THE TVOCs RISK INVESTIGATIONS FROM GASOLINE SERVICE STATIONS IN BANGKOK AREAS

WASSANA KANAWAPEE

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WASSANA KANAWAPEE
……
Miss Wassana Kanawapee
Candidate

……
Asst.Prof.Siranee Sreesai,
D.Tech.Sci (Nat.Res.Mgt.)
Major-Advisor

……
Assoc.Prof.Prayoon Fongsatitkul,
Ph.D. (Environmental Engineering)
Co-Advisor

……
Assoc.Prof.Dusit Sujirarat,
M.Sc. (Biostatistics)
Co-Advisor

……...
Prof.Banchong Mahaisavariya, M.D.
Dean
Faculty of Graduate Studies

……
Assoc.Prof.Pisit Vatanasomboon
M.Sc. (Environmental Health)
Chair
Master of Science Programme
in Environmental Sanitation
Faculty of Public Health

Thesis
Entitled

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for the degree of Master of Science (Environmental Sanitation)
on

23 January, 2009

WASSANA KANAWAPEE
.....
Miss Wassana Kanawapee
Candidate

.....	.....
Assoc.Prof.Dusit Sujirarat, M.Sc. (Biostatistics) Member	Assoc.Prof.Pisit Vatanasomboon, M.Sc. (Environmental Health) Chair
.....	.....
Prof.Pichit Skulbhram, M.P.H. (Environmental Health) Member	Asst.Prof.Siranee Sreesai, D.Tech.Sci (Nat.Res.Mgt.) Member
.....	.....
Assoc.Prof.Phitaya Charupoonphol, M.D., Dip Thai Board of Epidemiology Member	Assoc.Prof.Prayoon Fongsatitkul, Ph.D. (Environmental Engineering) Member
.....	.....
Prof.Banchong Mahaisavariya, M.D. Dean Faculty of Graduate Studies Mahidol University	Assoc.Prof.Phitaya Charupoonphol, M.D., Dip Thai Board of Epidemiology Dean Faculty of Public Health Mahidol University

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Wassana Kanawapee

THE TVOCs RISK INVESTIGATIONS FROM GASOLINE SERVICE STATIONS IN BANGKOK AREAS

WASSANA KANAWAPEE 4837854 PHES/M

M.Sc. (ENVIRONMENTAL SANITATION)

THESIS ADVISORS: SIRANEE SREESAI, D.Tech.Sci.,
PRAYOON FONGSATITKUL, Ph.D., DUSIT SUJIRARAT, M.Sc. (BIOSTATISTICS).

ABSTRACT

A cross-sectional study was conducted to investigate risks of total volatile organic compounds (TVOCs) from 39 gasoline service stations in Bangkok areas. The selected fuel company brands were Ptt, Esso, and Shell. 629 TVOCs concentrations at human breathing zones in different work places (pump-island, changing motor fuel station, and office) were determined and analyzed by One-way ANOVA. Work practices and health behaviors of 113 refuel attendants were interviewed by questionnaire. Statistical analysis of work practice and health behavior as well as relationship between TVOCs risk level and risk behaviors level were done using χ^2 test or Fishers' exact test. Factors influencing TVOCs levels during refuelling at pump-island area (amount of gasoline sold per time, vehicle engine conditions, sizes of fuel receptacle, and distances from refueled nozzle) were determined by Pearson correlation coefficient.

69.2% of gasoline service station attendants had high TVOCs risk level. 28.2% and 2.6% of them had a moderate level and safe level respectively. For gasoline service stations located in inner city, 90% had a high TVOCs risk level with an average concentration of 74.42 mg/m^3. Stations located in urban fringe areas and suburban areas had high (68%) and moderate (75%) TVOCs risk level, respectively. The average TVOCs concentration in the gasoline service stations of Ptt, Esso, and Shell were 35.74, 47.81, and 66.28 mg/m^3, respectively. Gasoline service station attendants who had filling duty in pump-island areas had a significantly higher exposure risk to TVOCs compared to mechanical employees in changing motor fuel stations and staff in offices ($p=0.006$, $p<0.001$). They were in general exposed to elevated TVOCs (64.62 mg/m^3). In contrast, the average TVOCs in changing motor fuel station was 3.16 mg/m^3 and was rarely found in offices. TVOCs risk levels also depended on the risk behavior of attendants. In terms of gasoline service stations, 94.9% had moderate risk behavior level. Only 5.1% (two stations) had high risk behavior levels. It was clear that refueling procedure is an important source of exposure to TVOCs for the filling station employees. Factors which affect the illness of gasoline service station attendants include work time period ($p=0.41$), working two shifts per day ($p=0.012$), skin exposure to gasoline ($p=0.38$ and $p<0.001$), and nuisance odor of attendants ($p=0.005$). Moreover, factors which affected in attendants' behavior were: refuelling knowledge and behavior ($p<0.001$), place of eating (p-value=0.001), and experience in refueling gallon containers ($p=0.042$). Only the amount of sold gasoline per time had a positive correlation significant with TVOCs concentration during refuelling ($p<0.001$, $r=0.31$), whereas the distance from the refuelling nozzle had a significant negative correlation with TVOCs concentration ($p<0.001$, $r=-0.28$). Others factors such as the receptacle's size of fuel tank and vehicle engine condition had no correlation.

The results suggest that gasoline service station attendants must change work practice and health behavior to reduce TVOCs exposure risk. There is also a need for safety policy application to all gasoline service stations.

KEY WORDS : GASOLINE SERVICE STATION / TVOCs / GASOLINE / RISK INVESTIGATION/ HEALTH BEHAVIOR

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การสืบสวนความเสี่ยงของสารอินทรีย์ระเหยทั้งหมดจากสถานีบริการน้ำมันเชื้อเพลิงในเขตกรุงเทพมหานคร
(THE TVOCs RISK INVESTIGATIONS FROM GASOLINE SERVICE STATIONS IN BANGKOK AREAS)

วาสนา คณะวาปี 4837854 PHES/M

วท.ม. (สุขาภิบาลสิ่งแวดล้อม)

คณะกรรมการควบคุมวิทยานิพนธ์: ศิราณี ศรีใส, D.Tech.Sci., ประยูร ฟองสถิตกุลย์, Ph.D.,
ดุสิต สุจิรารัตน์, วท.ม. (ชีวสถิติ)

บทคัดย่อ

การศึกษาภาคตัดขวางได้ดำเนินการเพื่อประเมินความเสี่ยงของสารอินทรีย์ระเหยทั้งหมดจากสถานีบริการน้ำมันเชื้อเพลิง จำนวน 39 แห่ง ในเขตกรุงเทพมหานคร เครื่องหมายการค้าบริษัทน้ำมันที่ได้รับการคัดเลือก คือ ปตท. เอสโซ่ และเชลล์ โดยตรวจวัดความเข้มข้นของสารอินทรีย์ระเหยทั้งหมดในระดับหายใจ จำนวน 629 ตัวอย่างในสถานที่ทำงาน (บริเวณเกาะจ่ายน้ำมัน สถานีเปลี่ยนถ่ายน้ำมันเครื่องและ สำนักงาน) และวิเคราะห์ข้อมูลด้วยสถิติ One-Way Anova สัมภาษณ์พฤติกรรมการทำงานและพฤติกรรมสุขภาพของพนักงานเติมน้ำมันจำนวน 113 คนด้วยแบบสอบถาม การวิเคราะห์ข้อมูลทางสถิติของพฤติกรรมสุขภาพและพฤติกรรมการทำงานรวมถึงความสัมพันธ์ระหว่างระดับความเสี่ยงสารอินทรีย์ระเหยทั้งหมดและระดับพฤติกรรมเสี่ยง โดยใช้ χ^2 test หรือ Fishers'exact test หาปัจจัยที่มีผลต่อระดับของสารอินทรีย์ระเหยทั้งหมดระหว่างเติมน้ำมันที่บริเวณเกาะจ่ายน้ำมัน (ปริมาณน้ำมันเบนซินที่จำหน่ายต่อครั้ง สภาวะเครื่องยนต์ของยานพาหนะ ขนาดช่องรับน้ำมัน และระยะทางจากหัวจ่ายน้ำมัน)โดยใช้สถิติสัมประสิทธิ์สหสัมพันธ์ของเพียร์สัน

พนักงานสถานีบริการน้ำมันร้อยละ 69.2 มีความเสี่ยงต่อสารอินทรีย์ระเหยทั้งหมดในระดับสูง พนักงาน ร้อยละ 28.2 และร้อยละ 2.6 มีความเสี่ยงในระดับปานกลางและอยู่ในระดับที่ปลอดภัยตามลำดับ สถานีบริการน้ำมันที่ตั้งในเขตการปกครองชั้นในร้อยละ 90 มีความเสี่ยงต่อสารอินทรีย์ระเหยทั้งหมดในระดับสูงด้วยความเข้มข้นเฉลี่ย เท่ากับ 74.42 mg/m^3 สถานีที่ตั้งในเขตการปกครองชั้นกลางและชั้นนอกมีความเสี่ยงต่อสารอินทรีย์ระเหยทั้งหมดในระดับสูง (ร้อยละ 68) และปานกลาง(ร้อยละ 75) ตามลำดับ ความเข้มข้นเฉลี่ยสารอินทรีย์ระเหยทั้งหมดในสถานีบริการน้ำมันของ ปตท. เอสโซ่ และ เชลล์ เท่ากับ 35.74 mg/m^3 , 47.81 mg/m^3, และ 66.28 mg/m^3 ตามลำดับ พนักงานสถานีบริการน้ำมันที่มีหน้าที่เติมน้ำมันในบริเวณเกาะจ่ายน้ำมัน มีความเสี่ยงต่อการสัมผัสสารอินทรีย์ระเหยทั้งหมดสูงกว่าเมื่อเปรียบเทียบกับช่างซ่อมรถยนต์ในสถานีเปลี่ยนถ่ายน้ำมันเครื่องและพนักงานในสำนักงาน อย่างมีนัยสำคัญ ($p=0.006$, $p<0.001$) และทั่วไปสัมผัสสารอินทรีย์ระเหยทั้งหมดในระดับ 64.62 mg/m^3 ตรงกันข้ามความเข้มข้นเฉลี่ยสารอินทรีย์ระเหยทั้งหมดบริเวณสถานีเปลี่ยนถ่ายน้ำมันเครื่องเท่ากับ 3.16 mg/m^3 และแทบไม่พบในสำนักงาน ซึ่งระดับความเสี่ยงต่อสารอินทรีย์ระเหยทั้งหมดขึ้นอยู่กับพฤติกรรมเสี่ยงของพนักงานเช่นเดียวกัน ในภาพรวมของสถานีบริการน้ำมัน ร้อยละ 94.9 มีระดับพฤติกรรมเสี่ยงในระดับปานกลาง มีเพียงร้อยละ 5.1 (2 สถานี) ที่มีระดับพฤติกรรมเสี่ยงสูง ข้อมูลยังชี้ชัดว่า ขั้นตอนการเติมน้ำมันเป็นแหล่งกำเนิดที่สำคัญของการสัมผัสสารอินทรีย์ระเหยทั้งหมดสำหรับพนักงานเติมน้ำมัน ซึ่งปัจจัยที่ส่งผลต่อการเจ็บป่วยของพนักงานสถานีบริการน้ำมัน ได้แก่ อายุงาน ($p=0.41$) การทำงานสองกะต่อหนึ่งวัน ($p=0.012$) การโดนน้ำมันหกรด/สัมผัสร่างกาย ($p=0.38$ และ $p<0.001$) และเหตุรำคาญเรื่องกลิ่นของพนักงาน ($p=0.005$) นอกจากนี้ปัจจัยที่ส่งผลต่อพฤติกรรมของพนักงาน คือ ความรู้และพฤติกรรม ($p<0.001$)บริเวณรับประทานอาหาร ($p<0.001$)และประสบการณ์เติมน้ำมันสู่ภาชนะบรรจุแบบแกลลอน ($p=0.042$) มีเพียงปริมาณน้ำมันเบนซินที่จำหน่ายต่อครั้งมีความสัมพันธ์เชิงบวกกับความเข้มข้นของสารอินทรีย์ระเหยทั้งหมดในระหว่างเติมน้ำมันอย่างมีนัยสำคัญ ($p<0.001$, $r=0.31$) ในขณะที่ ระยะทางจากหัวจ่ายน้ำมันมีความสัมพันธ์แบบแปรผกผันกับความเข้มข้นของสารอินทรีย์ระเหยทั้งหมด ($p<0.001$, $r=-0.28$) ปัจจัยอื่น เช่น ขนาดของช่องรับน้ำมันและสภาวะเครื่องยนต์ของยานพาหนะไม่มีความสัมพันธ์

จากผลการศึกษาจึงแนะนำว่าพนักงานสถานีบริการน้ำมันเชื้อเพลิงต้องเปลี่ยนพฤติกรรมการทำงานและพฤติกรรมสุขภาพเพื่อลดความเสี่ยงต่อการสัมผัสสารอินทรีย์ระเหยทั้งหมดและการใช้นโยบายด้านความปลอดภัยเป็นสิ่งที่มีความจำเป็นต่อทุกสถานีบริการน้ำมันเช่นเดียวกัน

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LIST OF ABBREVIATIONS

Abbreviation

1	VOC	-	Volatile organic compound
2	TVOCs	-	Total volatile organic compounds
3	t,t ma	-	Trans, trans muconic acid
4	MTBE	-	Methyl Tertiary Buthyl Ether
5	PTT	-	Petroleum Authority of Thailand
6	B	-	Benzene
7	T	-	Toluene
8	E	-	Ethel benzene
9	X	-	Xylene
10	PID	-	Photo ionization detector
11	NMHC	-	Non-methane hydrocarbon
12	STEL	-	Short-term exposure limit
13	TWA	-	Time-weighted average
14	CNS		Central nervous system
15	GC-FID	-	Gas chromatography-Flame ionization detector
16	GC-MS	-	Gas chromatography-Mass spectrometry
17	CPK	-	Creatine phosphokinase
18	Hb	-	Hemoglobin
19	Hct	-	Hematocrit
20	ALP	-	Alkaline phosphatase

CHAPTER I
INTRODUCTION

1.1 Statement of problems

Nowadays, Air pollution is one of pollution problems in Thailand. It results from a large amount of undesirables materials in the air. There are volatile organic compound (VOCs), sulfur oxides (SOx) and carbon monoxide (CO), and others. It causes not only health problem, but also gives various environmental impacts. One of the major sources of these pollutants is exhausted gas and evaporation of gasoline fuel from transportation, industrial as well as gasoline service stations. A study of Ruttanaprayoon I. (1995) in gasoline service station founded the amount of evaporated gasoline from transfer gasoline to underground storage tank was 670 tons per year or 24% of total evaporated and the amount of evaporated gasoline from refueling to automobile was 630 tons per year or 22 of total evaporated (1).

In Bangkok area, the 1998 statistics from department of land transport (2) showed the number of new register vehicles were 687,718 and it was increased to 734,115 in 2005. Gasoline service stations have been established to support the highly increasing rate of vehicles and rapid growth of gasoline consumption. In 1995, number of gasoline service station was approximately 600 and the consumption of gasoline was about 2 billion liters per year in Bangkok. The statistics from the department of public and municipal works (1999) (3) reported that a number of all types of gasoline service stations was increased to 820 in 1999 and 860 in 2006 (in which the biggest type was 798). This number in Bangkok area was counted as 4.67% of the total gasoline service station in Thailand (4). A study of Porpan S. (5) found that influenced factor to expanding number of gasoline station are an interest rate, amount of soled gasoline and diesel and number of a seller follow regulation number 6 of control motor fuel Act. It can be stated that the increase in both gasoline stations and

vehicles could directly contribute to the amount of hydrocarbons emitted into the air. Moreover, it implies the increasing number of workers in gasoline service station who have risk to expose pollutants from gasoline vapor.

Gasoline service station is considered to be one of the high health risks because, in any activities, workers can be exposed to gasoline vapor such as refuel of gasoline-powered vehicles, load fuel to storage containers, and remove and maintenance underground storage tanks. Volatile organic compounds in gasoline spilled on soil or surface water will rapidly evaporate to air.

Gasoline is a refined product of petroleum consisting of a mixture of hydrocarbons that are butane till C_{10} hydrocarbon, additives and blending agents. Due to the compositions have differ boiling points, they cause gasoline evaporate to hydrocarbon vapor at ambient temperature till temperature 200 °C. When hydrocarbons react with oxide of nitrogen which has sunlight as catalyst, it causes photochemical oxidants such as ozone (photochemical oxidant condition). These substances can cause health problems such as respiratory and irritation of eyes. Beside that, many of the harmful effects seen after exposed to gasoline are due to the individual chemicals in the gasoline mixture, such as benzene (B), toluene (T), ethyl benzene (E), and xylene (X). Gasoline is a skin irritant. Exposure to very high concentration of gasoline can cause irritation to the lungs when breathe in and to the stomach when swallowed, sign of nervous system such as dizziness, headaches, and may cause death at the end.

The statistics from the office of epidemiology, Ministry of health (6) showed numbers of petroleum poisoning in 2002 were 82 and increased to 92 in 2004. Mobility rate per 100,000 populations was equal to 0.15 and there were two people death with this problem in the year 1995 and 1997. Beside that, Tunsareungakan T. et al (2005) did a study on health effect of BTEX and Methyl Tertiary Butyl Ether (MTBE) among refueled workers. They found that their symptoms of headache, dizziness and fatigue were reported at 36.4, 36.4 and 20.5 percent, respectively (7).

The severity of this problem is slightly increased each year which the risk of gasoline vapor exposure of gasoline service station attendant is depends on many factors. There are work site, environmental factor, type of gasoline, work related factors and health behavior of workers. Work site and work related factors can cause

directly to the level of gasoline vapor exposure of workers. The awareness of these problems is very essential for improving and promoting the health of refueled workers. Thus, in this study, the levels of TVOCs concentration at human breathing zone of different work places were determined. The evaporated concentration during refuel was investigated at various distances from refueling nozzle. Beside this, the relationship between level of TVOCs concentration at refueling nozzle and factor influencing gasoline evaporation such amount of sole gasoline, conditions of vehicles engine, and size of fuel receptacle are aimed to observe. The results which indicate this air pollutant situation in gasoline service station, health behavior of attendant and other database were used for health risk problem solving and promoted refueled worker health in a term of better working practice.

1.2 Objectives of study

1.2.1 General objective:

To investigate risk of TVOCs from gasoline service stations.

1.2.2 Specific objectives:

1. To determine the level of TVOCs concentration at human breathing zone in different work places of gasoline service station and factors influencing its level at refuel nozzle in pump-island area.

2. To investigate the work practice and health behavior of forecourt gasoline service station attendant.

3. To evaluate the degree of TVOCs risk from gasoline service station.

4. To compare the level of TVOCs concentration at human breathing zone of different distances from refuel nozzle at pump-island area.

5. To study factors (amount of sole gasoline, condition of vehicle engine, and size of fuel receptacle) influencing the levels of TVOCs concentration at refuel nozzle in pump-island area.

1.3 Hypotheses of this study

1.3.1 The level of TVOCs concentration at human breathing zone would difference in each work place.

1.3.2 The TVOCs risk level would correlate with risk behavior level of gasoline service station attendant.

1.3.3 The level of TVOCs concentration at human breathing zone would decrease when the distance from refuel nozzle at pump-island area increase.

1.3.4 The level of TVOCs concentration at refuel nozzle of running vehicle engine condition would more than that of stopping vehicle engine condition.

1.3.5 The level of TVOCs concentration at refuel nozzle would increase when the size of fuel receptacle and amount of gasoline fuel increase.

1.4 Variables of study

1.4.1 Sources

1. Work places

Independent variables

(1) Pump-island area

(2) Changing motor fuel station

(3) Office

Dependent variables

(1) TVOCs concentration at human breathing zone

2. Factor influencing TVOCs emission

Independent variables

(1) Condition of vehicle engine

(2) Amount of sold gasoline per time

(3) Size of fuel receptacle

Dependent variables

(1) TVOCs of gasoline vent at refuel nozzle

1.4.2 Path way

Independent variables

(1) Distance from refuel nozzle

Dependent variables

(1) TVOCs concentration at human breathing zone

1.4.3 Receiver

Independent variables

(1) Work practice and health behavior

1.1 Low risk behavior

1.2 Moderate risk behavior

1.3 High risk behavior

Dependent variables

(1) TVOCs risk level

1.1 Low

1.2 Moderate

1.3 High

1.5 Definition of Terms

1.5.1 Gasoline fuel: Type of gasoline soled in gasoline service station. It this study, it includes only gasoline octane number 91 since it was used widely and can emit exhaust gas more than gasoline octane number 95 (8).

1.5.2 Gasoline service station: The gasoline service station type A and B which located nearby street wider than 12 meters and narrow than 12 meters or small roadside, respectively. They are situated in inner city, urban fringe, and suburb of Bangkok area and serviced for general customer. There were 39 studied gasoline service stations (see sampling methodology in chapter 3).

1.5.3 Gasoline service station attendant: Worker who is working as refuel staff in forecourt of studied gasoline service station and give a good collaboration.

1.5.4 Work place: a place of gasoline service station in which there are different sources of gasoline vapor. They were divided to pump-island, changing motor fuel station, and office.

1.5.5 Amount of sold gasoline fuel per time: Amount of gasoline which refueling to vehicle per time. It is checked from a meter of each gasoline refuel nozzle from pump-island and showed as unit of liters.

1.5.6 The distance from refuel nozzle: A distance from refuel nozzle at pump-island area to designed areas under wind direction.

1.5.7 The level of TVOCs concentration: The level of TVOCs concentration was divided to TVOCs concentration at human breath zone and TVOCs concentration of gasoline vent at refuel nozzle. TVOCs at human breathing zone was measured from gasoline vapor during refuel automobile/ changing motor fuel and motor cycle in selected condition by using Multirae IR that was hold at 1.50 meter from the ground in designed placed. On the other hand, TVOCs concentration of gasoline vent was measured only automobile by using this instrument that was hold at refuel nozzle in pump-island area. Both of them were kept records in ppm./m^3 of air.

1.5.8 Condition of vehicle's engine: The condition of vehicle's engine while refueling from studied gasoline service station. It was divided to stop the engine and run the engine.

1.5.9 Size of fuel receptacle: Size of fuel receptacle of vehicles which refueling from studied gasoline service station, they were measured by using ruler and showed as centimeter unit.

1.5.10 TVOCs risk: The risk in studied gasoline service station which concluded from TVOCs concentration at breathing zone on different work place; pump island area, changing motor fuel station, and office. The degree of TVOCs risk was divided into low, moderate, and high.

1.5.11 Risk behavior level: The risk behavior levels were divided into low, moderate, and high. They were investigated from work practice and health behavior of refuel workers.

1.5.12 Work practice and health behavior: The contents of work practice and health behavior of refuel gasoline service station attendant were smoking and drinking behavior, refuel behavior and other responsibility behavior, personal protective use, personal hygiene, ate behavior, received environmental problem, and safety training (see detail in appendix).

1.5.13 Zone of Bangkok area: They were divided into three zones according to a classification of the division of urban planning, Bangkok Metropolitan Administration; inner city, urban fringe, and suburb (see detail in Chapter 3).

1.5.14 Breathing zone: The level in vertical line which TVOCs concentrations were measured by using Muitirae IR. It was hold at 1.50 meters from the ground and/or in radius of noses' workers.

1.6 Scope of study

1.6.1 The study was conducted with gasoline service station attendants that have been worked in studied gasoline service station type A and B from inner city, urban fringe and suburb of Bangkok.

1.6.2 The data were collected by using inspection form, questionnaire and laboratory instruments.

1.6.3 The samples of TVOCs concentration were measured by direct reading instrument which has 10.6 electrons volt (eV). Thus total of measured VOC in this study included only VOC that has ionization potential (IP) less than 10.6 eV.

1.6.4 The data of samples were collected between March-May 2007.

1.7 Limitation of study

1.7.1 The study was done at only 39 gasoline service stations that located at inner city, urban fringe, and suburb areas of Bangkok.

1.7.2 The cross sectional study was done at only period of time and one visiting for each gasoline service station.

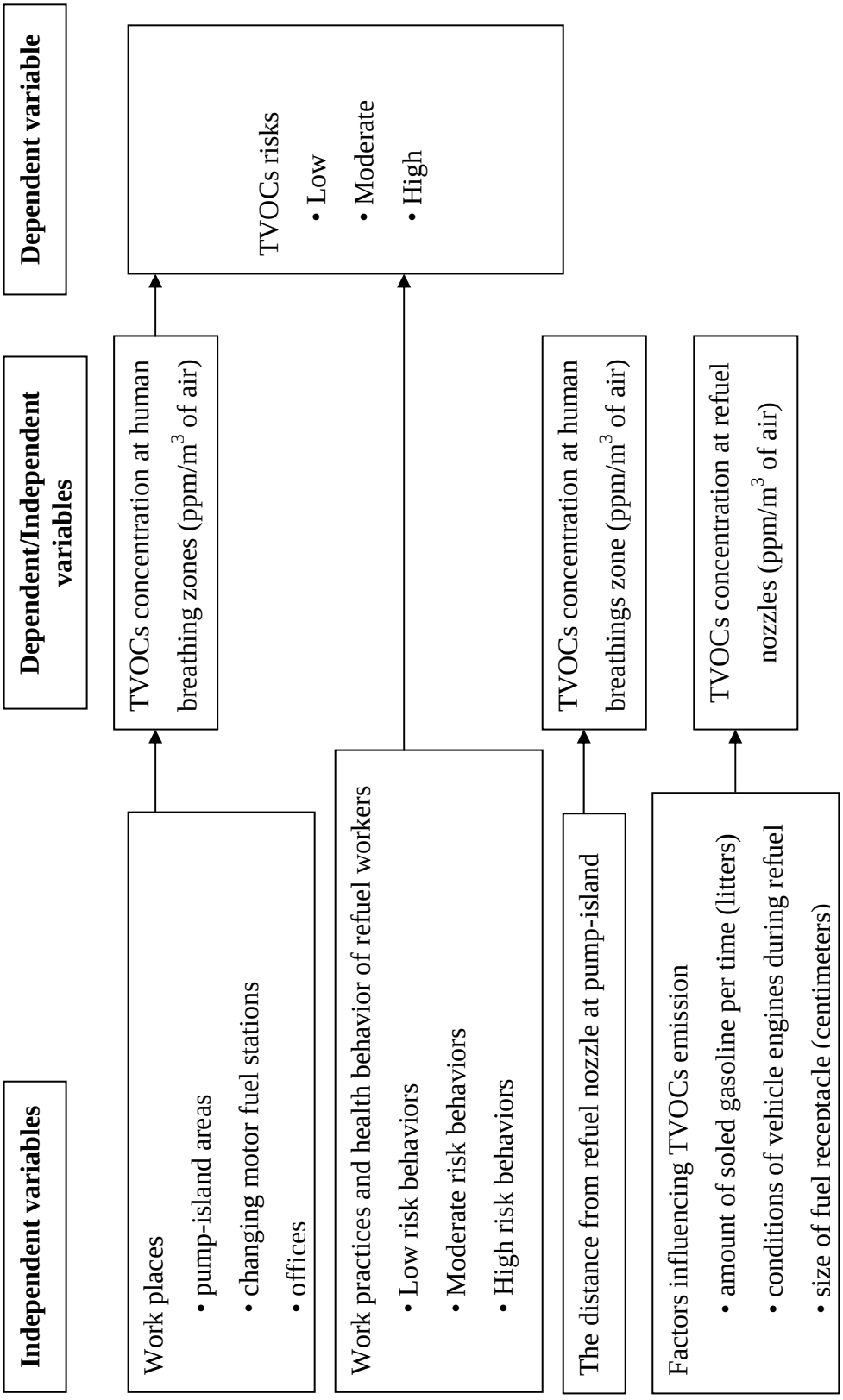
1.7.3 The level of TVOCs concentration was measured in shortly sampling time. It may not represent the total exposure of workers.

1.7.4 If there was some VOC which had IP more than 10.6 eV in air samples, the selected laboratory instrument can not detect.

1.8 Expected outcome

The results were used as the basis information for supporting priority setting of risk areas in gasoline service stations. Preventive measures were implemented and leading to safe and healthy workplaces for the workers.

1.9 Conceptual framework



CHAPTER II
LITERATURE REVIEWS

2.1 Gasoline (9)

2.1.1 Chemical identity

Gasoline is a refined product of petroleum consisting of a mixture of hydrocarbons, additives and blending agents. The composition of benzene varies widely depending on the crude oil used, the refinery process available, the overall balance of product demand, and the product specifications. The typical composition of gasoline hydrocarbon (% volume) are as follows; 4-8% alkanes; 2-5% alkenes; 25-40% isoalkanes; 3-7% cycloalkanes; 1-4% cycloalkenes; and 20-50% total aromatics (0.5-2.5% benzene). Information regarding the major component of gasoline is showed in Table1. Additives and blending agents are added to the hydrocarbon mixture to improve the performance and stability of gasoline. These compounds are included anti-knock agents, anti-oxidant, metal deactivators, lead scavenger, anti-rust agents, anti-icing agents, upper cylinder rubricant, detergent and dyes. At the end of production process, finished gasoline typically contains more than 150 separate compounds although as many as 1,000 compounds have been identified in some blends. Information regarding the chemical identity of gasoline is showed in Table 2.

2.1.2 Physical and chemical properties

Information regarding the physical and chemical properties for the gasoline mixture is showed in Table 3. In cases where data are not available for gasoline, ranges are given to indicate the difference values for the individual component

2.1.3 Gasoline specification

Gasoline is usually defined by government regulation, where properties and test method are clearly defined. Thailand specification and test methods are listed in Table 4.

Table 1 Major Component of Gasoline[a]

Component	Percentage Composition[b]	Component
n-alkanes		Other possible component
C_5	3.0	Octane enhancer
C_6	11.6	Methyl t-buthyl ether (MTBE)
C_7	1.2	t-butyl alcohol (TBA)
C_9	0.7	Ethanol
C_{10}-C_{13}	0.8	Methanol
Total of n-alkanes	17.3	Antioxidants
		N,N-dialkylphenylenediamines
Branched alkanes		2,6-dialkyl and 2,4,6-trialkylphenol
C_4	2.2	butylated methyl, ethyl and dimethyl phenols
C_5	15.1	Triethylene tatramines di (monononylphenolate)
C_6	8.0	Metal deactivator
C_7	1.9	*N,N* disalicylidine-1,2- ethanediamine
C_8	1.8	*N,N* disalicylidine propanediamine
C_9	2.1	*N,N* disalicylidine cyclohexanediamine
C_{10}-C_{13}	1.0	Disalicylidine-n-methyl-dipropylene-triamine
Total of branched alkanes	32.0	Ignition controller
		Tri-o-cresylphosphate (TOCP)
cycloalkanes		Icing inhibitor
C_6	3.0	Isopropyl alcohol

Table 1 Major Component of Gasoline[a] (Continued)

Component	Percentage Composition[b]	Component
C_7	1.4	Detergents/dispersants
C_8	0.6	Alkylamine phosphate
Total of cycloalkanes	5.0	Poly isobutene amine
		Long chain alkyl phenol
Olefins		Long chain alcohol
C_6	1.8	Long chain carboxylic acid
Total of Olefins	1.8	Long chain amines
Aromatics		Corrosion inhibitors
benzene	3.2	Carboxylic acid
Toluene	4.8	Phosphoric acid
Xylene	6.6	Sulfonic acid
ethylbenzene	1.4	
C_3-benzene	4.2	
C_4-benzene	7.6	
Other	2.7	
Total aromatics	30.5	

Note:

[a]Adapted from Air Force 1989

[b]Percentage by weight

Table 2 Chemical identity of gasoline

Characteristic	Information	Reference
Chemical name	Gasoline	RTECS 1990
Synonyms	Casing head gasoline; motor fuels; motor spirit; natural gasoline; petrol	HSDB 1993
Registered trade name (s)	No data	
Chemical formular	No data	
Chemical structure	No data	
CAS Registry	8006-61-9	RTECS 1990; SAX and Lewis 1989
NIOSH RTECS	LX3300000	RTECS1990; SANSS 1986; SAX and Lewis 1989
EPA Hazardous waste	No data	
OHM/TADS	7217073	OHM/TADS 1991 SANSS 1986
DOT/UN/NA/IMCO shipping	UN1203/UN1257	RTECS 1990
HSDB	No data	
NCI	No data	

Note:
CAS = Chemical abstract services; DOT/UN/NA/IMCO = Department of transportation/United Nations/North America/International Maritime Dangerous Goods Code; EPA = Environmental Protection Agency; HSDB = Hazardous Substance Data Blank; NCI = National Cancer Institute; NIOSH = Nation Institute for Occupational Safety and Health; OHM/TADS = Oil and Harzadous

Material/Technical assistance data system; RTECS = Registry of Toxic Effects of Chemical Substance; SANSS = Structure and nomenclature system.

Table 3 Physical and chemical properties of gasoline

Property	Information	Reference
Molecular weight	108	Anonymous 1989
Color	Colorless to pale brown	Sax and Lewis 1989;
	or pink	Weiss 1986
Physical state	Liquid	Sax and Lewis 1986
Melting point	No data	
Boiling point	Initially, 39 º C	Budavari et al. 1989
	After 10% distilled, 60 º C	OHM/TADS 1991;
	After 50% distilled, 110 º C	Sax and Lewis 1989
	After 90% distilled, 170 º C	
	Final boiling point, 204 º C	
Density	0.7-0.8 g/cm^3	IARC 1989
Odor	Gasoline odor	Weiss 1986
Odor threshold	0.025 ppm	Weiss 1986
Solubility:		
Water at 20º C	Insoluble	OHM/TADS 1991;
		Sax and Lewis 1989
Organic solvent (s)	Absolute alcohol, ether,	Budavari et al. 1989;
	Chloroform, benzene	Sax and Lewis 1989
Partition coefficients		
Log K_{ow}	2.13-4.87	Air Force 1989
Log K_{oc}	1.81-4.56	Air Force 1989
Vapor pressure		
At 60 º C	465 mmHg	ASTM 1989
At 56 º C	518 mmHg	
At 51 º C	593 mmHg	

Table 3 Physical and chemical properties of gasoline (Continued)

Property	Information	Reference
At 56 º C	518 mmHg	
At 51 º C	593 mmHg	
At 47 º C	698 mmHg	
At 41 º C	773 mmHg	
Henry ' s Law constant at 20 º C	$4.8x10^{-4}$-3.3 m^3/mol	Air Force 1989
Auto ignition Temperature	280-486 º C	NEPA 1986; Sax and Lewis 1989; Weiss 1986
Flashpoint	-46 º C	Sax and Lewis 1989
Flammability Limits	1.4-7.4%	Weiss 1986
Conversion factor	No data	
Explosive limits	1.3-6.0%	Budavari et al. 1989; Sax and Lewis 1989

Note:

[a]Average molecular weight

[b]Temperature ot specified

[c]Not specified whether data for air or water

[d]Since data are not available for gasoline, range are given indicating difference values for the individual component

[e]The American Society Testing and Materials (ASTM) has established guidelines on composition of gasoline that will permit satisfactory performance under carrying condition. This guideline defines five volatility classes that vary by season climatic change. The value given for vapor pressure at the given temperature is based on these volatility classes.

