COD, SS and FOG were significantly decreased at Day 30 about 26.7% (460 to 337 mg/L), 33.6% (883 to 586 mg/L), 72.6% (292 to 80 mg/L) and 35% (51.5 to 33.5 mg/L) respectively. As the food shop drainage probable discharge to the effluent tank (entrance side), most microbes from the coffee shop wastewater flow, mixed with wastewater in open drain and directly discharged to the effluent tank (entrance side). Thus, other wastewater strains mixed with microbes helped to continuously remediate the pollutants en route effluent stage and further. Despite that most of the parameters at the food shop significantly increased, the BOD value at effluent tank (entrance) reversed and decreased. Owing to this food shop

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location was far from the effluent tank (entrance), the retention time is therefore sufficient for organic degradation. It was also noticed that the retention time of the wastewater (open drain between grease trap tanks to effluent tank) was important with respect to degradation of organic matter. However, as the UST (Underground Storage Tank) have been installed at this side and some oil contaminated water from the manifold may have leaked out into the open drain. Another activity which generated high organic matter took place during service area cleaning. According to the QAS this area was to be cleaned once every month. The polluted organic runoff was being flushed to the open drain and further to the effluent tank (entrance side). It may be claimed that the BOD-value slightly decreased at Day 30 (about only 26.7%) from this effect. The COD value also changed in parallel with the BOD value. This impact might originate from oil leaking at UST manifold as explained above. In case of SS and FOG, it showed that there is still high biomass in the effluent tank (entrance side) and longer retention time of wastewater allows the microbes to degrade more organic matter. It is important to control other organic matter which would re-polluted en route open drain to effluent tank.

4.5.6 Effluent Tank (exit side)

Table 4-29: Results of WWQ from effluent tank at exit of GSE

Parameters	Day 1	Day 30	
pH	7.2	7	-2.8 %
BOD (mg/L)	111	41	-63.1 %
COD (mg/L)	453	129	-71.5 %
SS (mg/L)	256	135	-47.3 %
FOG (mg/L)	23.5	8	-66.0 %

Note: % refers to the percentage of change compared to Day 1

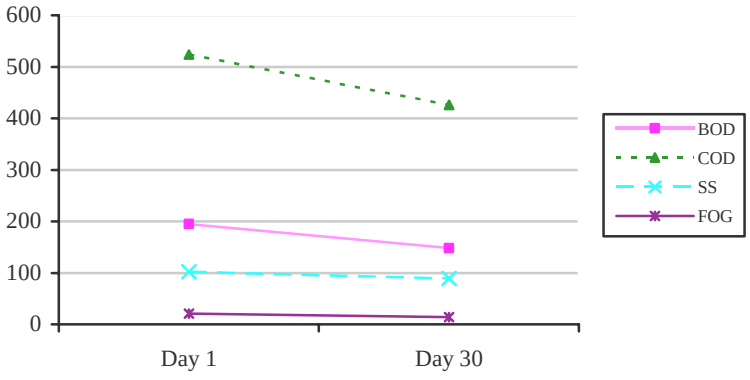

Figure 4-33: Charts of WWQ from effluent tank at exit of GSE

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According to the results of wastewater quality (WWQ) obtained from effluent tank at the exit side of GSE as shown in Table 4-29 and Figure 4-33, the pH value were varied between 7.2 to 7.0 that close to neutral condition and were within the standard range of 5.5 to 9. In addition, the of BOD, COD, SS and FOG were decreased significantly at Day 30 about 63.1% (111 to 41 mg/L), 71.5% (453 to 129 mg/L), 47.3% (256 to 135 mg/L) and 66% (23.5 to 8 mg/L) respectively. This might be due to good control and daily prescribed replenishment of microbial concentrate, and despite many activities at the exit side, such as, toilets, coffee shop, the BOD value significantly correlated with the mentioned activities. Owing to no food shop at exit side and there were no accumulated grease in short pipeline in the coffee shop and in the drainage system can be observed indicating high bio-reaction and cleaning effects of the wastewater flowing towards the effluent stage. Equal to the note of the BOD section, the COD value confirmed that the wastewater from all activities of the area correlated significantly with the mentioned activities. However, the Coffee shop was quite adjacent to the effluent (exit) tank, and the wastewater sometimes re-pollute again from these activities prior to being discharged to the effluent tank (exit side). It was important to control the remediation of the pollution at the waste source in order to prevent this effect. In addition, the sediment at the bottom of the effluent (exit) tank impacts the wastewater quality once again. However, the public WWS level in front of the station should be lower than the level of the effluent tank (exit side), otherwise outside wastewater will flow back and impact the WWS at this stage again, making sampling and tests unreliable. The SS shows that there was high biomass in the effluent tank (exit side) and it was important to control other organic matter, which re-pollutes en route the open drain to the effluent tank. The argument of FOG being the same as noted above under the COD comments, because of the above observation, there was still high biomass in the effluent tank and it was important to contain and limit other organic matter which would pollute in the open drain en route the effluent tank.

4.5.7 Correlation with Standard Value

According to Thai Standard Regulations, the study acted in accordance with applicable wastewater standard for gas stations, which is as follows:

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Parameter	Effluent tank (Entrance)	Effluent tank (Exit)	Standard
BOD mg/L	337	41	20 (domestic wastewater std.)
COD mg/L	586	129	200
SS mg/L	80	135	60
FOG mg/L	33.5	8	15

With respect to the above results, it was observed that the wastewater parameters at effluent tank (entrance side) do not meet the standard owing to the UST (Underground Storage Tank) manifold leaking to the open drain and high levels of organic matter is flushed from the service area during cleaning, the polluted organic runoff was being flushed to the open drain and further to the effluent tank (entrance side). As there are no more activities at the entrance side (only food shop), the amount of microbes might be insufficient for polluted organic matters in the effluent tank. However, our suggestion to remediate oil slick on the water surface in the drip tank at UST manifold, the application procedure of microbial concentrate must be considered imperative preventive action. Consequently, some parameters (COD, FOG) are quite firm, even if the biomass at the effluent tank (entrance side) was low.

At effluent (exit side), the all wastewater parameters were decreased significantly over 50% during a month. The COD (129 mg/L) and FOG (8 mg/L) value meet the standard value while BOD (41 mg/L) and SS (135 mg/L) were declined or remained close to standard level and reaching to the standard is foreseeable. Nevertheless, it was noticed that the retention time of wastewater (open drain between waste sources to the effluent tank) maintains higher degradation of organic matter. Therefore, it was important to control and regularly clean the open drain or remove sludge/SS which contaminate or block the WW flow.

4.6 Summary of all Stations

In order to see if the performance of each activity is the same, the situation of each activity in 5 representative gas stations are in consideration as follows

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4.6.1 Toilet

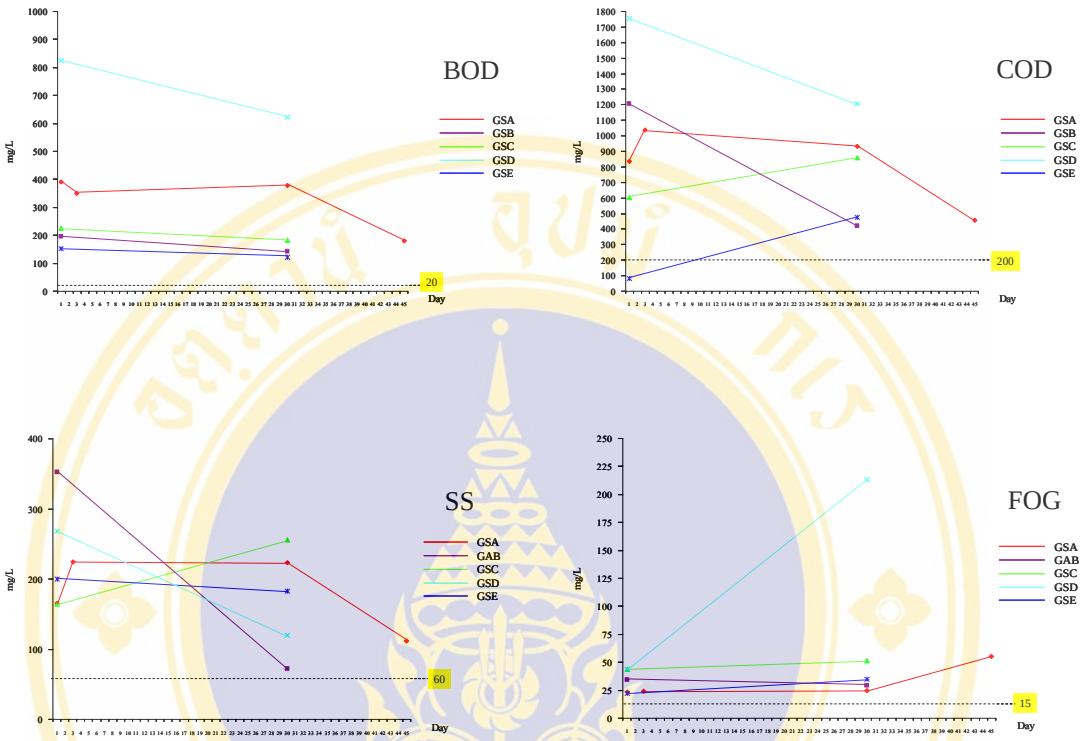

Figure 4-34: The BOD, COD, SS and FOG value of toilet in all gas stations

The BOD values of all stations were slightly decreased in the first week, then they were continually declined further with significantly decreased at Day 45.