Table 4 Thailand specification and test methods for gasoline

specification	Maximum rate/ Minimum rate	Gasoline Octane 91	Gasoline Octane 95	Test method
1. Octane number				
1.1 Research Octane number	Not less than	91.0	95.0	ASTM D 2699
1.2 Motor number	Not less than	90.6	94.6	ASTM D 2700
2. Lead content (g/l)	Not more than	0.013	0.013	ASTM D 5059
3. Sulpur content (% mass)	Not more than	0.05	0.05	ASTM D 4294 or equivalent
4. Phosphorus (g/l)	Not more than	0.0013	0.0013	ASTM D 3231
5. Copper strip corrosion	Not more than	1	1	ASTM D 130
6. Oxidation stability, min	Not less than	360	360	ASTM D 525
7. Solvent washed gun	Not more than	0.004	0.004	ASTM D 381
8. Evaporated				ASTM D 86
10%Evaporated Temp, º C	Not more than	70	70	
50% Evaporated Temp, º C	Not less than	70	70	
	Not more than	110	110	
90% Evaporated Temp, º C	Not more than	170	170	
end point, º C	Not more than	200	200	
Residue, %vol	Not more than	2.0	2.0	
9. Vapor pressure at 37.8 º C,KPA	Not more than	62	62	ASTM D 4953
10. Benzene (vol%)	Not more than	3.5	3.5	ASTM D 5580
11. Aromatics (vol%)	Not more than	35	35	ASTM D 5580
12. Water,%wt				
12.1 Non Oxygenate Bland		None	None	
12.2 Oxygenated blend		0.7	0.7	ASTM E 203
13. Oxygenated	Not less than	-	5.5	ASTM D 4815
compounds,%vol	Not more than	11	11.0	
14. PFI/IVDC additive				

Reference: Department of energy business, Thailand (10)

2.1.4 Production and use (11)

(a) Production

Gasoline are blended from several petroleum refinery process streams, including any of the various naptha streams from direct distillation of crude oil at atmospheric pressure (light straight-run naptha) by catalytic and thermal cracking process, by catalytic reforming processes and alkylation and isomerization of the lighter distillated streams. They may also contain one or more additional components. The actual composition of gasoline varies widely, depending on the crude oils used, the refinery process available, the overall balance of product demand, and the product speciation.

(b) Use

Gasoline was used primarily by vanish and paint makers as a solvent, and burnt for special lamps to illuminate park and streets around 1960. In the early 1990s, gasoline demand began to exceed supply because of the rapid development of the automobile. Gasoline becomes the primary product of most petroleum refineries and remains so today. Consumption of gasoline is for use as automotive and aviation gasoline. In Thailand an amount of used gasoline fuel per year as follow Figure 1 in which a major of Oil Company in Thailand that can sell amount of gasoline octane 91, 95 from highest to lowest (1-5 order) as the follow Table 5 and 6, respectively.

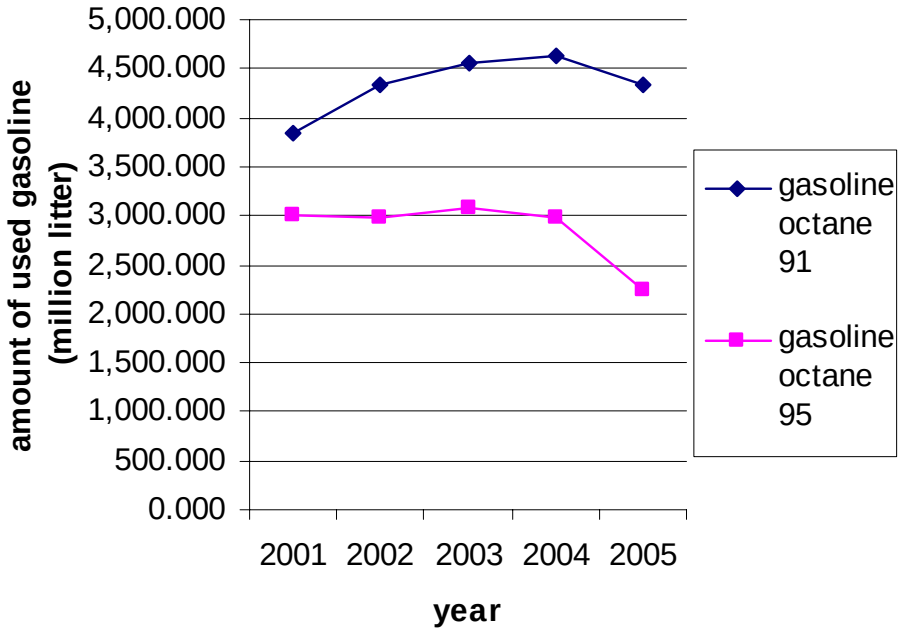


Figure 1 An amount of used gasoline in 2001-2005 (12)

Table 5 Amount of soled gasoline octane 91 divided by 5 orders of Oil Companies

(Million litters/year)

An order	Oil company	2001	2002	2003	2004	2005
1	Ptt	939.507	1,048.020	1,211.835	1,193.861	1,192.695
2	Shell	557.004	728.386	662.373	641.046	563.652
3	Esso	534.899	584.506	620.144	657.328	618.589
4	Caltex	408.110	454.813	448.235	457.061	499.948
5	Bangjak	382.161	444.531	416.370	410.965	391.366

Table 6 Amount of soled gasoline octane 95 divided by 5 orders of Oil Companies

(Million litters/year)

An order	Oil company	2001	2002	2003	2004	2005
1	Ptt	665.585	672.156	753.964	708.542	536.885
2	Shell	615.500	640.773	617.059	597.984	421.570
3	Esso	435.900	430.420	471.534	488.278	358.360
4	Caltex	346.165	330.711	321.272	302.607	287.088
5	Bangjak	249.115	253.885	244.807	228.642	154.181

(c) Regulatory status and guideline (11)

In Sweden, occupational exposure standards of 220 mg/m^3 (8-hour time-weighted average (TWA)) and 300 mg/m^3 (15–min TWA) have been established for gasoline with an assumed aromatic content of 46% (CONCAWE, 1987)

In the USA, occupational exposure limits for gasoline have been recommended at 900 mg/m^3 (8-hour TWA) and 1,500 mg/m^3 (15-min TWA; American Conference of Governmental Industrial Hygienists, 1987). A compilation of national occupational exposure limits for gasoline components has been published.

2.1.5 Occupational exposure (11, 13)

The jobs or operations that have been exposed to gasoline in the working environment are as follows: refinery operations leading to the production of gasoline;

tank dipping; pipeline and pump repairs and filter cleaning in refineries, distribution terminals and depots; maintenance, inspection and cleaning of gasoline storage tanks, gasoline distribution via bulk transfer refineries and terminals, service station attendants; engine and vehicle maintenance, and routine sampling and laboratory analysis of gasoline. Other operations or jobs involving gasoline exposure include adjustment of gasoline pumps in service stations, and the use of gasoline as a metal cleaning solvent.

In 1989, the international Agency for Research on Cancer (IARC) classified exposure to gasoline vapors as possibly carcinogenic to humans (Group 2B), mainly on the basis of the established carcinogenicity of some constituents such as benzene.

The studied indicated that the occupation potentially exposures to benzene were refinery workers, road tanker distribution workers, rail car terminal workers, ship/jetties workers and service station workers (14,15). The levels of exposure were significantly different for each group. The higher exposure groups were gasoline loading and unloading men. The service station attendants were also identified as a risk group of occupational benzene exposure (16). There were differences of exposure level from each studied ranging from non-detectable to more than 0.5 ppm; 1.6-2.5 ppm (17), 0.57-2.29 ppm for loader men (18), 0.72±0.45 ppm for vehicle maintenance men, 1.74±1.02 ppm for rail car loaders (19), and less than 0.5 ppm; 0.02-0.29 ppm (20), 0.14-0.24 ppm (21), 0.03-0.11 ppm (22) for gasoline service station attendants, car mechanics and operators and 0.25±0.06 ppm for petroleum refineries workers (23).

2.1.6 Release to environment (9, 24)

Gasoline vapors are released to the air during refueling of gasoline-powered vehicles which highest between pressing a nozzle, bulk transfer of gasoline at distribution terminals, the amount released during transfer operations will vary with the method used. Loading operations employing vapor recovery systems do not release as much vapor as those do not utilizing them which lowest releases in top or bottom loading operations with vapor recovery systems.

Gasoline vapors are leaks from storage containers and loading equipments, during filling, removal, and maintenance of underground storage tanks. Release of vapors occurs during all phases of the operations including transfer of gasoline from

the storage tanks, washing of the interior and removal of vapors, excavation, examination and maintenance. Volatile hydrocarbons in gasoline spilled on soil or surface water will rapidly evaporate, contributing to air contamination in certain amount.

At service station, there are emissions from three sources: during the filling of underground storage tanks, underground storage tanks breathing and emptying losses, and vehicle refueling losses. Splash filling losses and uncontrolled displacement losses during vehicle refueling are the largest emission sources at service station operations.

Vapors containing a mixture of VOCs and air are emitted when tank trucks are load with motor gasoline or if a truck contains gasoline vapors from a previous load. As product is loaded, it displaces the vapor in the tank truck, and these vapors are vented to the atmosphere or to a vapor processing system. Tank trucks load gasoline into underground storage tanks at service stations. This is called Stage I refueling. Gasoline tank trucks are normally divided into compartments, with a loading dome hatchway at the top of each compartment. The method of loading affects the amount of emissions generated. Loading can be by top splash or submerged fill through the dome using a fill tube or by bottom filling. Typically, splash or submerged filling methods are used.

A second source of VOC emissions gasoline service stations is breathing losses from underground tanks. Breathing losses vary by the frequency with which gasoline is withdrawn from the tank and also with barometric pressure. Stage II refueling is the process of loading fuel by pumping directly into motor vehicles fuel using a metering dispenser equipped with a flexible hose and nozzle. Vehicle refueling produces evaporative emissions (i.e., venting of vapor) when vapors are displaced from the automobile tank by dispensed liquid gasoline and from spillage.

2.1.7 Mechanism of evaporation of VOC (25, 1)

Tanks containing liquid VOCs can emit VOC vapors because of filling and emptying activities as well as changes in temperature and atmospheric pressure. These emissions are called filling or displacement losses, emptying losses, and breathing losses, or, collectively, working losses. As the liquid enter the tank and the liquid level rises, the vapor space above the tank must decrease in volume. Normally that vapor

space (called headspace) is connected by a vent to the atmosphere so the vapor, which is mostly air, will be expelled. When liquid is withdrawn from the tank, air will flow in through the vent to fill the space made available by the fall in liquid level. If the tank were not vented, changing the liquid level would cause an over pressure during filling or a vacuum during emptying.

The tank must breathe in and out when ever its temperature changes, normally out all of the time. This is called the breathing loss. The assumption of plug flow displacement of the vapor is plausible for a stationary tank, but not for the fuel tank of a moving vehicle, where slouching of the liquid will keep the vapor close to equilibrium at all times. In that case we would have to integrate the emission over the temperature change, assuming equilibrium vapor content at all temperatures

The third kind of loss, sometimes called emptying loss, arises from the slow vaporization of the contents of the tank after partial emptying.

In gasoline service stations, the transfer of gasoline from tank truck to underground storage tanks at service stations in the United States, the vapor displaced from the tank being filled is carried back to the tank being emptied. Withdrawing liquid from the tank truck creates a vacuum in it that sucks the vapor out of the underground tank into the tank truck. The vapor from the underground storage tank was gone to the refinery or bulk gasoline terminal, where there are treated in one of several way. The vent lines from all of the underground storage tanks are normally located at the side or rear of the service station building. The vent line remains open during tank filling to prevent any excessive pressure of vacuum in the system. The vent remains open between tank fillings so that, as gasoline is withdrawn and placed in the customers' vehicle, air can flow into replace it. The storage tank vent also handles breathing losses. In some versions the vapor from the customer's tank is forced back into the supply tank, other version use mechanical blowers to accomplish the same result. The blower systems bring a larger volume of air into the storage tank than the volume of liquid withdrawn, so some vapor passes out though the vent. This is normally passed through the gas burner that destroys the VOC before it reaches the ambient air.

In conclude, the mechanism of evaporation of motor fuel between refueling**,** In general, over the surface inside the fuel tank will be saturated vapor. When motor fuel

in fuel tank is pumped to use or interchange from tank. It causes space above liquid and outside air is sucked into fuel tank and then cause diluted fuel vapor inside the tank. Motor fuel inside tank will be evaporated arise to preserve an equilibrium so the space inside the tank is a mixture of air and fuel vapor. While the attendant refueling, some of fuel will be evaporated into space that is a vapor above liquid. When level of motor fuel increase, liquid fuel will be replace vapor inside the tank and push vapor to ambient. The outlet of vapor is a mixture of air and fuel vapor which consist of many of hydrocarbons. Losing of motor fuel due to replace of fuel vapor called displacement loss. Beside that, while he refueling, it may splash to droplet and spread in fuel vapor. This droplet are hydrocarbons which outlet with vapor. The quantity and composition of fuel vapor which can be dispused though the outlet while refueling depend on type and temperature of motor fuel inside the tank, type and temperature of motor fuel unloading into tank, level of turbulent between refueling. The mechanism of losing can appear while it refuels into loading truck, unloading from loading truck into underground storage tanks and refuel into automobiles.

2.1.8 Gas and vapor Sampling (26, 27, 28, 29)

Air sampling of gas and vapor consist of 2 methods 1) grab sampling 2) continuous active sampling.

1) In grab sampling, the equipments for collected air sample consist of evacuated flasks, passive canister, gas or liquid displacement container, flexible plastic containers

2) In continuous active sampling, the equipments for collect air sample consists of absorbers which used widely are simple gas washing bottle, spiral and helical absorber, fitted bubblers, glass bead columns. Cold-trap, sampling bag and solid absorbent especially activated charcoal tube are also used; samples are then analyzed in laboratory.

Instantaneous gas and vapor sampling may also be done with direct-reading instruments that have a response time measured in second. Instruments of this nature incorporate sensors utilizing infrared and ultraviolet radiation, flame and photo ionization, electro chemical reaction, and chemiluminescence. Most of these instruments may be equipped with automatic continuous recording devices to generic

real time data that can be converted easily into an average time from a few second to a few minute or longer.

VOC were classified to 6 groups which consist of non-methane hydrocarbon (NMHC, also termed light hydrocarbon), heavy hydrocarbon: C10-C20, Carbonyl compounds such as aldehydes and ketone, the most common being formaldehyde, acetone, and acetylaldehyde. (Carbonyls are operationally defined as C1-C7 oxygenated compounds), halogenated species such as trichloroethyene, trichloroethane etc, sulfur containing species such as mercaptans, thiophenes, and nitrogen containing species such as benzonitrile.

Several devices are available that can do an acceptable job estimating TVOC including PID (Photoionization Detectors), AirCuity monitors, the Nose (by Pure Choice), and several others. These are especially useful for continuous monitoring or for obtaining real-time data. However, the use of GC-FID (Gas Chromatography-Flame Ionization Detector) or GC-MS (Gas Chromatography-Mass Spectrometry) will provide the most accurate and useful data although GC-FID has the drawback of not providing secondary verification of compound identity. EPA method for measurement VOC as following Table 7-8

Table 7 Reference Methods Used to Determination VOC Compliance with EPA Standards

Source Category	Affected Facility	Manual Sampling Method
1.Surface coating metal furniture	Spray booth or application area	1, 2, 3, 4, 24, 25
2. Automobile and light duty truck surface coating operations	Prime coat operations Guide coat operations Topcoat operation	1, 2, 3, 4, 24, 25
3. Graphic arts industry: Publication rotogravure printing	Production process	24A

Table 7 Reference Methods Used to Determination VOC Compliance with EPA Standards (Continued)

Source Category	Affected Facility	Manual Sampling Method
4. Pressure sensitivity tape and label surface coating operation	Coating line: Precoater Flash-off area Drying oven	1, 2, 3, 4, 24, 25
5. Industrial surface coating: Large appliances	Surface coating operation	1, 2, 3, 4, 24, 25
6. Metal coil surface coating	Surface coating operation: Prime coat operation Finish coating operation	1, 2, 3, 4, 24, 25
7. Equipment leak of VOC in the synthetic organic chemicals manufacturing industry	All affected facilities; pumps, compressors, pressure relief devices, sampling connections, valves, and flanges; within process units of SOCMI	21
8. Beverage can surface coating	Coating area, flash-off area, curing oven area	1, 2, 3, 4, 24, 25
9. Bulk gasoline terminal	Loading racks	2A or 2B, 25A or 25B
10. Flexible vinyl and urethane coating and printing	Rotogravure printing line	1, 2, 3, 4, 24, 25A
11. Equipment leaks of VOC in petroleum refineries (except 7, 12)	Valve, pump, pressure relief device, sampling connection, flange, open-ended line	21
12. Equipment leak of VOC from onshore natural gas processing plants (except 7, 11)	Compressor, valves, pumps, etc.	21

Table 8 Title of EPA reference methods for VOC

An order	Method	Title
1	1	Sample and Velocity Traverses for stationary Sources
2	2	Determination of stack gas velocity and volumetric flow rate
3	2A	Direct measurement of gas volume through pipes and small ducts
4	2B	Determination of exhaust gas volume flow rate from gasoline vapor Incinerator
5	3	Gas analysis for carbon dioxide, Oxygen, Excess air, and dry molecular weight
6	4	Determination of moisture content in stack gas
7	21	Determination of VOC leak
8	24	Determination of volatile matter content, water content, density, volume solids, and weight solid of surface coating
9	24A	Determination of volatile matter content and density of printing inks and related coating
10	25	Determination of total gaseous non methane organic emission as carbon
11	25A	Determination of total gaseous organic concentration using a flame ionization detector
12	25B	Determination of total gaseous organic concentration using a non dispersive infrared analyzer

2.1.9 VOC Direct reading instrument

Multirae IR is a direct-reading instrument. It will be used to measure TVOCs concentration with photo ionization detector. Chemicals contaminants in sample air are ionized as a result of being bombarded by high energy ultraviolet (UV light). These compounds actually absorb the energy of the light which excites the molecule and results in the temporary loss of an electron and the formation of a positively

charge ion. This process is called photo ionization. The movement of ions or electrons from one electrode to another can generate an ion current which is measured in volts. The electron volt (eV) of this instrument is 10.6 eV. The specification of Multirae IR system photo ionization detectors (PIDs) is compliance with the specifications in EPA Method 21 in which the specification of Multirae IR consist of determination range from 0 to 2,000 ppm/m^3 of air, resolution 1 ppm, pump flow rate 0.15 cc/min, intrinsic safety class1 division 1, response time ≤10 sec, and precision ±3% of cal. gas value. The detectable and not detecable of VOCs by PIDS with 10.6 eV are as show following.

Volatile organic compounds detected by PIDS with 10.6 eV.

Detecable

Acetaldehyde	Benzene	Chloroacetophenone
Acetic anhydride	Benzyl Chloride	Chlorobenzene
Acetone	Bromoform	Chloromethyl Methyl Ether
Acrolein	Butadiene	Chloronitropropane
Acrylomide	Butoxyethanol	Chloroprene
Acrylonitrile	Buthyl Acetate	Chrysene
Allyl Alcohol	Bulthyl Alcohol	Cresol
Allyl Chloride	Buthyl Mercaptane	Crotonaldehyde
Allyl Glycidyl Ether	Buthylamine	Cumeme
Allyl Propyl Disulfide	Buthyl Glycidyl Ether	Cyclohexane
Amino Pyridine	Buthyl Toluene	Cyclohexanol
Amyl Acetate	Camphor Vapor	Cyclohexanone
Aniline	Carbon Disulfide	Cyclohexene
Anisidine	Chloroacetaldehyde	Cyclopentadiene
Diethylhexyl Phthalate	Ethyl Acrelate	Isopropyl Glycidyl Ether
Diacetone Alcohol	Ethyl Amy Ketone	JP 4, 6, 8
Diazomethane	Ethyl Benzene	Ketene
Dibuthylphthalate	Ethyl bromide	Mesityl Oxide
Dichlorobenzene	Ethyl Buthyl Ketone	Methyl Acetate
Dichloro Ethyl Ether	Ethyl Ether	Methyl Acetylene
Dichloroethylene	Ethyl Mercaptan	Methyl Acrylate

Volatile organic compounds detected by PIDS with 10.6 eV. (Continue)

Detectable

Dichlorvos	Ethyl Silicate	Methyl Amyl Ketone
Diesel	Ethylamide	Methyl Bromide
Diethylamino Ethanol	Ethylene Dibromide	Methyl Cellosolve Acetate
Diethylamine	Ethylenediamine	Methyl Ethyl Ketone
Diglycidyl Ether	Ethylineimine	Methyl Hydrazine
Diisobuthyl Ketone	Furtural	Methyl Iodide
Diisopropylamine	Furturyl Alcohol	Methyl mercaptane
Dimethylamine	Gasoline	Methyl Ether
Dimethylaniline	Glycidol	Methyl Methacrylate
Dimethylformamide	Heptane	Methyl Styrene
Dimethylhydrazine	Hexane	Methylamine
Dimethyloacetamide	Hexanone	Methylcyclohexane
Dimethylphthalate	Hexone	Methylcyclohexone
Dinitrotoluene	Hexylacetate	Methylcyclohexanol
Dinitro Cresol	Hydroquinone	Monomethylaniline
Dinitro Analine	Isoamyl Acetate	Morpholine
Dinitro benzene	Isobuthyl Acetate	Naphthalene
Dioxane	Isobuthyl Alcohol	Naphthylamine
Diphenyl	Isophorane	Nitroaniline
Dipropylene Glycol	Isopropyl Acetate	Nitrobenzene
Ethanolamine	Isopropyl Alcohol	Nitrochlorobenzene
Ethoxyethyl Acetate	Isopropyl Ether	Nitromethane
Ethyl Acetate	Propyl Acetate	Nitrosodimethylamine
Octane	Propyl Alcohol	Tetrahydrofuran
Pentaborane	Propylene Dichloride	Tetramethyl Lead
Pentane	Propylene Imine	Toluene
Pentanone	Propylene Oxide	Toluidine
Perchloroethylene	Pyridine	Toner Fluid Vapor
Phenol	Nitrotoluene	Trichloroethylene
Isopropylamine	Quinone	Triethylamine

Volatile organic compounds detected by PIDS with 10.6 eV. (Continue)

Detectable

Phenyl Ether	Stibine	Turpentine Vapor
Phenylene Diamine	Stoddord Solvent Vapor	Vinyl Chloride
Phenylhydrazine	Styrene	Vinyl Toluene
Phosphine	Terphenyls	White spirit
Phosphorus Trichloride	Tetrachloroethylene	Xylene
Phthalic Anhydride	Tetrachloronaphthelene	

Non Detectable

Acetic acid	Ethyl formate	Methyl Isocyanate
Carbon Tetrachloride	Formaldehyde	Nitroethane
Chlorobromomethane	Formic acid	Nitromethane
Chloroform	Hexachloroethane	Nitropropane
Dichloroethane	Liquid Petroleum Gas	Phosgene
Epichlorohydrin	Maleic Anhydride	Propane
Ethyl Chloride	Methyl Alcohol	Propyl Nitrate
Ethanol	Methyl Chloride	Propargy Alcohol
Ethylene Chlorohydrin	Methyl Chloroform	Tetrachloroethane
Ethylene Dichloride	Methylene Chloride	Tetraethyl Lead
Ethylene Oxide	Methyl Formate	Trichloroethane

2.1.10 Air pollution control measures at gasoline service stations (24)

Gasoline transfer operations at service stations are sources of hydrocarbon emissions. The transfer takes place in two stages, referred to as stage I and stage II. stage I refers to loading gasoline into underground storage tanks at the station, while stage II refers to vehicles refueling.

To control emission, Stage I vapor balance is usually used between the tank truck and the underground storage tank at the service station. Vapor balance systems can be used to transfer vapor displaced by liquid in the tank being filled into the tank being emptied. Vapor balance prevents the compression and expansion of vapor spaces that would otherwise occur during filling. Vapor balance systems can reduce storage tank

filling losses by more than 95%and tank truck loading losses by more than 90%. Stage II control can be vapor balanced between the service station underground storage tank and the vehicle gasoline tank. Vacuum-assist systems differ from vapor balance systems in that they use a vacuum pump to provide extra negative pressure at the nozzle-fill neck interface to increase vapor recovery. They require some venting of excess vapors to the atmosphere. Hybrid systems combine vapor balance and vacuum assist. They enhance vapor recovery at the nozzle-fill neck by vacuum, while keeping vacuum low enough to minimize vapor returned to the vapor-recovery system. The other control technique for vehicle refueling is the use of onboard controls. Here, a vapor seal in the vehicle fill neck forces vapors being displaced from the tank into a carbon canister on the vehicle, where they are adsorbed.

2.1.11 Factors influencing gasoline exposure

Initial review identified several variable thought to influence workers exposures to gasoline vapor (30-34)

1) Work site related factors
   - Loading technology
   - Control technology/reliability
   - Site layout/distances
   - Positions relative to emission sources
   - Product loading rate
   - Product offloading rate
   - Site emission source geometry

2) Environmental factors
   - Temperature of ambient, refuel gasoline, vapor of gasoline tank
   - Humidity
   - Wind direction
   - Wind speed
   - Other gasoline sources
   - Background concentration
   - Meteorology and site roughness

3) Gasoline related factors

Volatility of gasoline

Reid vapor pressure

Amount of each component in gasoline

Material in use; product mix

Volume handled

refuel flow rate

Trends in composition by time and or region

4) Work related factors

Work practice

Personal protective uses

Change of specific work characteristic

* Frequency

* Duration

* Job rotation

Routes of exposure

5) Personal behavior

Smoking behavior

Alcohol consumption behavior

Food consumption

Health behavior

6) Factor which influence exhaust from vehicle

Type of gasoline/ motor fuel

Type of catalytic converter

Mileage

2.1.12 Routes of Exposure (9)

(1) Inhalation

Inhalation is a common route of exposure to gasoline. Generally, gasoline's odor provides adequate warning of hazardous concentrations. The odor threshold is 0.025 ppm. Its vapors are heavier than air and may causes asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of gasoline vapor as adults may receive larger doses because they have greater lung surface area: body weight ratios and increased minute volumes: weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of gasoline vapor found nearer to the ground

(2) Skin/Eye Contact

Gasoline vapors are mildly irritating to mucous membranes; however, gasoline splashed in the eyes can result in transient corneal injury. Repeated or prolonged skin contact with liquid gasoline can degrease the skin, causing irritation and dermatitis. First- and second- degree skin burns can occur from continuous contact with liquid gasoline for several hours. Percutaneous absorption is slow.

(3) Ingestion

Gasoline is not as readily absorbed from the gastrointestinal tract as from the respiratory tract. In adults, about 20 to 50 g can cause severe intoxication and 350 g (12 oz.) can result in death for a 70 kg individual. As little as 10 to 15 g (less than one-half ounce), it may be fatal in children. Symptoms of intoxication by ingestion of gasoline can range from vomiting, vertigo, drowsiness and confusion to loss of consciousness, convulsions, hemorrhaging of the lungs and internal organs, and death due to circulatory failure. Ingestion can cause irritation to the gastrointestinal mucosa and can be complicated by pulmonary aspiration, resulting in chemical pneumonitis.

2.1.13 Health Effect

(1) Acute Exposure

Most adverse health effects from acute exposure to gasoline are caused by the hydrocarbon component. However, persons who have repeated or massive exposure (e.g., inhalation abuse, prolonged skin contact) to leaded gasoline may develop lead poisoning (lead is no longer added to gasoline in the United States and Thailand). Immediate effects of exposure to gasoline are primarily due to pulmonary injury and central nervous system (CNS) depression. Other systemic effects may develop over several hours. Components of gasoline probably cross the placenta and may be excreted in breast milk.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

(2) CNS

Acute gasoline exposure can cause transient CNS excitation followed by CNS depression. Confusion, giddiness, nausea, headache, blurred vision, dizziness, and weakness can occur. In massive exposures, rapid CNS depression, respiratory depression, seizures, loss of consciousness, coma, and deaths have been reported.

(3) Death

Inhalation of ≥5,000 ppm gasoline vapor (20,000 ppm for 5 minutes) has been shown to be lethal.It has been postulated that the cause of death following inhalation of high concentrations of gasoline vapors is either central nervous system depression due to asphyxia leading to respiratory failure, or cardiac sensitization to circulating catecholamines leading to a fatal arrhythmia.

The lethal ingested dose of gasoline has been estimated to be 12 ounces (350 g, or 5 g/kg for a 70-kg individual) of gasoline is either severe chemical pneumonitis resulting from the aspiration of gasoline that leads to asphyxiation, central nervous system depression leading to respiratory failure, or cardiac sensitization to circulating catecholamines resulting in the occurrence of fatal arrhythmias

(4) Systemic Effects

(4.1) Respiratory Effects

Adverse respiratory effects were described in one case report of inhalation of gasoline vapors that resulted in death. Intentional or accidental ingestion of gasoline often results in aspiration of the gasoline into the lungs because of its high volatility and low surface tension. Therefore, the most common effect associated with acute gasoline ingestion in humans is aspiration pneumonia which is often accompanied by respiratory distress, pulmonary edema, emphysema, and focal alveolar hemorrhage. Death from asphyxia is often the result in cases of gasoline ingestion when the aspiration pneumonia becomes severe. The only information located regarding the respiratory effects of gasoline following dermal exposure comes from a case report in which a 34-year-old man suffered from atelectasis, laryngeal edema, and upper airway

obstruction following immersion in a pool of unleaded gasoline for approximately 8 hours after an automobile accident.

(4.2) Cardiovascular Effects.

Cardiac sensitization to circulating catecholamines leading to a fatal arrhythmia has been postulated as one possible cause of death in humans following inhalation of high concentrations of gasoline vapors. Abnormal electrocardiograms (ECGs) of a nonspecific nature have been recorded in individuals with a history of chronic leaded gasoline sniffing. The only study located regarding the cardiovascular effects of ingested gasoline in humans was reported by Banner and Walson (1983). A 15-month-old male ingested approximately 1 pint (≈5,000 mg/kg) of gasoline and was found to be hypotensive upon hospital admission. However, because the child exhibited multi-organ system toxicity it is not possible to ascertain whether the hypotension was a direct effect of the ingested gasoline or a consequence of other adverse.

(4.3) Gastrointestinal Effects.

No effect on the gastrointestinal system of cases were observed in humans after inhalation exposure to gasoline. Damage to the digestive tract (severe esophagitis, gastritis, congestive failure, degeneration of the epithelium, and mucositis of the oral cavity) has been observed in individuals who accidentally or intentionally ingested gasoline.

(4.4) Hematological Effects

Several human cases studied had been reported that describe the occurrence of hematological effects in individuals with known long-term exposure to gasoline vapors. However, in all of these cases, the hematological effects reported were most likely due to a constituent of gasoline rather than the gasoline mixture itself. An increased incidence of various blood dyscrasias (anemia, hypochromia, thrombocytopenia, and neutropenia) had been observed in Nigerian males with known exposure to gasoline in their occupations as motor mechanics and road-side vendors of heavy motor oil and/or gasoline as compared to controls with unknown exposure to gasoline. Hemolysis, as evidenced by a decrease in hematocrit and an increase in free urine hemoglobin, and disseminated intravascular coagulation had been observed in cases of accidental or intentional ingestion of gasoline (Banner and Walson 1983;

Janssen et al. 1988). In addition, evidence of intravascular consumption of clotting factors (coagulopathy, hypofibrinogenima, and elevated prothrombin and partial thromboplastin times) was seen in a 15-month-old male who ingested approximately 1 pint (≈5,000 mg/kg) of gasoline (Banner and Walson 1983).

(4.5) Hepatic Effects.

A transient increase in serum enzymes indicative of liver function (creatine phosphokinase [CPK], SGOT, and SGPT) was noted in a 34-year-old male who was immersed in a pool of unleaded gasoline for approximately 8 hours

(4.6) Renal Effects

Inhalation of massive amounts of gasoline may result in fatty degeneration of the proximal convoluted tubules and glomeruli and renal failure. Ingestion of gasoline had been reported to cause oliguria, tubular necrosis, interstitial edema, hematuria, reduced creatinine clearance and elevated serum creatinine, elevated urinary protein, glucose, and hemoglobin, and elevated BUN.

(4.7) Gastrointestinal

Damage to the digestive tract following ingestion of gasoline may include severe esophagitis, gastritis, degeneration of the epithelium, and mucositis of the oral cavity.

(4.8) Dermal

Gasoline vapors can cause inflammation of the skin. Prolonged contact with liquid gasoline causes significant irritation (i.e., irritant contact dermatitis), degreasing, and burns. Redness and blisters may occur.

(4.9) Ocular

Eye irritation from gasoline vapors begins at about 200 ppm. Inflammation is generally slight. When splashed in the eye, gasoline may cause burning pain and transient corneal injury. Chronic exposure to gasoline may cause damage to the cornea, retina, and ciliary body.

(4.10) Potential Sequelae

Acute hydrocarbon-induced CNS depression generally is completely reversible after exposure ceases unless the episode has been complicated by lack of oxygen. Acute renal toxicity may persist for several weeks following ingestion of

gasoline, but usually resolves with treatment. Chronic lung dysfunction may result from pulmonary aspiration.

(5) Chronic Exposure

No health effects are expected from normal use of gasoline as a fuel. Chronic, excessive exposure such as occurs in intentional gasoline abuse (sniffing) can cause irritability, tremor, nausea, insomnia, loss of memory, drowsiness, mental dullness, confusion, seizures, muscle spasms, altered vision, hallucinations, impaired gait, inflammation of the optic nerve, dizziness, and involuntary eye movements. Some of these effects may be due to lead or other additives in gasoline (lead is no longer added to gasoline in the United States and Thailand). Sudden deaths have been reported.

Chronic abuse of gasoline may cause kidney disease (i.e., renal tubular dysfunction). Nerve disorders, causing motor weakness and muscular degeneration, can also occur in gasoline abusers. Abuse of leaded gasoline has been reported to cause brain disease (i.e., lead encephalopathy). Behavioral and intellectual changes, including immediate and delayed visual memory and perception, psychomotor disturbances, and visuomotor learning ability, have been reported (probably involving leaded gasoline). Chronic exposure may be more serious for children because of their potential longer latency period. Degreasing dermatitis with skin cracking and peeling results from skin has repeated or prolonged contact with gasoline.

(6) Carcinogenicity

The International Agency for Research on Cancer has classified gasoline in Group 2B, possibly carcinogenic to humans. The classification is based on inadequate evidence of carcinogenicity in humans and limited evidence for carcinogenicity in experimental animals.

(7) Reproductive and Developmental Effects

The hydrocarbons found in gasoline can cross the placenta. There is no direct evidence that maternal exposure to gasoline causes fetotoxic or teratogenic effects. Gasoline is not included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Special consideration regarding the exposure of

pregnant women is warranted, since gasoline may be a genotoxin; thus, medical counseling is recommended for the acutely exposed pregnant woman.

2.1.14 Criteria of TVOC (29, 35)

The literature generally seems to agree that <300 ng/l represents an "acceptable" TVOCs level and that >3000 ng/l represents a "hazardous" TVOCs level; however, few seem to want to address the hazards involved with levels between 300 and 3000 ng/l. The recognized symptoms above 3000 ng/l generally include drowsiness, eye and respiratory irritation, general malaise, headache, nausea, and exacerbation of symptoms of respiratory ailments. Some data suggested that high TVOCs levels amplify the hazardous effects of specific, harmful VOCs. The level of VOC and related effect to human were shown in Table 9.

Table 9 The level of TVOCs and related effect to human

The level of TVOCs	Effect to human
Less than 0.20 mg/m^3	No irritation or discomfort expected
0.20-3.0 mg/m^3	Irritation and discomfort may be possible
3.0-25.0 mg/m^3	Discomfort expected and headache possible
Greater than 25 mg/m^3	Toxic range where other neurotoxic effects may occur

2.2 Gasoline service stations in Thailand (36)

2.2.1 Type of gasoline service stations

Gasoline service stations in Thailand can be categorized in to 6 types.

(1) Type A: gasoline service stations that service for vehicle by land which locate closely to public or private road that have wide road more than 12 and 10 meters, respectively.

(2) Type B: gasoline service station that service for vehicle by land which locate closely to public or private road that have wide road not more than 12 and 10 m. respectively.

(3) Type C: can be classified 2 characteristics;

3.1 gasoline service stations service for vehicles by land which storage moderate inflammable or low inflammable of motor fuel which have amount of motor fuel not more than 10,000 liters and storage motor fuel in upper ground storage tank (a small floating storage tank pump which locate on a roadside).

3.2 gasoline service stations that service for a vehicle by land which storage moderate inflammable or low inflammable of motor fuel which have amount of motor fuel more than 10,000 liters and storage motor fuel in upper ground storage tank (a big floating storage tank pump which located on a roadside).

(4) Type D: gasoline service stations which storage a much ignition motor fuel, moderate inflammable motor fuel or low inflammable motor fuel in storage tank (a glass tube pump which rotate by hand).

(5) Type E: can be clarified 2 characteristics;

5.1 gasoline service station that service for boat which storage moderate inflammable or low inflammable of motor fuel which have amount of motor fuel not more than 10,000 lit and storage motor fuel in upper ground storage tank or storage tank which locates beside a iron pontoon (a small waterway service station).

5.2 gasoline service station that service for boat which storage moderate inflammable or low inflammable of motor fuel which have amount of motor fuel more than 10,000 lit and storage motor fuel in upper ground storage tank or storage tank which locate beside a iron pontoon or storage a much ignition, moderate ignition or little ignition of motor fuel in underground storage tank. (a big waterway service station).

(6) Type F: gasoline service station that service for an aircraft.

In Motor fuel control Act. 1998, all type of gasoline service stations were classified to 2 characteristics which consist of an enterprise type 2 and 3. An enterprise type 2 consist of gasoline service station type C characteristic 1, D, and E characteristic 1 which before running this business they have to get the license from

the authority. An enterprise type 3 consist of gasoline service station type A, B, C characteristic 2, E characteristic 2, and F which before running this business have to request an authority for permission. Both an enterprise type 2 and 3 has to practice follow regulation which consist of type of motor, used container of motor fuel and an amount of motor fuel which can storage in each type of gasoline service station as following Table 10 and 11.

Table 10 Regulation of an enterprise type 2

Order	Gasoline service station	A type of motor fuel	A container of motor fuel	An amount of motor fuel (liter)
1	A gasoline service station type C characteristic 1 (a small floating storage tank pump which locate on a roadside)	Very inflammable		(Not storage)
		Moderate inflammable	A big upper storage tank	Total of volume not exceed 10,000 litter
		Low inflammable	A big upper storage tank	
2	A gasoline service station type D (A glass tube pump which rotate by hand)	Very inflammable	Storage tank	- Not exceed 454 litter
		Moderate inflammable	Storage tank	- Not exceed 454 litter
		Low inflammable	Storage tank	- Not exceed 454 litter
3	A gasoline service station type E characteristic 1 (a small waterway service station)	Very inflammable		(not storage)
		Moderate inflammable	Storage tank locate inside an iron pontoon	Total of volume not exceed 10,000 litter
		Low inflammable	A big upper storage tank	

Reference: Department of energy business, Thailand (36)

Table 11 Regulation of an enterprise type 3

Order	Gasoline service station	A type of motor fuel	A container of motor fuel	An amount of motor fuel (liter)
1	A gasoline service station type A (a service station which locate on big roadside)	Very inflammable	An underground storage tank	Storage in area follow an Act of town plan which limit in very and moderate crowned area can storage not exceed 180,000 litters, outbound can storage 360,000 litters.
		Moderate inflammable	An underground storage tank	
		Low inflammable	bottle, can, a tank	
			An underground storage tank	
2	A gasoline service station type B (a service station which locate in small road)	Very inflammable	An underground storage tank	Not exceed 60,000 litters
		Moderate inflammable	An underground storage tank	Not exceed 20,000 litters
		Low inflammable	An underground storage tank	
			bottle, can, a tank	have no a specification
3	A gasoline service station type C characteristic 2 (a big floating storage tank pump which locate on roadside)	Very inflammable		(not storage)
		Moderate inflammable	A big an upper ground storage tank	- total of volume exceed 10,000 litters - but not exceed 60,000 litters
		Low inflammable	A big an upper ground storage tank	

Table 11 Regulation of an enterprise type 3 (Continued)

Order	Gasoline service station	A type of motor fuel	A container of motor fuel	An amount of motor fuel (liter)
4	A gasoline service station type E characteristic 2 (a big waterway service station)	Very inflammable Moderate inflammable Low inflammable	An underground storage tank	have no a specification
		Very inflammable		(not storage)
		Moderate inflammable Low inflammable	A big upper ground storage tank, A storage tank locate inside a iron pontoon	- each tank can storage not exceed 30,000 litters and total of volume not exceed 60,000 litters
5	A gasoline service station type F (gasoline service station for aircraft)	Very inflammable Moderate inflammable Low inflammable	- have no a specification	- have no a specification

Reference: Department of energy business, Thailand (36)

In general (5), gasoline service stations are composed of 2 characteristic as following;

(1) Gasoline service station under brand of oil company: such as Ptt, Shell, Esso, Caltex, Bangjak, Susco, Cosmo, BP, Q8, PC, TPI, and Jet. Most of them are standard gasoline service station which sale all types of oil and have some service such as mini-mart, restaurant, and car care. Gasoline service station under brand of oil company can divide to 2 characteristics.

●Gasoline service station under brand of large oil company. There are composed of 5 companies as Ptt, Shell, Esso, Caltex and Bangjak.

● Gasoline service station under brand of small oil company. There are composed of Susco, Cosmo, Q8, PT, TPI, Jet, and PC.

(2) Independent gasoline service station. They may belong to gasoline service station which are an agent of wholesale such as Syamnokmai, Piyamat or belonging to local people. Most of gasoline service station serves only motor fuel and has many services either but less than gasoline service station under brand of oil company.

In Bangkok, number of gasoline service station type A and B classified by Oil Company are as Table 12-14.

Table 12 Number of gasoline service station type A and B in inner city

	Number of gasoline service station type A and B						
Inner city	Ptt	Esso	Shell	Caltex	Bangjak	Other	Total
Phra Nakorn	2	2	4	1	0	0	9
Pomprap Sattruphai	0	1	3	1	0	1	6
Samphanthawong	0	0	0	0	0	0	0
Patumwan	3	1	3	1	0	0	8
Ratchatewi	3	2	4	2	0	0	11
Bang rak	0	0	2	3	1	0	6
Dusit	3	3	3	2	0	0	11
Phaya Thai	2	3	2	4	4	0	15
Bang plad	3	2	2	4	2	2	15
Bangkok Noi	3	2	1	0	1	1	8

Table 12 Number of gasoline service station type A and B in inner city (Continued)

Inner city	Number of gasoline service station type A and B						Total
	Ptt	Esso	Shell	Caltex	Bangjak	Other	
Bangkok Yai	1	2	3	2	0	0	8
Sathorn	3	0	3	3	4	5	18
Yannawa	5	2	5	2	3	3	20
Bangkho lame	2	0	1	1	2	1	7
Bang Sue	3	3	7	2	2	1	18
Klongsan	0	1	2	2	2	1	8
Thonburi	0	0	0	0	0	0	0
Chatuchak	8	6	4	7	2	7	34
Huay Kwang	6	5	4	0	5	5	25
Dindaeng	3	2	3	0	2	1	11
Khong Toey	2	2	4	3	2	2	15
Wattana	0	3	5	1	2	3	14
Total	52	42	65	41	34	33	267

Reference: Department of energy business, Thailand (37)

Table 13 Number of gasoline service station type A and B in urban fringe

urban fringe	Number of gasoline service station type A and B						Total
	Ptt	Esso	Shell	Caltex	Bangjak	Other	
Don Muang	8	1	1	1	2	1	14
Lak Si	3	2	3	2	2	2	14
Bang Khen	7	7	3	3	5	2	27
Sai Mai	2	1	2	0	3	0	8
Lad Phrao	7	5	4	2	7	5	30
Bangkapi	2	7	7	6	5	3	30
Bung Kum	3	8	6	4	4	6	31

Table 13 Number of gasoline service station type A and B in urban fringe (Continued)

urban fringe	Number of gasoline service station type A and B						Total
	Ptt	Esso	Shell	Caltex	Bangjak	Other	
Wang Thong Lang	4	5	4	1	4	6	24
Kanna Yao	3	5	0	2	2	2	14
Saphansoong	3	1	1	2	4	2	13
Suan Luang	3	7	5	4	2	3	24
Praves	2	5	3	2	5	5	22
Pra kanong	2	0	3	1	3	4	13
Bang Na	3	5	4	5	6	3	26
Taling Chan	6	7	3	3	3	5	27
Taweewattana	3	2	1	1	4	4	15
Phasicharoen	3	2	3	4	5	5	22
Bangkae	5	5	6	4	4	7	31
Nong Khaem	2	3	1	2	1	4	13
Ratburana	1	2	2	4	3	3	15
Thung Khru	1	1	1	0	1	4	8
Chom Thong	6	1	1	0	2	3	13
Total	79	82	64	53	77	79	434

Reference: Department of energy business, Thailand (37)

Table 14 Number of gasoline service station type A and B in The suburb

The suburb	Number of gasoline service station type A and B						Total
	Ptt	Esso	Shell	Caltex	Bangjak	Other	
Min Buri	4	1	4	5	4	7	25
Khlong Samwa	2	0	0	0	1	0	3
Lad krabang	3	3	0	3	2	2	13
Nong Chok	3	3	1	1	5	1	14
Bang Khunthian	4	2	1	2	3	6	18
Bang Bon.	4	4	6	0	4	6	24
Total	20	13	12	11	19	22	97

Reference: Department of energy business, Thailand (37)

2.2.2 The pattern of investment of gasoline service station (5)

1) Company Building & Company Operated (CBCO): It is the first pattern which use for selling retail. Some gasoline service stations of all companies are CBCO which number of this pattern depends on policy of each company. Oil companies can operate and control standard of each gasoline service station but they use more investment and personal officer. In general, these gasoline service stations are located in urban or main road. Now a day, all gasoline service stations of Jet are being used this pattern.

2) Company Building & Dealer Operated (CBDO): It is developed from CBCO due to reduce the capital of operation which an executive like as a gasoline service station tenant. An executive must practice following a condition which contract with oil company such as soled fuel must buy from only company, must sell more than minimal soled total, and must control service standards and cleanness of gasoline service station. Now a day, companies use this pattern are Shell, Esso, Caltex and other of foreign oil companies.

3) Joint Investment (JI): A gasoline service station of oil company coordinate investment with external personal which operated like CBOD. A coordinate investor has responsibility for operating following a condition which contracts with companies but it has more flexible. Now, it is not demonstrative investment.

4) Dealer Building (DB): It can call representative gasoline service stations due to these gasoline service stations sell motor fuel under trade mark of oil companies which oil companies will support some equipments such as a billboard, a pump and a dealer must construct gasoline service stations following a form of companies. It is fixed a contract for selling minimal motor fuel. Most of this pattern is Thai gasoline service stations. Companies have been succeeded for expanding gasoline service stations are Bangjak and Ptt.

2.2.3 Physical management of gasoline service stations (38)

Due to behaviors of customers have been changed so the gasoline service stations have been changed as well. In the past gasoline service stations which service only motor fuel for vehicles. Nowadays, gasoline service stations not only service motor fuel for vehicles but also include many services such as car park for resting between travel, toilet services, garage and the other for attractive their customers. Physical management of gasoline service stations can conclude by follows;

1. A board shows trade mark and prices which on the top of the board is logo which specify trade mark of each company. If any company has mini-mart, it will specify in a next line follow a name of company for example, name of Caltex minimart is star mart, Jet call jiffy shop, Bangjak call lemon green .The next line is a rate prices of any type motor fuels which each gasoline service station fixes for service their customers and some of them may be paste up an other service for example cleaning and lubricating services, changing motor oil services, restaurant, toilets.

2. Pump-island area: This area locates under rectangular or square roof follow a pattern of each trade mark which consist of a pump of gasoline between 2-6 pumps depend on size of service station. Each pump is installed nozzle on bilateral which each side has 2-4 nozzles depend on pattern of each company and trade mark.

On the top of each nozzle has a number which shows an amount of soled gasoline (litters). The next line is a figure of price per litter and next is amount of refueling for customers which has a lock knob follow need of customers and last line shows the amount of money which customers must pay that can lock money follow need of customers. Around a pillar of pump-island area may post a notice for customer

to do when refueling for example, To put out engine, stop smoking or including do not use mobile phone which can announce by massage or symbol

Beside that, a clerk works and sits down around pump-island area. They receive money from service station, record selling and look after for working of service station and helping service station for service customers in emergency time. More over, around pump-island area has a shelf of motor oil or distilled water, air compressor and dustbin for receiving solid wastes from customer cars and the others.

3. An office: The office is the work place for a manager, an assistant manager, a collected money official, an accountant, computer and include collected cargoes and worked equipments such as cabinet of documents, table, motor oil, distilled water and the others.

4. Mini-mart: Characteristic and name of mini-mart of each gasoline service station depends on trade mark of each gasoline service station which has pattern of organization like general franchise. An office of mini-mart consists of a collected money officer or call cashier and an assistant that has duty to arrange cargoes. Some service station has only sailed official which his responsibility is collected money and arrange cargoes.

5. Lubricate service: Lubricate service install equipment for working such as check an understructure a car, change motor oil, cleaning and lubricate, cleaning a car so a lubricate service area must almost behind the gasoline service station due to need of wide area and result from their activity cause a dirty area from spill of motor oil.

6. A toilet: Toilets are seam to be remarkable place. In general, toilets of gasoline service station are separated by sex due to security of customers but somewhere have no toilet for customers due to limit of an area so an the staffs must use a toilet inside an office.

7. A car park: a space area is used for any type of automobile which free service for customers but service station may keep an area for the staffs or for loading truck when it unloads motor fuel to storage tanks.

2.2.4 Social management of gasoline service station

In general, social management of gasoline service station can classify by a position which has duties or responsibilities as follows:

1. Manager: a responsibilities of managers are work efficiency management, control and look after enterprise of service station, good sale planning and service, put manpower for suitable service, take care staffs for good discipline, to check stocks and to import quantity of goods for selling, to check a sales account, concluded accounting, money security, to deposit money in a bank, to check motor fuel and personal development. Working hours of manager generally starts from 08.30 a.m. to 04.30 p.m. (but uncertainly to finish working in each day).

2. A bill collector: His duty receives money from service station attendants to give to manager. The mainly duties of them are collected money from all service station attendants, business journal, concluding account for manager, report of checking stock. In gasoline service station in Thailand this person is called cashier.

Cashier is a permanent employer which starts working at 08.30 a.m. and stops the work at about 05.00 p.m. Cashier works in the office.

3. A salesman in mini-mart: His responsibilities sell goods in mini-mart and serve satisfied customers. He works a shift time like service attendants who do refuel. Main duty serve customer good, control and look after in mini-mart, check stocks for customers.

4. A leader of served employees who work in front of a courtyard: His main responsibility is took care a service to work as follow standards with full efficient. The services are practiced and warned for eager working. They take care of cleaned service station, check equipments completely, look after a discipline of service station attendant and deal with assigned working from manager such as deposit money in a bank. Name of leader of in front of service is called foreman.

5. A section of service that works in forecourt: Duty for refueling and serve satisfied customers, serve good service to customers, take care of their section to clean all time and check equipments to prepare for working.

A section of service that work in front of a courtyard consist of a clerk who works in front of a courtyard and a staff who serves in front of a courtyard (refueling). A duty of clerk receives and collects money from a staff which works in front of a

courtyard, checks a bill, keeps record selling each day after stops working before gives money to collected money staff.

The staff of this section works a shift which consists of first shift starts at 06.00-07.00 a.m. to 03.00-06.00 p.m., second shift starts at 03.00-06.00 p.m. to 11.00 p.m.-06.00 a.m. and last shift starts at 11.00 p.m.-12.00 p.m. to 06.00 a.m.-07.00 a.m. in 8 hour time per day and 6 day per week which has emergency time between 06.30-08.30 a.m. Most of gasoline service stations change a shift every week.

6. A section of service that works behide a courtyard: Duties for cleaning, lubricating, changing motor oil station, checking a state of automobile, anti-rust and maintenances, taking care of their section to clean.

A section of service that works behide a courtyard consists of leaders of the section who are a mechanics and assistant mechanics.

7. A housekeeper: Duties for take care of an office in front of the station and behide of a courtyard, takes care of cleaning inside and outside of an office around gasoline service station and takes care of garden.

The numbers of positions depend on size and location of service station. If gasoline service station is big and consist of many activities or locates in crowded areas, the employees will increase which numbers of gasoline service station attendants in Bangkok areas around 12,678 persons in which consist of inner city 4,272 workers, urban fringe 6,944 workers, and the suburb 1,552 workers but these numbers are uncertainly in any time as most of gasoline service station have many frequency changes of their works.

2.2.5 A general customer service process of forecourt gasoline service station attendant.

1.To wave one's hand to call cars: When a customer's car drives into gasoline service station, a served worker will wave one's hand for a signal to well come inside at zone of gasoline service station and parks closely to a nozzle next to other customers which come later will be served more easily.

2. Say hello and ask for types of fuel which they need: While a customer opens a windscreen or not open a windscreen, a served worker will say hello or sawasdee and asks for type of fuel and the amount of litters or Bath to buy.

3. Refueling: The customer may give his key of the car to the worker or pulls/press a knob to allow the cup of gas tank open. The worker can refill the fuel by the order.

Some gasoline service station have a cloth to hold under a nozzle to prevent a motor fuel will gush a customer' car or spill to floor as well as sometime a fuel tube of car has small size or ever accident cause a curved fuel tube so the fuel will gust or spill to customers' cars or workers. Beside that, before refueling a served worker will say to customer to put out a motor in some gasoline service stations.

4. Scrub a windscreen: When a served worker refueling, he may scrub a windscreen for customer's car. Equipments will be prepared ready to use which consist of a detergent container, a brush, and a dry clean cloth. The served worker will scrub from top to down and left to right (using a cloth) and top to down for using a brush.

5. Checking under a bonnet of a car: consist of checking level of distilled water battery, water in a water filter, and level of motor oil. In general, a served worker will serve when the customer asking or he intends to do the service.

6. Throw away rubbish service: It is a special service for customers. A served worker who has free time from scrubbing a windscreen, checking the pressure of tires, checking under a bonnet of a car or not providing these kinds of services.

7. Receiving money and say thank you: A served worker will receive money from customers after finishing any services, and then they will wave one's hand for a signal to let the cars move from a pump area.

These are standard process services of each gasoline service station but in true situation, a served worker may not serve over all depend on a served worker, a strict practice of each gasoline service station or a number of vehicles are served in an interval of the time.

2.2.6 An oil dealer in Thailand (5)

An oil dealer means one who have traded motor fuel in each type or all types per year exceed 100,000 matrix tons (120 million litters). The business must be received the permission from the authority. Oil dealers in Thailand are as followings Table 15.

Table 15 Oil Dealers in Thailand

An order	Name of oil dealer	Trade mark of gasoline service station
1.	Petroleum Authority of Thailand: Ptt (Public Company Limited: PCL.)	Ptt
2.	Shell Company Ltd.	Shell
3.	Esso Company Ltd.	Esso
4.	Caltex Company Ltd.	Caltex
5.	Thai Oil Company Ltd.	Thai Oil
6.	Bangjak Company Ltd.	Bangjak
7.	Siam saha service Company Ltd.	Susco
8.	Southern Fuel Company Ltd.	PT
9.	Petrochemical Industry Thai Company Ltd.	
10.	Rayong Refinery Company Ltd.	
11.	Petronas Retel (Thailand) Company Ltd.	
12.	Star Petroleum Refining Company Ltd.	
13.	T.P.I Company Ltd.	TPI
14.	Siam Chemee Company Ltd.	
15.	Conaco (Thailand) Company Ltd.	Jet
16.	Rayong Purifier Company Ltd.	
17.	Cosmo Energy and Trading Company Ltd.	
18.	Picnic Corporation Company Ltd.	
19.	P.C. Siam Petroleum Company Ltd.	PC
20.	Kuwet Petroleum Aviation (Thailand) Company Ltd.	Q8
21.	Thai Loopbes Company Ltd.	
22.	Green Power Petroleum Company Ltd.	
23.	B.P. oil (Thailand) Company Ltd.	BP
24.	Aromatic (Thailand) Company Ltd.	
25.	Egatt Company Ltd.	
26.	Sangthong Industry gas's tank Company Ltd.	

Table 15 Oil Dealers in Thailand (Continued)

An order	Name of oil dealer	Trade mark of gasoline service station
27.	Unic gas and Petrochemical Company Ltd.	
28.	Gas Siam Industry Company Ltd.	
29.	World gas (Thailand) Company Ltd.	
30.	Cosmo oil Company Ltd.	Cosmo
31.	Etosue (Thailand) Company Ltd.	
32.	Hart oil Siam import- export Company Ltd.	
33.	Thai public port Company Ltd.	

Reference: Department of energy business, Thailand (5)

2.3 Related studies

2.3.1 The studies of evaporated gasoline and their components to atmosphere.

(1) Ruttanaprayoon I. (1) evaluated gasoline volatile from Petrochemical and gasoline service stations in different activities which consist of standing storage loss in petrochemicals, load-unload to storage tanks, transfer to loading trucks, transfer to underground storage tanks and volatile from refueling to vehicles in gasoline service stations. It found that the amount of gasoline volatile from transfering to underground storage tanks in gasoline service stations were 670 tons per year or 24% of all studied activity and refueling to automobiles were 630 tons per year or 22% of volatile all studied activities.

(2) Kulchanyavivat S. (39) studied the emission of gasoline vapor from storage tanks. The unleaded gasoline with number octane 95 was used in this experimental. The experimental results showed that the amount of gasoline emission increased with increasing temperature and decreasing vent height. Initial gasoline volume had very little effect on the gasoline emission rates.

(3) Keprasertsup C. et al. (40) studied concentration of MTBE, benzene, toluene, ethyl-benzene, and xylene in the ambient air at gasoline service stations in Bangkok areas. The samples were collected from 9 stations by using thermal desorption tubes which were analyzed by GC/FID. The pump- island means of MTBE and BTEX were 719±1,285.45, 69.44±107.04, 216.07±257.15, 26.70±25.99, and 100.68±114.03 $\mu g/m^3$, respectively. The border means of MTBE and BTEX were 44.97±49.44, 12.45±13.31, 56.32±37.55, 7.69±9.14, and 22.86±17.23 $\mu g/m^3$, respectively. The pump-island concentrations of MTBE and BTEX were closely related to the amount of gasoline sales and vehicles in samplings period ($r>0.74$).

(4) Periago JF (41) studied about evaluation of environmental levels of aromatic hydrocarbons (benzene, toluene and xylenes) in gasoline service stations with located on three roads around a city in southeast Spain. A significant relationship between the volume of gasoline sold during the shift and the ambient concentration of benzene, toluene, and xylenes was found for each personal samples in breathing zone workers. Furthermore, a significant difference was found between the time-weighted average concentration of aromatic compounds measured in March, with ambient temperatures of 14-15°C and July, with temperatures of 28-30°C.

(5) Talamanca IF and Salera EA. (42) studied about benzene exposure of workers in a petroleum transport company. The results showed the mean eight hour benzene concentration were 11.13, 0.19, 1.44 mg/m^3 for job of loading and unloading, single autocistern and multiple autocistern, respectively. The problem seemed to be particularly evident in worker who supervised the loading and unloading operations, and among those who drove multiple autoisterns.

(6) Hakkola M. et al. (43) studied about gasoline vapor exposure during offloading of tankers and railway wagons. The studied group consisted of depot workers who worked at three coastal depots (eight workers) offloading tankers and two inland depots (five workers) offloading railway wagons. During the offloading of tankers, the geometric means, geometric standard deviation and arithmetic mean±SD values for the total gasoline vapor concentration at TWA 8 hours were 10.7 mg/m^3, 2.5 and 16.6 mg/m^3, respectively. At inland depots during offloading of railway wagons, the values were 3.77 mg/m^3, 3.8 and 4.19±1.75 mg/m^3. The difference between the group in exposure levels was significant ($p<0.05$).

(7) Christine A. et. al. (44) studied about gasoline vapor exposure at a high volume service station. It was found the total gasoline vapor TWA exposure for attendant was ranged from 0.6 to 4.8 ppm with a geometric mean of 1.5 ppm. Short-term personal samples collected during refueling were ranged from detectable to 38.8 ppm with a geometric mean of 5.8 ppm.

(8) Kearney CA and Dunham DB. (45) studied about gasoline vapor exposure in workplace. It was found gasoline vapor exposure from refueling of test cars by using SKC charcoal tube and 3M organic vapor diffusion badge were non-detectable to 4.3 ppm and non-detectable to 8.1 ppm, respectively.

(9) Mcdermott HJ and VOS GA. (46) studied about gasoline service station attendants' exposure to benzene and gasoline vapors in seven gasoline service stations which one station was equipped with vapor recovery nozzle. It was found short term personal gasoline vapor exposure was ranged from 1.81 to 99.2 ppm.

(10) Batterman S. et al. (47) measured concentration of gasoline and other vapors from 15 residential vehicle garages in Michigan. It was found VOC sources which attributed to garage emissions were evaporative gasoline, solvents, paints, oils, and cleaners. The average TVOC concentration in garage was 633±554 μg/ m^3. Beside this, it was found TVOCs concentration which measured by using adsorbent-based sampling and GC/MS and direct photoionization detector could represent the collectively target compounds of evaporated gasoline around 43% of the PID measurement

(11) Egeghy PP. et. al. (48) measured benzene exposure and uptake among 39 self-service customers. Benzene exposure averaged 2.9 mg/m^3, and post exposure breath levels averaged 160 μg/m^3. It found three significant predictors of benzene exposure, namely, fuel octane grade, duration of exposure, and season of the year.

(12) Karakitsios SP. et al. (49) assessed and predicted employees' exposure to benzene at gasoline service stations which were equipped with stage I fuel evaporation recovery system. It was found that although vapor recovery technologies are installed in the refueling system, benzene emissions are significantly reduced compared to the past. The attendants were still highly exposed to benzene (15-52 μg/m^3). Benzene exposure is strongly correlated to car refueling (exposure levels up to 85), while activities like car washing or working in cash machine inside an office contribute to

lower levels (up to 44 and 24 μg/m^3). Daily variation of the employees' exposure levels revealed the correlation with the parameters affecting the exposure pattern, where the amount of fuel traded was significant parameter, followed by ambient temperature and wind speed.

(13) Esteve-Turrillas FA. et al. (50) assessed air quality inside vehicle and at filling stations by monitoring benzene (B), toluene (T), ethylbenzene (E) and xylenes (X) with the used of semipermeable devices. It was found BTEX concentration inside motor vehicles was ranged from 0.2 to 145 μg/m^3. For exposure times from 2 to 40 min, BTEX concentration during refueling at gasoline service station was range from 0.03 to 79 mg/m^3.

(14) Vainiotalo S. et al. (51) studied about customer exposure to MTBE, TAME, C_6 Alkyl Methyl Ethers, and Benzene during gasoline refueling. The measurements were carried out during 4 days in summer 1996 at two Finnish self gasoline service stations with stage I vapor recovery system. It was found the geometric mean concentrations of the individual samples were 3.9 mg/m^3 (MTBE) and 2.3 mg/m^3 (TAME) at station A and 2.4 mg/m^3 (MTBE) and 1.6 mg/m^3 (TAME) at station B. It was found the correlation of the make and model of the vehicle with the time spent in refueling or with the exposure level was not significant. While, the high correlation between VOC concentrations and daily wind speed were found significant.

(15) Hakkola MA and Saarinen LH. (54) studied the difference in the exposure of customers to gasoline and oxygenate vapors during refueling in service stations with and without vapor recovery system. The geometric mean concentrations of hydrocarbon (C3-C11) in the customers' breathing zone was 85 mg/m^3 at the stage I service station and 18 mg/m^3 at the stage II service station. The geometric mean of the exposure of customers to MTBE during refueling at the stage I service station was 15.3 mg/m^3, and 3.4 mg/m^3 at stage II service station.

(16) Lekcharernkul N. (55) estimated benzene and toluene exposure model of gasoline service attendants. The subjects were 165 gasoline service station attendants of 46 gasoline service stations belonging to three gasoline companies in Bangkok and boundary areas. The results showed average benzene and toluene in breathing zone air of attendants were 54.48±30.16 and 78.63±38.02 ppb, respectively. The atmospheric benzene in the three brands were significantly different. The relationship of

atmospheric VOC with other factors showed a significant difference for VOC concentration in gasoline and amount of gasoline sold.

(17) Jo WK and Moon KC. (56) studied the relationship between housewives' exposure to VOC and the proximity to roadside service stations. It was found the outdoor concentrations were higher during the daytime that at night. The residential outdoor VOC levels were higher when measured in close proximity to roadside service stations compared to those measured a short distance away. The indoor VOC concentrations in smoking households were significantly higher than in nonsmoking household.

(18) Vainiotalo S. et al. (61) measured MTBE concentration in ambient air in the vicinity of two self gasoline service stations in May-June and October, 1995. These stations were equipped with stage I vapor recovery system. The mean concentration measured in the centre of the pump island was ranged from 247 to 1347 μg/ m^3. The levels of MTBE are station-specific and depended on many factors, such as volumes of gasoline sold, wind speed, exhaust emissions from passing traffic, and deliveries of gasoline to the station.

(19) Karakitsios SP. et al. (62) studied about ambient benzene concentrations which contributed in the vicinity of five gasoline service stations. It was found that the VOC concentration was decreased with increasing distance from the gasoline service station. The measured benzene concentration was good correlation with road traffic flow, number of cars that refuel, total amount of the fuel being consumes, and wind speed is higher indicates the possibility of significant benzene emission source in the upwind direction, excess of refuel evaporative losses.

(20) Foo Sc. (63) studied the exposure of gasoline service station attendants to short-term exposure level (STEL) of 0.064-179 ppm. Their 8 hours time-weighted averaged (TWA) exposure was ranged from 0.028 to 0.71 ppm. For motorcar service mechanics, TWA exposure level was ranged from 0.014 to 1.7 ppm.

(21) Egeghy PP. et al. (65) studied about low benzene exposure of automobile mechanic in 12 garages. It was found the benzene concentration in exhaled breathing of mechanical in non-smoking and smoking workers were 18.9 and 39.1 μg/m^3, respectively.

(22) Van der Westhuisen H. et al. (68) evaluated evaporative emissions from gasoline vehicle under South African conditions. It was found the standard diurnal test shows that evaporative emissions increase progressively with increasing fuel temperature and fuel circulation does not significantly increase the rate of evaporative emissions.

(23) Poolma S. (69) studied about VOCs exposure of Bangkok metropolitan residents. VOCs concentrations were measured at roadside and non-roadside in nine areas which measured at outdoor, indoor, and personal exposure. It was found the concentration of 6 majors component in samples; Benzene, Toluene, Ethylbenzene, m-xylene, p-xylene, and o-xylene were 18.9-76.1, 60.2-213.7, 2.6-15.9, 5.7-26.2, 4.1-21.5, and 3.7-18.9 $\mu g/m^3$, respectively. The relationship between indoor VOCs concentration and personal VOCs concentration was found.

(24) Braddock JN, Gabele PA, and Lemmons TJ. (70) studied the factors influencing the composition and quantity of passenger car refueling emission. It found that size, configuration, and position of fuel tank, size and length of nozzle, and loading rate were not influenced the weight of gasoline vapor during refueling. The weight of gasoline vapor depended on refueled volume of gasoline. Beside this, an amount of evaporative gasoline vapor increased when fuel temperature which loading increased and fuel temperature in tank decreased.

(25) Chen ML. et al. (71) evaluated the relationship between the breath concentrations and personal exposure to toluene, xylene and ethylbenzene of thirty workers from ten gasoline service stations. The results indicated that breath concentrations of toluene and xylene were significantly correlated with personal monitoring concentration. Furthermore, it showed that exhaled toluene levels were highly influenced by personal toluene concentrations and the amount of personal gasoline sold, while exhaled xylene levels depended on wind speed and personal xylene exposure concentration. It found average number of symptoms per person according to neurotoxic questionnaire was 4.1 and six workers showed over six symptoms.

2.3.2 The studies of gasoline vapor exposure and bio monitoring of gasoline service station attendants.

(1) Tunsaruengakan T. (72) studied bio monitoring of refuel workers exposed to volatile organic compounds in gasoline service stations. They compared the level of hematology, biochemistry, cholinesterase between symptom and non-symptom group. The result showed that eosinophill of the risk workers who had dizziness was found to be significantly lower than the non symptoms group ($p< 0.05$). Abnormal blood smear of the headache group was significantly higher than the non symptom group ($p< 0.05$) but average level of hemoglobin, serum SGOT, SGPT, ALP, cholinesterase of all symptom groups were not difference.

(2) Intarasunanon P. (73) studied effects of exposure to air pollution from petrochemical (Benzene) in gasoline service stations. The results showed that the median and range of benzene level in the ambient air of gasoline service stations, control sites were 22.70 (1.60-216.95), 2.08 (0.00-59.42) ppb respectively. The median and range of benzene levels in breathing zone of exposed and control subjects were 84.78 (2.80-439.56) and 10.10 (0.25-167.38) ppb, respectively. A correlation between benzene levels in the workplace and benzene levels in breathing zone were statistical significant at $p<0.01$. For biomarkers, the levels of two biomarkers which consisted of benzene in blood, urinary trans,trans-muconic acid (t,t-ma) detected in the exposed group were significantly higher than those in the control group ($p<0.01$-0.05). The correlation of benzene levels in breathing zone with benzene levels in blood or levels of urinary t,t-ma were statistical significant ($p<0.01$-0.05). Beside that, she found the decreased hemoglobin (Hb) and hematocrit (Hct) in the benzene expose group.

(3) Tunsaruengakan T. et al (7) studied health effect of BTEX and MTBE among 44 gasoline station workers (preliminary studied). Their symptoms of headache, dizziness and fatigue were reported at 36.4, 36.4 and 20.5 percent respectively. The hematological studied and blood clinical chemistry showed that there were abnormal blood smear, lower hemoglobin and hematocrit than normal range 68.2, 45.5 and 31.8 percent respectively. The liver enzymes of SGOT, SGTP, and ALP were higher than normal range 9.1, 15.9 and 38.6 percent respectively. The physical examinations found the most of the workers were healthy even though 84.1 percent of them were

thalassemia carriers. This study could not find the association between volatile organic compounds exposures and health effect of the workers.

(4) Leelaphaiboon S. (74) studied about a relationship between benzene exposure and urinary trans, trans-muconic acid (t,t-ma) in gasoline service station attendants in the Bangkok and Nonthaburi provinces. The results showed that average benzene concentration at breathing zone, the average urinary t,t-ma of the gasoline service station attendants were 0.19±0.16 (non detecable-0.65) ppm, 0.86±0.58 (non detecable-2.66) μg/ml urine, or 458.42±446.42 (non detecable-2274) μg/g creatinine, respectively. There were no significant difference of benzene concentration and t, t-ma levels between the non-smoker and the smoker groups. In conclusion, there were the different concentrations of urinary t,t-ma excretion when the levels of benzene exposure were difference. However, there was no linear correlation between benzene concentration and urinary t,t-ma level among the gasoline service station attendants.

(5) Navasumrit P. et al (75) studied environmental and occupational to exposure benzene in Thailand which consisted of main roads, schools, gasoline service stations, petrochemical factories, cloth venders, and grilled-meat venders. For gasoline service stations, the results showed the mean ambient levels of benzene, individual exposure to benzene were 64.78, 121.67 ppb, respectively. They were exposed to significantly higher levels of benzene than their control work places or workers. In accordance with the increased benzene exposure, levels of urinary trans,trans-muconic acid (t,t-ma) and blood benzene (641.84 ppt; $p<0.05$) were significantly increased when compared with respective controls. DNA damage, determined as DNA strand break, was found to be elevated in gasoline service attendants ($p<0.001$). The cytogenetic challenge assay, which measures DNA repair capacity, showed varying levels of significant increases in the number of dicentrics and delations in gasoline service attendants.