The COD values of most stations (GSA, GSB, GSD) slightly decreased in the first interval, then continuously declined further with significantly decreased in the fifth week. Except for some stations (GSC, GSE) that reversed results were appeared, owing to large number of services and out of control for using detergent for cleaning that limit the function of microbe in remediating organic matter in the water column only.

The SS values of toilet in most gas stations (except GSC) were significantly decreased since the first interval. Only GSC, the SS value significantly increased because this station used aerobic water treatment system (other stations use anaerobic system).

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Accordingly, there were high suspended matters in the septic tank derived from efficient bio-reaction.

The FOG values of most stations were slightly increased in the first interval (except GSD) and significantly increased in the fourth week (GSD). According to microbes are not able to remediate or oxidize impenetrable fat or greases at ambient temperatures and conditions. As well as human excrements contain undigested organic matter, microbes degrade organic matter found in larger molecules to smaller molecules, and some of these fatty molecules are oxidized to fatty acid.

However, after applied Micro-Blaze instead of detergent for cleaning and adding microbes with spraying dispenser at any urinals, all the results showed that the quality of wastewater at septic tank gradually better. Most parameters; BOD, COD and SS (except FOG) were significantly declined up to 53.8%, 65.3% and 79.5% respectively, as shown in Figure 4-29.

4.6.2 Food Shop

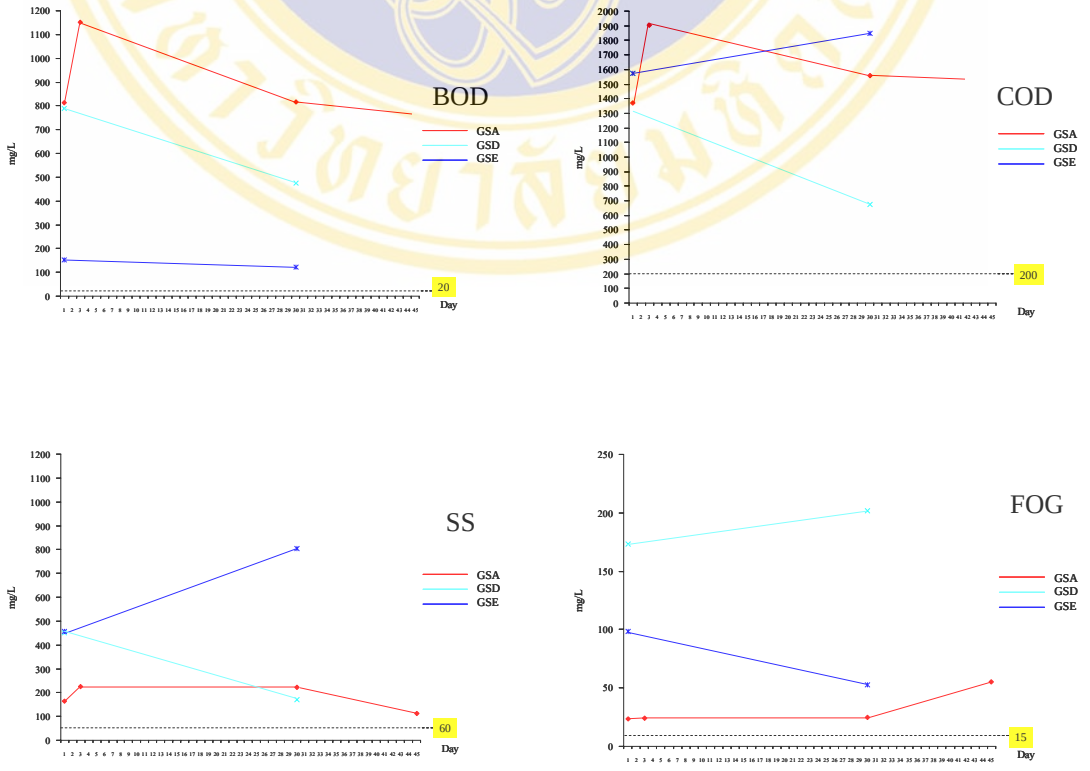

Figure 4-35: The value of BOD, COD, SS and FOG of food shop in all gas stations

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The BOD, COD and SS values of food shop in all gas stations were slightly increased since the first interval owing to the accumulated greases in lone pipeline, then they were continuously declined further with significantly decreased at the fifth week from high bio-reaction.

The FOG values of most station slightly increased owing to the limitation of microbe remediating organic matter in the water column only, not able to remediating fat or oil above water surface and settle organic matter. The retention time at grease trap tank (as waste source) might be insufficient to degrade more organic matters as a result of the system overload i.e. waste accumulation above water level etc.

However, after applied Micro-Blaze instead of detergent for cleaning and adding microbes with spraying dispenser at any strainers, all the results showed that the quality of wastewater at grease trap tank gradually become better. Most parameters; BOD, COD, SS (except FOG) significantly be declined up to 40%, 57.2%, 61.8% respectively as shown in Figure 4-35.

4.6.3 Minimart

The BOD, COD, SS and FOG values of all stations significantly decreased in the first interval, then, they were continuously declined further with significantly decreased in the fifth week. Owing to the short pipeline from kitchen to drainage system and the mini-mart food mostly take home, not much grease would accumulate in the pipeline system. There was high biomass in the pipeline system.

However, after applied Micro-Blaze, instead of detergent for cleaning, and adding microbes with spraying dispenser at all strainers, the results show that the quality of wastewater at grease trap tank were gradually improved significantly. As shown in Figure 4-31, most parameters; BOD, COD, SS and FOG were significantly declined up to 67.3%, 70.1%, 83.3% and 58.6% respectively.

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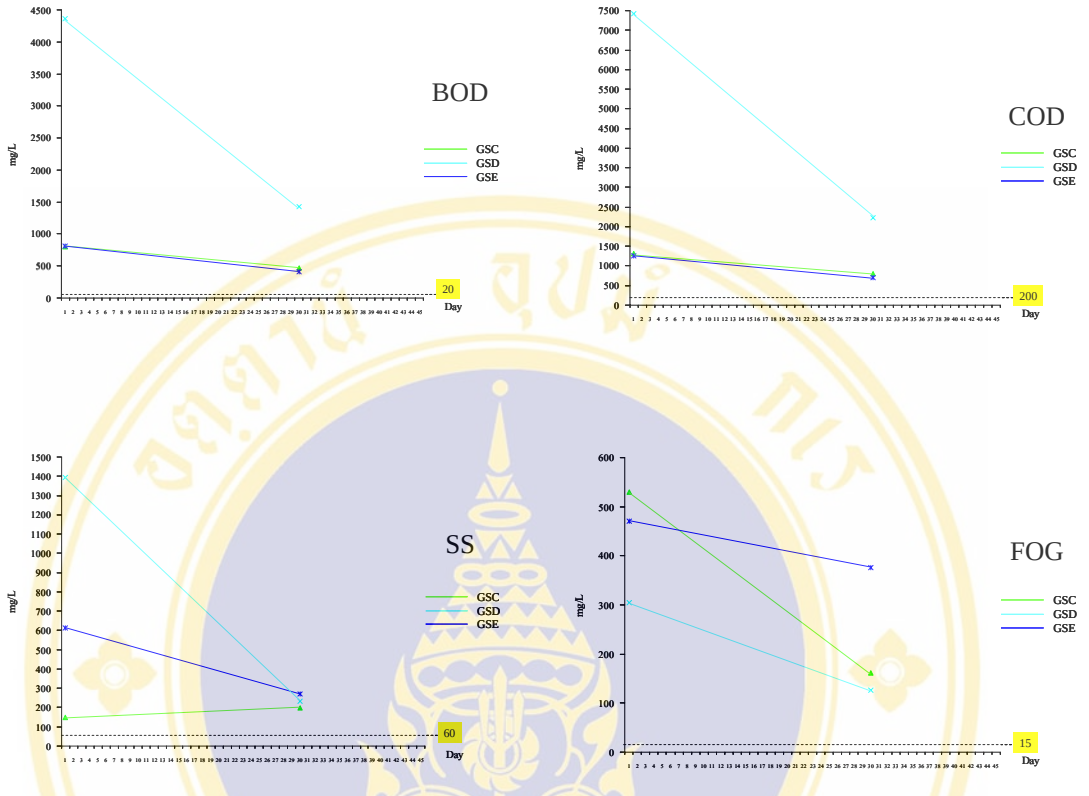

Figure 4-36: The value of BOD, COD, SS and FOG of minimart in all gas stations

4.6.4 Coffee Shop

The BOD, COD, SS and FOG values of all stations significantly decreased in the first interval, then they were continuously declined further with significantly decreased in the fifth week. Owing to the short pipeline from coffee kitchen to drainage system and the coffee shop that was not a full restaurant, only baking and coffee-making, in which not much grease will accumulated in the pipeline system.