(6) Tongbo A. (76) studied the levels of phenol in urine of gasoline service station attendants. It was found the average phenol levels in urine of refuel workers were 16.70±18.88 mg/gCr. The average phenol levels in urine of other duties were 8.13±8.59 mg/gCr. Beside this, it was found no statistical significant relation between the level of phenol in urine of refueling worker and sex, duration of work time, working behavior; ate during working, hand washing before and after ate, alcohol drinking, and smoking.

(7) Verma Y and Rana SVS et al. (77) studied about biological monitoring of exposure to benzene in petrol pump workers and dry cleaners. It was found the level of phenol in urine of gasoline service station attendant was higher than dry cleaner workers. Beside this, it was found the people who drank alcohol had phenol in urine more than smoking people.

(8) Brugnone F. et al. (78) studied benzene in blood as a biomarker of low level occupational exposure. It was found that the median blood benzene concentration was significantly higher in smoker than in non-smokers, both in the general population (210 ng/l and 110 ng/l) and in the exposed workers at the end of the shift (476 ng/l and 132 ng/l).

2.3.3 The studies of risk assessment.

(1) Tongpoo A. (79) studied risk assessment of toluene exposure among wood furniture workers. It found that the workers in spray painting area, coating area, office had degree of risk ≥ 1 = 54.17%, 12.50%, and 0%, respectively. It was statistically significantly different in three working areas. After adjusting for pre-HA, toluene concentration was statistically associated with log Post-HA. Quantitative risk assessment and prioritization were set up from toluene concentration and urine hippuric acid. The result showed that spray painting workers were graded in low risk level while coating and office workers were trivial risk levels.

(2) Kaepraseartsup C. (80) studied risk assessment of MTBE in gasoline in Bangkok areas. The samples were collected from pump-island and the border from gasoline service station in summer and winter season. The results showed that concentrations of MTBE in pump-island were higher than the border which the range concentration of MTBE in pump-island was 0.011-4.616 mg/m^3 and in the border area was 0.001-0.23 mg/m^3 and was found that the amount of MTBE at pump-island and the border of gasoline stations were related to amount of gasoline sold (r^2 = 0.505 and r^2 = 0.458 respectively). The concentration of MTBE at pump-island in summer season was higher than the winter significantly but the concentration of MTBE at the border of gasoline service stations in summer and winter season was not different significantly ($p>0.05$).

The value of hazard quotient for acute which non-carcinogen from exposure of MTBE in the ambient for 8 hours per day of gasoline service stations was less than 1 (0.006-0.87) in which the value of hazard quotient at pump-island of the gasoline service station which service amount of gasoline was 178-650 liters per hours nearby 1 (0.8) but the value of hazard quotient for chronic which non-carcinogen at pump-island of the gasoline service station which service amount of gasoline about 178-650 liters per hours was more than 1(1.33-2.20) that imply the pump-island area was risk from exposure to MTBE for long time.

(3) Hansamah M. (81) studied risk evaluation of toluene exposure: Case studies in paint A&B factories which were different in their effective engineering controls. The correlation coefficients between toluene concentration and urinary hippuric acid were 0.66. By stepwise the multiple regression, only two variables, toluene concentration and dermal exposure were statistically significance at $p < 0.001$ and $p=0.009$, respectively. The best model could be represented as: y=0.298+0.01689 (toluene concentrations) + 0.08568(dermal exposure).

The results among four difference tasks, mixing group, and laboratory group, packing group and preparation group in the two plants showed that the mean values of toluene concentration were statistically significant between the tasks in both plants. The mean toluene concentration in plant A was higher than plant B which had effective engineering control. However, the mean urinary hippuric acid in the plant was not different. The mean values of toluene concentration and the mean value of urinary hippuric acid in the mixing group were higher than the other groups.

(4) Sripong N. (82) studied about organic solvent exposure of worker in petrochemical industry. It was found the level of VOC in ambient air depended on task which the worker in chemical laboratory had higher risk to VOC exposure more than other duty. Beside this, it was found the level of metabolite substance in human body depended on duration time of exposure.

2.3.4 The studies of shift workers.

(1) Sondakh W. (83) studied the prevalence of stress among female shift workers in a weaving textile factory. It was found the prevalence of stress was 14.29% and

mean stress score was 26.77 with was ranged from 20 to 45 and standard deviation 4.78.

(2) Upakaew A. (84) studied the level of stress and cortisol changes in female shift workers. It was found two levels of stress; normal and moderate level. The rates of released cortisol of worker in morning shift were difference from evening shift. It concluded that shift working resulted to change of release cortisol pattern of worker.

(3) Sidabutar T. (85) studied the relationship between shift work and sleep disturbance among nurses. The studied found that the sufficient of income, perceived burden on caring of family member and working unit were significantly associated to sleep disturbance. Also working without night shift and three levels of the amount of with night shift per month (1-5 night shifts, 6-10 night shifts, >10 night shifts) were significantly associated to sleep disturbance. The study also found that 25.6% of the nurses used sleep medication.

(4) Ircham M. (86) studied the relationship between demographic factors, migration factors and mental health status among 169 shift workers of electronics factory. It was found that 80.5% of the worker were in the poor mental health, 19.5% were in likely normal mental health, and none of worker assess them self as good mental health. The statistically significant association was founded between mental health and type of job.

(5) Chokwittaya T. (87) evaluated adjustment problems of shift workers in computer component factories in Ayudhaya province. The results showed the most of worker had low adjustment problem in overall. However, most of them confronted some problem such as insufficient sleep, headache symptom, a lack of time to relax.

2.3.5 The studies of consumers' behavior on using gasoline service station.

(1) Sungkamongkolkit N. (88) studied the factors affecting consumers' behavior on using gasoline service station in Chiangmai province. It was found that most of customer spent money for refueling 401-600 bath per time and often refueled in evening. The factors affecting amount of spent money of customer were career, income, sex, age, and married status. The customers' career was correlated with the time to refuel.

(2) Tongtha Y. (89) studied consumers' behavior on using gasoline service station in Samutsakorn province. It was found that most of customer spent money for refueling 301-600 bath per time and often refueled in morning (7.01-9.00 a.m.) and evening (5.01-7.00 p.m.) Beside this, career and income were correlated to amount of money for refueling.

(3) Nalinrat C. (90) studied consumers' behavior on using gasoline service station in Bangkok and boundary area. The studied was conducted at Shell, Esso, Caltex, Ptt, Bangjak and Jet companies. 415 of samples were interviewed. It was found that the customer often refueled 201-400 bath per time.

(4) Pearksapunthawee A. (91) studied factors affecting comsumers' selection of gasoline service stations in Chiangmai province. The samples size of samples was 400. It was found that the customers often spent money around 300 bath per time for refueling 4 wheels car and 30 bath per time for refueling motorcycle. The customers often refueled in evening before they went home.

(5) Suphawilai W. (92) studied the factors influencing consumers' selection on gasoline service station in Ayudhaya province. It was found that customer often spent money for refueling 301-500 bath per time and refueled frequency 2-3 times per week. Beside this, it was found an income of customer results to money which they spent per time.

2.3.6 The studies of work practices and health behaviors of workers.

(1) Soruj W. (93) studied the relationship between health beliefs, pesticide use and safety behaviors with acute poisoning symptoms. It was found 83.3% of farmers had moderate health belief. They had low safety behaviors on used pesticide. The relationship between the trouble perception and safety behavior of using pesticide were found significantly. It found pesticide behavior usage; the frequency of usage, duration time to use, concentration and the method were related to acute poisoning symptoms of farmers.

(2) Nakma Y. (94) studied about danger protection behavior from using pesticide. Most of farmer (64.2%) had moderate danger protection behavior. It was found the relationship between the knowledge and skill of protection danger and protection behavior from danger of pesticide.

(3) Kesaro W. (95) studied about the usage personal protective equipment of employees in wooden factory. It found that the wooden employees used safety devices at the moderate level. The factors significantly influencing their behavior of using safety devices while working were age, work environment, information related to work safety.

(4) Chalermwipas P. (96) studied about the relationship between selected factors and sensorineural hearing loss prevention behaviors in factories using pressing machines. The results showed that the prevalence rate of sensorineural hearing loss of workers were 641.4:1000. Most of worker (49.6%) had low sensorineural hearing loss prevention behavior. It was found education level, income, disease belief, and charitable factors to prevent disease were correlated significantly with sensorineural hearing loss prevention behavior.

(5) Inprasit N. (97) studied about the relationship between health beliefs and health behaviors in silicosis prevention among rock grinding workers. The results showed that most of them (70.5%) had moderate perception to opportunity and risk of disease. Most of them (70.0%) had moderate the severity of disease while 59.9% of them had low perception to benefit and trouble. Most of them (63.3%) had moderate health behavior in silicosis prevention. Beside this, it was found the positive relationship between the perception to benefit and trouble, and income with the health behavior.

(6) Preechaworawech S. (98) studied the factors influencing behavior of textile factory workers' usages of personal ear protector devide. The result showed that most of worker had moderate perception to hearing loss disease in work place. It was found the perception to hearing loss disease and the severity of disease were correlated with personal protective equipment usage.

(7) Changkaw W. (99) studied the relationship between health belief factors and behavior in usage of dust protecting mask in worker of the cement irrigation factory. The results showed that most of worker (76.1%) had high usage personal protective equipment. They had high health beliefs 76.1%. Most of them (88.3%) had high perception to opportunity and risk from dust while most of them (85.6%) had high perception to benefit and trouble of usage mask. It was found the perception to opportunity and risk from dust, the perception to severity of disease, and the

perception to benefit and trouble of usage mask were related to behavior in usage of dust protecting mask.

(8) Thongbai W. (100) studied the factors affecting health promotion behavior among 420 textile woman workers in Pathumthani province. The results showed that the factors influencing health promotion behavior were the age, the work experience, knowledge of health promotion, the attitude to health promotion, and the perception to health condition.

(9) Keatikun P. (101) studied about safety behavior of the workers before and after promotion of 5s activities and safety course in the workplaces. It found the knowledge, attitude, and safety behavior of worker was low. The results showed that the outcome of 5s process and safety course in the workplaces influenced safety behavior of worker. The incident rate and the severity of accident were significant decreased.

(10) Chayusthit P. (102) studied health impact factors of the workers' exposure to Thinner. The results indicate that most of them work on the shift basis. The worker had high knowledge level of health concerns involving working condition. Most of them had good health. Most of them use individual hazard protection. There were two factors that affected the health of workers exposure to thinner. Theses factors were work experience and health history.

(11) Hwangjaisuk P. (103) studied on factors affected working behavior of workers in aluminium manufacturing plant. The findings were the opinion in the safety system, the environment and the safety behavior of the manufacture workers were in medium level. It was found the worker which had different safety training, they had different safety knowledge. There were positive relationship between safety behavior, safety system, and safety environment.

(12) Leardpreechaphol S. (104) studied about job satisfaction of Ptt gasoline service station employee. The results showed that most of attendants (63.8%) were male. Most of them (55.8%) were 15-21 years old. Most of them had moderate pleasure to their work. It found that the age, size of station, and knowledge about their duties were resulted to satisfaction of workers.

(13) Buddee P. (105) studied the factors affected service quality of gasoline service station attendant. The results showed that most of attendants (52.6%) were

female. Most of them (73.7%) were 16-25 years old. It found that most of them had moderate quality of working and had moderate service quality as well.

(14) Tanggenkit J. (106) studied the relationship between quality of work life and intention to leave of gasoline service station employee. The results showed that most of attendants (61.4%) were female. Most of them (55.8%) were 16-26 years old. Most of them (57.9%) had moderate quality of working. It found 39.85% and 9.14% of them had moderate and high intend, respectively to resign from gasoline service station.

(15) Ruttanamanee K. (107) studied of working conditions and aspiration of the child laborers in gasoline service station. The results showed that most of them (84%) were male which had primary education (70%). The important reason that causes the children have to work was the insufficient income (20%). Most of child labor (69%) worked more than 8 hours per day. For the aspiration of them, most of them (75%) would like to study while 12% of them would like to be a mechanic.

(16) Sririwong Na Ayudhaya A. (108) evaluated health behavior of people in economic crisis. The study was conduced in Pitsanulok and Srisakes province. It was found that a crisis of economic is threatening behavior of patient. The ratio of patient went to hospital was decreased while the ratio of patient take care themselves or bought medicine was opposited.

CHAPTER III
MATERIALS AND METHODS

3.1 Research design

The research was designed as a cross-sectional study which aims to investigate TVOCs risks from gasoline service stations. Three sources of gasoline vapor in gasoline service stations which consisted of different distances from refuel nozzles at pump-island area, changing motor fuel stations, and office were measured TVOCs concentration at human breathing zone. Beside this, factors influencing their levels in vent vapor at refuel nozzles in pump-island area which consisted of amount of sold gasoline per time, conditions of vehicle engines, and size of refuel receptacle were studied. Stratified sampling was used for selecting studied gasoline service stations and attendants in tree zones of Bangkok areas; inner city, urban fringe, and suburb (see details in section 3.3). There were 39 studied stations for over viewing their environmental health situation by inspection form, questionnaires. There were about three forms for each station thus total samples were 113. In addition, it was studying the TVOCs concentrations in the air by using laboratory instrument which consisted of samples from pump-island area, samples in changing motor fuel stations and samples from office areas. The totals of samples for TVOCs measurement in this study were 776 samples (see 3.5.2). Therefore the overall samples were 889 (113+776).

3.2 Place of study

The level of TVOCs concentrations and related data were studied at the selected gasoline service stations in inner city, urban fringe and suburb of Bangkok areas.

3.3 Sample size of studied gasoline service stations and gasoline service station attendants

3.3.1 Determination of number of studied gasoline service stations

The type A and B gasoline service stations in Bangkok areas during the year 2006 were around 798 (37). The purposive random samplings were used to select studied gasoline service stations which gave well participation. Three brands of motor fuel were represented for the studying; Ptt, Shell, and Esso. Numbers of total gasoline service stations were 151, 137, 141 stations, respectively. 30% of these gasoline service station equal to 129 stations. By this way, the sample size of studied gasoline service station equal to 30% of 129. Thus, it was 39 stations which equaled to 9% of total these brand stations which was calculated as following equation;

Where $n = \frac{30\ (N)}{100}$

n = sample size

N = size of population

$N = \frac{30\ (129)}{100}$

n = 39

3.3.2 Determination numbers of studied gasoline service station attendants

They were around 12,678 gasline service station attendants working in 798 gasoline service stations located in Bangkok areas (109). Gasoline service station attendants in this study were selected based on the following criteria:

1. The studies were made while the attendants were working to fill the refuel.
2. They had willing to participate in this study.

In this study, the overall samples size of workers were 113 since numbers of selected stations were 39 and around three workers per station were chosen. The

reason was come from preliminary field study. It was found that each station had forecourt workers not more than 4-5 workers/shift. Thus, the selected three workers/shift of each station were equaled to 50% of total forecourt workers/shift.

3.3.3 The sampling method

The selection criteria for studied stations were based on proportional numbers of gasoline service stations in three zones of Bangkok areas, distribution in district and brands of motor fuel. Steps of sampling were as follow;

1) The gasoline service stations in Bangkok were divided into three zones according to a classification of the Division of Urban planning, Bangkok Metropolitan Administration (110): inner city, urban fringe, and suburb. They are;

1.1 The inner city was consisted of 22 districts: Phra Nakorn, Pomprap Sattruphai, Samphanthawong, Patumwan, Ratchatewi, Bang rak, Dusit, Phaya Thai$ Bang plad, Bangkok Noi, Bangkok Yai, Sathorn, Yannawa, Bangkho lame, Bang Sue, Klongsan, Thonburi, Chatuchak, Huay Kwang, Dindaeng, Khong Toey, and Wattana.

1.2 The urban fringe composed of 22 districts divided into fourteen districts in the east, namely, Don Muang, Lak Si, Bang Khen, Sai Mai, Lad Phrao, Bangkapi, Bung Kum, Wang Thong Lang, Kanna Yao, Saphansoong, Suan Luang, Praves, Pra kanong, and Bang Na, and eight districts in the west, namely, Taling Chan, Taweewattana, Phasicharoen, Bangkae, Nong Khaem, Ratburana, Thung Khru, and Chom Thong.

1.3 The suburb covers six districts, four in the east: Min Buri, Khlong Samwa, Lad krabang and Nong Chok, and two districts in the west: Bang Khunthian and Bang Bon.

2) In each zone of Bangkok, the district was divided by using number of gasoline service stations located to three groups which consist of low, moderate and high number. The used method for grouping district was as follow;

2.1 Ranging numbers (minimum to maximum) of gasoline service stations in the district in each zone.

2.2 Finding the interval numbers of gasoline service stations in the district in each zone by

X_{max} - X_{min} (X = numbers of gasoline service stations in the district)

2.3 Refine the numbers of group districts in each zone equal to 3

2.4 Finding the wide of stratum by divided the range in 2.2 with 3, then grouping the district as calculated wide of stratum. The district's groups in each zone were shown in Table 16.

3) In each group of districts, divided the gasoline service stations by brands of motor fuel. There were Ptt, Esso, and Shell.

3.1 Samples size in each zone were determined by proportional allocation with the numbers of population in each zone as the following formula (111):

$$nh = \frac{Nh}{N} \times n$$

When nh = sample size in each zone

n = total sample size (39 stations)

Nh = population size in each zone

N = total population of three brand in Bangkok (429 stations)

The samples size in each zone were then also calculated in each group of the district and three brands of motor fuel in the districts' group by using the formula as mentioned.

3.2 The samples were selected by using stratified samplings to determine number of selected gasoline service stations for 39 stations. The overall stratified samplings were as Figure 2.

Table 16 Group of the districts in each zone classified by numbers of gasoline service stations which located in the areas

Bangkok's zone	Group of district	District
Inner city	Low	Phra Nakorn Pomprap Sattruphai Samphanthawong Patumwan Bang rak Bangkok Noi Bangkok Yai Bangkho lame Klongsan Thonburi
	Moderate	Ratchatewi Dusit Phaya Thai Bang Sue Bang plad Sathorn Yannawa Dindaeng Khong Toey Wattana
	High	Chatuchak Huay Kwang

Table 16 Group of the districts in each zone classified by numbers of gasoline service stations which located in the area (Continued)

Bangkok's zone	Group of district	District
Urban fringe	Low	Don Muang Lak Si Sai Mai Kanna Yao Saphansoong Pra kanong Taweewattana Nong Khaem Ratburana Thung Khru Chom Thong.
	Moderate	Praves Phasicharoen Bang Khen Lad Phrao Bangkapi
	High	Bung Kum Wang Thong Lang Suan Luang Bang Na Taling Chan Bangkae
	Low	Khlong Samwa
	Moderate	Lad krabang Nong Chok Bangkhunthian
	High	Min Buri Bang Bon

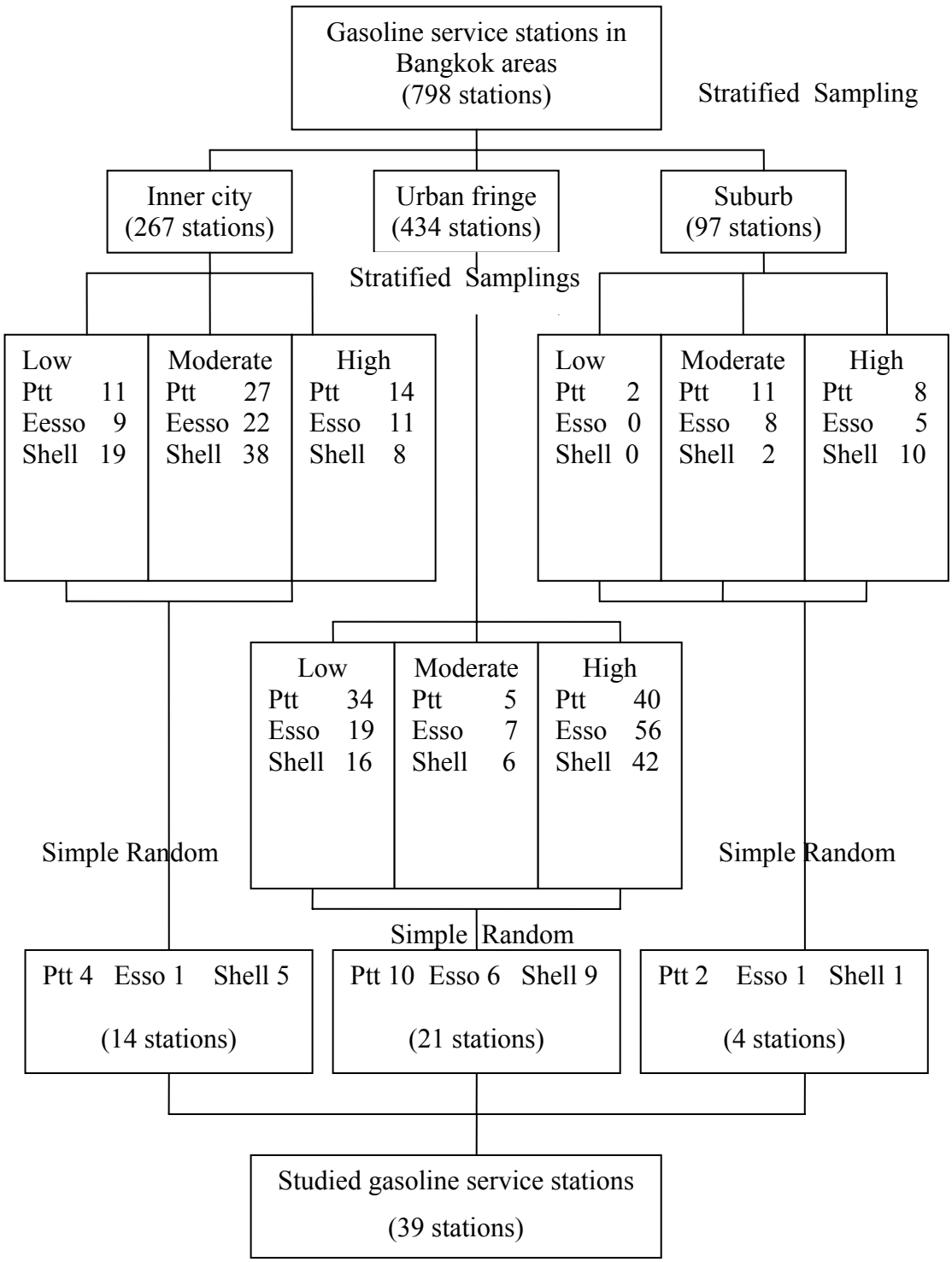


Figure 2 Stratified sampling for 39 gasoline service stations

3.4 Research Instrument

3.4.1 Inspection form

The inspection form was designed as an open end questions and check lists. It concludes general gasoline service station information and other qualitative data of environmental health conditions beyond those in the questionnaires.

3.4.2 Questionnaire

The questionnaires were used for interviewing gasoline service station attendants about his/her personal data, history of working, history of illness and health conditions, characteristics of refueled services, work practices and health behavior. There were designed as a multiple choices and filled in blank questions. The developing steps were as follow;

Step 1 Design core content of questionnaires. The contents were divided to five parts as follow;

Part 1: Personal characteristics

Part 2: History of workings

Part 3: History of illnesses and health conditions

Part 4 : Characteristics of refueled services

Part 4: Work practices and health behaviors

Step 2 Determine content validity. The first draft of questionnaires were sent to specialist for auditing the contents.

Step 3 Correct wordings and vocabularies. All the contents were revised as recommendation from specialists and the edited draft was called second draft.

Step 4 Pretest the second draft questionnaires. The questionnaires were tested to find content validity one more times and made sure understood any questions which designed. Samples group who had similar characteristics with the research population were selected and trialed with questionnaires.

Step 5 Rewrite the third draft questionnaires. The questionnaires were rewritten according to all corrections from a pretest study.

The questionnaires were used to interview selected refuel gasoline service station attendants. They were informed for the purposes of the study and provided an assurance that the confidentialities of respondents were respected.

3.4.3 Laboratory instrument

Multirae IR is a direct-reading instrument. It was used to measure TVOCs concentrations with photo ionization detector. Chemical contaminants in normal air were ionized as a result of being bombarded by high energy ultraviolet (UV light). These compounds actually absorb the energy of the light, which excites the molecule and results in the temporary loss of an electron and the formation of a positively charge ion. This process was called photo ionization. The movement of ions or electrons from one electrode to another can generate an ion current which was measured in voltage units and the electron volt (eV) of this instrument is 10.6 eV. The specification of Multirae IR system photo ionization detectors (PIDs) is compliance with the specifications in EPA Method 21 in which the specification of Multirae IR consist of determination range from 0 to 2,000 ppm/m^3 of the air, resolution 1 ppm, pump flow rate 0.15 cc/min, intrinsic safety class1 division 1, response time ≤10 sec, and precision ±3% of cal. gas value. The detecable were not detecable of VOCs by PIDS with 10.6 eV and they had been shown in chapter 2.

3.5 Research Methodology

3.5.1 Field studies

1. Preparation the equipments for collecting data in field study. They were inspection forms, questionnaires (see in appendix), and laboratory instruments.

2. Describing data collector about details of inspection forms, questionnaires, target samples and some techniques to collect data.

3. Requesting for the cooperation from Bangkok Metropolis Administration to assist data collecting from studied gasoline service stations.

4. At gasoline service stations, the environmental situations of gasoline service stations were observed by using inspection forms and around three refueling workers were interviewed by using questionnaires.

3.5.2 Measurement of TVOCs concentration

3.5.2.1 TVOCs concentration which may expose during workings

The level of TVOCs concentrations at human breathing zone in different distances from refueling gasoline nozzles down wind direction in pump-island areas, Changing motor fuel station sites, and office were measured by using Multirae IR (direct reading instrumeft) which had the determination ranges from 0 to 2,000 ppm. It was hold at 1.50 meters above the ground. Air sample flow of 150 cc/min was regulated to use. The unit of TVOCs concentrations were recorded in ppm/m^3 of air.

3.5.2.2 Factors influencing amount of TVOCs

To study factors influencing amount of TVOCs concentration in the vent gasoline vapor, the level of TVOCs concentrations were measured from gasoline vent at refuel nozzles by using Multirae IR which had similar measurement conditions in section 3.5.2.1.

The overall samples measurements of TVOCs in studied gasoline service stations were shown as follows:

Table 17 Conclusion of TVOCs measurements in studied gasoline service stations.

An area	The distance from refuel nozzle (m.)	Number of samples	Selected measurement	Sampling measurement
1. TVOCs concentration which may expose during working				
Pump-island	0	273	Motor cycle	Breathing zone
	0< m.≥2.00	7	Motor cycle	Breathing zone
	2.01-4.00	138	Motor cycle	Breathing zone
	4.01-6.00	17	Motor cycle	Breathing zone
	> 6.00	11	Motor cycle	Breathing zone

Table 17 Conclusion of TVOCs measurements in studied gasoline service stations (Continued)

An area	The distance from refuel nozzle	Number of samples	Selected measurement	Sampling measurement
	0	42	Automobile in running engine	Breathing zone
	0	77	Automobile in stopping engine	Breathing zone
Changing motor fuel station	-	25	-	Breathing zone
Office	-	39	-	Breathing zone
Total of samples in this section = 629				
2. Factors influencing TVOCs emission				
Pump-island	0	48	Automobile in running engine	Refuel nozzle
	0	99	Automobile in stopping engine	Refuel nozzle
Total of samples in this section = 147				

During TVOCs measurements in the ambient air and gasoline vent, ambient temperature and wind velocity were measured simultaneously.

3.5.3 Unit of analysis

3.5.3.1 TVOCs concentration in different work place.

Unit of analysis in this section was measured TVOCs in each time of each work place. Numbers of total measured TVOCs were 337 samples. At pump-island area, TVOCs concentration was measured at human breathing zone 273 samples. Beside this, there were 25 samples from changing motor fuel station and 39 samples at inside office.

3.5.3.2 TVOCs risk in each gasoline service station, Unit of analysis in this section was 39 gasoline service stations. The data were managed as follow;

(1) Individual 337 TVOCs concentration of ppm unit were converted to mg/m^3 unit. The unit conversion was conduced by using molecular weight of calibrated substance for Mutirae IR instument. It was Isobutylene (C_4H_8). The molecular weight of this substance was 56.11 (112). The equation which used for converting unit to mg/m^3 was Y mg/m^3 = (X ppm)(Molecular weight)/24.45. The conversion equation was based on 25 °C, 1 atmosphere (113). Whereas X ppm was measured TVOCs concentration in ppm unit.

(2) If any work place had many samples, average individual TVOCs concentration in each work place was used to represent TVOCs concentration in each work place of gasoline service station.

(3) Then, the average TVOCs concentration at each work place; pump-island area, changing motor fuel station, and office in each gasoline service station was formed into groups by the level of TVOCs criteria using SPSS Version 11.5. There were safety exposure risk level (TVOCs concentration less than 0.20 mg/m^3), low risk level (TVOCs concentration range from 0.20-3.0 mg/m^3), moderate risk level (TVOCs concentration range from 3.0-25.0 mg/m^3), and high risk level (TVOCs concentration greater than 25 mg/m^3) (29, 35).

(4) After grouping TVOCs concentration at each work place, TVOCs concentrations at different work places were analyzed to conclude an overall TVOC risk level in each gasoline service station. From SPSS data editor, click transform bottom and choose compute order. Finally, choose max value for numeric expression order.

3.5.3.3 Work practice and health behavior of attendant

Unit of analysis of this section was the data of each attendant. It was 113 samples. For risk behavior level of gasoline service station attendant, the data was managed as follow;

(1) The data from questionnaires of gasoline service station attendant in part of work practice and health behavior were given a score in order to assess risk behavior level. In positive question, if attendant had high frequency of behavior, they

would have high score. In contrast, if attendant had high frequency of behavior in negative question, they would have low score.

(2) Sum the total score of each gasoline service station attendant.

(3) Divide the total of received score by the overall score of suitable behavior and transform to the percentage in order to give level of risk behavior.

(4) The percentage score of each worker was classified to low risk behavior, moderate risk behavior, and high risk behavior (114) as shown in Table 18. The lower percentage was pointed out the higher risk level and size of problem.

Table 18 Percentage of score classified by risk behavior level

% of score	Characteristic of behavior	The level of risk behavior
<60	Low suitable behavior	High risk behavior
60-79	Moderate suitable behavior	Moderate risk behavior
≥ 80	High suitable behavior	Low risk behavior

(5) For the risk behavior level in each gasoline service station, unit of analysis was 39 gasoline service stations. Then, the average risk behavior level of individual gasoline service station attendant in each studied gasoline service station was determined. It was represented the risk behavior level of each station.

3.5.3.4 TVOCs concentration at different distance.

The unit of analysis of this section was TVOCs concentration in each time which was measured at breathing zone in pump-island area between refueling of motorcycles. The total number of samples was 446. Individual 446 TVOCs concentration of ppm unit were converted to mg/m^3 unit as same as section 3.5.3.2 (1) and was formed into groups by using TVOCs criteria. While, the distance was formed into 4 groups; ≤ 2 meters, 2.01-4.00 meters, 4.01-6.00 meters, and > 6 meters.

3.5.3.5 TVOCs concentration at refuel nozzle.

The unit of analysis of this section was TVOCs concentration in each time which was measured at refuel nozzle in pump-island area between refueling of automobile. The total number of samples was 147. The volume of refueled gasoline

and TVOCs concentration in ppm unit was formed into 3 groups by using equation; min-$\bar{x}$-½SD, the score between $\bar{x}$±½SD, $\bar{x}$+½SD-max (115).

3.6 Statistical analysis

3.6.1 Descriptive statistics

Mean, standard deviation and percentage were used for the personal characteristics, history of working, history of illnesses and health conditions, work practices and health behaviors of gasoline service station attendants.

3.6.2 Inferential statistics

1. Determination statistically significance TVOCs concentrations in each work place by using One-way ANOVA.

2. Determination statistically significance of levels of TVOCs concentrations and the vehicle engine conditions using t-test.

3. Determination the relationship between the levels of TVOCs concentration with amount of sold gasoline per time, the distance from refuel gasoline nozzles and size of refuel receptacles by using Pearson correlation coefficient.

4. Determination the relationship between worker behavior with illness symptom and sign of behavior as well as between risk behavior level and TVOCs risk using χ^2 test or Fishers' exact test when expected outcome less than 5.

CHAPTER IV
RESULTS

During the period of study (March-May 2007), number of total gasoline service stations type A and B in Bangkok areas were 798 stations which were Ptt., Esso, Shell, Bangjak, Caltex, and the others. These brands of motor fuel sellers were sampled by purposive random as representative of brand fuel sellers. There were Ptt, Esso, and Shell. The numbers of total gasoline service stations for Ptt, Esso, Shell were 151, 137, 141 stations, respectively. 9% of them were sampled by random method. Thus, numbers of gasoline service stations in this study were 39 stations that were Ptt.16 stations, Esso 8 stations and Shell 15 stations.

This research was analytical survey. In each gasoline service station, around 3 gasoline service station attendants were interviewed to evaluate health behaviors and work practices which numbers of received sample were 113. TVOCs concentrations in breathing zone were measured at pump-island areas, changing motor fuel stations, and the offices which numbers of total samples were 629 samples. Beside, TVOCs concentrations were measured at refuel nozzles in pump-island areas which numbers of total samples were 147 samples. Thus, numbers of total samples were 889 samples.

One-way ANOVA was used to compare the level of TVOCs concentrations in breath zones at difference work places. Beside, Pearson correlation coefficient was used to finding the relationship between TVOCs concentration in breath zones at pump-island areas and the distances from refueled nozzles. In addition, the relationship of TVOCs concentrations at refuel nozzles, the volume of sold motor fuel and receptacles' size were determined. T-test was also used to compare the level of TVOCs concentrations between stopping and running engines.

4.1 TVOCs concentration in different work place

TVOCs concentration at human breathing zone was measured at three work places in gasoline service station; pump-island area, changing motor fuel station, and office. There were 337 samples which consist of 273 samples from pump-island areas, 25 samples from changing motor fuel station, and 39 samples from office.

There were different TVOCs concentrations in pump-island area. TVOCs concentration was ranged from non-detectable to 640.27 mg/m^3 (non-detectable to 279 ppm). Most of measured TVOCs concentration (49.5%) in pump-island area was >25 mg/m^3. 27.5%, 14.7%, and 8.4% of them was ranged 3.1-25 mg/m^3, 0.2-3.0 mg/m^3, and <0.2 mg/m^3, respectively. The average TVOCs concentration was 64.62±100.63 mg/m^3 (28.16±43.85 ppm). For the average TVOCs concentration at pump-island area in each zone of Bangkok were shown in Figure 3.