However, after applied Micro-Blaze instead of detergent for cleaning and adding microbes with spraying dispenser at any strainers, all the results show that the quality of wastewater at grease trap tank become gradually better. As shown in Figure 4-32, most parameters; BOD, COD, SS and FOG were significantly declined up to 67.1%, 67.3%, 68.1% and 86.2% respectively.

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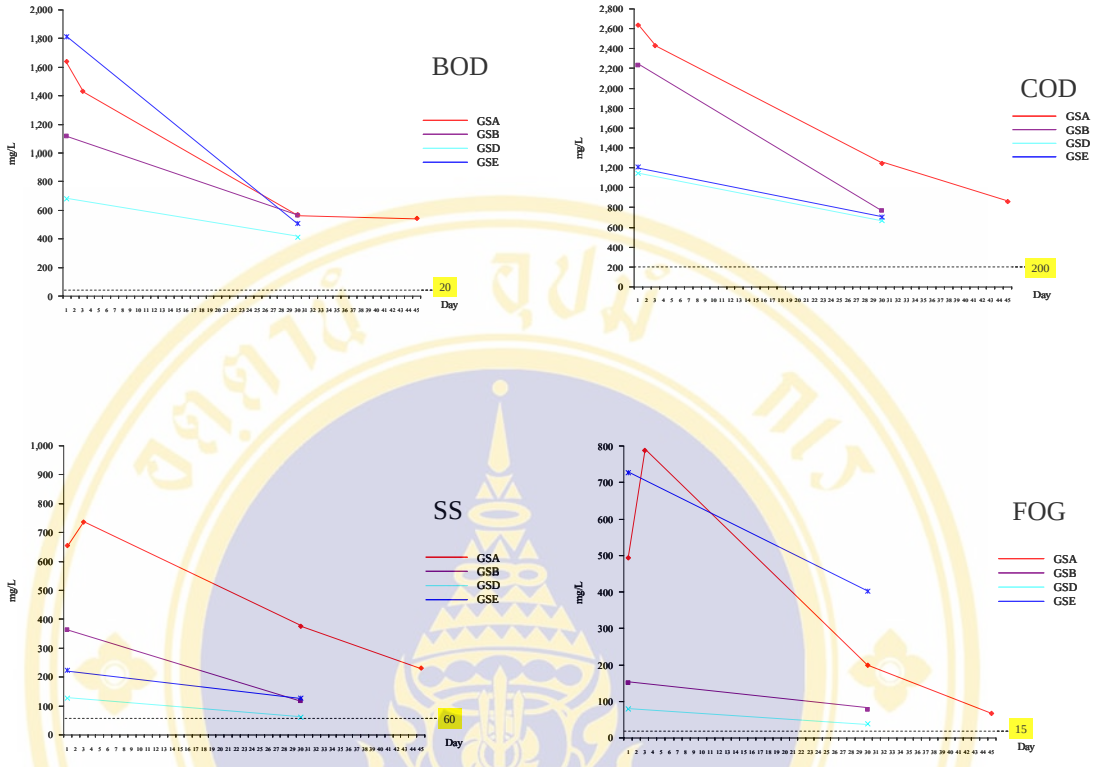

Figure 4-37: The value of BOD, COD, SS and FOG of coffee shop in all gas stations

4.6.5 Effluent Tank (entrance side)

The BOD, COD, SS and FOG value from effluent tank (entrance side) of most gas stations were slightly decreased in the first interval, then, they were continuously declined in the fourth week. However, the UST (Underground Storage Tank) that have been installed at this side and some oil contaminated water from the manifold may have leaked out in the open drain as well as no microbial replenishment at this side (no more activities) causing the small amount of microbes is insufficient to degrade the organic matter at the effluent tank (entrance side). Except for GSC and GSD, the reversed value are appeared owing to there are small kitchen near the effluent tank (entrance), and the unexpected construction site adjacent to the effluent tank (entrance).

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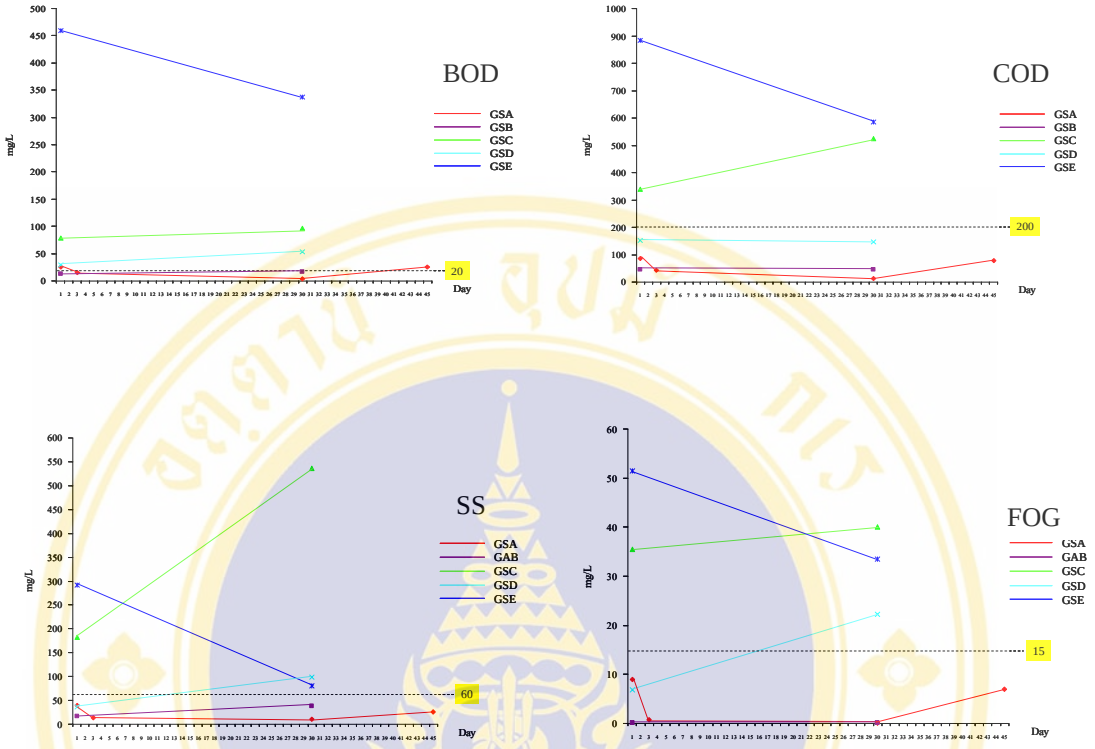

Figure 4-38: The value of BOD, COD, SS and FOG of effluent tank (entrance side) in all gas stations

However, there is no Micro-Blaze application at this side; all the results showed that the quality of wastewater at the effluent tank (entrance) be controlled at steady level and close to the standard level. Only GSA was gradually better, owing to there was microbial replenishment from Coffee shop at this side. As shown in Figure 4-33, most parameters; BOD, COD and SS were controlled at steady level (close to standard) or slightly declined up to 3.8%, 9.2% and 35% respectively.

4.6.6 Effluent Tank (exit side)

The BOD, COD, SS and FOG value of effluent tank (exit side) in most stations (except GSD) were slightly decreased in the first interval, then they were continuously declined in the fourth week. Only GSD significantly increased, owing to considerable service area cleaning took place during the forth week according to the QAS auditor

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who visited the site at that period. The polluted organic runoff was being flushed to the open drain and further to the effluent tank (exit side). Accordingly, the reversed results are inconsistent with the application of microbes and deviating with the parameters derived from the organic matter. In case of FOG, there was although UST inlet at this side but there was no further oil contaminated into open drain. Accordingly, there was quite sufficient biomass to degrade organic matters causing low level of FOG.

However, after applied Micro-Blaze instead of detergent for cleaning and adding microbes with spraying dispenser at any waste sources along exit side, all the results show that the quality of wastewater at effluent tank (exit side) were gradually improved. As shown in Figure 4-34, most parameters; BOD, COD, SS and FOG were significantly declined up to 54.1%, 60.8%, 39.7% and 54.6% respectively. Even though some of the results are unable to reach the standard but its trend showing the significant improvement with extended period of microbe application

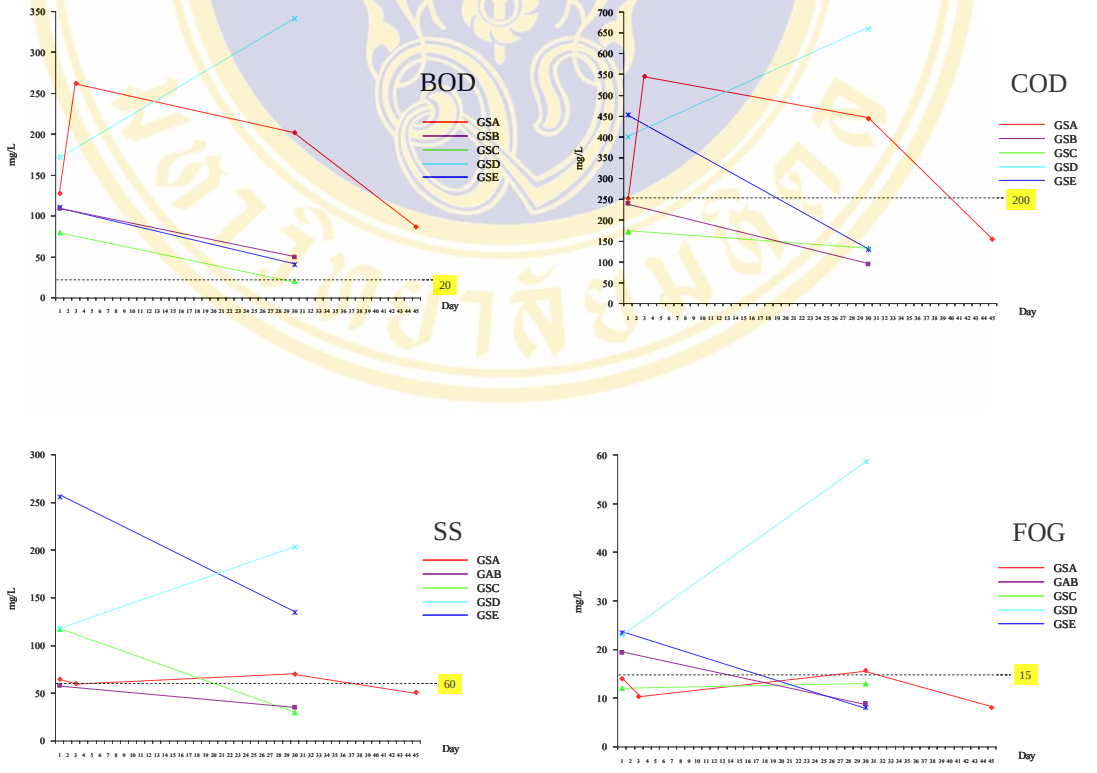

Figure 4-39: The value of BOD, COD, SS and FOG of effluent tank (exit side) in all gas stations

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4.7 Cost Effectiveness

Regarding to the efficiency of biotechnology wastewater treatment, it was able to improve the wastewater quality in gas station. In the meantime, instead of using chemical cleaning agent, this technology are able to minimize some chemical cleaning agents, such as, detergents, heavy cleaning solvent which generated to secondary pollutant to the effluent stage. In addition, also reduce using sand for adsorb oil spill which is hazardous waste. However, the emptied grease & oil and septic tank cost were still remain but likely to be extend more emptied period time.

According to PTIT research, the successful wastewater system cost, recommended design, are about 500,000 baht per stations *(The Shell Company of Thailand, 2002).* However, the physical investment as wastewater treatment systems at a gas station might be inapplicable, due to the installation of such systems may have many limitations, namely availability of space and ability to invest. Moreover, it is necessary to have an engineer or specialist to control and inspect the wastewater treatment system including electricity, maintenance cost, etc. which will also make additional operating cost for gas stations.

It may be claimed that this biotechnology are able to solve the problem of wastewater treatment installation and also reduce waste treatment cost together with minimizing environmental impact as well. *Therefore, this wastewater treatment biotechnology is a quite promising technology and should be used as an alternative treatment for wastewater in gas station.*

It could be concluded from the result that any waste sources from gas stations are the main sources, which generate BOD/COD. High services of gas station, for instance, toilets, coffee or bakery shop, food shop, in-front area, etc., make them difficult to treat wastewater, their system have short retention time or under-design for afford varieties of inputs. Their conventional cleaning agents mostly used for cleaning are detergents that are chemical cleaning agents which generate secondary pollutant to outside station or environment. Most of detergents make high COD and difficult to be degraded in nature. Moreover, most gas stations are not able to construct the

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appropriate wastewater treatment system as high investment cost and also need more areas. In the meantime, their profit margins of oil sale are not enough and they have to increase profit from other business, for instance, convenience store, coffee shop, etc. Accordingly, their business makes more income, meanwhile also generated more polluted wastes or BOD/COD matter.

Biotechnology treatment for wastewater might be one of the “Alternative waste treatments” for gas stations in Thailand. This technology was able to effectively remediate wastes or BOD/COD input since waste sources until the end of wastewater or effluent stage. This can be used instead of detergents or chemical cleaning agents for general cleaning, such as, cleaning floor, washing rags or mops, etc and particularly oil spill at oil dispenser in in-front area. It also was able to reduce grease & oil in G/T tank or pipeline in kitchens.

However, the important challenges for gas station were land construction structure, slope of open drain in station, some crash or leakage of open drain beside station and level of public drain or road in front of station. Theoretically, most treated wastewater discharge to effluent tank and the government enforce the quality of water at this stage. But in real, some above challenges were obstacle circumstance for station to control outside water or arrange direction of discharged wastewater, as well as, human practice management. Regarding to the research results, most waste sources are remediated and microbes from Micro-Blaze can control BOD/COD significantly.

However, the FOG value still gradually increased at septic tank from its own inappropriate condition of structure, such as, accumulated sediment on water surface or in the bottom, owing to high occupation (services) and particularly from human error is out of control for routine application. Moreover, at the effluent tank (entrance side) the FOG value slightly increased and the BOD, COD or SS value slightly decreased owing to some oil contaminated water from the UST manifold may have leaked out in the open drain. According to these all circumstances, it showed that human error in microbial application is significantly important. Therefore, controlling microbial application constantly in appropriate way was necessary.

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For these reasons, biotechnology application seems to be helpful for gas stations in Thailand due to the wastewater are being remediated at waste sources, i.e. in situ, thus do not generate secondary pollutants to the environment. Moreover, this technology can reduce wastewater treatment system investments and minimize some operational cost, such as, hazardous waste disposal cost from oil spill, odorant in toilet, emptied grease & oil cost, maintenance cost for repair pipeline leakage from grease clog, etc. This scenario is referred to as a “win-win situation”. This technology is, by all means, the foremost ***sustainable wastewater treatment*** for gas station in the future. The natural occurring microbes in septic- and wastewater systems may be an imperative, but a condition that require assistance by replenishment of microbes with high affinity towards the pollutants in question. Thus the retention time for a cleaner world may be better managed.

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CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

The purpose of this chapter is to summarize all findings from the study of “Alternative Bioremediation of Wastewater from Gas Stations”. The conclusion can be drawn from this work are as follows:

5.1 Conclusion

Gas Stations are handling HC products, which demand lots of oxygen for degradation. Volatile Organic Compounds (VOC) are being emitted as gasses from all HC products handled at a Gas station.

Consequently, a certain percentage of the petrol and diesel products acquired by the station will contribute to pollution and demand of oxygen. Generally we refer to the oxygen demand as BOD (biological oxygen demand) and COD (chemical oxygen demand). In gas station, many activities of toilets, food shop, coffee shop, in-front area release the waste referred to above. Exceeding their normal capacity makes it difficult to treat wastewater correctly. Their system suffer from short retention time, which is caused by the increase of activities given a design for a different inputs. The conventional cleaning agents, are basically based on phosphate detergents, with a pH close to 12. Detergents or chemical cleaning agents are referred to a secondary pollutants and they generate high BOD/COD values. The use of detergents cause high COD values and they are difficult to degrade in nature. The half life may be about 20 years for the most popular makes. The investment in a gas station must be kept low. Construction of an appropriate wastewater system is expensive, and up till now it has been subjected to priority. Investments have been required for other good purposes in the company as well, and the present awareness of the consequences of insufficient wastewater quality has not always been known to engineers and authorities. Legislation has been laid down as such, but enforcement has been subject to interpretation and lenience. Profit margins (PM) of oil sale have been generally

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insufficient to cover all costs. Thus, priorities taken will most often suffer from lack of significant consideration. Alternatives have frequently been implemented in attempting to contain the activity. Thus, to increase the total revenues and profit margins the Gas station's activity had to be extended to comprising convenience store, coffee shop, etc. Consequently, the amended operation would generate more income, at the same time as generating more waste i.e. BOD/COD matter as well, without having a WWS capable of covering the altered capacity.