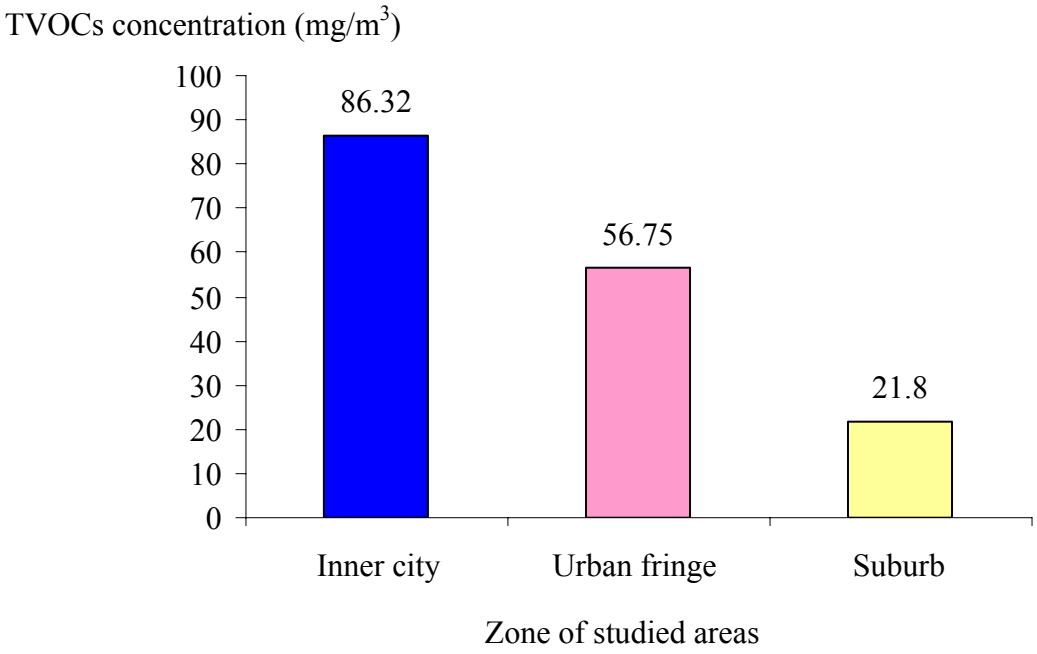


Figure 3 The average TVOCs concentration at pump-island area in each zone of areas

In changing motor fuel station, the TVOCs concentration was ranged from non-detectable to 27.77 mg/m^3 (non-detectable-12.10 ppm). The average TVOCs concentration was 3.16±6.22 mg/m^3 (1.38±2.71 ppm). For the average TVOCs concentration at changing motor fuel station in inner city, it was 0.59 mg/m^3. While,

there were 3.97 mg/m^3 and 5.62 mg/m^3 for urban fringe and suburb, respectively. These results were shown in Figure 4.

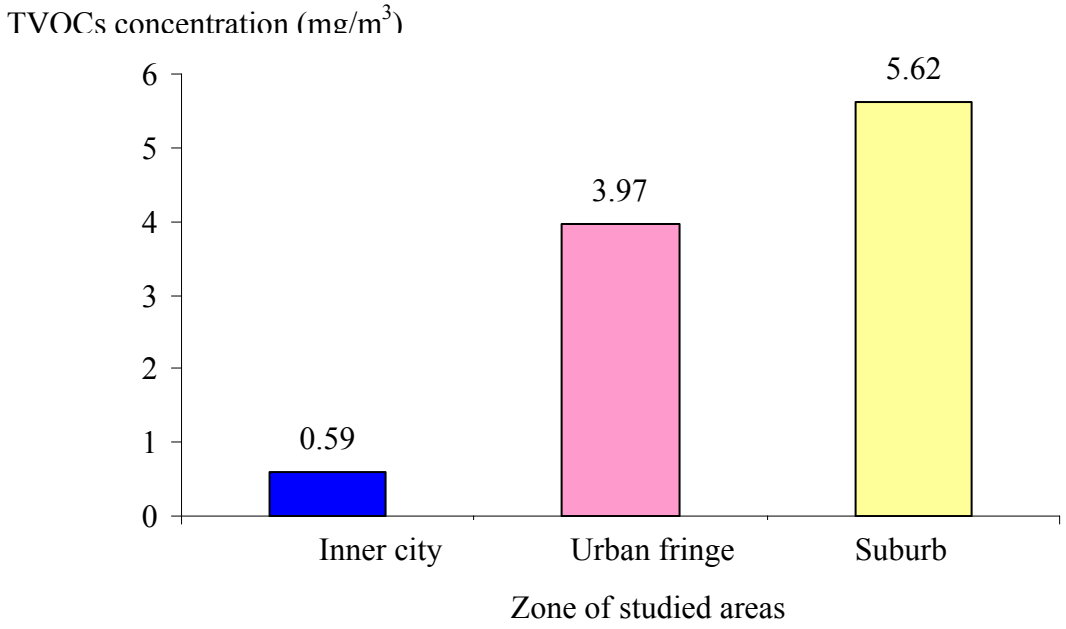


Figure 4 The average TVOCs concentration at changing motor fuel station in each zone of areas

Beside this, it was not detectable TVOCs concentration in most office of gasoline service station. Only 1 sample of TVOCs concentration was detected. It was 0.46 mg/m^3.

The difference between TVOCs concentration of different work place which consists of pump-island area, changing motor fuel station and office were determined by using One-way ANOVA. It was found that TVOCs concentration was difference between pump-island area and changing motor fuel station ($p=0.006$), pump-island area and office ($p<0.001$). It is accepted research hypothesis that the level of TVOCs concentration at human breathing zone would difference in each work place.

Although there were variety levels of TVOCs concentration in changing motor fuel station, the difference of TVOCs concentration between at changing motor fuel station and an office was not high. Thus, there was no statistical significant difference between them which was rejected research hypothesis.

Generally, environmental conditions of gasoline service stations may have an influence on gasoline vapor exposure for gasoline service station attendants. The average relative humidity during the period of TVOCs measurement was 47.26±10.28%. It was ranged from 31% to 76%. The average temperature was 33.19±2.55 °C. It was ranged from 24.46 to 38.98 °C. The average atmospheric pressure was 759.04±2.35mmHg. It was ranged from 753 mmHg to 790 mmHg. The average wind velocity was 0.65±0.68 m/s. It was ranged from non-detectable to 3.72 m/s.

4.2 TVOCs risks level in gasoline service stations

There were difference amount of average TVOCs concentration at pump-island area in each gasoline service station. The range of average TVOC concentration was 0-248.97 mg/m^3. From a total number of 39 stations, most of average TVOCs concentration (69.2%, 27 stations) in pump-island area was >25 mg/m^3. 28.2% (11 stations) and 2.6% (1 station) was 3.1-25 mg/m^3 and <0.2 mg/m^3, respectively.

While, in changing motor fuel station, most of measured TVOCs concentration (60%) in changing motor fuel station was ranged 0.2-3.0 mg/m^3. 20%, 16%, and 4% of them were <0.2 mg/m^3, 3.1-25 mg/m^3, and >25 mg/m^3, respectively. Beside this, only one sample of TVOCs concentration was detected from one office of gasoline service station. It was 0.46 mg/m^3.

It was found that 2.6% of gasoline service station had safety TVOCs risk level, 28.2 % of them had moderate TVOCs risk level, and 69.2% of them had high TVOCs risk level. For TVOCs risk level which classified by zone of Bangkok areas were shown in Figure 5.

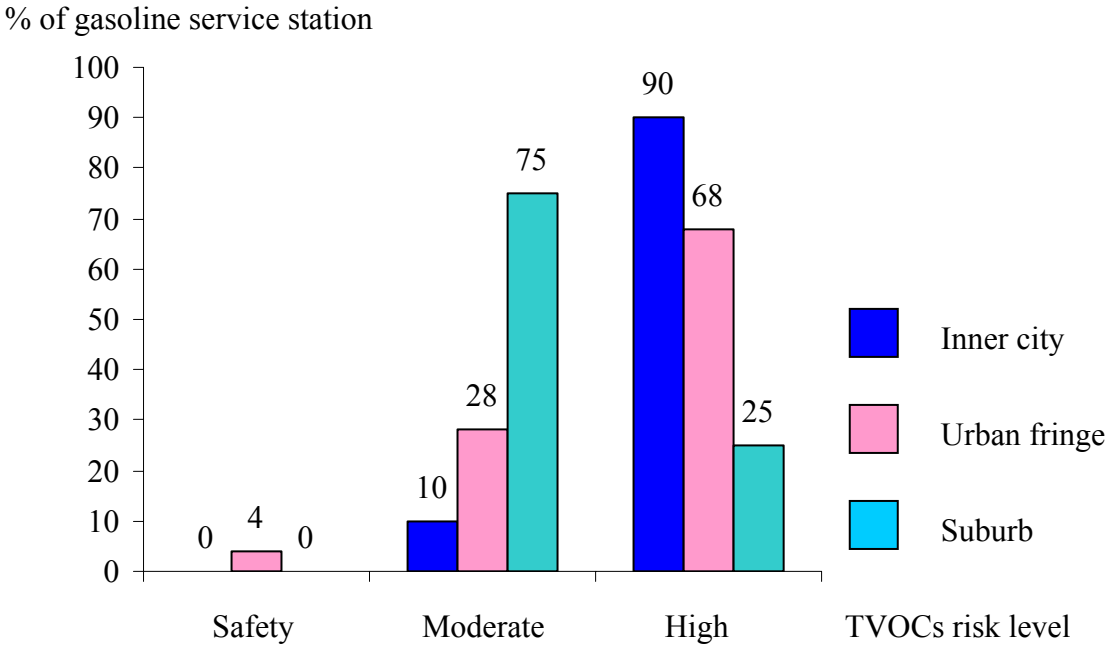


Figure 5 TVOCs risks level classified by zone of areas.

Beside this, the results of average TVOCs concentration from three work places classified by the established of gasoline service station in three zones of area were shown in Figure 6. It was found that the average TVOCs concentration in inner city area was 74.42 mg/m^3. While, in urban fringe and suburb area, average TVOCs concentration was 44.03 mg/m^3 and 18.48 mg/m^3, respectively.

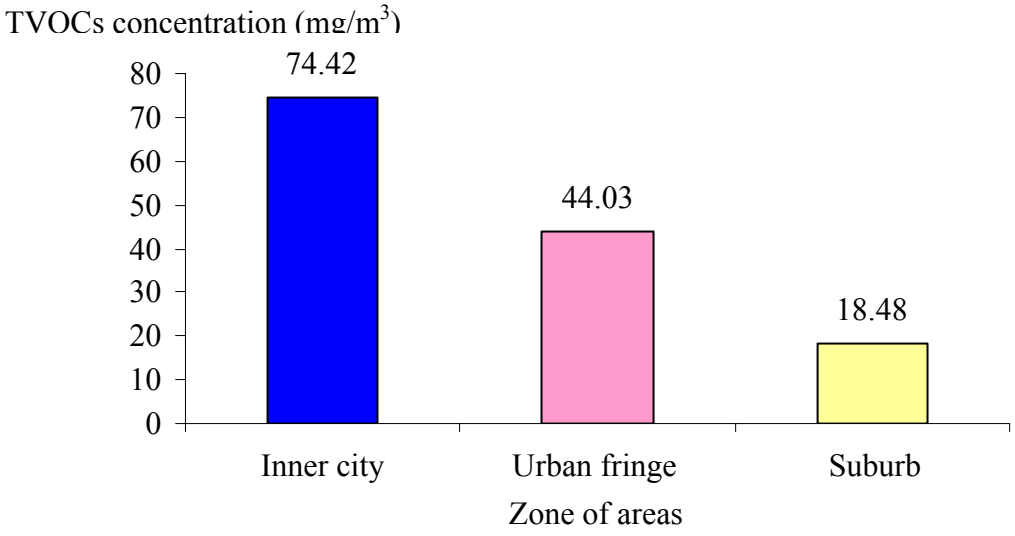


Figure 6 The average TVOCs concentration (mg/m^3) classified by zone of areas

Beside this, the results of average TVOCs concentration from three work places classified by brands of gasoline were shown in Figure 7. It was found that the average TVOCs concentration of Ptt, Esso, and Shell were 35.74, 47.81, and 66.28 mg/m^3, respectively.

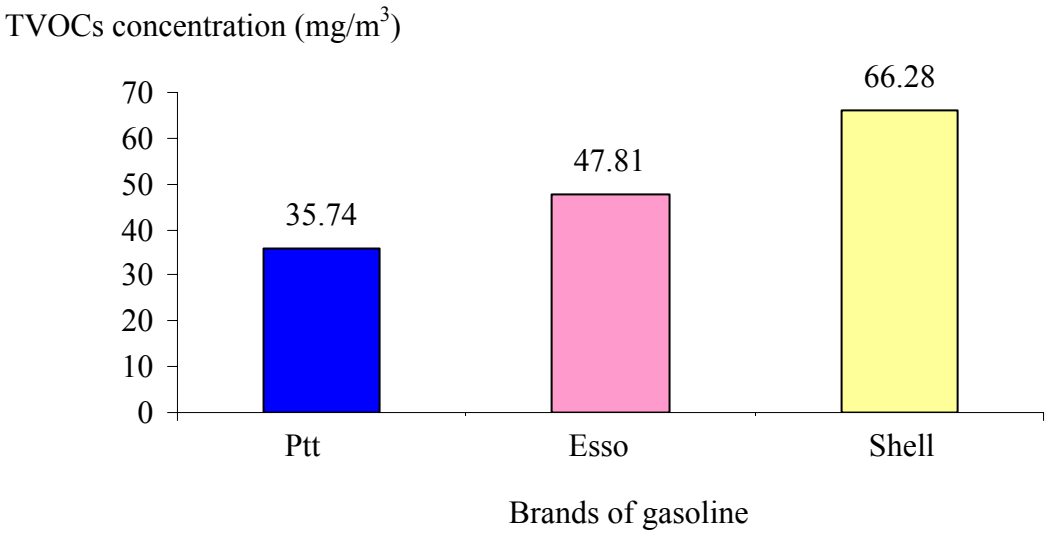


Figure 7 The average TVOCs concentration (mg/m^3) classified by brands of gasoline

4.3 Information of gasoline service station attendants

Gasoline service station attendants worked at forecourt of gasoline service stations were interviewed about personal information, history of workings, history of illnesses and health conditions, characteristics of refueled services, and work practices and health behaviors. The results were presented as follow;

4.3.1 General personal information

Most of gasoline service station attendants were male (67.3%). The ages of them were <18 years old 19.5%, 18-25 years old 34.5%, 26-35 years old 33.6%, and >36 years old 12.4%. For the level of education, 48.7%, 36.3%, 10.6%, and 4.4%, of gasoline service station attendants were illiterate/primary, a secondary education, high school education, and vocational education, respectively. Regarding to the salary (bath per month), 48.7% had salary 5,001-6,000, 29.2% had salary >6,000, 18.6% had salary 4,001-5,000, and only 3.5% had salary <4,001. For their married status, they were

single 53.1%, married 45.1%, and divorce/widow 1.8%. The results were presented as Table 19.

Table 19 The general personal information of gasoline service station attendants

The characteristics	Number of subjects	%
The gender		
Male	76	67.3
Female	37	32.7
Age (years old)		
<18	22	19.5
18-25	39	34.5
26-35	38	33.6
>36	14	12.4
The education level		
Illiterate/primary	55	48.7
Secondary	41	36.3
High school	12	10.6
Vocational	5	4.4
The salary (bath/month)		
<4,001	4	3.5
4,001-5,000	41	18.6
5,001-6,000	55	48.7
>6,000	33	29.2
The married status		
Single	60	53.1
Married	51	45.1
Divorce/widow	2	1.8

4.3.2 History of working

Gasoline service station attendants had work experience < 6 months 36.3%, 6-12 months 24.8%, 13-18 months 5.3%, and >18 months 33.6% . Last three years before working at the present gasoline service stations, 40.7% of them had been worked in the other places in which 50%, 37.9%, 13.1% of them worked in the other gasoline service stations, industries, and others, respectively. They had work periods in the other places 1-25 months 78.3%, 26-50 months 8.7%, 51-75 months 6.5%, and >75 months 6.5%. The ages for starting work were < 19 years old 78.8%, 19-24 years old 14.2%, 25-30 years old 3.5%, and >30 years old 3.5%. They worked as gasoline service station attendants 44.2%, industries 15.9%, and employees in the other fields 39.8%, respectively.

In studied gasoline service stations, the main duties of gasoline service station attendants were refueling 82.3%, supervisors/captains 10.6%, and cashiers/ mechanics in changing motor fuel stations/vehicle receptions 7.1%. They never did other duties before 83.2%, while 3.5% of the total works at car wash, 2.7% work as cashiers/mechanics, and 10.6% worked as refueling/captains. Beside, work time period of present duties were 0-25 months 75.2%, 26-50 months 13.3%, 51-75 months 8%, and >75 months 3.5%. However, 60.2% of gasoline service station attendants had no contract of the employment.

Regarding to the place of work in gasoline service stations, most of them worked at pump-island areas 98.2%, only 1.8% worked at changing motor fuel stations. 85.8% and 14.2% of them had started working in morning shift and afternoon shift. For the work hours of gasoline service station attendants, 92% and 5.3% of them worked 9-12 hours/day and ≤8 hours/day whereas 2.7% worked > 12 hours/day. For the changed a shift between gasoline service station attendants, most of them never changed a shift after working 63.7%, whereas 14.2% changed a shift once a week every week, 13.3% changed a shift twice a month every month, 5.3% changed a shift once a month every month, and 3.5% uncertainly. Regarding to work over time, 60.2% of gasoline service station attendants did not work over time, whereas 30.1%, 6.2%, and 3.5% worked over time rarely, always, and almost every day, respectively. The average of over time hour was 3.4 hours per day. Beside this, 5.3% of them always worked two shifts in one day but 33.6% of them worked rarely and 61.1% of them

never worked over time. 58.4%, 40.7%, and 0.9% had worked 7, 6, and 5 days per week, respectively. The results of this section were presented in Table 20.

Table 20 The history of working of gasoline service station attendants

The characteristics	Number of subjects	%
Work experience (months)		
<6	41	36.1
6-12	28	24.8
13-18	6	5.3
>18	38	33.6
Work experience in other places		
Never	67	59.3
Ever	46	40.7
Characteristic of work in other places		
Gasoline service station	23	50
Industries	17	37.9
Others	6	13.1
Work period in other places (months)		
1-25	36	78.3
26-50	4	8.7
51-75	3	6.5
>75	3	6.5
Age for starting work (years old)		
<19	89	78.8
19-24	16	14.2
25-30	4	3.5
>30	4	3.5
First job		
Gasoline service station attendant	50	44.2
Industrial	18	15.9
Employee in other field	45	39.8

Table 20 The history of working of gasoline service station attendants (Continued)

The characteristics	Number of subjects	%
The main duty of attendant		
Refueling	93	82.3%
Supervisor/captain	12	10.6%
Cashier/ mechanical/ vehicle reception	8	7.1%
The experience for working in other duty		
Never	94	83.2
Car wash	4	3.5
Cashier/mechanic	3	2.7
Refueling/captain	12	10.6
Work time period of present duty (month)		
0-25	85	75.2
26-50	15	13.3
51-75	9	8
>75	4	3.5
Contract of employment		
Yes	45	39.8
No	68	60.2
Place of work		
Pump-island area	111	98.2
Changing motor fuel station	2	1.8
Work shift of attendant		
Morning shift	97	85.8
Afternoon shift	16	14.2
Work hour of attendant (hours)		
<9	6	5.3
9-12	104	92
>12	3	2.7

Table 20 The history of working of gasoline service station attendants (Continued)

The characteristics	Number of subjects	%
Change shift of attendant		
Never	72	63.7
Once a week every week	16	14.2
Twice a month every month	15	13.3
Once a month every month	6	5.3
Uncertainly	4	3.5
Work over time		
Never	68	60.2
Rarely	34	30.1
Always	7	6.2
Almost every day	4	3.5
Worked two shifts in one day		
Never	69	61.1
Rarely	38	33.6
Always	6	5.3
Work day per week (days)		
5	1	0.9
6	46	40.7
7	66	58.4

4.3.3 Characteristics of refueled service

For numbers of refueled vehicles, they replied that the morning shift had been more refueled vehicles 51.3%, on the other hand, 14.2% replied that the afternoon shift while 21.2% and 13.3% replied numbers of refueled vehicles were similar and uncertainly between two shifts. In case of timing which had high numbers of refueled cars, most of them (55.8%) replied a period of 04.00-09.00 a.m. Moreover, 83.2% of them replied numbers of refueled cars in each day were differences. 60.6% of them replied Monday had high number of refueled vehicles in which 41.5%, 48.9%, and 9.6% of them pointed out that there were more refueled vehicles all times,

morning shift, and afternoon shift, respectively. Regarding to types of refueled vehicles which had high frequency to refuel were 4 wheels cars 54%, motor cycles 39.8%, and had no different 6.2%. Numbers of served motor cycles were about ≤100 cars/day (28.9%), 101-250 cars/day (46.7%), 251-400 cars/day (15.6%) and >400 cars/day (8.9%). The amount of refueled motor fuel (bath/time) which were ≤50 51.1%, 51-100 40%, and >100 8.9%. For the numbers of 4 wheels car, were served about ≤ 100 cars/day (36.07%), 101-300 cars/day (44.26%), 301-500 cars/day (8.19%), and >500 cars/day (11.48%) which refueled 601-900 bath/time (39.3%), 301-600 bath/time (31.1%), ≤300 bath/time (21.3%), and >900 bath/time (8.3%). Furthermore, customers bought motor fuel using gallon containers was rarely 54.9% and always 26.5%. The amount of selling fuel (bath/time) were <301 (80.4%), 301-600 (10.9%), 601-900 (1.1%), and more than 900 (7.6%). The results were shown in Table 21.

Table 21 The characteristics of refueled service of gasoline service station attendants

The characteristics	Number of subjects	%
Work shift which had high number refueled vehicle		
Morning shift	58	51.3
Afternoon shift	16	14.2
Not difference	24	21.2
Uncertainly	15	13.3
Timing which had high number of refueled car		
04.00-09.00 a.m.	63	55.8
09.01-12.00 a.m.	28	24.8
00.01-03.00 p.m.	2	1.8
03.01-06.00 p.m.	16	14.2
06.01-09.00 p.m.	4	3.5
Number of vehicle in each day		
Difference	94	83.2
Not difference	13	11
Uncertainly	6	5.3

Table 21 The characteristics of refueled service of gasoline service station attendants (Continued)

The characteristics	Number of subjects	%
The day which had high number of refuel vehicle		
Monday	57	60.6
Monday-Friday	12	12.8
Monday-Saturday	8	8.5
Monday and Friday	6	6.4
Friday	5	5.3
Monday Tuesday Saturday	2	2.1
Saturday	2	2.1
Thursday	1	1.1
Tuesday Thursday Saturday	1	1.1
High number of refueled vehicle both two shifts		
Yes	39	41.5
Only morning shift	46	48.9
Only afternoon shift	9	9.6
Type of refueled vehicle which had high frequency to refuel		
4 wheels car	61	54
Motorcycle	45	39.8
Had no different	7	6.2
Number of motorcycle (cars/days)		
≤100	13	28.9
101-250	21	46.7
251-400	7	15.6
>400	4	8.9
Amount of refueled motor fuel (bath/time)		
≤50	23	51.1
51-100	18	40

Table 21 The characteristics of refueled service of gasoline service station attendants (Continued)

The characteristics	Number of subjects	%
Number of 4 wheel car (cars/day)		
≤100	22	36.07
101-300	27	44.26
301-500	5	8.19
>500	7	11.48
Amount of refueled motor fuel (bath/time)		
≤300	13	21.3
301-600	19	31.1
601-900	24	39.3
>900	5	8.3
Customer bought motor fuel by using gallon		
Never	21	18.6
Rarely	62	54.9
Always	30	26.5
Amount of sold fuel (bath/time)		
≤300	74	80.4
301-600	10	10.9
601-900	1	1.1
>900	7	7.6

4.3.4 History of illnesses and health conditions.

85% of gasoline service station attendant had no illness to admit at the hospitals in a pass years. Around 15% of them ever had severe illnesses such as influenza (17.6%), food poisoning (17.6%), accident (17.7%), diabetic (11.8%), stomach ache (11.8%), coughing 5.9%, and allergic to medicine (5.9%). Beside, 88.5% of them had no personal illnesses. However, 11.5% of them had personal illnesses. There were an allergy 23.1%, blood pressure problem 15.4%, migrane/head ache 23.1%, stomach ache 15.4%, asthma 7.7%, hemorrhoids 7.7%, and exhausted 7.7%.

Only 9.7% always had some drugs to treat themselves. There were medicine for pain 54.5%, blood pressure 18.2%, hemorrhoids 9.1%, stomach ache 9.1%, and inflamed 9.1%. 85.8% of them had no headache symptoms before working at the present gasoline service stations. There were 14.2% of them had headache symptom. They were migrane 12.5%, gasoline vapor exposure 12.5%, sleepless 25%, chemical substances exposure 12.5%, blood pressure 25%, and illnesses 12.5%. But, after working at gasoline service stations, 40.7% of them had headache symptom. There were only one time 3.5%, rarely 30.1%, and always 7.1% and 50% of them still had these symptoms. The results were presented in Table 22.

Table 22 The history of illnesses and health conditions of gasoline service station attendants

The characteristics	Number of subjects	%
Experience of illness until admit at hospital in a pass year		
Yes	17	15
No	96	85
Personal illness		
Yes	13	11.5
No	100	88.5
Had medicine intake		
Yes	11	9.7
No	102	90.3
Had headache symptom before working at gasoline service station		
Yes	16	14.2
No	97	85.8
Had headache symptom after working at gasoline service station		
No	67	59.3
Only one time	4	3.5

Table 22 The history of illnesses and health conditions of gasoline service station attendants (Continued)

The characteristics	Number of subjects	%
Rarely	34	30.1
Always	8	7.1
Still had headache symptom		
No	23	50
Yes	23	50
Had skin irritating symptom before working at gasoline service station		
No	109	96.5
Yes	4	3.5
Had skin irritating symptom after working at gasoline service station		
No	96	85
Only one time	3	2.7
Rarely	9	8
Always	5	4.4
Still had skin irritating symptom		
No	11	64.7
Yes	6	35.3

The relationship between work time period and headache symptom of gasoline service station attendants were determined by using Chi-square test. There were found that 36.6%, 60.7%, and 31.8% of them worked < 6 months, 6-12 months, and >12 months, respectively had headache symptom. It pointed out that percentages of gasoline service station attendants which had headache symptoms were slightly increased when work time period of them increased ($p=0.041$). Gasoline service station attendants which worked 6-12 months had higher headache symptom more than other work time period. However, the percentages of attendants which worked >12 months had headache symptom less than the attendants which worked 6-12

months. It may be due to attendant which had high work time period, their duties were not refueling. The results of headache symptoms of gasoline service station attendants classified by work time period were shown in Table 23.

Table 23 Work time period of gasoline service station attendants classified according to headache symptoms of them

Work time period (months)	Headache symptoms		p from χ^2 test
	Never	Ever	
<6	26(63.4%)	15(36.6%)	0.041
6-12	11(39.3%)	17(60.7%)	
>12	30(68.2%)	14(31.8%)	
Total	67(59.3%)	46(40.7%)	

Regarding to skin irritating symptoms of gasoline service station attendants before working in the gasoline service stations, only 3.5% of them had skin irritating symptom due to expose of gasoline and gas from previous stations, weather, and chemical substances. Skin irritating symptoms of them increased to 15% after work at gasoline service stations. There were rarely (8%), only one time (2.7%), and always (4.4%) and 35.3% of them still had these symptoms (Table 22). There were found that working two shifts per day could influence skin irritating symptom. Gasoline service station attendant did not work two shifts per day; most of them never had skin irritating symptom. But, 21.1% of workers who worked rarely ever had this symptom and increased to 50% for workers who always worked at all of the time. If they had more frequency of working two shifts per day, they would have higher skin irritating symptom. There were significant association between skin irritating symptom and worked two shifts per day of gasoline service station attendant (p=0.011). The results of skin irritating symptom of gasoline service station attendants classified by work two shifts per day were shown in Table 24.

Table 24 Working two shifts per day of gasoline service station attendants classified according to skin irritating symptom

Double shift per day	Skin irritating symptom		p from χ^2 test
	Never	Ever	
No	63(91.3%)	6(8.7%)	0.011
Rarely	30(78.9%)	8(21.1%)	
Always	3(50%)	3(50%)	
Total	96(85%)	17(15%)	

4.3.5 Work practices and health behaviors

Most of gasoline service station attendants, 78.8%, refueled all of the times while 16.8% and 4.4% refueled often and rarely, respectively. They were a main responsibilities of them (83.2%) whereas 16.8% refueled because they helped their friends in case of emergency. 45.1%, 31.9%, and 9.7% of them had to stand during refueling all of the times, often, and rarely, respectively. Most of them (73.3%) had to stand far from refueled nozzles around 1 meter. There was only 13.3% of them did not stand at refueling point and went away from refueled nozzles. Besides this, some gasoline service station attendants had other duties such as loading motor fuel from the transports to underground storage tanks 18.6%, checking the level of motor fuel in underground storage tanks (11.5%), and helped government officers for testing the quality of motor fuel (7.1%). In case of loading motor fuel from the transports to underground storage tanks, it was a major responsibility of workers (52.4%) while 47.6% was assisted others. During unloading, 95.2% of them worked till finish. They stood at down wind direction/uncertainly (85.7%). Only 14.3% replied standing at up wind direction. For checking the volume of motor fuel residual in the underground storage tank, 7.1%, 2.7%, and 1.8% checking the volume of motor fuel all of the times, often, and rarely, respectively. They did because it was a major responsibility (76.9%). All of them worked this activity till finish. 65.5% of them had knowledge of standing position during refueled while 34.5% replied the answer of standing at down wind direction of refueled nozzle point and did not known how to do. On the other

hand, in practical, 65.5% of them standing at down wind direction/uncertainly of refueled nozzle point.

The relationship between knowledge and behavior of standing position during refueled in real situation were determined and shown in Table 25. The result was quite clear. The gasoline service station attendant who replied standing down wind from refueled nozzle was correct, all of them behaved as they thought. For rest worker who replied standing at up wind of refueled nozzle point was correct, around half of them standing at up wind of the refuel nozzle point. The relationship was significant ($p<0.001$). Refueled behavior of gasoline service station attendants were influenced by knowledge. If gasoline service station attendants had knowledge of standing position between refueling, they had suitable behavior between refueling. The results of refuel behavior of gasoline service station attendants classified by refuel knowledge were showed in Table 25.

Table 25 Relationship of refueled knowledge and refueled behavior of gasoline service station attendants

Refueled knowledge	Refueled behavior		p from χ^2 test
	Stand up wind	Stand down wind	
Stand up wind	39(52.7%)	35(47.3%)	<0.001
Stand down wind	0(0%)	39(100%)	
Total	39(34.5%)	74(65.5%)	

For personal protective equipments, most of them did not wear mask during working. There were only two workers wore mask which were cotton/plastic masks. One worker wore mask all of the time to work in every day and the mask was changed it every day whereas the other worker used mask 4-6 hour/day, 2-3 day per week, and changed it one time per month. Wearing uniform, mean number of wearing uniform of gasoline service station attendants had equal to 2.77. They wore t.-shirt 100%, pants 99.1%, and hats 74.3%. After finish the work, almost gasoline service station attendants took a bath at home 93.8% and 73.5% of them did not change uniform which they had been worn between working before they went to their homes. In case

of wore uniform, 91.2%, 8%, and 0.9% washed them all of the times, 2-3 day per time, and once a week, respectively.

For the eating behavior of gasoline service station attendants, 75.8% of them ate at gasoline service stations. Most of them (83.5%) ate at gasoline service stations every day. 47.1% of them always ate at pump-island areas. Regarding to hand washing behavior of gasoline service station attendants before eating, 76.5% of them washed hand every times, 4.7% often, and 18.8% rarely. They washed hand with soap 44.7%, detergent/mirror cleaner 37.6%, and used water only 17.6%. Beside this, they always refueled during eating 47.1%, and rarely 25.9%. Ate at pump-island area result to the worker had higher a chance of refueling between eating ($p<0.001$). The results of refuel during ate behavior of gasoline service station attendants and place of eating were presented in Table 26. Data of Table 26 pointed out that 95% of workers which ate at pump-island areas had ever been refueling during eating more than workers which ate at the other places which were 46.6%. There was 53.2% of them never wash hand after finish refueled and before get back to their meals. For gasoline service station attendants which replied the answers of washing hands before back their meals, most of them washed hand with only water 58.6%.

Table 26 Places of eating of gasoline service station attendants classified according to refuel during eaten behaviors

Place of eating	Refueling during ate behavior			p from χ^2 test
	Never	Rarely	Always	
The other	21(46.6%)	16(35.6%)	8(17.8%)	<0.001
Pump-island area	2(5%)	6(15%)	32(80%)	
Total	23(27.1%)	22(25.9%)	40(47.1%)	

When gasoline service station attendants had a free time, almost of them were at pump-island area 99.1%. Regarding to the opinion of attendants to a chance of gasoline vapor exposure, most of them (70.8%) replied high opportunity, 15.9% replied moderate opportunity, 8% replied low opportunity, and 5.3% replied had no opportunity. Besides the chance to expose gasoline via vapor, they may had skin

exposure from a splashing of gasoline to their body/skin. 73.5% reported never, 19.4% rarely, and 7.1% always. The numbers of splashed gasoline (times per year) were <4 63.3%, 4-6 23.3%, 7-9 3.3%, and >9 10%. For the solution when the gasoline splashed to them, they washed their bodies/skins with soap 60%, water 16.7%, changed uniform 6.7%, whereas 16.7% do nothing.

Splashing of gasoline to their bodies/skins may cause headache symptom and skin irritating symptom of gasoline service station attendant. The results of skin exposure of gasoline service station attendant were classified according to headache symptom and skin irritating symptom were concluded in Table 27 and Table 28.

Table 27 Skin exposures to gasoline of gasoline service station attendants classified according to headache symptom

Skin exposure to gasoline	Headache symptom of attendant		p from χ^2 test
	Never	Ever	
Never	54(65.1%)	29(34.9%)	0.038
Ever	13(43.3%)	17(56.7%)	
Total	67(59.3%)	46(40.7%)	

Table 28 Skin exposure to gasoline of gasoline service station attendant classified according to skin irritating symptom

Skin exposure to gasoline	Skin irritating symptom of attendant		p from fisher's exact test
	Never	Ever	
Never	77(92.8%)	6(7.2%)	<0.001
Ever	19(63.3%)	11(36.7%)	
Total	96(85%)	17(15%)	

From two above tables, skin exposure to gasoline could give direct effect to health condition of gasoline service station attendant both in term of headache symptom and skin irritating symptom. The statistical between skin exposures and

headache symptom and skin irritating symptom were determined and found significant ($p=0.038$, $p<0.001$), respectively. For headache symptom of gasoline service station attendant, 40.7% of them were came from worker which had skin exposure 56.7%. For the skin irritating symptom of gasoline service station attendant, 15.2% of them were came from the worker which had skin exposure 36.7%. Thus, skin exposure to gasoline was related to headache symptom and skin irritating symptom of gasoline service station attendant. The gasoline service station attendant which had experience of skin exposure, they had higher headache symptom and skin irritating symptom more than gasoline service station attendant which had no experience of skin exposure.

Splashing of gasoline to their bodies/skins may cause from the refueled behavior of gasoline service station attendant. The results were confirmed by the relationship between refueled behavior and skin exposure ($p<0.001$). In the table 24, 36.5% of gasoline service station attendant who had skin exposure stood at down wind of refueled nozzle point. The percentage of them is more than gasoline service station attendants which stood at up wind of refuel nozzle point (7.7%). It was concluded that the behavior of stood position during refueled of gasoline service station attendants were related to skin exposure to gasoline of them. When gasoline service station attendant stood at down wind, they had higher skin exposure to gasoline more than stood at up wind of refuel nozzle point. The results were shown in Table 29.

Table 29 Refueled behavior of gasoline service station attendants classified according to skin exposure to gasoline

Refueled behavior of attendants	Skin exposure to gasoline		P from χ^2 test
	Never	Ever	
Up wind	36(92.3%)	3(7.7%)	<0.001
Down wind	47(63.5%)	27(36.5%)	
Total	83(73.5%)	30(26.5%)	

Beside the refuel behavior, refueling to separate fuel gallon also resulted in skin exposure of gasoline service station attendant. The result point out, 30% and

32.3% of the gasoline service station attendant who refuel to separate fuel gallon always and rarely ever had skin exposure. A group of gasoline service station attendant who never refueled to separate gallon had shown exposed only 4.8%. The relationship between skin exposure of gasoline service station attendant and experience for refueling to gallon was found significant (p=0.042). It was concluded that the skin exposure to gasoline of gasoline service station attendant was correlated with frequency of experience for refueling to gallon. When gasoline service station attendant had high frequency of experience for refueling to gallon, they had high skin exposure to gasoline. However, the percentage of skin exposure to gasoline of the workers which had always experience for refueling to gallon was quite a bit less than the workers which refueled rarely group. It may be results from the gasoline service station attendant which had higher experience for refueling to gallon, they happened learning process that affect to higher skill more than the worker which had lower experience. Thus, an accident was low happened. The results were shown in Table 30.

Table 30 The experience for refueling to gallon of gasoline service station attendant classified according to skin exposure to gasoline

Experience for refueling to gallon	Skin exposure to gasoline		p from χ^2 test
	Never	Ever	
Never	20(95.2%)	1(4.8%)	0.042
Rarely	42(67.7%)	20(32.3%)	
Always	21(70%)	9(30%)	
Total	83(73.5%)	30(26.5%)	

For the environmental problem in gasoline service station, 48.7% of gasoline service station attendant replied there had no odor problem, 7.1% rarely, 9.7% a few (haft day), and 34.5% all the day long. The odor sources were from refueling 56.9%, refueling and exhaust 19%, exhaust 12.1%, solid waste 3.4%, and the other 8.5%. However, most of them did not use protective equipment (86.2%). Odor nuisance has correlation with headache symptom of gasoline service station attendants (p= 0.005). 53.4% of gasoline service station attendants which got odor nuisance ever had

headache symptom. It was 27.3% of them had no odor nuisance but ever had headache symptom. It was concluded that gasoline service station attendant which got odor nuisance, they had headache symptom more than gasoline service station attendant which had no odor nuisance. The results were shown in Table 31.

Table 31 Odor nuisance of gasoline service station attendants classified according headache symptom of them

Odor nuisance of attendants	Headache symptom		P from χ^2 test
	Never	Ever	
Never	40(72.7%)	15(27.3%)	0.005
Ever	27(46.6%)	31(53.4%)	
Total	67(59.3%)	46(40.7%)	

For the noise problem (time per day), they replied there had no problem 70.8%, 1 time 15%, 2 times 5.3%, 3 times per day 2.7% and all day 6.2%. There were many noise sources; transport on the road 81.8%, racing 6.1%, refueled vehicle engine 3%, transportation and industries 3%, lubricant activity 3%, and whistle and industries 3%. All of them did not used protective equipment. Beside this, 26.5% and 24.8% of gasoline service station attendants had heat and dust problem, respectively. In case of heat problem sources, they replied ultraviolet 73.3%, vehicle engine 20% and both sources 6.7%. For the sources of dust problem, they replied their from vehicle engine 14.3%, transportation on the road 53.6%, construction 7.1%, industries 10.7%, and vehicle engine and transportation 14.3%. Regarding to protection of dust nuisance, 96.4% of them did not have any measure to protect this problem. Moreover, 81.4% of gasoline service station attendants replied they never had seen/uncertainly/did not know whether the government officer came to gasoline service stations for inspection of environmental and safety. Only 5.2% and 13.4% replied the authority came frequent, and only one time.

Beside the risk factors which consist of work practice, personal protective used, eating behavior, and accidental of slashed gasoline to body of attendant, other behavioral problem which influence their health condition, the alcohol drinking and

tobacco smoking were also important risk. For alcohol drinking, most of them (59.3%) drank alcohols which were beer 44.8%, alcohol and beer 47.8%, alcohol 4.5%, and other 3%. Most of them (61.2%) started drinking since less than 18 year old. For the frequency of drinking alcohol, they drank rarely 43.3%, once a week 19.4%, twice a week 23.9%, and every day 13.4%. Amount of alcohol which they drank per time were more than 1 bottle 52.2%, not more than 1 bottle 32.8%, and not more than 1 glass 14.9%. Beside this, 38.9% of them smoked. For amount of ziggarat which smoked per day, 84.1% smoked less than 1 pack (around 6.56 piece), 13.6% smoked 1-2 pack (around 25 piece), and 2.3% smoked more than 2 packs. Almost of them (88.6%) were smoking every day and 77.3% had begin smoking since less than 18 year old. Moreover, 76.1% of gasoline service station attendants never checked health condition in resent year.

4.3.6 Risk behavior level of gasoline service station attendants

From a total number of 113 received gasoline service station attendants and Table 28, the range of risk behavior was level between 54.21%-74.77%. The average percentage of score of entire gasoline service station attendant was 65.89%.

Most of gasoline service station attendant (88.5%) had moderate risk behavior level while 11.5% of them had high risk behavior level. The brand of motor fuel which each group of gasoline service station attendant classified according to the risk behavior level had been working was concluded in Table 32. However, it was found that the relationship between these two factors were not statistic significant ($p=0.389$). The results pointed out, gasoline service station attendant who worked at difference brand of station was not difference between the risk behavior levels.

Table 32 The brand of motor fuel which gasoline service station attendants worked classified according to the risk behavior level

Brand of motor fuel	The risk behavior level		p from χ^2 test
	Moderate	High	
Shell	40(88.9%)	5(11.1%)	0.389
Esso	22(95.7%)	1(4.3%)	
Ptt	38(84.4%)	7(15.6%)	
Total	100 (88.5%)	13(11.5%)	

The average risk behavior level of individual gasoline service station attendant in each studied gasoline service station was determined. It was represented the risk behavior level of each station. From the total number of 39 gasoline service station, it was found that the range risk behavior level in each station was ranged from 55.61%-71.34%.

Most of gasoline service station (94.9%) had moderate risk behavior level; Shell 35.1%, Esso 21.6%, and Ptt 43.2%. Only 5.1% of them (two stations) had high risk behavior level. It was not difference between the brand of motor fuel in gasoline service station and the risk behavior level (p=0.185).

4.4 The relationship between risk behavior level and TVOCs risk level

The correlation between risk behavior level and TVOCs risk level in gasoline service stations were determined and shown in Table 33.

Table 33 The risk behavior level classified according to TVOCs risk level in gasoline service stations

Risk behavior level	TVOCs risk level			p from χ^2 test
	Safety	Moderate	High	
Moderate	1(2.7%)	11(29.7%)	25(67.6%)	0.626
High	0(0%)	0(0%)	2(100%)	
Total	1(2.6%)	11(28.2%)	27(69.2%)	

From Table 32, gasoline service station which had moderate risk behavior level had safety, moderate and high TVOCs risk level 2.7%, 29.7%, and 67.6%, respectively. While, it had no gasoline service station which had high risk behavior level had safety and moderate TVOCs risk level. There were high TVOCs risk levels. Thus, the percentage was not consistency. The difference among percentage of TVOCs risk levels classified by risk behavior level had no statistic significant (p=0.626). The result pointed out that different risk behavior level did not influence different TVOCs risk level of gasoline service station attendant. It is rejected research hypothesis that the TVOCs risk level would correlate with risk behavior level of gasoline service station attendant.

4.5 TVOCs concentration at different distances

At each gasoline service station, breathing zone TVOCs concentration was measured at difference distances down wind direction during refueled gasoline octane 91 to motorcycle. The total samples were 446. The distances were ranged from 0 meter in horizontal line to 7.95 meters far away. It was varied depend on wind direction, wind characteristic and lay out of pump-island area.

The results of TVOCs concentration classified by the distance from refueled nozzle in figure 8 pointed out that when the distances were increasing, TVOCs concentrations were decreased. To clarify this conclusion, average TVOCs concentration was determined to compare with the different distances from refueled

nozzle. From Figure 8, it was found when the distance was ≤2.00 meters, average TVOCs concentration was 21.73 mg/m^3. Average TVOCs concentration was 8.89, 4.02, and 2.32 mg/m^3 when the distances from refueled nozzle were 2.01-4.00, 4.01-6.00, and >6.00 meters, respectively.

The relationship between distance from refueled nozzle in pump-island area and TVOCs concentration was determined by Pearson correlation coefficient. It was found inversed; ($p<0.001$, $r=-0.28$). When the distance was increased, TVOCs concentration was decreased. It is accepted the research hypothesis that the level of TVOCs concentration at human breathing zone would decrease when the distance from refuel nozzle at pump-island area increase.

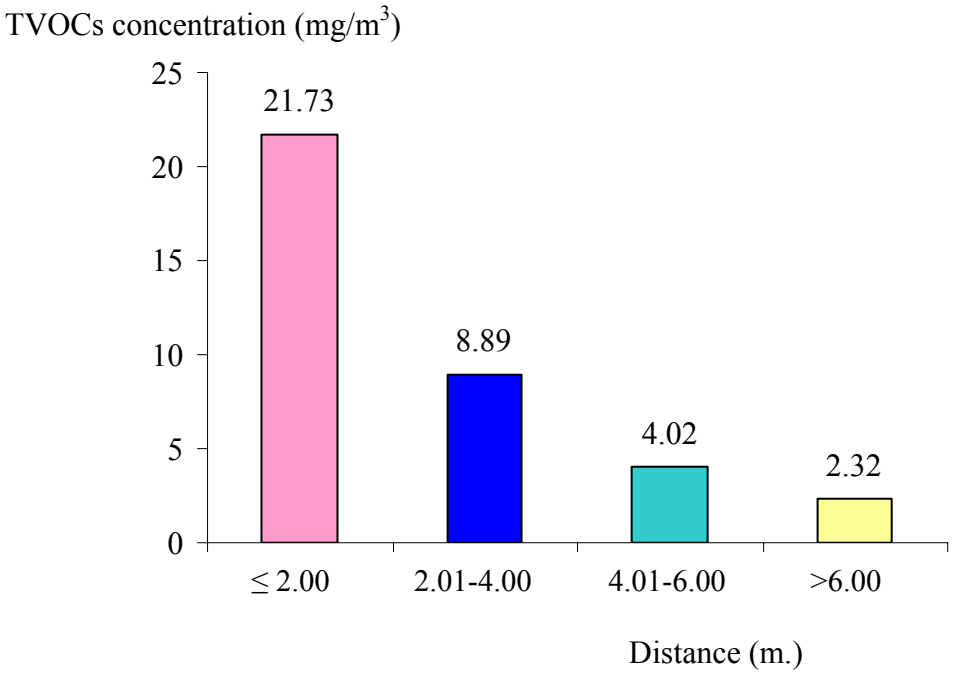


Figure 8 The average TVOCs concentration classified by distance

4.6 TVOCs concentration at refuel nozzle

At pump-island area of each studied gasoline service station, TVOCs concentration was measured at refueled nozzle during refueling to a car. The information was evaluated to finding factors influencing TVOCs concentrations which

consist of volume of refueled fuel, size of fuel receptacle, and condition of vehicle. The received overall samples were 147.

There was varieties TVOC concentration at refuel nozzle. TVOCs concentrations at refuel nozzle were ranged from 22.80-2,000 ppm. The average TVOCs concentration was 349.88 ppm.

4.6.1 TVOCs concentration at different volume of refueled fuel.

There were different TVOCs concentrations at different volume of refueled fuel. The average TVOCs concentration was 280.10 ppm when the car was refueled 1.72-13.30 litters. But, when the car was refueled 13.31-26.91 litters, the average TVOCs concentration was increasing to 316.75 ppm. For the car which refueled 26.92-59.09 litters, the average TVOCs concentration was highest. It was 478.23 ppm. The measured TVOCs concentrations at different refueled volumes were presented in Table 34.

Table 34 The measured TVOCs concentration at different refueled volumes of motor fuel

Results	Volume of motor fuel (Litters)		
	1.72-13.30	13.31-26.91	26.92-59.09
No. of sample	61	42	44
Range of TVOCs (ppm)	22.80-892	111-745.70	96.30-2000
TVOCs average (ppm)	280.10	316.75	478.23
Median of TVOC (ppm)	260	296	375.50

The relationship between TVOCs concentration and volume of refueled fuel was analyzed by Pearson correlation coefficient. There was the positive relationship between TVOCs concentration and volume of refueled fuel ($p<0.001$, $r=0.31$). When

the volume of motor fuel was increasing, TVOCs concentration was increasing together. It is accepted research hypothesis that the level of TVOCs concentration at refueled nozzle would increase when amount of gasoline fuel increase.

4.6.2 TVOCs concentration in different fuel receptacle's size.

Most of refueled car (79.6%) had fuel receptacle's size ≤ 2 centimeters. It was 20.4% of refueled car had fuel receptacle's size > 2 centimeters. Regarding to TVOCs concentration at different fuel receptacle's size, when the refueled car had receptacle' size was ≤ 2 centimeters, 25.6%, 55.6%, and 18.8% of TVOCs concentration was 22.80-216.81 ppm, 216.82-482.94 ppm, and 482.95-2000 ppm, respectively. Fuel receptacle's size > 2 centimeters, 60%, 26.7%, and 13.3% of measured TVOCs concentration was 216.82-482.94 ppm, 22.80-216.81 ppm, and 482.95-2000 ppm, respectively.

Although, there was varieties TVOCs concentration at different fuel receptacles's size, average TVOCs concentration was 356.02 ppm when fuel receptacles's size was ≤ 2 centimeters. Average TVOCs concentration was 325.93 ppm when fuel receptacles's size was > 2 centimeters. The result of average TVOCs concentration classified by fuel receptacles's size is shown in Figure 9.

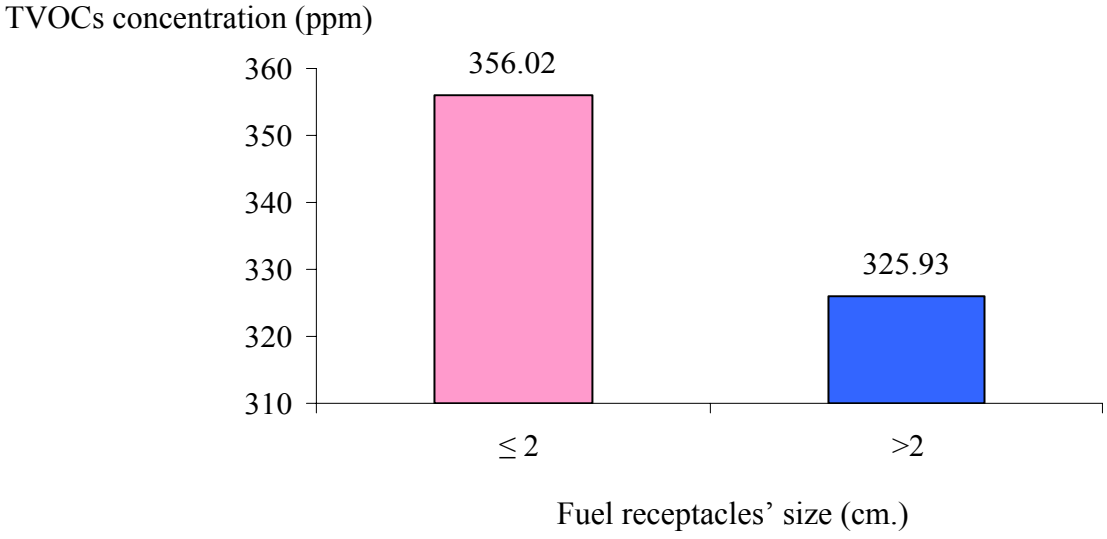


Figure 9 The average TVOCs concentration in different fuel receptacle's size

The relationship between TVOCs concentration and size of fuel receptacle was determined by Pearson correlation coefficient. From figure 9, average TVOCs concentration between 2 groups of fuel receptacle size was not high difference. Thus, there was not statistical significant relationship between TVOCs concentration and size of fuel receptacle (p=0.37). It is rejected research hypothesis that the level of TVOCs concentration at refueled nozzle would increase when the size of fuel receptacle increase.

4.6.3 TVOCs concentration at different vehicle engine conditions.

Most (68.8%) of refueled vehicle was in the stopping engine condition, while 31.2% was running engine. Regarding to the TVOCs concentration at stopping engine, most of TVOCs concentration (54.5%) was 216.82-482.94 ppm. For running engine, 62.2% of TVOCs concentration was 216.82-482.94 ppm. The measured TVOCs concentrations classified by condition of engines were presented in Table 35.

Table 35 The vehicle engine conditions classified according to TVOCs concentration

Vehicle engine condition	**TVOCs concentration (ppm.)**		
	22.80-216.81	**216.82-482.94**	**482.95-2000**
Stopping engine	30(30.3%)	**54(54.5%)**	15(15.2%)
Running engine	7(15.6%)	**28(62.2%)**	10(22.2%)

In stopping engine, average TVOCs concentration was 324.09 ppm. In running engine, average TVOCs concentration was 407.22 ppm. The result of vehicle engine condition classified by TVOCs concentration was shown in Figure 10. The statistic T-test was used to analyze the difference of TVOCs concentration between two conditions. Although, the average TVOCs concentration of running engine was more than stopping engine, it was not high difference. Thus, there was not statistical significant difference between TVOCs concentration of stopping and running engine (p=0.084). It is rejected research hypothesis that the level of TVOCs concentration at refueled nozzle of running vehicle engine condition would more than that of stopping vehicle engine condition.

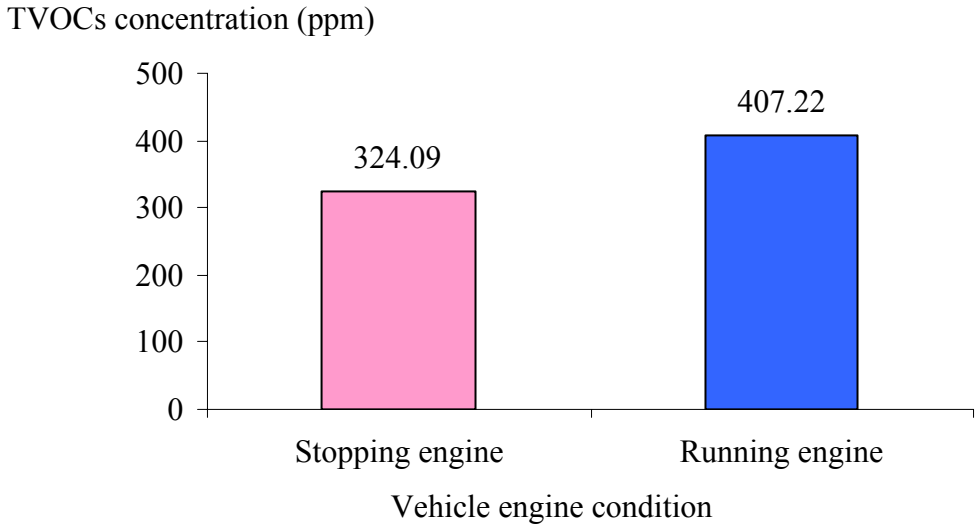


Figure 10 The average TVOCs concentration classified by vehicle engine condition

CHAPTER V
DISCUSSION

Gasoline has been used widely as fuel in motor vehicle for the transportation for a long time. Gasoline is a refined product of petroleum consisting of a mixture of hydrocarbons, additives and blending agents. At gasoline service station, gasoline vapor is emission from three sources; during the filling of underground storage tank, underground storage tank breathing and emptying losses, and vehicle refueling losses. Splash filling losses and uncontrolled displacement losses during vehicle refueling are the largest emission sources at service station operations. Vapors containing a mixture of VOCs that affect to human health. The occupational gasoline vapor exposure can be determined by measuring TVOCs concentration in breathing zone. It is necessary to measure the level of TVOCs concentration in breathing zone among the worker group to protect them from harmful working environmental. It was pump-island area as the major activity, refueling of motor vehicle, of gasoline service station. The frequency of refueling motor fuel was depended on the number of customers (the amount of automobiles). There was also a changing motor fuel station as it was other TVOCs contribution source. For control sites, an office located in their station was studied which the major activity in each control site was office activity and unrelated to the use of gasoline. Beside this, the factors influencing TVOCs concentration at refueled nozzle was determined; volume of gasoline sold, receptacle's size, and condition engine. Health behavior and health practice of gasoline service station attendant was evaluated together with a risk behavior level study in 39 selected gasoline service stations. There were three gasoline companies as Ptt, Esso, and Shell that located in Bangkok area.

5.1 TVOCs concentration in different work place

TVOCs concentration was measured at three different work places; pump-island area, changing motor fuel station, and office. At pump-island area, 273 vehicles was determined TVOCs concentration in breathing zone during refueling.

For the TVOCs concentration in this research, it was ranged from non-detectable to 640.27 mg/m^3 (non-detectable to 279 ppm). The average TVOCs concentration ±SD at pump-island area was 64.62±100.63 mg/m^3 (28.16±43.85 ppm) which nearly half of TVOCs concentration (49.5%) in there was >25 mg/m^3. It would give neurotoxic effect to human health (29, 35). Beside this, exposure to gasoline over 100 ppm may result in benzene exposure approaching around 1 ppm. TVOCs concentration of this research was more than the results of Kearney CA, et al. (44), Halder CA, et al. (45), and Mcdermott HJ, et al. (46) which studied about gasoline vapor exposure during refueling. It was found that these results were more than the above previous reports 7 times, 34-65 times, 3-154 times, respectively. There are many reasons for explain higher TVOCs concentration found in this study. Different method of measurement would give different results. TVOCs concentration which measured by using adsorbent-based sampling and GC/MS and direct photoionization detector could represent the collectively target compounds of evaporated gasoline around 43% of the PID measurement (47). Received TVOCs concentration of this study is a maximum value which was measured during pressing a nozzle of one tank. There was area monitoring sample and no personal sample. Some previous studies were done at gasoline service stations which were equipped with vapor recovery nozzle (46). However, vapor recovery nozzle was not used generally in Thailand. Our target value covered TVOCs and was not measured only hydrocarbon compound or individual VOC. There were many previous studies of individual VOC or gasoline vapor exposure in gasoline service station. TVOCs concentration of this result had more than many previous studies; Egeghy PP, et al. (48), Karakitsios SP, et al.(49), Esteve-Turrillas FA**,** et al.(50), Vainiotalo S, et al. (51) which reported concentration of benzene and MTBE between refueling. Our TVOCs concentration was more than the above previous reports around 22 times, 123 times, 8-21,342 times, and 16.56-27

times, respectively. The reason for this result was the major component of gasoline was aliphatic hydrocarbon (9). However, the finding from this study was not difference with the study of Cheng WK. that found the total hydrocarbon concentration was 68 mg/m^3 (52). Wixtrom RN and Brown SL (53) found that during refueling at self service station, concentrations in air of total hydrocarbons typically fall in the range of 20-200 parts per million by volume (ppmV). Concentrations of the aromatic compounds; benzene, toluene, and xylene rarely exceed 1 ppm. The geometric mean concentration of hydrocarbon (C3-C11) in the customer breathing zone during refueling was 85 mg/m^3 (ranged 2.5-531 mg/m^3). The gasoline service station attendants were exposed to short term exposure levels (STEL) of 0.064-179 ppm (54).

The high variation in the TVOCs concentration in this study depend on the activities of each time, environmental factors, and the general condition of gasoline service station. In general, gasoline vapor can be released into the atmosphere during refueling (48). Thus, the gasoline service station that had more refueling activities would likely have an increase in atmospheric TVOCs level. Beside this, TVOCs emission could also arise from automobile exhaust, gasoline service station that had served more vehicles might leave a higher TVOCs concentration accumulate (40-41). Since gasoline vapor has a high volatility, environmental factors affecting the level of TVOCs concentration in ambient air at breathing zone of work place include temperature, humidity, ventilation, wind velocity, wind direction, topography and physical features of each station. Other factors that may affect the TVOCs concentration at breathing zone are the condition of storage and transfer of gasoline, location of the station and automobile garage. Volatility of solvent, lubricants or oil being used in the garage also affected the concentration of TVOCs in ambient air. Leakage of gasoline from another part of the gasoline service station or oil spill from accident on ground surface may result in increasing the TVOCs concentration in ambient air. Some liquid gasoline is also released, generally as drops less than 0.1 g each, but with enough larger spills to raise the average loss per gallon dispensed to 0.23 g for stations with conventional nozzles and 0.14 g per refueling for stations with vapor recovery nozzles (51). From our environmental field survey, most of gasoline service station (94.9%) had oil spill in pump island area. Most of them were not

difference in the lay out of gasoline service station which had pump-island area parallel to the road 82.1%. For the environmental characteristic which closed the gasoline service station, 61.5% of them was closed with building around three sides, 25.6% of them was closed with the building 2 sides. 10.3% of them were closed with the building only one side. Only 1 station closed with rice field. It may result to the ventilation and wind turbulent though the gasoline service station. The volume of gasoline sold, aromatic hydrocarbon content, and ambient temperature could also increase the levels of gasoline vapors (7, 41, 55-56). Wind speed, wind direction as well as ventilation around the gasoline service station may affect the distribution of TVOCs (51, 57-62).

For the TVOCs concentration in changing motor fuel station, it was ranged from non-detectable-27.77 mg/m^3 (non-detectable-12.10 ppm.). The average TVOCs concentration was 3.16±6.22 mg/m^3 (1.38±2.71 ppm.). 60% of TVOCs concentration at changing motor fuel station was <3.1 mg/m^3 which can cause irritation and discomfort to mechanical while 20% set to a safety range. There were not different between TVOCs concentration in this research and many past studies about individual VOC in the garage which had low concentration than pump-island area. For motor car service mechanic, TWA exposure levels ranged from 0.014-1.7 ppm (63). Parking garage attendants had benzene concentration after work 24.0±11.1 $\mu g/m^3$, toluene 61.4±21.4 $\mu g/m^3$, ethylbenzene 6.2±2.8 $\mu g/m^3$, p-xylene 6.4±3.1 $\mu g/m^3$, m-xylene 4.6±2.6 $\mu g/m^3$, and o-xylene 10.6±4.9 $\mu g/m^3$ (64). TWA geometric mean gasoline vapor concentration of mechanic was 2.9 mg/m^3 (1 ppm) which had range 1.1-22.3 mg/m^3 (44). The benzene concentration in exhaled breathing of mechanical was 18.9-39.1 $\mu g/m^3$ (65). The mean TVOCs concentration in 15 garages was 633±554 $\mu g/m^3$ (47).

For the TVOCs concentration in an office that was a control site of this study, almost of them were <0.2 mg/m^3 which was the lowest criteria and had no effect to human health.

TVOCs concentration at breathing zone in this research was differed according to three work areas; pump-island area and changing motor fuel station, pump-island area and office. The reason for this is due to the major activity of gasoline service station at pump-island area was refueling. The property of gasoline was easily volatile at low

temperature for easily start up engine of vehicle and volatile increase when temperature arise. In gasoline service station, refueling motor vehicle gave largest emission of TVOCs especially during pressing a nozzle (66). In changing motor fuel station, motor fuel had high viscosity and difficult to volatile more than gasoline (67). The major activity was changing motor fuel. It might keep gasoline container to use well. Few amount of gasoline is used for washing and cleaning mechanical equipment. The vehicle was stored in the changing motor fuel station, solvent, and other VOC-containing materials were stored on shelves, floor, and open areas (47). In field survey of this study, an average distance of changing motor fuel station from pump-island area was around 15.21 meters (ranged 5.39-31.40 meters). The evident of oil or other spills was found in changing motor fuel station 25.6%. Where as the concentrations of TVOCs are significantly reduced. In an office, the major activity was office activity and unrelated to the used of gasoline. It was agreed with the previous reports. Benzene exposure is strongly correlated to car refueling (exposure levels up to 85 $\mu g/m^3$), while activities like car washing or working in cash machine inside an office contribute to lower exposure levels (up to 44 and 24 $\mu g/m^3$ respectively) (49). A study of Tongpoo A. found that worker in spray painting area had the highest level of toluene in breathing zone (3.55 ± 0.83 mg/m^3) while coating and office activity were 2.67 ± 0.63 and 1.25 ± 0.59 mg/m^3, respectively (79). Sripong N. found that worker in chemical laboratory area had the highest level of hydrocarbon in ambient air while the other area was lower (82). A study of Thongbo A. found that the level of phenol in urine of refueling attendant was higher than the other duty group in gasoline service station (76). A study of Romieu I, et al. reported that refueling worker of gasoline service station had higher exposure than other group such as salesman and office worker (116). In conclusion, working area had statistically affected on the level of TVOCs concentration in breathing zone.

5.2 TVOCs risks level in gasoline service stations

It was found that 2.6% of gasoline service station had safety TVOCs risks level. 28.2 % of them were moderate TVOCs risks level. The gasoline service station attendant in these stations may feel discomfort and result to their health which had

headache symptom follow. Especially, 69.2% of gasoline service stations were high TVOCs risks level. It was in a toxic range. Their worker may have neurotoxic effects. This study was agreed with the similar study of Kaepraseartsup J. and Chen ML., et al. (71, 80). It was found that pump-island area was risk from exposure to MTBE for a long time and the average number of symptoms per person, according to neurotoxic questionnaire was 4.1 and six workers showed over six symptoms.

The TVOCs risks level of TVOCs in gasoline service station of this study was agreed with the study of Ruangput S. (117). It found, 61.6%, 20.3, and 18.1% of gasoline service station had moderate, good, and improvement environment health. Beside this, this result was agreed with the study of department of health (118). It reported that most of gasoline service station environment was lower than the criteria of environmental sanitation.

5.3 Information of gasoline service station attendant

The general personal information of 113 gasoline service station attendants in this study was obtained from questionnaires. The result of gasoline service station attendant was discussed as following;

5.3.1. General personal information

Most of gasoline service station attendants were male 67.3%. It may be resulted from the characteristic of refueled work. They often walk up and down to refuel for the customer all time. They confronted with hard work and working in the open air which faced with heat problem from ultraviolet and vehicle engine as well as dust. These could well explain for gender of most gasoline service station should be male. This study was agreed with the study of Department of labor and welfare and other reports about gender of gasoline service station attendant (76, 104, 107, 119-120) which found most of the private employees were male. However, result in this study was difference with the study of Buddee P. and Tankgenkit J. (105-106) which found most of gasoline service stations were female.

For the ages of gasoline service station, most of them (34.5%) were 18-25 years old and 33.6% was 26-35 years old. It may be due to the characteristic of

refueled job which need high flexible worker which suddenly service. It was one of the reasons for employer to consider new worker of gasoline service station. Then, most of them had lower age. This study is confirmed with a study of department of labor and welfare and other reports about gasoline service station attendant (76, 104-105, 119-120). They found that the age of the private employees were not high. Beside this, our study was found child labor 19.5% according to Labor Protection Act B.E.1998 (121). Thus, they were susceptible host to gasoline vapor exposure.

For the level of education, 48.7% and 36.3% of gasoline service station attendants were illiterate/primary and a secondary education, respectively. It may be due to the characteristic of refueled job does not require high skill education. Then, they could start their work since young after left from school. This result was matched for most of them (78.8%) start work < 19 years old which worked as gasoline service station attendant 44.2%. The important reason that causes the children have to work is the poverty and lack of education (122**)**. Beside this, the study about welfare and development of child labor in produced industry found the reason which cause child labor had to work was graduate of compulsory and had not been continually study are important reasons (123).

Regarding to the salary (bath per month), most of them (48.7%) had salary 5,001-6,000. The average salary of them was less than the average income per person per month of Bangkok people. It was 8,509 baths (124). For their married status, they were single 53.1%.

5.3.2 History of working

Gasoline service station attendants had work experience < 6 months 36.3%. The often of worker interchange may be due to result from a few income of gasoline service station attendant. It was confirmed by a study of Tanggenkit J. whose found 39.85% and 9.14% of them had moderate and high intend, respectively to resign from gasoline service station (106). Beside this, Leardpreechaphol S. reported gasoline service station attendant had moderate pleasure to their work (104).

In studied gasoline service station, the duty of gasoline service station attendants were refueling 82.3%. They start work in this duty 83.2% while 16.8% start work with other duty. However, 60.2% of gasoline service station attendant had no

contract of employment. It quite importance since these gasoline service station attendant may not be protected by the Labor Protection Act B.E.1998.

Most of gasoline service station worked at pump-island, start working in morning shift, worked 9-12 hours/day and ≥ 6 days per week. The worked hour and day of them were more than the regulation of Labor Protection Act B.E.1998 which specify a duration should not more than 8 hours/day and has to suspend from job at least one day per week (121). This result was agreed with a study of department of labor and welfare which found that the served worker had higher work hours per week. It was 54 hours (119). Beside this, 39.8% of them worked over time. From the hard work behavior, it could affect to their health and they had high opportunity for gasoline vapor exposure during work time period. Moreover, the risk behavior to TVOCs exposure and accumulate to their health was increased. It results from 63.7% of gasoline service station attendant shown that they never change shift for working.

5.3.3 Characteristic of refueled service

For number of refueled vehicle, morning shift had more refueled vehicle at a period of 04.00-09.00 a.m. on Monday. It may be due to most of Bangkok people work outside. The information of national statistic office reported that Bangkok employee was work in 3 branches; commerce, service, and industry more than 80% (125).

In work day, people has to go to work or study especially in the early morning. This reason is confirmed with amount of transportation in Bangkok area in each day is high in the morning especially in early day of week. This result was agreed with a study of Tongtha Y. (89). It was found that customer often refueled in the morning (07.00-09.00 a.m.). The day which customers often refuel was uncertainly followed Friday and Saturday. Beside this, it was found that the factor of customer career could affect the time which refuel. However, this result was not agreed with other reports which study about the consumer's behavior on using gasoline service station. It found that most of consumer often refueled in the evening before went their home (88, 91). The change might may be a resulted from increasing of received news of fuel price on television. Customer would hurry to refuel in evening at the day before the price of fuel is increasing. Regarding to type of refueled vehicle which had high

frequency to refuel was 4 wheels car 54% which was served about 600-900 bath/time. It may be due to a crisis of gasoline price which had high variation and caused customer confidence for paying a lot of money for refuel. However, amount of money which customer paid for refuel in our study was more than other reports which were served about 200-600 bath (88-91). The factors affecting amount of spent money of customer were career, income, sex, age, and married status (88-89, 92). Bangkok people had income per month more than other province. Beside this, some customer bought fuel by using separate container such gallon.

5.3.4 History of illness and health condition.

85% of gasoline service station attendant had no illness until admit at hospital in pass year. It may be resulted from they had low age which were quite strong. The illness of gasoline service station attendant was took place when they had been gasoline vapor exposure for long time period. Beside this, it may be resulted from they had few income. When they had illness, they would buy a medicine instate a choice of going to hospital to save their money. This opinion was match with the previous study (108). It was found that a crisis of economic is threatening behavior of patient. The ratio of patient went to hospital was decreased while the ratio of patient take care themselves or bought medicine was opposited.

The results show that after working at gasoline service station, 40.7% of them had headache symptom. The previous study involved hematology of gasoline service station attendant found that eosinophil of the dizziness worker was lower than the non symptom group ($p<0.05$). Abnormal blood smear of the headache group was significantly higher than the non symptom group ($p<0.05$) (72). The results show that gasoline service station attendant who had been worked <6 months, 6-12 months, and >12 months had headache symptom after working in their gasoline service station 63.4%, 39.3%, and 68.2%, respectively. The statistic was confirmed the relationship between work time period and health effect as headache symptom ($p<0.05$). It was agreed with the theoretical exposure (126). The health effect depended on exposure time, amount of substance, rout of exposure, and toxicity of substance. The longer work time period, the more opportunity of gasoline exposure. Beside this, our study

was agreed with the previous reports (48, 102, 127). It found that duration time of exposure was influenced VOC exposure of worker.

Skin irritating symptom of them was increased to 15% after work at studied gasoline service station. The relationship between worked two shifts per day and skin irritating symptom was found significance. Many reports pointed out shift workers had health problem such as sleepless, headache, insufficient of sleep, sleep disturbance, and stress. These may give adverse affect to their health such as increasing weakness and simplifying to accident (83-87). Then, worked two shifts per day of gasoline service station would give higher problem. Beside this, gasoline service station attendant was received higher chance of gasoline vapor exposure. Fuel might vent out from refuel nozzle to contact the skin of gasoline service station attendant during holding the refueled nozzle. Splashed gasoline would occur from accident due to hard working of worker. From reason above, it may cause more skin irritating symptom of them.