Microbial treatment of wastewater might be the most important method of bringing the WWS capacity up to the demand for effluent standard for gas stations in Thailand. This technology is able to effectively remediate waste and/or reduce BOD/COD input by using artificial replenishment of indigenous microbes, which may not be present in sufficient numbers to tackle the remediation and odour requirements. Microbial concentrate can substitute detergents and chemical cleaning agents in full for general purpose cleaning (GP) such as floor, washing rags or mops, etc as well as occasional oil spills at oil the dispenser in the front area. It also is able to reduce grease & oil in G/T tank or kitchen pipelines.

However, the important challenges for gas station staff is to relate to the land construction structure, fall of open drain in station, cracks or leakage of open drain to adjacent area or to the public drain or road in front of station.

In principle, most treated wastewater flow to the effluent tank by gravity and the authorities check the WW quality at this point only. Challenges are often an obstacle to relate to as the station employees must at times control the direction of the effluent water flow as other particulars of great importance may be overlooked.

With reference to the documentation of project results, most waste sources are remediated and the microbial concentrate used (Micro-Blaze®) can easily maintain the BOD/COD level in an acceptable way. However, owing to the elevation at the effluent tank the flow to the public WWS does not always go in the desired direction. BOD/COD level will be greatly affected if the flow is turned from the public WWS to the Gas Station rather than the opposite way. This phenomenon is referred to as the Gas station flow syndrome, and will create large and unproductive discussions about

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the reliability of gauging and subsequent methodology. Consequently, effluent flow turned into influent may be difficult to apprehend.

The logical conclusion derived from applied use of biotechnology, is that the benefits of remediation “in situ” is tangible. Without exception these benefits can only be credited microbial technology. The wastewater HC pollutants are being subjected to continued remediation from the waste sources and further down the public lines to the WW treatment plant. As secondary pollutants are no longer present, their effects have been successfully removed as well, and no secondary pollutants will appear in the public WWS outside the station rendering negative environmental impact.

In addition to the argumentation and findings mentioned above, the microbial technology will minimize particular operation costs, such as hazardous waste disposal after oil spill, odour in toilet, grease & oil disposal, water consumption, maintenance of clogged pipelines etc.

The above scenario may be referred to as a “win-win situation.” ***It is imperative for the success of “in situ remediation” and sustainable wastewater treatment***. This technology can minimize some operation cost, such as, hazardous waste disposal cost from oil spill, odorant in toilet, emptied grease & oil cost, water consumption, maintenance cost for repair pipeline leakage from grease clog, and wastewater treatment installation investment. In addition, the utilisation of microbial technology will also provide improved:

- significant preventive action parameters
- significant corrective action parameters
- significant profit scorecard effects

5.2 Recommendations

In case of some station which the wastewater at effluent stage still are unable to achieve standard level after microbial application at the experiment period. Some suggestions are recommended as follows:

- Application procedure should be more strictly control.
- The extend period is necessary for high service gas station. Due to application time may be insufficient for biodegradation.

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- The amount or concentration of microbial replenishment or (Micro-Blaze) may be not sufficient for waste input loading.

The recommendation can be drawn from this work are as follows:

5.2.1 In order to reduce human errors with regard to application of microbes as previously mentioned, mechanical instrument for controlling microbial application might be able to apply at waste source application. Therefore, auto feeding system is recommended to be used as controller the amount of biomass at the waste sources

5.2.2 Application of microbes at the UST manifold is important as preventive actions. After application the microbes may attain the spore state owing to lack of water. However, they will be easily activated by application of water. Thus, maintaining the presence of the three elements required for microbial activities – Water, Food and Oxygen

5.2.3 Drainage system elevation of gas station should be improved for gravity water flow to both effluent tanks.

5.2.4 Drainage canal from the service area, i.e. area adjacent to the pumps, to the nearest open drain would enhance safety and ability to contain oil spills

5.2.5 In order to maintain good operation result, continuous staff training is imperative as well as application of motivating safety factors to incentive the individual's participation in work procedures.

5.2.6 Understanding the benefits of utilising the common procedures:

5.2.6.1. Contingency procedures and associated obligations

5.2.6.2. Emergency procedures and associated obligations

5.2.6.3. Redundancy procedures and associated obligations

5.2.7 The benefits gain are associated with the following performances:

5.2.7.1 Follow the QAS and the training, checking that ample stock is at hand and ready for use

5.2.7.2 Determine firmly when there is an emergency situation and what to do about it. Use the resources available according to the contingency stock at hand.

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5.2.7.3 Determine clearly which requirements are required in relation to time and how to acquire supplies within a predefined time assessment.

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APPENDIX

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APPENDIX A

Category Definition and classification of Gas station

In accordance with the Fuel Control Act B.E. 2542, the Department of Civil Services stated that the gas station mean the place that store fuel oil in order to service vehicles and their main activities include fuel sale, lubricated oil transfer services, service building and alternative services in the station's area.

The location, layout, pattern, characteristics of the gasoline station, collection transportation, usage, sale, packing and any other controls relevant to fuel packing and transportation including with characteristics of the operator which involve fuel control must comply with the Fuel Control Act B.E.2542. The classification of gas station is 6 types as follow:

1) Gasoline station **type A** or gasoline station which locate adjacent to big road, such as, main road, public road or private road. They also normally have underground storage tanks.

2) Gasoline station **type B** or gasoline station which locate adjacent to small road (Soi), such as, minor road. They also have underground storage tanks.

3) Gasoline station **type C** that divided in 2 characters :

3.1) character 1: gasoline station in small road which store fuel oil volume not exceed 10,000 l and storage tanks put on the ground (floating drum gasoline in minor road).

3.2) character 2: gasoline station in main road which store fuel oil volume exceed 10,000 l and put on storage tank put on the ground (floating drum gasoline in main load).

4) Gasoline station **type D** or gas station which use manual dispensing or called "hand operated gasoline".

5) Gasoline station **type E** divided in 2 characters:

5.1) character 1: gasoline station which service boat that have fuel oil volume not exceed 10,000 l and storage tank put on the ground or floating platform. (Small floating gasoline station)

5.2) character 2: gasoline station which service boat that have fuel oil volume exceed 10,000 l and storage tank put in underground. (Big floating gasoline station)

6) Gasoline station **type E** or gasoline station which service aircraft.

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However, in accordance with the Department of Civil works notification and Ministry of Science, Technology and Environment legislation enforced only gasoline station type A and type B that are located adjacent to main road, public or private road and have underground storage tank. And they notified further specification of gasoline station as follow:

Gasoline station type I: the gasoline station which located adjacent to main or public road or public way that have the width not less than 12.0 m or private way that have the width exceed 10.0 m with connected main road that have the width exceed 12.0 m.

Gasoline station type II: the gasoline station which located adjacent to public road or public way that have the width not less than 8.0 m but less than 12.0 m or private way that have the width not less than 8.0 m but less than 10.0 m with connected main road or public road which have the width not less than 8.0 m.

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APPENDIX B

Application Procedure for Staff Training

In case of staff training application procedure for every activities including scorecard have been produced as a guideline for daily implementation and performance controlling. The following are the procedure for Micro-blaze application in toilets, food shop, coffee shop, minimart and in-front area of the gas station.

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วิธีการใช้ Micro-Blaze® สำหรับ Food Shop

ขั้นตอนการเตรียม Micro-Blaze® 2 แบบ

- การเตรียม Micro-Blaze® 100% หรือหัวเชื้อ (ไม่ผสมน้ำ)
  - ใช้กับกระบอกฉีดน้ำ

- การเตรียม Micro-Blaze® 1% (ผสมน้ำ)
  - ใช้ผสมในกระบอกฉีดน้ำ
  - ใช้ผสมในถังน้ำ

1% ตัวอย่างเช่น ถ้าใช้น้ำปริมาตร 1,000 มล. จะต้องใช้ Micro-Blaze® 10 มล.
(สูตรคำนวณอย่างง่าย คือ $\frac{\text{ปริมาตรน้ำที่ใช้}}{100}$ = ปริมาณ Micro-Blaze® ที่ต้องใช้)

งดใช้ผงซักฟอกและสารเคมีทุกชนิด

บ่อดักไขมัน 1

1) ใช้ MB 100% บรรจุในกระบอกฉีด
2) ฉีดลงในบ่อดักไขมัน
ความถี่ – เช้าพ่น 4 ครั้ง เย็นพ่น 4 ครั้ง

บ่อดักไขมัน 2

1) ใช้ MB 100% บรรจุในกระบอกฉีด
2) ฉีดลงในบ่อดักไขมัน
ความถี่ – เช้าพ่น 4 ครั้ง เย็นพ่น 4 ครั้ง

ทำความสะอาดอ่าง

1) ใช้ MB 100% บรรจุในกระบอกฉีด
2) ฉีดลงในอ่าง
ความถี่ – เช้าพ่น 2 ครั้ง เย็นพ่น 2 ครั้ง

ทำความสะอาดพื้น

1) ใช้ MB 1% ผสมกับน้ำในถัง
2) เช็ดถูทำความสะอาดพื้นตามปกติ
ความถี่ – เมื่อพื้นสกปรก หรือตามกะเวลา

วิธีการใช้ Micro-Blaze® สำหรับ BLACK CANYON COFFEE SHOP

ขั้นตอนการเตรียม Micro-Blaze® 2 แบบ

- การเตรียม Micro-Blaze® 100% หรือหัวเชื้อ (ไม่ผสมน้ำ)
  - ใช้กับกระบอกฉีดน้ำ

- การเตรียม Micro-Blaze® 1% (ผสมน้ำ)
  - ใช้ผสมในกระบอกฉีดน้ำ
  - ใช้ผสมในถังน้ำ

1% ตัวอย่างเช่น ถ้าใช้น้ำปริมาตร 1,000 มล. จะต้องใช้ Micro-Blaze® 10 มล.
(สูตรคำนวณอย่างง่าย คือ $\frac{\text{ปริมาตรน้ำที่ใช้}}{100}$ = ปริมาณ Micro-Blaze® ที่ต้องใช้)

งดใช้ผงซักฟอกและสารเคมีทุกชนิด

ผสมแทนน้ำยาล้างมือ

1) ใช้ MB 0.3% บรรจุในกระบอกฉีด
2) ฉีดลงในอุปกรณ์สำหรับบรรจุน้ำยาล้างมือ
ความถี่ – เช้าพ่น 4 ครั้ง เย็นพ่น 4 ครั้ง

บ่อดักไขมันหน้าร้าน

1) ใช้ MB 100% บรรจุในกระบอกฉีด
2) ฉีดลงในช่องที่ 3
ความถี่ – เช้าพ่น 4 ครั้ง เย็นพ่น 4 ครั้ง

บ่อดักไขมันในครัว

1) ใช้ MB 100% บรรจุในกระบอกฉีด
2) ฉีดลงในช่องที่ 3
ความถี่ – เช้าพ่น 4 ครั้ง เย็นพ่น 4 ครั้ง

ทำความสะอาดพื้น

1) ใช้ MB 1% ผสมกับน้ำในถัง
2) เช็ดถูทำความสะอาดพื้นตามปกติ
ความถี่ – เมื่อพื้นสกปรก หรือตามกะเวลา

ทำความสะอาดโต๊ะ

1) ใช้ MB 1% ผสมกับน้ำในกระบอกฉีด
2) เช็ดถูโต๊ะตามปกติ
ความถี่ – เมื่อโต๊ะสกปรก หรือตามกะเวลา

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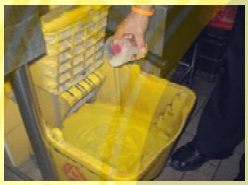
วิธีการใช้ Micro-Blaze® สำหรับ Minimart

ขั้นตอนการเตรียม Micro-Blaze®

- การเตรียม Micro-Blaze® 100% หรือหัวเชื้อ (ไม่ผสมน้ำ)
  - ใช้กับกระบอกฉีดน้ำ

MB 100%



งดใช้ผงซักฟอกและสารเคมีทุกชนิด

กิจกรรมที่ต้องใช้

อ่างล้างในครัว ภายในร้าน

1) ใช้ MB 100% บรรจุในกระบอกฉีด
2) ฉีดลงในอ่างล้างในครัว ภายในร้าน

ความถี่ – เช้าพ่น 6 ครั้ง บ่ายพ่น 6 ครั้ง

ทำความสะอาดพื้น

1) ใช้ MB 1% ผสมกับน้ำในถัง
2) เช็ดถูทำความสะอาดพื้นตามปกติ

ความถี่ – เมื่อพื้นสกปรก หรือตามกะเวลา

ขั้นตอนการเตรียม Micro-Blaze® 2 แบบ

- การเตรียม Micro-Blaze® 100% หรือหัวเชื้อ (ไม่ผสมน้ำ)
  - ใช้กับกระบอกฉีดน้ำ

MB 100%

- การเตรียม Micro-Blaze® 1% (ผสมน้ำ)
  - ใช้ผสมในกระบอกฉีดน้ำ
  - ใช้ผสมในถังน้ำ

1% ตัวอย่างเช่น ถ้าใช้น้ำปริมาตร 1,000 มล. จะต้องใช้ Micro-Blaze® 10 มล.
(สูตรคำนวณอย่างง่าย คือ $\frac{\text{ปริมาตรน้ำที่ใช้}}{100}$ = ปริมาณ Micro-Blaze® ที่ต้องใช้)

MB 1% ผสมกับน้ำในกระบอกฉีด

MB 1% ผสมกับน้ำในถัง

งดใช้ผงซักฟอกและสารเคมีทุกชนิด

กิจกรรมที่ต้องใช้

เช็ดทำความสะอาดตู้จ่ายน้ำมัน

1) ใช้ MB 1% ลงในถังน้ำ
2) ใช้ผ้าชุบน้ำ (ที่ผสม MB แล้ว) เช็ดทำความสะอาดอุปกรณ์

ความถี่ – เมื่อมีน้ำมันหยด ฉีด 2 ครั้ง (โดยประมาณ)

คราบน้ำมันบริเวณหัวจ่าย

1) ใช้ MB 100% บรรจุในกระบอกฉีด
2) ฉีดตรงบริเวณที่มีน้ำมันหยด
3) ใช้น้ำชะล้างตาม

ความถี่ – เมื่อมีน้ำมันหยด ฉีด 2 ครั้ง (โดยประมาณ)

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APPENDIX C

Standard Methods for the Examination of Water and Wastewater

One of the analytical mainstays of environmental engineering is the **BOD test** for Biochemical Oxygen Demand. This is a slow, laborious, and inaccurate method, but its result is a good index of how pollution would affect a stream or other body of water.

There are many possible organic compounds that can be present in wastes. Furthermore, several different organic compounds are usually present, and it is difficult to select an appropriate analytical procedure. An analyst could perform many tests for a variety of pollutants, add up the results, and report the level of pollution.

The concept of BOD is the stoichiometry of carbon and oxygen to form carbon dioxide. Carbon compounds, however, may already be partially oxidized; a gram of alcohol will not exert the same BOD as a gram of fat. Nevertheless, measuring how much oxygen is consumed by a pollutant in a laboratory test is a good index of how the dissolved oxygen of a stream will be affected. The BOD test mixes dilution water that is rich in dissolved oxygen with sufficient sample to consume much but not all of the total dissolved oxygen (there may be a little in the sample). Oxygen is measured at the start and again after a time interval, and the amount consumed is corrected to the sample size and is called the BOD. The chemistry of the test expresses all concentrations in terms of oxygen. Thus the BOD is the oxygen consumed per unit volume of sample, e.g., pounds of BOD per million gallons, or more often parts per million, ppm.

A very serious drawback to the BOD test is the change with time. Reaching a final, stable concentration of dissolved oxygen takes roughly 25 days for a sample of a typical wastewater, although some industrial discharges that are composed of very easily metabolized compounds may take less time. Fortunately, the BOD often levels off fairly well or is close enough to a plateau in 5 days, and this has been accepted as the commonly reported BOD.

A peculiar feature of the BOD test is an increase at extended times to a second plateau. When the microorganisms exhaust the organic compounds that were in the sample, they seek an alternative source of energy. They can oxidize nitrogenous compounds, and this consumes some more dissolved oxygen.

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Biochemical Oxygen Demand (BOD)

The main details of this method are taken specifically from *Standard Methods for the Examination of Water and Wastewater* (Method 507: 1985, and Method 218B: 1971) and the *United States Environmental Protection Agency of 1979* (Method 405.1).