5.3.5 Work practice and health behavior

The main duty of gasoline service station attendant was refueled. Most of them (86.7%) stood during refueling which far from refueled nozzle around 1 meter. This result was agreed with a study of Thongbo A. (76). It found that all of gasoline service station stood during refueling. A few distances from refueled nozzle during refueling could result to high TVOCs exposure of gasoline service station. Besides this, they could receive TVOCs exposure from other duties. The result shown that some gasoline service station attendant had other duties such as loading fuel from transports to underground storage tank 18.6%, checking the level of fuel in underground storage tank 11.5%, and helping government officer for testing the quality of fuel 7.1%. Especially in loading fuel from transports to underground storage tank activity, only 14.3% replied the stood at up wind direction.

Most of them (65.5%) had knowledge of standing position during refueled. On the other hand, on opposite in practical, 65.5% of them standing at down wind direction/uncertainly of refueled nozzle point. It may be forced from lay out and physical structure of gasoline service station. The relationship between knowledge and behavior of standing position during refueled in practical situation were found.

Refueled behavior of gasoline service station attendant was influenced by knowledge. This relationship was agreed with a study of Nakma Y. (94). It was found the relationship between the knowledge and skill of protection danger and protection behavior from danger of pesticide. Beside this, it was agreed with a study of Thongbai W. (100). It was found the relationship between the knowledge of health promotion and health promotion behavior.

For personal protective equipment, most of them did not used mask during working. The reason that gasoline service station attendant did not used mask were annoyed feeling and frustrate 31.5%, no available mask 44.1%, perception of no dangerous between work 9%, not convenient to work and speak 9%, no company policy 2.7%, and others 3.6%. From above results, it pointed out gasoline service station was lack of concern to their health. It may be due to most of them had lower age (18-35 years old) and they was quite strong. Thus, they did not interest to their health. This reason was agreed with the study of Prompunjai P. and Kesaro W. (95, 128). It found that the age was influenced health promotion behavior. A lack of factor that was charitable to use mask is important reason. Low income and had no mask as well as wrong perception of them could enhance danger between works. For the opinion of gasoline service station to chance of gasoline vapor exposure, most of them (70.8%) replied high opportunity, 15.9% replied moderate opportunity, 8% replied low opportunity, and 5.3% replied no opportunity. This reason was confirmed with a study of Inprasit N. and Chalermwipas P. (96-97). It found that income of worker was correlated with protection behavior of disease. Beside this, Preechaworawech S. and Changkaw W. found the perception to opportunity and risk of disease was influenced the personal protective used (98-99). There were only 2 workers used mask which was cotton/plastic mask. It was not suitable for protect gasoline vapor exposure. The suitable respiratory protective device should be chemical cartridge respirator or gas mask (129).

All of them take a bath after finish work. For uniform, 8.9% of gasoline service station did not washed after used all times. It may result to skin disease due to some fuel could block up the pore of skin and may be result to skin infection (130).

For the eating behavior of gasoline service station attendant, most of them ate at gasoline service station every day in which 47.1% of them always eat at pump-

island area. Regarding to hand washing behavior before eating of gasoline service station attendant, 76.5% of them wash hand every times. Only 44.7% wash hand with soap. Beside this, 63% of them refueled during eating which there was 53.2% of them never wash hand after finish refueled and before back to their meals. Ate at pump-island area caused worker had a chance to increase the frequency of refuel although they did not finished ($p<0.01$). The worker which ate at pump-island area could receive TVOC if their friends refuel at the same time. Beside this, the worker which did not wash hand before eat could receive toxic substance and bacteria by oral intake. Beside this, Larson was reported that the factors which influence efficiency of wash hand were the hand detergent, duration time to wash, and the technique of hand washing (131).

Besides the chance to expose gasoline via vapor, they may have skin exposure from a splashing of motor fuel to their body/skin. This reason was confirmed by the relationship between splashing of gasoline to skin/body and skin irritating symptom ($p<0.001$). Splashing of gasoline to skin/body may result to headache symptom ($p=0.038$) as well. This result may due to behavior between refueling which standing down wind direction and increasing a chance to gasoline vapor exposure ($p<0.001$). Beside this, the frequency of refueled to separate gallon would result to more chance of splashing of gasoline to skin/body of gasoline service station attendant as well. It due to most of gallon had small receptacle and unsuitable shape. When gasoline service station attendant pressing a nozzle, gasoline may splash from inside container ($p=0.042$). This result was related with a study of Soruj W. (93). It found pesticide behavior usage; the frequency of usage, duration time to use, concentration and the method were related to acute poisoning symptoms of farmers.

For the environmental problem in gasoline service station, gasoline service station attendant who had odor nuisance problem, 53.4% of them had headache symptom which more than a group who had no odor nuisance problem and had this symptom only 27.3% ($p=0.005$). This result may be most people can begin to smell gasoline at concentration of over 0.25 ppm (132). If gasoline service station create odor nuisance problem, it clearly prove that the amount of gasoline vapor which gasoline service station attendant exposure at least would above 0.25 ppm.

Beside TVOCs exposure from breathing and skin exposure to gasoline, these people could have TVOCs exposure especially benzene from another source such as smoking. From the result 38.9% of gasoline service station attendant smoked and 84.1% of these smoked was less than one pack (around 6.56 pieces). Each cigarette contains 6-73 μg of benzene (133). Persons who smoking one pack of cigarettes a day inhale a daily dose of approximately 1 mg of benzene (134). This opinion was verified by a study of Brunone F, et al. (78). The median blood benzene concentration was significantly higher in smokers than in non-smokers, both in the general population and in the exposed workers. Beside this, drinking alcohol could result the metabolite of Benzene exposure. The refueled worker which drank could have phenol in urine more than those who did not drink. It was confirmed with a study of Verma Y., et al. (77). It found that the people who drink alcohol had phenol in urine more than smoking people.

5.3.6 Risk behavior level of gasoline service station attendant

From a total number of 113 received gasoline service station attendant, 88.5% and 11.5% of them had moderate and high risk behavior level, respectively. This result was agreed with the study of Hwangjaisuk P. whose found that most of worker had moderate safety behavior level (103). Beside this, Tangjenkit J. found that most of gasoline service station attendants think they had moderate quality of life (106). Our result may be due to only 68.1% of them ever had training before starting work and 64.6% of them ever had safety training. Keatikun P. found safety course in the workplace influenced safety behavior of worker (101). This result was agreed with the previous study of Reaungput S. (117). This report shown that the problems were associated with the environmental health management of gasoline service station such lack of knowledge among workers (49.3%).

5.4 The relationship between risk behavior level and TVOCs risk level

From Table 33, the result pointed out different behavior risk level did not influence TVOCs risk level of gasoline service station attendant. It may be due to TVOCs concentration was depended on other factors; work site related factors, environmental factors, and gasoline related factors. However, this result was agreed with the study Thongbo A. (76) which found no statistic significant relation between the level of phenol in urine of refueling worker and sex, duration of work time, working behavior; ate during working, hand washing before and after ate, alcohol drinking, and smoking.

However, most of gasoline service station attendant especially refueling worker had high TVOCs risk level in ambient air of their work place. They had high chance to receive many substances of TVOCs in ambient air by breathing or splashing of gasoline from the accident and others to their body. The study of Wu BZ., et al (135) measured VOCs concentration from four gasoline service stations. It detected 54 compounds in the samples. While, the other report found 80 compounds in samples collected at the gasoline service stations (136). Beside this, many studies was reported the relationship between VOC concentration in ambient air and personal exposure. (55, 69).

5.5 TVOCs concentration at different distances

For the overall TVOCs concentration at different distances in pump-island area, it was found when the distance was ≤2.00 meters, average TVOCs concentration was 21.73 mg/m^3. Average TVOCs concentration was 8.89, 4.02, and 2.32 mg/m^3 when the distances from refueled nozzle were 2.01-4.00, 4.01-6.00, and >6.00 meters, respectively. The relationship between TVOCs concentration and the distance from refuel nozzle was found inverse. The reason for decreased TVOCs concentration when increasing distance may be when gasoline vapors transport though ambient air, TVOCs concentration was diluted with volume of air that passed. Although, the

relationship between TVOCs concentration and the distance were found. Wind velocity and wind direction were important interference factors to TVOCs concentration (55-58). Thus, the received relationship between TVOCs concentration and the distance in this study was a bit low (r=-0.28).

This result was agreed with the previous study reports (40) which found the means of MTBE and benzene, toluene, ethyl benzene, and xylene level at the pump-island higher than at the borders of gasoline service station. Concentration of MTBE in pump-island is higher than the border which the range concentration of MTBE in pump-island was 0.011-4.616 mg/m^3 and in the border area was 0.001-0.23 mg/m^3 (80). VOCs concentration within 30 meters of the service stations were consistently 1.3-2.1 times and higher than those between 60-100 meters of the service stations (56). Beside this, Karakitsios SP, et al. reported that benzene concentration was decreased with increasing distance from the petrol station (62). On the other hand, one previous study was found the increase in VOC concentrations in the downwind zone which is estimated to be due to the double impact of fugitive emissions from a service island and accumulation of downwind contaminants (57).

5.6 TVOCs concentration at refuel nozzle

5.6.1 TVOCs concentration in different volume of gasoline

For TVOCs concentration classified by volume of gasoline**,** the average TVOCs concentration was 280.10 ppm when the car was refueled 1.72-13.30 litters. But, when the car was refueled 13.31-26.91 litters, the average TVOCs concentration was increasing to 316.75 ppm. For the car which refueled 26.92-59.09 litters, the average TVOCs concentration was highest. It was 478.23 ppm. The relationship between gasoline sold and TVOCs concentration was found in positive correlation ($p<0.001$). This study was agreed with other previous report. The previous study (40) found that the pump-island concentrations of MTBE and BTEX were closely related to the amount of gasoline sale and vehicles ($r>0.74$) and the border concentration of MTBE and benzene were also correlated with gasoline soled (MTBE: r=0.48 and benzene r=0.69). Periago JF (41) evaluated environmental level of benzene, toluene and xylenes in gasoline service station. The results shown that there was a significant

relationship between the volumes of gasoline sold during the shift and the ambient concentration of benzene, toluene, and xylenes for each personal sample in breathing zone of workers (41). Kaepraseartsup J. (80) found the range concentration of MTBE in pump-island was 0.011-4.616 mg/m^3 and in the border area was 0.001-0.23 mg/m^3. It also found that the amount of MTBE at pump-island and the border of gasoline station were related to amount of gasoline sale (r^2 = 0.505 and r^2 = 0.458, respectively). Legjaroenkul N. (55) found that benzene and toluene concentration at breathing zone of gasoline service station attendant were 54.48±30.16 and 78.63±38.02 ppb., respectively which benzene concentration was correlated with gasoline sole in work shift and amount of benzene in gasoline octane 95 (r=0.512, r=0.547) while toluene concentration was correlated with gasoline sold in work shift and amount of toluene in octane 95 (r=0.529). However, in this study, had the correlation was less than those previous studies (r=0.31) which may be caused from the interference of environmental factor such as ambient temperature, wind velocity, and relative humidity that range of observe value was 28.67-38.98°C **,** non-detecable-3.56 m/s, and 34%-76%, respectively. The previous study was reported, fuel temperature in fuel tank and discharged fuel were influenced amount of vapor during refueled (70). Moreover**,** Coker DT., et al. observed that refueling is potentially exposed to gasoline vapor from four sources: (1) opening the fuel tank cap (cars with pressurized gas tanks release vapors when opened); (2) displaced vapor from the tank during refueling; (3) evaporative emissions from the wet gas nozzle after refueling; and (4) evaporative emissions from incidental spills (137). These gasoline vapor sources could also interfere TVOCs concentration. Beside this, the previous study was shown high correlation with overall gasoline sold in work shift. While, this study specified volume of gasoline sold between refueling**.** It may have interfered with other refueled nozzle as well as exhaust from vehicle.

5.6.2 TVOCs concentration in different fuel receptacle's size

TVOCs concentration was 356.02 ppm when fuel receptacles's size was ≤ 2 centimeters. Average TVOCs concentration was 325.93 ppm when fuel receptacles's size was > 2 centimeters. It was slightly difference from that of a smaller size receptacle. Thus, the results showed no statistic significant relationship between

TVOCs concentration and size of receptacle. The reason for these results may be all vehicles had ventilation pore in fuel tank of vehicle. In this field survey, 94.9% of vehicle had receptacle's size ≤ 2 centimeters had ventilation pore in fuel tank. It may be relieved vale pressure. Gasoline vapor was vented to ambient air though this during refueling. A function of pore at tank cover was ventilated pressure from refuel tank when the temperature was changed (58). This result was similar to the study of Braddock JN., et al. (70). It found that the size of fuel tank, shape of fuel tank, position of fuel tank, size and length of nozzle, and flow rate of refueled fuel were not influenced quantity of gasoline vapor during refueling. Beside this, this result was also similar to the study of Vainiotalo S., et al. (51). It was found that the make and model of the vehicle was not correlated with the time spent in refueling or with the exposure level. However, TVOCs concentration which measured from receptacle's size > 2 centimeters was seems quite more than other group.

5.6.3 TVOCs concentration in different vehicle engine condition.

TVOCs concentration was classified by condition of vehicle which composed stopping engine and running engine to compare the level of TVOCs concentration between 2 groups. Regarding to the TVOCs concentration in stopping engine, the average of TVOCs concentration was 324.09 ppm., where as in running engine, the average TVOCs concentration was 407.22 ppm. However, the results showed no statistic significant difference between TVOCs concentration of stopping and running engine.

TVOCs concentration was measured at refuel nozzle during running and stopping engine. Therefore, the major two kinds of emission were evaporative emission and refueling emission. Evaporative emissions occur from the carburator bowl and the fuel tank. The carburator losses occur primarily during the so-call hot soak period, when the engine is shut down after running and the heat of the engine can heat the fuel in the carburator bowl above its boiling point. This causes distillation of a substantial amount of the fuel into the intake manifold and to the atmosphere through the carburetor vents. Evaporative emissions from the fuel tank occur while the vehicle is running and the fuel tank temperature rises. The resulting increase in vapor pressure causes evaporation of fuel into the vapor space of the tank, pushing other vapor-

ladeden gases out of the tank vent into the atmosphere. Refueling emissions are quite similar to evaporative emissions. They occur during a fueling operation when incoming fuel displaces the hydrocarbon-laden vapors in the fuel tank.

The reason for TVOCs concentration between two conditions had no difference may be due to in stopping engine, TVOC concentration was occur from caburator and refueled emission. Whereas, in running engine, TVOCs concentration were occur from fuel tank and refueled emission together. Therefore, the evaporative loss from carburator and fuel tank should be regarded. The SAE Recommended Practice J171a indicates the average ratio of hydrogen to carbon atom in hydrocarbon evaporative losses as 2.2 for carburator emissions and 2.33 for fuel tank emissions (138). The evaporative loss was calculated by using equation. At standard conditions assuming ideal gas behavior, the average density of evaporative hydrocarbon from carburetor emissions as $CH_{2.2}$ was 634.8 gm/m^3 and 640.5 gm/m^3 for fuel tank emissions as $CH_{2.33}$.(139). It had no high difference. The present study was agreed with the report of previous study (68). It indicated that fuel evaporation is driven mainly by fuel temperature and that fuel circulation which pumping does not significantly increase the rate of evaporates emission (evaluation of evaporative). However, it was seem that TVOCs concentration of running engine quite a bit higher than the TVOCs concentration of running engine. For reason, the fuel temperature in fuel tank may increase during refuel in running engine but this increasing was not affected time since which time spent for refuel was short. It was around 14.93 second. Beside this, TVOCs concentration from exhaust of running engine may influence the measured TVOCs value. It was found that evaporative while the vehicle is driven (running losses) are reported to fall in the range of 0.2 to 2.8 g of total hydrocarbons per mile driven, while Tailpipe emissions amount was 0.3 to 1.0 g/mile of total hydrocarbons (53) and the estimated discharge of hydrocarbon from vehicle was crankcase 25%, fuel tank and carburetor 20%, and exhaust 55% (140).

CHAPTER VI
CONCLUSION AND RECOMENDATIONS

6.1 Conclusion

This cross-sectional study was to investigate TVOCs risk from 39 gasoline service stations which were a representative of Bangkok Metropolitan Region (BMR) stations. The studied gasoline service stations were distributed in three zones of BMR; inner city, urban fringe, and suburb. The sample sizes of gasoline service station attendants were 113 samples. A variety of TVOCs measurements were performed. TVOCs concentration at human breathing zone among different work places; pump-island area, changing motor fuel station, and office were measured for evaluate risk area sources in gasoline service stations. In pump-island area, amount of sold gasoline per time, size of receptacles' fuel tank, and vehicle engine conditions were investigated to study factors influencing TVOCs concentration at refuel nozzle. In pathway, TVOCs concentrations at human breathing zone in different distances were measured to study the relationship between two factors. Number of TVOCs samples which measured at breathing zone and refuel nozzle were 629 and 147 samples, respectively. For the receivers, 113 gasoline service station attendants were interviewed by questionnaire to study work practices and health behaviors for evaluating risks behavior levels of them. The overall of samples in this study were 889 samples (629+147+113).

The results pointed out most of gasoline service station attendant (69.2%) had high TVOCs risk level. While, 28.2% and 2.6% of them had moderate and safety TVOCs risk level. For gasoline service stations which located in inner city, most of them (90%) had high TVOCs risk level. It was found that the average TVOCs concentration in inner city area was 74.42 mg/m^3. For gasoline service station

which located in urban fringe, most of them (68%) had high TVOCs risk level. Gasoline service station which located in suburb area, most of them (75%) had moderate TVOCs risk level. For urban fringe and suburb area stations, average TVOCs concentration was 44.03 mg/m^3 and 18.48 mg/m^3, respectively. Beside this, it was found that the average TVOCs concentration in gasoline service station of Ptt, Esso, and Shell were 35.74, 47.81, and 66.28 mg/m^3, respectively. Gasoline service station attendants who worked as filling attendant in pump-island area had significant higher risk from exposure to TVOCs concentration more than mechanical employees in changing motor fuel station and staff in office. The results shown that filling station employees are in general may be exposed to elevate TVOCs that was 64.62 mg/m^3. While, The average individual TVOCs concentration in changing motor fuel station was 3.16 mg/m^3 and rarely had TVOCs in the office.

TVOCs risk levels depend on risk behavior of gasoline service station attendants. The results pointed out most of gasoline service station attendant (88.5%) had moderate risk behavior level. While, 11.5% of them had high risk behavior level which risk behavior level of them was not difference in different brand of gasoline. In term of gasoline service station, most of gasoline service station (94.9%) had moderate risk behavior level. Only 5.1% of them (two stations) had high risk behavior level. It was clear that refueling procedure is an important source of exposure to TVOCs for the filling station employees. There were factors which affect the illness of gasoline service station attendants; work time period, experience for working two shifts per day, experience for skin exposure to gasoline, and odor nuisance of attendant. Moreover, for the factors which results in attendant behavior were refueled knowledge and behavior, place of eating, experience for refueling to gallon. Although, it was not found the significant relationship between exposure risk level and risk behavior level. Most of gasoline service station attendant especially refueling worker had high TVOCs risk level in ambient air. They had high chance to receive many substances of TVOCs in ambient air by breathing and/or splashing of gasoline from the accident to their body.

However, it was found only amount of sold gasoline per time had positive correlation significant with TVOCs concentration during refuel. On the other hand, the distance from refueled nozzle was significant negative correlation with TVOCs

concentration. While, the receptacle's size of fuel tank and vehicle engine condition had no correlation with TVOCs concentration during refuel. The conclusion of factors which were influenced TVOCs risks levels of gasoline service station attendants were presented in Table 36.

Table 36 The factors influencing TVOCs risks of gasoline service station attendants

The factors	TVOCs risks level	Statistical Test
Work places	Difference	One-way ANOVA
Work time period	Positive relationship	χ^2 test
Experience for working two shifts per day	Positive relationship	χ^2 test
Experience for skin exposure to gasoline	Positive relationship	Fisher's exact test
Odor nuisance of attendant	Positive relationship	χ^2 test
Refueled knowledge and behavior	Negative relationship	χ^2 test
Place of eating	Difference	χ^2 test
Experience for refueling to gallon	Positive relationship	χ^2 test
Gasoline sold per time	Positive relationship	Pearson correlation coefficient
The distance from refueled nozzle	Negative relationship	Pearson correlation coefficient

6.2 Recommendations

6.2.1 Specific recommendations for application

According to the result of study, the gasoline service station attendant needs to improve as following:

1. From the study of relationship between the distance from refueled nozzle and gasoline sold per time to TVOCs concentration were found. The results suggest that in order to reduce the exposure TVOCs levels, gasoline service station attendant should

standing during refuel far away from nozzle as possible and up wind direction especially during refueled high volume of gasoline.

2. Due to pump-island area had higher TVOCs risk level more than changing motor fuel station area and office. Thus, in order to disincline accumulated exposure of employees refueling vehicle, duty interchange must be performing among other duties especially for a person who had long work time period.

3. Due to some fuel could block up the pore of skin and may be resulted to skin infection. Then, gasoline service station attendant should take a bath and change uniform before they went home regularly.

4. Before eating, the study was found only 76.5% of them washed hand every times and 44.7% washed hand with soap. The workers which did not wash hand before eat could has a chance to receive toxic substance and/or microbial organisms by oral intake. Thus, gasoline service station attendant should wash hand with soap every times before eating.

5. The simple equipment for measuring of wind direction should be installed in gasoline service station in order to indicate up wind standing point for attendant between refueling.

6. Gasoline service station should be posted a notice about the suitable procedure and warning of prohibition during work which could obviously see at pump-island area.

6.2.2 General recommendations for application

1. In gasoline service station, vapor recovery nozzle which was used for gasoline vapor control between refueling is necessary for reduce TVOCs concentration that vent to ambient air.

2. The results were found 63.7% of attendants never changed a shift between working. Thus, shift interchange should be a policy for gasoline service station in order to reduce TVOCs exposure accumulated to gasoline service station attendant.

3. Personal protective equipment is importance. Gasoline service station attendant should use them all times between working. Thus, there is a need for wearing personal protective equipment policy in gasoline service station.

4. There is a need for specify place of eating policy in order to reduce TVOCs exposure of gasoline service station attendant during eats at pump-island area as well as refueled worker interchanged should be perform during ate time.

5. From the positive relationship between experience for working two shifts per day and skin irritating symptom of attendant, working two shifts per day have to restrict for gasoline service station attendant in order to decrease TVOCs exposure chance of them.

6. The employer of gasoline service station should introduce and train for practices of refueling to any other fuel containers in order to protect accident which may occur.

7. Gasoline service station attendant should have health inspection at least one time per year. Thus, the employer of gasoline service station should be provided welfare of health inspection.

8. Government officer or motor fuel company should educate gasoline service station attendant about safety behavior before starting work and usually recovery train during working.

6.2.3 Recommendations for further study

1. The study of TWA-TVOCs concentration of personal sample should be performed to evaluate TVOCs risk of gasoline service station attendant.

2. The study of biomonitoring of TVOCs exposure in human blood or urinary should be performed to find bioindicator exposure to TVOCs in order to occupational exposure standards in work place.

3. The study of the relationship between personal TVOCs concentration and work practice and health behavior should be performed to study behavior factors which influence TVOCs concentration.

4. The study of TWA TVOCs criteria which related to human health should be performed in order to regulate occupational exposure standards in work place.

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APPENDIX

APPENDIX A
QUESTIONNAIRES FOR REFUEL WORKER

แบบสัมภาษณ์ผู้ให้บริการประจำสถานีบริการน้ำมันเชื้อเพลิง

เลขที่…….

ชื่อสถานีบริการน้ำมันเชื้อเพลิง……..

ที่ตั้งเลขที่……หมู่ที่……ตำบล……

ถนน……อำเภอ……..จังหวัด……

ชื่อ-สกุล ผู้ให้สัมภาษณ์……..……....

ชื่อผู้สัมภาษณ์…….....วันที่สัมภาษณ์……

1. ข้อมูลส่วนบุคคล

1.1 เพศ ☐ ชาย ☐ หญิง

1.2 อายุ (ปี) ☐ < 18 ☐ 18-25 ☐ 26-35 ☐ 36-60 ☐ > 60

1.3 ระดับการศึกษาสูงสุด ☐ ประถมศึกษา ☐ มัธยมศึกษาตอนต้น ☐ มัธยมศึกษาตอนปลาย ☐ อาชีวศึกษา ☐ อุดมศึกษา ☐ อื่นๆระบุ.....

1.4 รายได้รวม (บาท)/เดือน ☐ ≤ 4,000 ☐ 4,001-5,000 ☐ 5,001-6,000 ☐ >6,000

1.5 สถานภาพ ☐ โสด ☐ แต่งงาน ☐ แยกกันอยู่ (หย่า) ☐ หม้าย

2. ประวัติการทำงาน

2.1 ท่านทำงานที่สถานีบริการแห่งนี้ตั้งแต่เมื่อใด (ระบุ) .....

หรือคิดเป็นระยะเวลาทำงานถึงปัจจุบันเท่ากับ ……ปี ……..... เดือน

2.2 ในรอบ 3 ปีที่ผ่านมาท่านเคยทำงานที่สถานีบริการน้ำมันอื่นๆหรือสถานประกอบการประเภทอื่นนอกจากสถานีบริการน้ำมันมาก่อนหรือไม่

☐ เคย ระบุรายละเอียด ☐ ไม่เคย (ข้ามไป 2.3)

ที่	ชื่อโรงงาน/สถานประกอบการ	ลักษณะงานที่ทำหรือตำแหน่งงาน	พ.ศ. ที่เข้าทำงาน	ระยะเวลาทำงาน ปี/เดือน
1				/
2				

2.3 ท่านเริ่มทำงานครั้งแรกเมื่ออายุเท่าใด อายุ……ปี โดยประกอบอาชีพ.....
2.4 ปัจจุบันท่านมีหน้าที่รับผิดชอบงานอะไรบ้าง ☐ เติมน้ำมัน ☐ เก็บเงิน ☐ทั้งเติมน้ำมันและเก็บเงิน ☐ หัวหน้าพนักงาน ☐ ทำงานเอกสารในสำนักงาน ☐ อื่นๆ ระบุ….....
2.5 ท่านเคยทำงานในหน้าที่อื่นก่อนทำงานในหน้าที่ปัจจุบันในสถานีบริการแห่งนี้หรือไม่ ☐ ไม่เคย ☐ เคย หน้าที่….....เป็นเวลา….....เดือน
2.6 ท่านทำงานในหน้าที่ปัจจุบันเป็นระยะเวลา ….....สัปดาห์….....เดือน….....ปี
2..7 ลักษณะงานที่ท่านรับผิดชอบต้องประจำอยู่บริเวณใดของสถานีบริการ ☐ ลานจ่ายน้ำมัน ☐ ภายในสำนักงาน ☐ ไม่แน่นอน ☐ อื่นๆ ระบุ.....
2.8 ปัจจุบันท่านทำงานในกะเวลาทำงานใด ☐ กะเช้า (ตั้งแต่….....ถึง……..... น.) ☐ กะบ่าย (ตั้งแต่….....ถึง……..... น.) ☐ อื่นๆ ระบุ …..... (ตั้งแต่….....ถึง……..... น.)
2.9 โดยเฉลี่ยในแต่ละวันท่านทำงานปกติกี่ชั่วโมง ☐ <9 ชั่วโมง ☐ 9-12 ชั่วโมง ☐ > 12 ชั่วโมง ☐ อื่นๆระบุ….....
2.10 ทุกๆวันท่านทำงานในกะเวลาทำงานเดิมใช่หรือไม่ ☐ ใช่ ☐ ไม่ใช่ ☐ ไม่แน่นอน เพราะ..... ☐ มีการสลับ/หมุนเวียนกะทุก.....
2.11 ท่านมีการทำงานล่วงเวลา (OT) ด้วยหรือไม่อย่างไร ☐ ทำนานๆครั้ง ☐ ทำเป็นประจำ ☐ ทำเกือบทุกวัน ☐ ไม่ได้ทำ (ข้ามไปข้อ 2.13)
2.12 ท่านมักทำงานล่วงเวลากี่ชั่วโมงต่อวัน .....ชั่วโมง/วัน
2.13 ท่านเคยทำงานจำนวน 2 กะทำงานหรือ2 แรงในหนึ่งวันหรือไม่อย่างไร ☐ ทำนานๆครั้ง ☐ ทำเป็นประจำ ☐ ทำเกือบทุกวัน ☐ ไม่ได้ทำ
2.14 ในหนึ่งสัปดาห์ท่านทำงานกี่วัน ☐ 5 วัน ☐ 6 วัน ☐ ทุกวัน ☐ ไม่แน่นอน
3. ลักษณะการให้บริการ
3.1 ท่านทราบหรือไม่ว่าระหว่างกะเช้าและกะบ่ายกะเวลาทำงานใดที่มีลูกค้ามารับบริการเติมน้ำมันมากสุด ☐ ทราบ ☐ ไม่ทราบ ☐ ไม่แน่นอน ☐ กะเช้า ☐ กะบ่าย

3.2 ท่านคิดว่าช่วงเวลาใดในกะทำงานของท่านที่ลูกค้ามาใช้บริการมาก

☐ 04.00-09.00 น. ☐ 09.01-12.00 น. ☐ 12.01-15.00 น.

☐ 15.01-18.00 น. ☐ 18.01-21.00 น. ☐ หลัง 21.00 น.เป็นต้นไป

3.3 ท่านคิดว่าวันใดในรอบสัปดาห์ที่ลูกค้ามารับบริการจากสถานีบริการน้ำมันมากสุด
(ตอบเรียงลำดับ 3 ลำดับ โดยใส่ตัวเลข 1= มากสุด, 2=ปานกลาง, 3=น้อย)

☐ อาทิตย์ ☐ จันทร์ ☐ อังคาร ☐ พุธ

☐ พฤหัส ☐ ศุกร์ ☐ เสาร์

3.4 วันที่ลูกค้ามารับบริการมากสุดนั้นเหมือนกันทั้งกะเช้าและกะบ่ายใช่หรือไม่

☐ ใช่ (ข้ามไปข้อ 3.6) ☐ ไม่ โดย มากสุดเฉพาะ

☐ กะเช้า ☐ กะบ่าย

3.5 สำหรับกะ ☐ กะเช้า ☐ กะบ่าย วันที่ลูกค้ามารับบริการมากสุดคือ.....

3.6 ส่วนใหญ่ท่านมีการเติมน้ำมันเบนซินให้แก่ลูกค้าเป็นจำนวนเงินเท่าใด (ตอบเรียงลำดับ 3 ลำดับโดย 1=มากสุด, 2=ปานกลาง, 3=น้อย)

☐ < 150 บาท ☐ 150-300 บาท ☐ 301- 500 บาท

☐ 501-1000 บาท ☐ 1001-1500 บาท ☐ > 1500 บาท

3.7 รถประเภทใดที่มารับบริการเติมน้ำมันเบนซินบ่อยที่สุดในแต่ละวัน (ตอบเรียงลำดับ 3 ลำดับ 1=มากสุด, 2=ปานกลาง, 3=น้อย)

☐ รถเก๋ง ประมาณ.....คัน/วัน เติมประมาณ.....บาท/ครั้ง

☐ มอเตอร์ไซด์ ประมาณ.....คัน/วัน เติมประมาณ.....บาท/ครั้ง

☐ รถกะบะ/ปิ๊กอัพ ประมาณ.....คัน/วัน เติมประมาณ.....บาท/ครั้ง

☐ อื่นๆระบุ.....ประมาณ.....คัน/วัน เติมประมาณ.....บาท/ครั้ง

3.8 เคยมีลูกค้ามาซื้อน้ำมันโดยให้ท่านหรือเพื่อนของท่านเติมใส่แกลลอนหรือถังน้ำมันแบบอื่นๆบ้างหรือไม่

☐ มีเป็นประจำ ☐ มีนานๆครั้ง ☐ ไม่เคยเลย

ส่วนใหญ่ซื้อประมาณ .....บาท

3.9 ท่านได้มีการทำสัญญาการจ้างงานกับนายจ้างของท่านหรือไม่

☐ไม่ได้ทำ ☐ ทำ

4. ประวัติการเจ็บป่วยและภาวะสุขภาพ

4.1ในรอบปีที่ผ่านมาท่านเคยมีการเจ็บป่วยที่รุนแรงหรือไม่ (หมายถึง การเจ็บป่วยที่ต้องรักษาตัวในโรงพยาบาลโดยเป็นคนไข้ใน)

☐ ไม่มี ☐ มี ระบุสาเหตุ (1).....ผ่านมาแล้ว.....เดือน

(2).....ผ่านมาแล้ว.....เดือน

(3).....ผ่านมาแล้ว.....เดือน

4.2 ท่านมีโรคประจำตัว/โรคที่เป็นบ่อยหรือไม่ ☐ ไม่มี ☐ มี ระบุโรค (1)..... (2)..... (3).....
4.3 ท่านมียาที่รับประทานเป็นประจำหรือไม่ (ยาที่แพทย์สั่งให้รับประทานหรือยาที่ซื้อรับประทานเองเป็นประจำ) ☐ ไม่มี ☐ มี ระบุโรค (1)..... (2).....
4.4 ท่านเคยมีอาการเวียนศรีษะ ปวดศรีษะ หายใจลำบาก ก่อนเริ่มทำงานในสถานีบริการแห่งนี้หรือไม่ ☐ มี ระบุ พ.ศ. ..... ☐ ไม่มี ระบุสาเหตุ.....
4.5 ท่านเคยมีอาการเวียนศรีษะ ปวดศรีษะ หายใจลำบาก หลังจากทำงานในสถานีบริการแห่งนี้หรือไม่อย่างไร ☐ ไม่มี (ข้ามไปข้อ4.7) ☐ มีเป็นประจำ ☐ เป็นนานๆครั้ง ☐ เป็นครั้งเดียว
4.6 ปัจจุบันท่านยังมีอาการเวียนศรีษะ ปวดศรีษะ หายใจลำบาก หรือไม่ ☐ หายแล้ว ☐ ยังเป็นอยู่
4.7 ท่านเคยมีอาการผิวหนังแห้ง คันและอักเสบบริเวณมือก่อนเริ่มทำงานในสถานีบริการแห่งนี้หรือไม่ ☐ ไม่มี ☐ มี ระบุ พ.ศ .....สาเหตุ.....
4.8 ท่านเคยมีอาการผิวหนังแห้ง คันและอักเสบบริเวณมือหลังจากทำงานในสถานีบริการแห่งนี้หรือไม่ ☐ ไม่มี (ข้ามไปส่วนที่ 5)☐ เป็นครั้งเดียว ☐ มีบ้างเป็นบางครั้ง ☐ เป็นประจำ
4.9 ปัจจุบันท่านยังมีอาการผิวหนังแห้ง คันและอักเสบบริเวณมือหรือไม่ ☐ หายแล้ว ☐ ยังเป็นอยู่
5. ลักษณะการทำงานและพฤติกรรมสุขภาพ
5.1 ปัจจุบันท่านดื่มเครื่องดื่มที่มีแอลกอฮอล์หรือไม่ ☐ ดื่ม ☐ ไม่ดื่ม (ข้ามไปข้อ 5.6)
5.2 ท่านดื่มเครื่องดื่มที่มีแอลกอฮอลล์ชนิดใดบ้าง (ตอบเรียงลำดับ 1= มากสุด) ☐ สุรา ☐ เบียร์ ☐ ไวน์ ☐ อื่นๆระบุ.....
5.3 ท่านมีการดื่มเครื่องดื่มที่มีแอลกอฮอลล์บ่อยมากน้อยเพียงใด ☐ ทุกวัน ☐ 2-3 วันครั้ง ☐ สัปดาห์ละครั้ง ☐อื่นๆระบุ.....
5.4 ท่านดื่มเครื่องดื่มที่มีแอลกอฮอล์ในแต่ละครั้งโดยเฉลี่ยรวมเป็นปริมาณเท่าใด ☐ ประมาณ 1 ถ้วยชา ☐ $\geq$ 1 แก้ว ☐ ประมาณ 1 ขวดแม่โขง ☐ > 1 ขวดแม่โขง
5.5 ท่านเริ่มดื่มเครื่องดื่มที่มีแอลกอฮอล์เมื่ออายุเท่าใด (ปี) ☐ < 18 ☐ 18-25 ☐ 26-35 ☐ 36-60 ☐ > 60

5.6 ปัจจุบันท่านสูบบุหรี่หรือไม่ (ยาเส้น ยาสูบ ยาฉุน)

☐ ไม่สูบ (ข้ามไปข้อ 5.9) ☐ สูบ โดยสูบปริมาณ

☐ น้อยกว่า 1 ซอง/ ต่อวันหรือ ประมาณ.....มวน/วัน

☐ 1-2 ซอง/ ต่อวัน หรือประมาณ .....มวน/วัน

☐ มากกว่า 2 ซอง/ ต่อวันหรือประมาณ.....มวน/วัน

5.7 ท่านมีความถี่ในการสูบบุหรี่มากน้อยเพียงใด

☐ ทุกวัน ☐ สัปดาห์ละครั้ง ☐ 2-3 ครั้งต่อสัปดาห์ ☐ นานๆครั้ง

5.8 ท่านเริ่มสูบบุหรี่ตั้งแต่อายุเท่าใด (ปี)

☐ < 18 ☐ 18-25 ☐ 26-35 ☐ 36-60 ☐ > 60

5.9 ท่านเคยได้เข้าไปมีส่วนเกี่ยวข้องโดยปฏิบัติงานหรืออยู่ในบริเวณที่มีกิจกรรมต่อไปนี้บ้างหรือไม่ อย่างไร (ตอบได้มากกว่า 1 ข้อ)

☐ เติมน้ำมัน ความถี่ ☐ ทุกครั้ง ☐ บ่อยครั้ง ☐ นานๆครั้ง ☐ ไม่เคย

เพราะ ☐ หน้าที่หลัก ☐ ช่วยเหลือผู้อื่น ☐ อื่นๆระบุ.....