The test for *Biochemical Oxygen Demand* is especially important in waste water treatment, food manufacturing, and filtration facilities where the concentration of oxygen is crucial to the overall process and end products. High concentrations of *dissolved oxygen* (DO) predict that oxygen uptake by microorganisms is low along with the required break down of nutrient sources in the medium (sample). On the other hand, low DO readings signify high oxygen demand from microorganisms, and can lead to possible sources of contamination depending on the process.

Performing the test for *Biochemical Oxygen Demand* requires a significant time commitment for preparation and analysis. The entire process requires ***five days***, and it is not until the last day where data is collected and evaluated. During this time, samples are initially seeded with microorganisms and supplied with a carbon nutrient source of glucose-glutamic acid. The sample is then introduced to an environment suitable for bacterial growth at reproducible temperatures, nutrient sources, and light within a 20 degree Celsius incubator such that oxygen will be consumed. Quality controls, standards and dilutions are also run to test for accuracy and precision. The difference in initial DO readings (prior to incubation) and final DO readings (after 5 days of incubation) predicts the BOD of the sample. A suitable detection limit as per environmental QC is 1 mg/L.

Why does it require period of five Days?

It can take as long as 25 days before no further changes can be detected in a bottle in which a BOD test is being conducted. Depending on the nature of the sample, the test may be near completion in a few days. A reasonable compromise between waiting too long to get results and getting unreliable answers is 5 days. As long as the samples are pretty much the same from one sampling period to another, the 5-day test works fairly well. For example, samples from a process in a waste treatment plant will have essentially the same nature over long periods. The 5-day BOD will be highly meaningful in showing variations in plant performance.

The following figure shows simulation of the BOD test with different rate coefficients:

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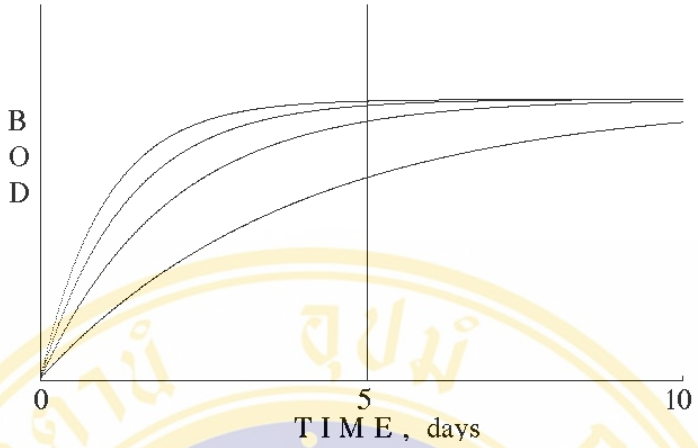

Note: the vertical line for 5 days. If the samples are quite different in their composition, the error in comparing them at 5 days will be great, and a longer time for the test would be better. This must be balanced by a long wait before having results, and delay in making adjustments based on these results may be costly.

Equipment

The following is a list of necessary materials and equipment for starting the procedure:

1. Series of 250-300 ml BOD bottles with ground glass stoppers, and caps
2. Incubator set at 20 degrees Celsius
3. Two large carboys (20 liter capacity depending on sample amount)
4. Series of class A pipets (0.2 ml-10 ml)
5. Aeration device
6. pH meter
7. Six 500 ml ehrlenmeyer flasks
8. Millipore water
9. Phosphate buffer pillows for every 6 liter carboy volume
10. DO meter with membrane electrode
11. Seed
12. 50 ml class A buret
13. Stir plates and stir bars
14. Series of volumetric flasks
15. Series of beakers
16. Deionized water

Reagent

The following is a list of reagents used in this method that are commercially prepared:

1. Concentrated Sulfuric Acid
2. 0.0375 N Sodium Thiosulfate
3. Starch indicator

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4. Crystalline D-glucose and glutamic acid
5. Bleach (5.25%)
6. Acetic Acid
7. Potassium Iodide
8. Sodium hydroxide pellets
9. Manganese sulfate
10. Sodium sulfite

BOD Calculation

The calculations for BOD take into account the unseeded blanks and the seeded solutions. These values must be subtracted out in order to obtain reasonable BOD results. The following calculations are taken from Standard Methods (Method 507: 1985, p. 531).

A. the BOD of the blanks are calculated by subtracting the final DO from the initial DO:

BOD blank=DO1-DO2;

B. the BOD of the seeds are calculated by subtracting the final DO from the initial DO and multiplying this number by the dilution factor:

BOD seed=(DO1-DO2) * Dilution factor per 300 ml

C. the BOD of sample and standards are calculated by subtracting the final DO from the initial DO and multiplying this number by the dilution factor. The final value is determined by substracting out the BOD blank and the seed blank for each delta DO.

If the testing procedure was carried out correctly and the dilutions of the sample were made appropriately, the analyst should have obtained BOD values that are within a reasonable percent error and relative percent difference. Generally, values are discarded for a specific sample dilution if the final DO of the sample is < 1.0 mg/L of if delta DO is < 1.0 mg/L. This also stresses the importance of using different dilutions for each sample to key in on the appropriate BOD when little is known about how the sample will react and how high its BOD levels are.
The majority of the information for this tutorial came from:

Standard Methods for the Examination of Water and Wastewater. 16th Edition: 1985. Method 507, pg 525-532.

Standard Methods for the Examination of Water and Wastewater. 13th Edition: 1971. Method 218B, pg 477-481.

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The laboratory procedure with which I am familiar also makes reference to the *United States Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes.* March 1979: 1974 editorial revision. Method 405.1.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is defined as the amount of a specified oxidant that reacts with the sample under controlled conditions. The quantity of oxidant consumed is expressed in terms of its oxygen equivalence. It is a measure of the oxygen equivalent of organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. The chemical oxidants include: potassium permanganate and potassium dichromate. The COD-analysis may be carried out automatically and relatively fast (1-2 hours) and the measured COD-values give a good picture of the total content of organic matter.

Reagent

The following is a list of reagents used in this method that are commercially prepared:

1. Mercuric sulphate
2. Sulfuric acid
3. Ferroin indicator
4. Standard Potassium dichromate (conc.) 0.250 N
5. Potassium hydrogen phthalate (KHP) Standard
6. Standard Ferrous ammonium sulphate (FAS)

COD analysis has been carried out using the Dichromate Reflux Method according to APHA (93). This method is preferable over the other because of the oxidizability and applicability of dichromate, as an oxidant, is superior to a wide variety of samples and ease of manipulation.

Total Suspend Solids (TSS)

The suspended solid matters in leucaena-soaked water were analyzed using technique recommended by APHA (93). The well mixed sample (25 ml) was filtered under vacuum using known weight (A) of filter paper. The filtrates was dried in oven at 103-105^{o}C for at least 1 hour to constant weight and then cool in desiccators to room temperature, Weight (B) and calculate as followed.

$$\text{Total residues (mg/l)} = \frac{(B - A)}{\text{Vol. of sample (ml)}}$$

where A = weight of filter paper

= weight of filter paper + residues

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Grease & Oil (FOG)

FOG analysis Soxhet Extraction method has been carried out using the Dichromate Reflux Method according to APHA (93). The measurement described herein encompasses the partition-gravimetric method, whereby dissolved, or emulsified, oil and grease are extracted from a spent water sample b intimate contact with the organic solvent trichlorotrifluoroethane.

Reagent

The following is a list of reagents used in this method that are commercially prepared:

1. HCI (1+1)
2. n-Hexane boiling point 49^{o}
3. Kirselguhr (Diatomaceous earth)

In this experiment a sample of 100 ml was placed in 500 ml refluxing flask, follwed by 2 ml of HCI (1+1) with water 500 ml. And filtrate with filter paper on Buchner Funnel by Vaccump Pump. Take the sample to dry in oven at 103^{o}C for 30-6- min. And take n-Hexane into Boiling flask (dried) about 150-200 ml for 3-4 hrs. After that take Evaporating dish put on Water bath in order to dry n-Hexane in oven at 103^{o}C not less than 1 hr. and take all sample into Dessicator to weight the additional.