ลักษณะการเติมน้ำมันหรือการสัมผัส

☐ ยืนรอจนเติมเสร็จทุกครั้ง ☐ ยืนรอจนเติมเสร็จบ่อยครั้ง

☐ ยืนรอจนเติมเสร็จนานๆครั้ง ☐ ไม่ยืนรอแต่กดล๊อคแล้วถอยห่าง

ห่างจากจุดเติมประมาณ.....ม.

☐ ขนถ่ายน้ำมันสู่ถังใต้ดิน

ความถี่ ☐ ทุกครั้ง ☐ บ่อยครั้ง ☐ นานๆครั้ง ☐ ไม่เคย

เพราะ ☐ หน้าที่หลัก ☐ ช่วยเหลือผู้อื่น ☐ อื่นๆระบุ.....

ระยะเวลาในการสัมผัส ☐ ตลอดกิจกรรม ☐ นานพอควร ☐ เล็กน้อย

ตำแหน่ง ☐ เหนือลม ☐ ใต้ลม ☐ ไม่แน่นอน

☐ ตรวจวัดปริมาตรน้ำมันในแต่ละวันหรือกะทำงาน

ความถี่ ☐ ทุกครั้ง ☐ บ่อยครั้ง ☐ นานๆครั้ง ☐ ไม่เคย

เพราะ ☐ หน้าที่หลัก ☐ ช่วยเหลือผู้อื่น ☐ อื่นๆระบุ.....

ระยะเวลาในการสัมผัส ☐ ตลอดกิจกรรม ☐ นานพอควร ☐ เล็กน้อย

☐ ตรวจสอบคุณภาพน้ำมันขณะเจ้าหน้าที่มาตรวจสอบ

ความถี่ ☐ ทุกครั้ง ☐ บ่อยครั้ง ☐ นานๆครั้ง ☐ ไม่เคย

เพราะ ☐ หน้าที่หลัก ☐ ช่วยเหลือผู้อื่น ☐ อื่นๆระบุ.....

ระยะเวลาในการสัมผัส ☐ ตลอดกิจกรรม ☐ นานพอควร ☐ เล็กน้อย

5.10 เวลาเติมน้ำมัน/ขนถ่ายน้ำมัน/หรือทำกิจกรรมอื่นใดที่มีความเสี่ยงต่อการสัมผัสไอระเหยของน้ำมันท่านทราบหรือไม่ว่าต้องยืนอยู่ทิศทางใดของลม ☐ ทราบ ☐ ไม่ทราบ ☐ เหนือลม ☐ ใต้ลม
5.11 ในขณะให้บริการเติมน้ำมัน/ขนถ่ายน้ำมัน/หรือทำกิจกรรมอื่นใดที่มีความเสี่ยงต่อการสัมผัสไอระเหยของน้ำมันท่านได้มีการยืนในทิศทางใดของลม ☐ เหนือลม ☐ ใต้ลม ☐ ไม่แน่นอน
5.12 ในขณะปฏิบัติงานท่านใช้หน้ากากป้องกันไอระเหยจากน้ำมันหรือไม่ ☐ ใช้ ☐ ไม่ใช้ เพราะ (ข้ามไปข้อ 5.17) ☐ รำคาญ ☐ ไม่มี ☐ คิดว่าไม่มีอันตราย ☐ อื่นๆ ระบุ..... .....
5.13 หน้ากากป้องกันไอระเหยที่ท่านใช้ในปัจจุบันเป็นชนิดใด ☐ ชนิดเปลี่ยนไส้กรองได้ ☐ ผ้าปิดจมูกธรรมดา ☐ อื่นๆ ระบุ.....
5.14 ระยะเวลาการใช้หน้ากากหายใจในขณะปฏิบัติงานต่อวัน ☐ น้อยกว่า 2 ชม./วัน ☐ 2-4 ชม./วัน ☐ 4-6 ชม./วัน ☐ ตลอดเวลาทำงาน
5.15 ท่านมีความถี่ในการใช้หน้ากากหายใจบ่อยมากน้อยเพียงใด ☐ ทุกวัน ☐ 2-3 วันต่อสัปดาห์ ☐ สัปดาห์ละครั้ง ☐ นานๆครั้ง
5.16 ท่านได้มีการเปลี่ยนหน้ากากหายใจภายหลังจากใช้งานบ้างหรือไม่ ☐ ไม่เปลี่ยน ☐ เปลี่ยน โดยมีระยะเวลาในการเปลี่ยนหลังใช้แล้วประมาณ .....
5.17 ท่านมีเครื่องแบบสำหรับการปฏิบัติงานหรือไม่ ☐ มี จำนวน.....ชุด ☐ ไม่มี
5.18 ลักษณะของเครื่องแบบ/การแต่งกายในขณะปฏิบัติงานของท่านเป็นอย่างไร ☐ กางเกงขายาว ☐ กางเกงขาสั้น ☐ อื่นๆระบุ..... ☐ เสื้อแขนยาว ☐ เสื้อแขนสั้น ☐ อื่นๆระบุ..... ☐ ไม่สวมหมวก ☐ สวมหมวก ☐ อื่นๆระบุ.....
5.19 หลังปฏิบัติงานท่านได้ทำความสะอาดชำระล้างร่างกายโดยการอาบน้ำหรือไม่ ☐ ไม่อาบ ☐ อาบทุกครั้ง ☐ อาบบางครั้ง ☐ อาบนานๆครั้ง
5.20 หลังปฏิบัติงานท่านเปลี่ยนเครื่องแต่งกายก่อนออกจากที่ทำงานหรือไม่ ☐ เปลี่ยนทุกครั้ง ☐ เปลี่ยนบางครั้ง ☐ ไม่เปลี่ยนเลย

5.21 ชุด/เครื่องแบบที่ท่านใส่ทำงานเป็นประจำได้รับการซักล้างก่อนนำมาสวมใส่หรือไม่อย่างไร

☐ สัปดาห์ละครั้ง ☐ 2-3 วัน/ครั้ง ☐ ทุกครั้ง ☐ อื่นระบุ.....

5.22 ท่านเคยดื่มหรือกินอาหารในขณะปฏิบัติงานในมื้ออาหารใดบ้าง (ตอบได้มากกว่า1ข้อ)

☐ เช้า ☐ กลางวัน ☐ เย็น ☐ ไม่มีเลย (ข้ามไปข้อ 5.29)

5.23 ท่านดื่มหรือกินอาหารในขณะปฏิบัติงานบ่อยแค่ไหน

☐ ทุกวัน ☐ 2-3 ครั้งต่อสัปดาห์ ☐ สัปดาห์ละครั้ง ☐ นานๆครั้ง

5.24 โดยส่วนใหญ่ท่านรับประทานอาหารเช้า,อาหารกลางวันหรืออาหารเย็นในบริเวณใดของสถานที่ทำงาน (ตอบเรียงลำดับ 3ลำดับ 1=มากสุด,2=ปานกลาง,3=น้อย)

☐ บริเวณลานจ่ายน้ำมัน ☐ ร้านอาหารบริเวณสถานีบริการน้ำมัน

☐ ภายในสำนักงาน ☐ สวนหย่อมในสถานีบริการน้ำมัน

☐ อื่นๆ ระบุ.....

5.25 ก่อนรับประทานอาหารท่านล้างมือหรือไม่

☐ ไม่ล้าง ☐ ล้างเป็นบางครั้ง ☐ ล้างบ่อยครั้ง ☐ ล้างทุกครั้ง

5.26 ท่านล้างมือด้วยวิธีการใด

☐ สบู่ ☐ ผงซักฟอก ☐ น้ำเปล่า ☐ อื่นๆ.....

5.27 หลังจากให้บริการเติมน้ำมันแก่ลูกค้าเรียบร้อยแล้ว ก่อนกลับมารับประทานท่านได้มีการล้างมือหรือไม่

☐ ไม่ล้าง ☐ ล้าง

☐ ทุกครั้ง ☐ เป็นบางครั้ง ☐ บ่อยครั้ง

5.28 หลังจากให้บริการแก่ลูกค้าในระหว่างมื้ออาหารเรียบร้อยแล้ว ท่านได้มีการล้างมือก่อนรับประทานอาหารด้วยวิธีการใด

☐ สบู่ ☐ ผงซักฟอก ☐ น้ำเปล่า ☐ อื่นๆ.....

5.29 เมื่อท่านว่างจากการเติมน้ำมันท่านมักจะอยู่ในบริเวณใดของสถานีบริการน้ำมันเชื้อเพลิง (ตอบเรียงลำดับโดยใส่ตัวเลข 1= มากสุด, 2=ปานกลาง, 3=น้อย)

☐ บริเวณลานจ่ายน้ำมัน ☐ ร้านอาหารบริเวณสถานีบริการน้ำมัน

☐ ภายในสำนักงาน ☐ สวนหย่อมในสถานีบริการน้ำมัน

☐ ร้านเครื่องดื่มภายในสถานี ☐ มินิมาร์ท

5.30 ท่านคิดว่าลักษณะงานของท่านมีโอกาสต่อการสัมผัสน้ำมันมากน้อยเพียงใด

☐ มาก ☐ ปานกลาง ☐ น้อย ☐ ไม่มี

5.31 ปีที่ผ่านมาท่านเคยตรวจสุขภาพหรือไม่

☐ เคย โดยตรวจ(ระบุ) ☐ ไม่เคย

1. ……..
2. .....

5.32 ท่านคิดว่าภายในสถานีบริการน้ำมันของท่านมีเหตุรำคาญ/ปัญหาสิ่งแวดล้อมในประเด็นใดบ้างอย่างไร

☐ กลิ่น

ได้กลิ่นมากน้อยเพียงใด ☐ ตลอดเวลา ☐ เป็นพักในช่วง½ - 1 วัน ☐ นานๆครั้ง

จากกิจกรรมใดมากสุด ☐ เติมน้ำมัน ☐ ควันท่อไอเสียรถยนต์ ☐ ควันจากการปรุงอาหาร

☐ น้ำเสีย ☐ ขยะ ☐ อื่นๆ.....

มีวิธีการใดในการลด/ป้องกันกลิ่นนั้น ☐ ไม่มี ☐ มี ระบุ.....

☐ เสียงดัง

รบกวนเวลาใดมากที่สุด ☐ เช้า ☐ กลางวัน ☐ เย็น ☐ กลางคืน

คิดว่ามีแหล่งกำเนิดจากที่ใด☐ โรงเรียน ☐ จราจร ☐ ก่อสร้าง ☐ อื่นๆระบุ.....

มีวิธีการใดในการลด/ป้องกันเสียงนั้น ☐ ไม่มี ☐ มี ระบุ.....

☐ ความร้อน สาเหตุจาก ☐ แสงแดด ☐ ความร้อนจากเครื่องยนต์ ☐ อื่นๆ.....

☐ ฝุ่นละออง

จากกิจกรรมใด ☐ ปะเปลี่ยนยางรถยนต์ ☐ ศูนย์ซ่อมเปลี่ยนถ่ายน้ำมันเครื่อง

☐ รถยนต์ที่เข้ามาเติมน้ำมัน ☐ บริการล้างอัดฉีด

☐ การจราจรบนท้องถนน ☐ การก่อสร้าง ☐ อื่นๆ.....

มีวิธีการใดในการลด/ป้องกันฝุ่นละออง ☐ ไม่มี ☐ มี ระบุ.....

☐ อื่นระบุ.....

5.33 ความถี่ที่ท่านเคยได้รับการอบรมชี้แจง เรื่องมาตรการความปลอดภัย

☐ มีเป็นประจำ (มากกว่า 1 ครั้ง) ☐ มีตอนเข้าทำงานครั้งเดียว

☐ ไม่เคยมี ☐ อื่นๆ ระบุ……

หากมีครั้งสุดท้ายได้รับการอบรมเมื่อใด.....

5.34 ท่านเคยถูกน้ำมันหกรดตัว/สัมผัสร่างกาย

☐ เคย ☐ ไม่เคย

ความถี่ ☐ เป็นประจำ ☐ นานๆครั้ง และระบุจำนวนครั้ง.....ครั้ง

วิธีจัดการ☐ รีบล้างออกด้วยสบู่ทันที ☐ รีบล้างออกด้วยน้ำเปล่าทันที

☐ เปลี่ยนเครื่องแต่งกาย ☐ รอจนกว่าว่างจากงานบริการจึงล้างออก

☐ อาบน้ำ ☐ เช็ดออกด้วยผ้า

☐ ไม่ได้ดำเนินการใดๆเลย ☐ อื่นๆ.....

5.35ที่สถานีบริการแห่งนี้เคยมีเจ้าหน้าที่ของรัฐ/หน่วยงานอื่นมาเยี่ยมชมหรือตรวจตราหรือไม่

☐ ไม่เคย ☐เคยครั้งเดียว ☐ เคยเป็นประจำ ☐ ไม่แน่ใจ/ไม่ทราบ

APPPEXDIX B
INSPECTION FORM

แบบสำรวจระบบสิ่งแวดล้อมและความปลอดภัยสถานีบริการน้ำมันเชื้อเพลิง

ส่วนที่ 1: สิ่งแวดล้อมโดยรวมและพื้นที่ข้างเคียง

ผู้สำรวจ 1. นาย/นาง/นางสาว……นามสกุล…….....

2. นาย/นาง/นางสาว……นามสกุล…….....

3. นาย/นาง/นางสาว.....นามสกุล…….....

วัน/เดือน/ปีที่สำรวจ วันที่.....เดือน.....ปี.....

ชื่อสถานีบริการน้ำมัน.....เลขที่.....ถนน.....

ตำบล.....อำเภอ.....จังหวัด.....รหัสไปรษณีย์.....

พิกัดทางภูมิศาสตร์ .....

ประเภทของสถานีบริการ ☐ ประเภท ก ☐ ประเภท ข

สถานีบริการในเครือบริษัท ☐ ปตท. ☐ เชลล์ ☐ คาลเท็กซ์ ☐ บางจาก

☐ เอสโซ่ ☐ อื่นๆ ระบุ.....

วิธีสำรวจ: เดินสำรวจ สังเกต และทำการวัดระยะทางและทิศทางภาคพื้นดิน		
1. พื้นที่ของสถานี	1.1 กว้าง.....ม.	ยาว.....ม. รวม.....ตารางเมตร
	1.2 บ้านที่อยู่อาศัยข้างเคียง	ใกล้สุด.....ม.
	1.3 ลักษณะชุมชนข้างเคียง	
	● ด้านข้างขวาเป็น	☐ ย่านที่อยู่อาศัย ห่าง.....ม.จากสถานี ☐ ย่านธุรกิจ ห่าง.....ม.จากสถานี ☐ ย่านที่อยู่อาศัยและธุรกิจห่าง..... ....ม.จากสถานี ☐ ย่าน..... ห่าง.....ม.จากสถานี
	● ด้านข้างซ้ายเป็น	☐ ย่านที่อยู่อาศัย ห่าง.....ม.จากสถานี ☐ ย่านธุรกิจ ห่าง.....ม.จากสถานี ☐ ย่านที่อยู่อาศัยและธุรกิจห่าง.....ม.จากสถานี ☐ ย่าน..... ห่าง.....ม.จากสถานี

	● ด้านข้างหลังเป็น	☐ ย่านที่อยู่อาศัย ห่าง.....ม.จากสถานี ☐ ย่านธุรกิจ ห่าง.....ม.จากสถานี ☐ ย่านที่อยู่อาศัยและธุรกิจห่าง.....ม.จากสถานี ☐ ย่าน..... ห่าง.....ม.จากสถานี
2. ลักษณะปรากฏบนพื้นผิวภายในสถานี		
☐ ไม่มีคราบ/หยดน้ำมัน ☐ มีคราบ/หยดน้ำมัน 1) บริเวณ.....เกิดจาก..... 2) บริเวณ.....เกิดจาก..... 3) บริเวณ.....เกิดจาก.....		
3. สภาวะสิ่งแวดล้อมที่ปรากฏให้เห็นโดยรวม		
3.1สิ่งแวดล้อมข้างเคียงโดยรอบสถานี		
☐ ด้านหน้าของสถานี..... ☐ ด้านข้างขวาของสถานี..... ☐ ด้านข้างซ้ายของสถานี..... ☐ ด้านหลังสถานี.....		
3.2 สิ่งแวดล้อมภายในพื้นที่สถานีบริการ		
☐ ห้องน้ำ	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
☐ ร้านกาแฟ/เครื่องดื่ม	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
☐ ร้านอาหาร/ศูนย์จำหน่ายอาหาร	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง ☐ มีบ่อดักไขมัน.....แห่ง ☐ ไม่มีบ่อดักไขมัน	
☐ มินิมาร์ท	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
☐ ตู้โทรศัพท์	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
☐ ตู้ ATM	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
☐ ที่เปลี่ยนถ่ายน้ำมันเครื่อง	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
☐ ล้างอัดฉีด	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
☐ ซ่อม/เปลี่ยนยาง	☐ ด้านข้างซ้าย .....แห่ง ☐ ด้านข้างขวา.....แห่ง ☐ ด้านหลังสถานี.....แห่ง	
3.3 สิ่งแวดล้อมโดยรอบตามความเห็นของผู้สำรวจ		

รายละเอียดบริการเสริมที่มีภายในสถานีบริการ		
บริการเสริม/ บริเวณ	ขนาดพื้นที่ กว้างxยาว เมตร	ระยะห่างจากปั๊มจ่ายน้ำมัน (เมตร)

ส่วนที่ 2 พื้นที่บริเวณปั๊มหัวจ่ายน้ำมัน

ช่วงที่	จำนวนตู้ของปั๊มหัวจ่าย	จำนวนหัวจ่ายน้ำมัน	จำนวนหัวจ่ายแยกตามชนิดน้ำมัน				
			ดีเซล	B 91	B 95	G 91	G 95
พื้นที่จอดรถรับบริการบริเวณแต่ละช่วงของปั๊มหัวจ่าย กว้าง.....ยาว.....ม.							
ระยะห่างระหว่างปั๊มหัวจ่ายที่อยู่ในช่วงเดียวกัน.....ม.							

APPENDIX C
NAME OF 39 STUDIED GASOLINE SERVICE STATIONS

ตารางที่ 37 ตารางแสดงรายชื่อสถานีบริการน้ำมันเชื้อเพลิง 39 แห่งที่ทำการศึกษา

ชั้นการปกครอง	เขตพื้นที่	ยี่ห้อ	ที่อยู่
ชั้นใน	ป้อมปราบศัตรูพ่าย	เชลล์	บจก.รุ่งเกษมบริการ 960 ถ.กรุงเกษม แขวงวัดโสมนัส เขตป้อมปราบฯ
		เชลล์	บจก.ปั๊มน้ำมันสวนมะลิ 210/9 ถ.ยุคล2 แขวงเทพศิรินทร์ เขตป้อมปราบฯ
	พญาไท	ปตท.	ปตท.สนามเป้า 208/1 ถ.พหลโยธิน แขวงสามสนใน เขตพญาไท
	ดินแดง	เชลล์	บจก.เพชร แพรว พราว บริการ 1758 ถ.ประชาสงเคราะห์ แขวงดินแดง เขตดินแดง
		ปตท.	บ.สมบูรณ์สินปิโตรเลียม 250 ถ.สุทธิสารแยก1 แขวงดินแดง เขตดินแดง
	บางคอแหลม	ปตท.	สำนักงาน ปตท. สาขาเจริญกรุง 87 2211 ถ.เจริญกรุง แขวงวัดพระยาไกร เขตบางคอแหลม
	ดุสิต	เอสโซ่	หจก.ประสิทธิ์ออยล์ 1256/45 ถ.นครไชยศรี แขวงถนนนครไชยศรี เขตดุสิต
	บางซื่อ	เชลล์	หจก.พรพรรณรุ่งเรือง 9/223 ม.34 ถ.รัชดาภิเษก แขวงบางซื่อ เขตบางซื่อ
	จตุจักร	ปตท.	หจก.ศรีเจริญภัณฑ์ปิโตรเลียม 1093 หมู่9 ถ.วิภาวดี-รังสิต แขวงจตุจักร เขตจตุจักร
		เชลล์	เลิศรัชดา 90 ถ.รัชดาภิเษก แขวงลาดยาว เขตจตุจักร
ชั้นกลาง	หลักสี่	ปตท.	ปตท.สนง.การประปานครหลวง 18/137 ถ.ประชาชื่น แขวงทุ่งสองห้อง เขตหลักสี่
		ปตท.	หจก.เอกรินทร์แอนด์ออยล์เซอร์วิส 345 ม.2 ถ.แจ้งวัฒนะ10 แขวงทุ่งสองห้อง เขตหลักสี่
	พระโขนง	เชลล์	บจก.กฤตย์ สุขุมวิท 62 2040 ถ.สุขุมวิท62 แขวงบางจาก เขตพระโขนง

ตารางที่ 37 ตารางแสดงรายชื่อสถานีบริการน้ำมันเชื้อเพลิง 39 แห่งที่ทำการศึกษา (ต่อ)

ชั้นการปกครอง	เขตพื้นที่	ยี่ห้อ	ที่อยู่
ชั้นกลาง	ประเวศ	ปตท.	หจก.ศิริสมบูรณ์เซิร์ฟ 13/26 ม.1 ถ.ศรีนครินทร์ แขวงหนองบอน เขตประเวศ
	ภาษีเจริญ	เอสโซ่	บจก.ไทยซี-เซ็นเตอร์ สาขาพาณิชย์ธน 16/4 ม.8 ถ.จรัญสนิทวงศ์ (ซ.13) แขวงบางแวก
		เชลล์	บจก.วี.พี.รุ่งเรือง 259/1 ถ.เพชรเกษม (ซ.13) แขวงปากคลองภาษีเจริญ
		เชลล์	สุกิจบริการ 141/1 ถ.เพชรเกษม แขวงบางแค เขตภาษีเจริญ
	ราษฎร์บูรณะ	ปตท.	หจก.วีตระการวิจิตรแก๊ส 100 ม.8 ถ.สุขสวัสดิ์ แขวงราษฎร์บูรณะ เขตราษฎร์บูรณะ
		เอสโซ่	หจก.สยามบียู 91/1 ม.9 ถ.ประชาอุทิศ แขวงราษฎร์บูรณะ
		เชลล์	หจก. ณัฐพลออยล์ เซอร์วิส สาขา 3 83 ม.9 ถ.ราษฎร์บูรณะ แขวงบางปะกอก เขตราษฎร์บูรณะ
	บางเขน	เอสโซ่	บจก.จิตรอิสระ 52/25 ม.8 ถ.พหลโยธิน แขวงอนุสาวรีย์ เขตบางเขน
	หนองแขม	เชลล์	บจก.เอส.ซี.หนองแขม 32/6 ม.11 ถ.เพชรเกษม แขวงหนองค้างพลู เขตหนองแขม
	บางกะปิ	ปตท.	บจก.ตรีทิพย์ปิโตรเลียม 153 ถ.ศรีนครินทร์ แขวงหัวหมาก เขตบางกะปิ
		เอสโซ่	บจก.ไทยซี-เซ็นเตอร์ สาขาสุขาภิบาล 3 324/264 ถ.รามคำแหง แขวงหัวหมาก เขตบางกะปิ
		เชลล์	บจก. เต็มใจ เซอร์วิส สาขา 1 3498/1-2 ถ.ลาดพร้าว แขวงคลองจั่น เขตบางกะปิ
	จอมทอง	ปตท.	หจก.วีรา 25/3 ถ.วุฒากาศ แขวงบางอ้อ เขตจอมทอง
	วังทองหลาง	เชลล์	บจก.สหรุ่งเรืองพัฒนา 2523 ถ.ลาดพร้าว แขวงวังทองหลาง เขตวังทองหลาง
		เชลล์	แพทโทรบิส 124 ถ.ลาดพร้าว วังทองหลาง

ตารางที่ 37 ตารางแสดงรายชื่อสถานีบริการน้ำมันเชื้อเพลิง 39 แห่งที่ทำการศึกษา (ต่อ)

ชั้นการปกครอง	เขตพื้นที่	ยี่ห้อ	ที่อยู่
ชั้นกลาง	บางนา	ปตท.	บมจ.105 ปิโตรเลียม 50/867 ม.3 ถ.สุขุมวิท105 แขวงบางนา เขตบางนา
		เชลล์	บจก. เคแอนด์ ทริเพิล-ที สาขา 2 4429 ถ.สุขุมวิท แขวงบางนา เขตบางนา
	บึงกุ่ม	เอสโซ่	หจก.เค สยาม เซอร์วิส 115/19 ม.4 ถ.สุขาภิบาล2 แขวงคลองกุ่ม เขตบึงกุ่ม
	สวนหลวง	เอสโซ่	บจก.ไทยซี-เซ็นเตอร์ สาขาศรีนครินทร์ O/B(ขาออก) 1111 ม.1 ถ.ศรีนครินทร์ แขวงสวนหลวง เขตสวนหลวง
	ตลิ่งชัน	ปตท.	บมจ.ปตท. ราชพฤกษ์ 31/12 ม.13 ถ.ราชพฤกษ์ แขวงบางระมาด เขตตลิ่งชัน
		ปตท.	บ.ซีเอส เทพพล เอ็นจิเนียริ่งแอนด์เซอร์วิส จำกัด 42/7 ม.14 ถ.วัดแก้ว-พุทธมณฑลสาย 2แขวงบางพรหม
	สะพานสูง	ปตท.	ปตท.สาขาถนนสุขาภิบาล3 33/30 ม.3 ถ.รามคำแหง (สุขาภิบาล3) แขวงสะพานสูง เขตสะพานสูง
ชั้นนอก	คลองสามวา	ปตท.	ปตท.นิมิตรใหม่ 71 ม.2 ถ.นิมิตรใหม่ แขวงสามวาตะวันออก
	หนองจอก	ปตท.	หจก.แสงพรนพรัตน์ 49 ม.3 ถ.ประชาสำราญ แขวงคลองสิบสอง เขตหนองจอก
	บางขุนเทียน	เอสโซ่	บจก.บางบอนประเสริฐศิริ 54/100 ม.6 ถ.บางขุนเทียน แขวงแสมดำ เขตบางขุนเทียน
	บางบอน	เชลล์	บจก.อรรจนา ออยล์ จำกัด 75/91 ม.8 ถ.เอกชัย แขวงบางบอน เขตบางบอน
			รวม 39 ปั๊ม

APPENDIX D
THE AVERAGE TVOCs CONCENTRATION IN BREATHING ZONE OF GASOLINE SERVICE STATIONS

Table 38 The average TVOCs concentration in breathing zone at different work places of gasoline service stations

Gasoline service station	TVOCs concentration (mg/m^3)		
	Pump-island	**Changing motor fuel station**	**Office**
Thaisee center sukaphibal 3	100.82	1.15	0
K siam service	76.76	-	0
Ptt sukaphibal 3	45.73	-	0
Sirisomboon serf	62.27	-	0
Thaisee center srinakarin	193.46	-	0
Treethip petroleum	0	-	0
Suanmali	41.47	1.84	0
Rungkasem	59.31	0	0
Prasitoil	64.06	-	0
Somboonsin petroleum	36.08	0.69	0.46
Phethprawpraw	20.17	0	0
Temjai service	74.52	-	0
S.C.knongklam	110.43	27.77	0
Thaisee center phanitthon	72.75	-	0
Ptt nimitmai	18.63	-	0
Ptt sanampoa	103.12	-	0
Sricharoanpun petroleum	86.98	0.46	0
Phattrobit	39.70	1.38	0
Akarin and oil service	18.45	0.92	0

Table 38 The average TVOCs concentration in breathing zone at different work places of each gasoline service stations (Continued)

Gasoline service station	TVOCs concentration (mg/m^3)		
	Pump-island	**Changing motor fuel station**	**Office**
Sangpornnoparut	35.15	-	0
Pornpunrungraung	248.97	0.69	0
Nutthaponoil service	28.26	8.03	0
Weethakan wijit gas	9.37	-	0
Siam B.U.	33.51	0	0
Jitissara	43.60	0.23	0
Water supply	23.78	0	0
V.P. rungruang	20.35	7.80	0
Klit sukumvit 62	10.96	0.92	0
105 petroleum	14.08	0	0
K and triple three	110.48	12.16	0
Saharungruangpattana	119.94	0.92	0
Sukit	64.75	0.69	0
Leardrachada	176.20	0.46	0
Bangbonprasertsiri	14.50	0.23	0
C.S.theppon	24.71	0.46	0
Ptt. Rachapeak	77.31	-	0
Achana	20.48	11.02	0
Ptt. charoankrung	30.75	-	0
Weera	89.79	1.15	0
Average	**64.39**	**3.16**	**0.46**

Note; 0 = Not detectable, - = Not measurement

APPENDIX E

THE AVERAGE PERCENTAGE OF SCORE IN GASOLINE SERVICE STATION

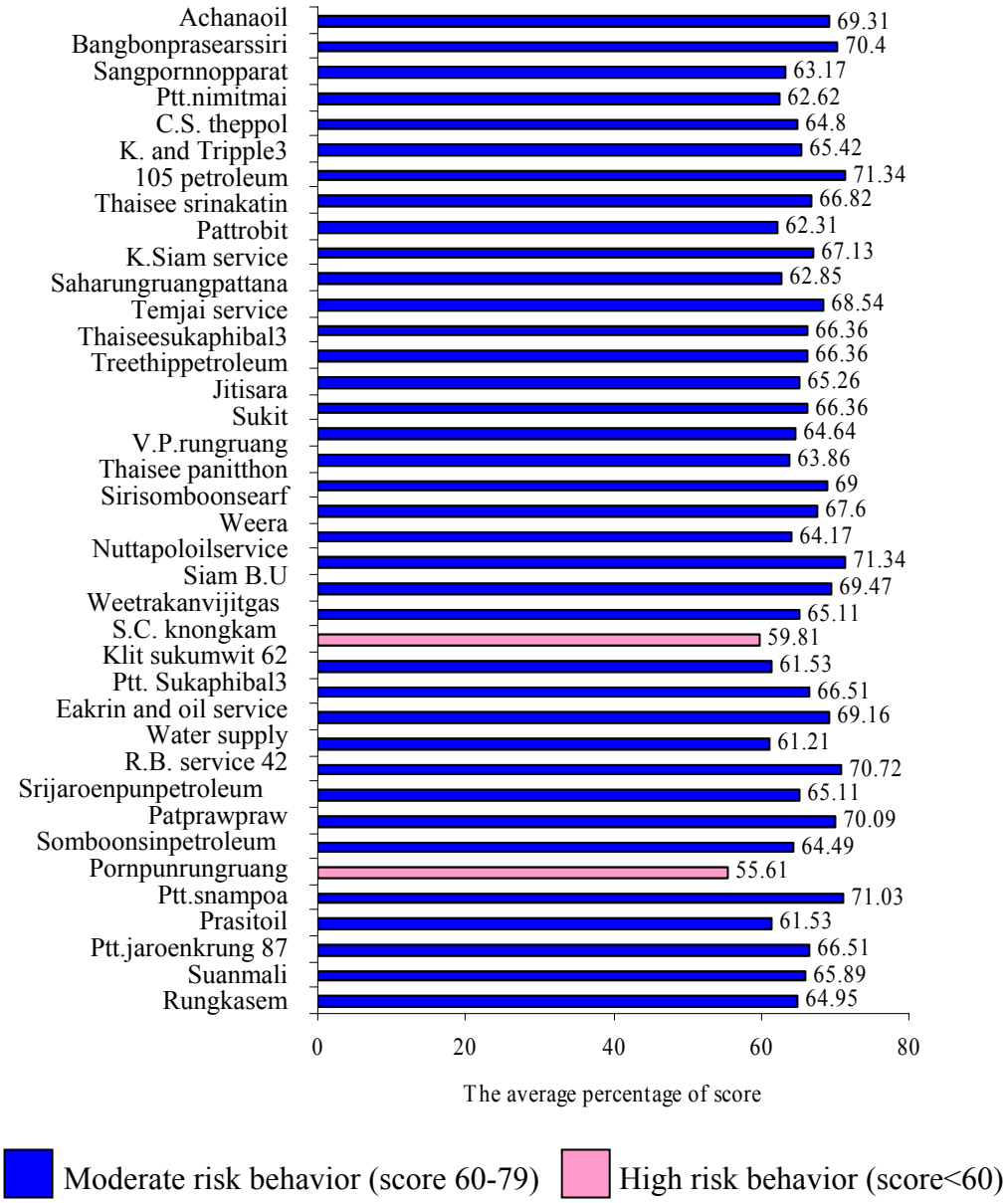

Figure 11 The average percentage of score in gasoline service stations

APPENDIX F

DOCUMENTARY PROOF OF ETHICAL CLEARANCE

COA. No. MU-IRB 2008/173.1711

Documentary Proof of Mahidol University Institutional Review Board

Title of Project: TVOCs Risk Investigation from Gasoline Service Station in Bangkok Area (Thesis for Master Degree)

Principle Investigator: Miss Wassana Kanawapee

Name of Institution: Faculty of Public Health

Approval includes: Annual Report version received date 31 October 2008

Mahidol University Institutional Review Board is in full compliance with International Guidelines for Human Research Protection such as Declaration of Helsinki, The Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

Date of Renewal (1st): 28 February 2008

Date of Expiration: 27 February 2009

Signature of Chairman: .....

(Professor Rutja Phuphaibul)
Vice Chair for Chair

Signature of Head of the Institute: .....

(Associate Professor Sansanee Chaiyaroj)
Vice President for Research and Academic Affairs

Office of the President, Mahidol University, 999 Phuttamonthon 4 Rd., Salaya, Phuttamonthon District, Nakhon Pathom 73170. Tel. (662) 8496223-5 Fax. (662) 8496223

BIOGRAPHY

NAME	Miss Wassana Kanawapee
DATE OF BIRTH	1 May 1980
PLACE OF BIRTH	Udonthani, Thailand
INSTITUTIONS ATTENDED	Mahidol University, 1999-2003 Bachelor of Science (Public Health) Mahidol University, 2005-2009: Master of Science (Environmental Sanitation)
HOME-ADDRESS	9 M.6, Bantad T., Muang A., Udonthani Mobile Phone: 08-9548-0786 E-mail: nooniim@hotmail.com