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APPENDIX D

Results of wastewater quality (WWQ)

Results in Gas Station A (GSA)

Sampling point	Day 1	Day 3		Day 30		Day 45	
		Wt.	%	Wt.	%	Wt.	%
Gentlemen Toilet							
pH	7.8	7.8		8.1		7.6	
BOD (mg/l)	392.0	351.0	-10.5	378.0	-3.6	181.0	-53.8
COD (mg/l)	834.0	1036.0	24.2	934.0	12.0	456.0	-45.3
SS (mg/l)	165.0	224.0	35.8	223.0	35.2	112.0	-32.1
FOG (mg/l)	23.7	24.0	1.3	24.7	4.2	55.0	132.1
Lady Toilet							
pH	7.9	7.7		7.7		7.4	
BOD (mg/l)	324.0	341.0	5.2	190.0	-41.4	213.0	-34.3
COD (mg/l)	622.0	936.0	50.5	457.0	-26.5	549.0	-11.7
SS (mg/l)	74.0	208.0	181.1	46.0	-37.8	139.0	87.8
FOG (mg/l)	15.0	23.0	53.3	9.3	-38.0	19.0	26.7
Food Shop							
pH	4.5	4.8		4.4		4.5	
BOD (mg/l)	812.0	1151.0	41.7	817.0	0.6	770.0	-5.2
COD (mg/l)	1370.0	1904.0	39.0	1557.0	13.6	1529.0	11.6
SS (mg/l)	131.0	290.0	121.4	194.0	48.1	210.0	60.3
FOG (mg/l)	65.0	153.0	135.4	86.0	32.3	77.7	19.5
Coffee Shop							
pH	4.9	4.3		5.2		5.2	
BOD (mg/l)	1642.0	1431.0	-12.9	567.0	-65.5	541.0	-67.1
COD (mg/l)	2637.0	2432.0	-7.8	1245.0	-52.8	862.0	-67.3
SS (mg/l)	654.0	736.0	12.5	376.0	-42.5	230.0	-64.8
FOG (mg/l)	493.0	788.0	59.8	198.0	-59.8	68.0	-86.2
Effluent (entrance)							
pH	7.0	6.8		7.2		7.2	
BOD (mg/l)	26.0	15.0	-42.3	3.7	-85.8	25.0	-3.8
COD (mg/l)	87.0	43.0	-50.6	12.0	-86.2	79.0	-9.2
SS (mg/l)	40.0	13.0	-67.5	11.0	-72.5	26.0	-35.0
FOG (mg/l)	9.0	0.7	-92.2	0.2	-97.8	7.0	-22.2
Effluent (exit)							
pH	7.4	7.2		7.3		7.3	
BOD (mg/l)	128.0	262.0	104.7	202.0	57.8	87.0	-32.0
COD (mg/l)	252.0	545.0	116.3	444.0	76.2	155.0	-38.5
SS (mg/l)	65.0	60.0	-7.7	70.0	7.7	51.0	-21.5
FOG (mg/l)	14.0	10.3	-26.4	15.7	12.1	8.0	-42.9

Note: % refers to the decreasing percentage compared to Day 1

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Results in Gas Station B (GSB)

Sampling point	Day 1	Day 30	% Reduction
Gentlemen Toilet			
pH	7.2	7.1	-1.4
BOD (mg/l)	195	141	-27.7
COD (mg/l)	1206	419	-65.3
SS (mg/l)	352	72	-79.5
FOG (mg/l)	34.2	29.3	-14.3
Lady Toilet			
pH	7.8	7.8	0.0
BOD (mg/l)	148	87	-41.2
COD (mg/l)	302	165	-45.4
SS (mg/l)	54	17	-68.5
FOG (mg/l)	20.6	6.6	-68.0
Coffee Shop			
pH	4.9	5.2	6.1
BOD (mg/l)	1117	564	-49.5
COD (mg/l)	2231	764	-65.8
SS (mg/l)	364	116	-68.1
FOG (mg/l)	151	78	-48.3
Effluent (entrance)			
pH	6.5	6.8	4.6
BOD (mg/l)	13	17	30.8
COD (mg/l)	45	45	0.0
SS (mg/l)	17	38	123.5
FOG (mg/l)	0.2	0.2	0.0
Effluent (exit)			
pH	6.5	6.8	4.6
BOD (mg/l)	109	50	-54.1
COD (mg/l)	240	94	-60.8
SS (mg/l)	58	35	-39.7
FOG (mg/l)	19.4	8.8	-54.6

Note: % refers to the decreasing percentage compared to Day 1

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Results in Gas Station C (GSC)

Sampling point	Day 1	Day 30	% Reduction
Toilet			
pH	8.1	8.2	1.2
BOD (mg/l)	225	183	-18.7
COD (mg/l)	604	859	42.2
SS (mg/l)	164	256	56.1
FOG (mg/l)	44	51.3	16.6
Minimart			
pH	4.7	5.3	12.8
BOD (mg/l)	800	470	-41.3
COD (mg/l)	1312	791	-39.7
SS (mg/l)	149	198	32.9
FOG (mg/l)	530	161	-69.6
Lube			
pH	7.6	7.6	0.0
BOD (mg/l)	100	57	-43.0
COD (mg/l)	296	224	-24.3
SS (mg/l)	193	208	7.8
FOG (mg/l)	10	8.5	-15.0
Effluent (entrance)			
pH	8.1	7.9	-2.5
BOD (mg/l)	79	97	22.8
COD (mg/l)	338	525	55.3
SS (mg/l)	182	536	194.5
FOG (mg/l)	35.5	40	12.7
Effluent (exit)			
pH	7.5	7.3	-2.7
BOD (mg/l)	80	20	-75.0
COD (mg/l)	173	133	-23.1
SS (mg/l)	117	30	-74.4
FOG (mg/l)	12	13	8.3

Note: % refers to the decreasing percentage compared to Day 1

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Results in Gas Station D (GSD)

Sampling point	Day 1	Day 30	% Reduction
Gentlemen Toilet			
pH	8.8	7.9	-10.2
BOD (mg/l)	825	621	-24.7
COD (mg/l)	1754	1206	-31.2
SS (mg/l)	268	120	-55.2
FOG (mg/l)	44	213	384.1
Lady Toilet			
pH	7.3	7.2	-1.4
BOD (mg/l)	173	84	-51.4
COD (mg/l)	1130	276	-75.6
SS (mg/l)	340	72	-78.8
FOG (mg/l)	37.5	16.6	-55.7
Food Shop			
pH	5.6	5	-10.7
BOD (mg/l)	790	474	-40.0
COD (mg/l)	1576	675	-57.2
SS (mg/l)	450	172	-61.8
FOG (mg/l)	173	202	16.8
Minimart			
pH	4	4.6	15.0
BOD (mg/l)	4366	1427	-67.3
COD (mg/l)	7432	2222	-70.1
SS (mg/l)	1392	233	-83.3
FOG (mg/l)	304	126	-58.6
Coffee Shop			
pH	4.65	4.3	-7.5
BOD (mg/l)	681	411	-39.6
COD (mg/l)	1143	667	-41.6
SS (mg/l)	126	60	-52.4
FOG (mg/l)	79.3	38.6	-51.3
Effluent (entrance)			
pH	6.8	7.2	5.9
BOD (mg/l)	29	53	82.8
COD (mg/l)	151	148	-2.0
SS (mg/l)	36	98	172.2
FOG (mg/l)	6.8	22.3	227.9
Effluent (exit)			
pH	7.2	6.8	-5.6
BOD (mg/l)	172	341	98.3
COD (mg/l)	400	659	64.8
SS (mg/l)	118	203	72.0
FOG (mg/l)	23	58.6	154.8

Note: % refers to the decreasing percentage compared to Day 1

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Results in Gas Station E (GSE)

Sampling point	Day 1	Day 30	% Reduction
Gentlemen Toilet			
pH	7.3	7.1	-2.7
BOD (mg/l)	152	123	-19.1
COD (mg/l)	80	477	496.3
SS (mg/l)	200	183	-8.5
FOG (mg/l)	22.2	35	57.7
Lady Toilet			-5.1
pH	4.95	4.7	12.2
BOD (mg/l)	967	1085	17.2
COD (mg/l)	1575	1846	76.5
SS (mg/l)	456	805	-46.5
FOG (mg/l)	98.2	52.5	
Minimart			
pH	6.2	6.1	-1.6
BOD (mg/l)	815	409	-49.8
COD (mg/l)	1250	707	-43.4
SS (mg/l)	614	270	-56.0
FOG (mg/l)	471	376	-20.2
Coffee Shop			
pH	5.5	5.1	-7.5
BOD (mg/l)	853	507	-40.6
COD (mg/l)	1348	704	-47.8
SS (mg/l)	275	126	-54.2
FOG (mg/l)	868	403	-53.6
Effluent (entrance)			
pH	6.1	6	-1.6
BOD (mg/l)	460	337	-26.7
COD (mg/l)	883	586	-33.6
SS (mg/l)	292	80	-72.6
FOG (mg/l)	51.5	33.5	-35.0
Effluent (exit)			
pH	7.3	7.1	-2.8
BOD (mg/l)	152	123	-63.1
COD (mg/l)	80	477	-71.5
SS (mg/l)	200	183	-47.3
FOG (mg/l)	22.2	35	-66.0

Note: % refers to the decreasing percentage compared to Day 1

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BIOGRAPHY

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